European
Environment
Agency

Europe's state of water 2024

The need for improved water resilience

EEA Report 07/2024

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Key messages

Europe's water

Europe's water is under significant pressure, presenting serious challenges to water security, now and in the future. As such, Europe urgently needs to improve its resilience and ensure sustainable freshwater supplies for people and the environment.

Water stress and flooding

Water stress is already occurring in Europe. It affects 20% of Europe's territory and 30% of the population every year, figures that are likely to increase in the future due to climate change.

As climate change unfolds in Europe, managing flood risk affordably and sustainably will become increasingly important. Intense rainfall has already increased in parts of Europe, leading to floods and growing flood risks. Flooding affects human well-being and ecosystems, with potential loss of life and significant economic losses.

Status of water

The deadline set by the Water Framework Directive (WFD) for European rivers, lakes, transitional, coastal and groundwaters to meet good status was 2015. That was not met and there has been little improvement since 2010. In 2021, only 37% of Europe's surface water bodies achieved a good or high ecological status. 29% achieved a good chemical status.

The majority of protected aquatic habitats and species in the EU are assessed as having a poor or bad conservation status. Reporting under the WFD shows that the status of some aquatic plants has improved, but this rarely translates into attaining overall good ecological status.

Europe's waters continue to be impacted by chemicals, predominantly by atmospheric pollution from coal-powered energy generation and diffuse pollution from agriculture. The lack of improvement in chemical status can be partly attributed to long-lived pollutants, such as mercury and brominated flame retardants. If these long-lived pollutants were not considered, 80% of surface waters would achieve good chemical status rather than 29%.

Groundwater supplies two thirds of the EU's drinking water and supports ecosystems such as wetlands and rivers. EU Member States report that 77% of groundwater body area is in good chemical status; major pollutants causing failure are nitrates and pesticides. 91% of groundwater is reported to be in good quantitative status. WFD data in this report are based on the 19 Member States that reported to the European Environment Agency.

Pressures on Europe's water

Member States have reported that the most significant pressure impacting both surface and groundwaters arises from agriculture, resulting from water use and pollution from the intensive use of nutrients and pesticides. Changes in farming practices and new technologies can help ensure continued productivity while enabling agriculture to reduce pollution and adapt to lower water use.

Surface waters are widely affected by mercury and brominated flame retardants. Mercury, released to the air particularly from coal burning for energy production, later returns to the earth's surface with rainfall. The pathways taken by brominated flame retardants are not well understood, although these persistent substances are no longer approved for use.

The use of nature-based solutions should be expanded to enhance water retention and 'slow the flow' of intense rain to mitigate flooding. Major pressures include changes to physical features and natural flow, such as dams and channelisation, which degrade natural habitats. Achieving free-flowing rivers and restored wetlands is essential for healthy, biodiverse freshwater ecosystems.

Improving Europe's water resilience to a changing climate

Urgent action is required to improve Europe's water resilience. Climate change is disrupting weather patterns and further increasing pressures on our water resources and ecosystems. Europe's water management practices are poorly adapted to cope with such rapid and large-scale change, which will compromise water security.

Reducing water use and improving water efficiency are key to tackling water stress. Reducing leakage, using water-efficient devices and processes and increasing water reuse would improve efficiency. Water pricing can also be an important driver for reducing water use and improving efficiency, while also providing a mechanism to fund water investments. Target setting, focused on saving water or reducing demand, could drive action and facilitate the monitoring of progress towards greater water resilience.

Improved water management is needed to strengthen Europe's water resilience and reduce pollution. Up-to-date and timely information on water quantity and quality are critical to Europe's ability to manage its water. A more robust knowledge base is also needed to enable more equitable and sustainable water allocation between competing uses, including the environment.

37%
of **surface waters**
are in **good** or **better**
ecological status

29%
of **surface waters**
are in **good**
chemical status

91%
of **groundwater area**
is in **good**
quantitative status

77%
of **groundwater area**
is in **good**
chemical status


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Executive summary

This report presents the state of Europe's water. It outlines three overarching challenges facing future European water management:

1. protecting and restoring aquatic ecosystems;

2. achieving the zero pollution ambition;

3. adapting to water scarcity, drought and flood risks.

Europe's citizens, environment and economy are intrinsically dependent on water, yet the continuing availability of sufficient, good quality water cannot presently be assured. Major pressures challenging Europe's water resilience include pollution, changes to physical features and natural flow of rivers, and abstraction of water. As set out in the European Climate Risk Assessment (EUCRA) (EEA, 2024a), climate change is a further critical pressure expected to compromise Europe's future water security. Urgent action is required to improve resilience and ensure a secure, sustainable supply of freshwater for people and the environment.

EU water policy comprises complementary legislation and strategies which address water from different angles, such as the Water Framework Directive and Water Industry Directives, the newly adopted Nature Restoration Law, the biodiversity strategy for 2030 and the zero pollution action plan (EC, 2021c). Ensuring a balance between competing demands for water is a key challenge for Europe.

Box ES.1

Key data sources for this report

This assessment is based on reporting by European Environment Agency (EEA) member countries under the Water Framework Directive and other water-related reporting, as follows:

- Member States (and Norway) reporting under the WFD. The report focuses on the EU-27 and the 19 EU Member States which had reported their WFD data to the EEA by July 2024. The complete reporting and datasets can be accessed and visualised through the WISE Freshwater WFD.
- Water Information System for Europe — State of the Environment data reporting by the Eionet network.
- Reporting under the Habitats Directive and the Birds Directive and State of Nature in the EU (EEA, 2020).
- European Climate Risk Assessment (EEA, 2024a).

Increasing water stress, drought and floods

Climate change represents a major threat to water resources and aquatic ecosystems. Floods and water scarcity compromise food and water security and the health of the general population, ultimately affecting social cohesion and stability (EEA, 2024a).

As demonstrated by this report, water stress is already experienced in Europe. It affects 20% of the European territory and 30% of the population on average every year. These stresses are expected to increase with climate change, potentially leading to competitive pressures and undermining the EU's internal cohesion.

Alongside water stress, Europe will become subject to more extreme floods because weather patterns are changing. Within a few months in 2023, there were severe floods with loss of life in Italy, Norway, Slovenia and along the Mediterranean coast (EEA, 2024a). Managing water scarcity and flood risks affordably and sustainably will assume increasing importance across Europe.

Water scarcity and flooding also come with high economic costs. In recent years, single events such as the continent-wide drought and heat event in 2022 cost up to EUR 40 billion (EEA, 2023d). The 2021 flood event in Germany, Belgium and the Netherlands cost EUR 44 billion (EEA, 2024a). Without any climate mitigation and adaptation, direct damage from flooding is estimated to increase six-fold from present losses by the end of the century (JRC, 2020).

Water stress also impacts aquatic and water-dependent ecosystems and the ecosystem services they deliver. For example, if drought reduces the size of a wetland, it will provide less habitat, less water purification and less carbon sequestration and storage. Abstraction of water can magnify the impacts of water stress. At the European level, agriculture is the largest net consumer of water, with most abstracted water consumed by crops or evaporating (59% of EU water consumption) (EEA, 2023b). Other demands on water resources include public water supply, cooling water for electricity production, industry and nature. Current trends indicate that better information on water resources is needed to manage competing water demands sustainably.

The overall quality of Europe's waters is not improving

The WFD set a solid foundation for integrated water management at the river basin level. It set the objective that European waters should meet a good status by 2015, with progress reporting through 6-yearly river basin management plans (1). This has led to EU Member States, Iceland and Norway making significant efforts towards monitoring surface waters and groundwaters and investing to reduce pressures — the aim being to improve the conditions of aquatic ecosystems and ensure availability of surface and groundwater resources for wildlife and human needs.

Since 2010, Member States have achieved some improvement in biological quality elements and in reducing some chemical pollutants. By 2021, the status of algae, plants and invertebrates had improved in lakes, while rivers and transitional waters had seen improvements for invertebrates in sediment. The status for fish has slightly deteriorated in rivers and lakes but has improved in transitional waters. There is also better knowledge of chemicals. The list of monitored chemicals has been expanded, and improved scientific understanding of toxicity has led to more stringent quality standards to protect human health and the environment.

However, such efforts have rarely translated into improved status overall. In 2021, only 37% of surface water bodies in Europe were in good or high ecological status and 29% were in good chemical status. These figures have hardly changed since 2015. The lack of improvement in ecological status reflects the continued combined pressures on surface waters across the continent, in particular pollution and habitat degradation.

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(1) For newly added priority substances in 2013, good status must be met by 2033 at the latest.

37%
of **surface waters**
are in **good** or **better**
ecological status

29%
of **surface waters**
are in **good**
chemical status

The lack of significant progress in chemical status in surface waters can partly be explained by long-lived pollutants that are particularly challenging to remediate (2), such as mercury and brominated flame retardants. As elsewhere in the WFD, failing just one parameter means that good status overall cannot be achieved. Without considering such long-lived substances, good chemical status is achieved in 80% of surface waters, with 14% in unknown status.

Groundwater supplies two thirds of the EU's drinking water and supports ecosystems such as wetlands and rivers. In 2021, 91% of the groundwater area was reported as being in good quantitative status, however, water stress affects a much larger area (EEA, 2023g). Member States also report that 77% of the groundwater area is in good chemical status. Nutrients and pesticides are a particular threat to groundwaters, with 14% of groundwater area failing due to nutrients and 10% due to pesticides.

91%
of **groundwater area**
is in **good**
quantitative status

77%
of **groundwater area**
is in **good**
chemical status

Failure to achieve good ecological status shows that European aquatic ecosystems are still seriously degraded. Complementary evidence reported under the Habitats Directive shows that only 17% of protected river, lake, alluvial and riparian habitats are in good conservation status (2013-2018). The data also show that 89% of protected wetland habitats have poor or bad conservation status and are still

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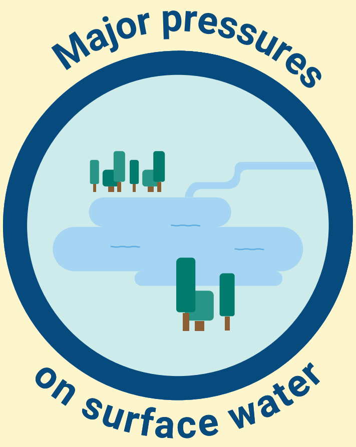
(2) uPBT: ubiquitous, persistent, bioaccumulative and toxic priority substances. See Chapter 3.

suffering from multiple pressures such as land drainage, habitat conversion and agricultural intensification. The large majority of protected fish and amphibian species are in poor or bad conservation status. They are at risk of becoming locally extinct and need restorative action. This shows that the EU is far from achieving its biodiversity ambition in aquatic ecosystems.

Multiple pressures impact Europe's water

To improve Europe's water status and build resilience, pressures which cause failure of good status will need to be reduced. Countries report that the main pressures on surface waters are linked to pollution from diffuse sources such as atmospheric deposition (52%), changes to the physical features and natural flow of rivers, lakes, transitional and coastal waters (51% of surface waters), agriculture (29%) and point sources such as from wastewater discharges (13%) and abstraction (8%).



52%	**Diffuse atmospheric pollution**
51%	**Natural form and function (hydromorphology)**
35%	**Diffuse pollution (excluding atmospheric)**
29%	**Diffuse agricultural pollution**
18%	**Point source pollution**

The main pressures for groundwaters are reported to be diffuse pollution, especially from agriculture (32%), and abstraction (18%), most commonly from agriculture, public water supply and industry.

34%	**Diffuse pollution**
32%	**Diffuse agricultural pollution**
18%	**Abstraction**

Member States' reports show that the most significant driver impacting the quality of both surface and groundwaters is the intensive use of nutrients and pesticides in agricultural production. Agriculture is also by far the highest net water consumer in Europe and, without changes in practices, demand from irrigated agriculture is likely to increase with climate change. In relation to pollution where agriculture is a major contributor, one or more pesticides were detected above their effect threshold at 10-25% of all surface water monitoring sites reported to the EEA between 2013 and 2021 (EEA, 2024c). Likewise, average concentrations of nitrates in groundwater have not been reduced over the period 2000-2021 (EEA, 2023d).

The natural flow and physical features of surface water bodies are altered by many human activities, including urban development, hydropower, irrigation and drinking water, navigation, flood protection and drainage. Such changes affect or destroy natural habitats and affect species dependent on the original habitat, such as spawning of migratory fish. Restoring natural features to improve aquatic ecosystems therefore requires careful planning with affected sectors but can lead to additional benefits such as drinking water purification, improved carbon storage, flood protection and recreation. These benefits are difficult to quantify, but one study showed that restored rivers in Europe yielded a net societal economic benefit over unrestored rivers of EUR 1,400 per hectare per year (Vermaat et al., 2015). In recent years, there has been emphasis on removing river barriers and improving the conditions for fish migration. More efforts are needed across Europe to achieve the goals of the EU Nature Restoration Law and biodiversity strategy for 2030 to restore the natural flow and functions of rivers and floodplains.

Priority substances are chemicals in surface waters under the WFD which present a significant risk to or via the aquatic environment and human health. Those causing the most failures of chemical status in surface waters are mercury and brominated flame retardants (each responsible for 49% of the surface waters failing). Other priority substances causing widespread failure are polycyclic aromatic hydrocarbons, which are carcinogenic and can arise from burning solid fuels, including organic matter. Such diffuse pollution is complicated to prevent, as are cases where pollution pathways are unclear, such as brominated flame retardants.

As monitoring becomes more comprehensive and analytical and screening methods are improved, new harmful substances will continue to be found in water and we will increasingly become aware of their harmful effects. Well-known examples include the 'forever chemicals' per- and polyfluoroalkyl substances (PFAS), which are harmful to human health and are widespread where they have been investigated, but for which we currently lack a good understanding of their overall presence in water at the European level.

Results presented in this report clearly indicate that the zero pollution ambition for water will need continued effort to protect the health and well-being of people and the environment. Continued vigilance to identify new pollutants and implement measures to prevent pollution is required. Innovation and increased focus on sustainability provide opportunities for industry, driving the transition to a circular economy.

Actions to improve Europe's water resilience

The existing policy framework for water management is an important pillar for managing climate risks. When fully implemented, it delivers key components of water resilience for the environment and human health. However, there are gaps in current policy implementation and climate change is worsening existing pressures. Other economic sectors are increasingly being forced to recognise their critical dependency on water, e.g. energy, agriculture and inland navigation.

It is therefore urgent for Europe to increase its water resilience, to secure a sustainable supply of good quality freshwater and supported by adequate structural investments and innovation.

Reducing over-abstraction

Climate change is disrupting weather patterns and further increasing pressures on our water resources and ecosystems. Europe's water management practices are poorly adapted to handling such rapid and large-scale change, compromising water security. A stronger knowledge base on water is needed to enable more equitable and sustainable allocation of water between competing uses, including the environment.

A key part of managing demand is to become more water efficient in industry and at home and to reduce leakage. In the agricultural sector, there are opportunities to develop more water-efficient and drought-resistant crops and build water storage in soils. Together with increasing water reuse, such innovation can reduce reliance on irrigation and rainfall. The setting of targets, including encouraging water saving or reducing water demand, could drive action and facilitate monitoring progress towards greater water resilience. Water pricing is an important driver for water efficiency, while the revenue can be used towards funding more sustainable solutions.

Sectoral policies can have significant roles in addressing both the demand and supply of water, thereby supporting a transition towards a water-resilient society. There are competing demands between and among sectors, with different policies often addressing different angles, for example, hydropower generation and restoring river connectivity. Balancing demands from across different sectors clearly requires strong and integrated planning across different scales of governance.

Reliable access to up-to-date information is also needed to help improve risk management. Floods develop in hours, so early warning systems are essential for saving lives. Water management needs to be enabled to adapt abstraction and permitting conditions to extreme conditions such as drought, to prevent catastrophic events such as occurred in the Oder River (EC, 2023a). Remote sensing data through tools such as Copernicus offer new opportunities. Digital innovation can improve timely information for the prediction of and response to water-related risks.

Reducing pollution

To prevent harm to people and the environment, pollution must be prevented in line with the long-term objectives of the zero pollution action plan. In the short term, there is a need to reduce the use of harmful substances and nutrients to improve the overall status of water.

As in the second cycle of reporting under the WFD, diffuse atmospheric pollution remained a major pressure on surface waters in 2021 (EEA, 2018a, 2018b). Action should be taken to further reduce atmospheric emissions of substances which later return to the earth's surface with rainfall, such as arise from the burning of fossil fuels. Brominated flame retardants have already been restricted under the Stockholm Convention. However, improved understanding of the pathways taken by them through the environment is needed to identify appropriate measures.

By establishing targets in the zero pollution action plan to reduce nutrient losses by 50% and reduce the use and risk of pesticides by 50% by 2030, the urgency of tackling excessive emissions of nutrients and pesticides has been recognised. To achieve these objectives, full implementation and further strengthening of existing

EU directives such as the Nitrates Directive and the Sustainable Use of Pesticides Directive is necessary. European agriculture needs to increase its use of more sustainable organic and agroecological practices, accompanied by incentives and a change in our food and dietary habits.

Need for restoration

Reconnecting rivers and their floodplains and restoring wetlands and peatlands should be seen as an essential step to restore healthy, biodiverse freshwater ecosystems and secure the delivery of essential ecosystem services, such as the supply of good quality water, nutrient recycling, water retention and carbon storage.

Finally, more emphasis should be given to the large-scale adoption of nature-based solutions to enhance water retention and 'slow the flow' of intense rain to mitigate flooding. These include green infrastructure in cities, agroforestry practices, development and restoration of wetlands, and reforestation. Nature-based solutions can be key measures that will also contribute to nutrient retention, improved water quality, biodiversity and enhanced carbon storage.

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1 Introduction

1.1 Context and aim of the report

The Water Framework Directive (WFD) recognises water as a fundamental part of Europe's heritage 'which must be protected, defended and treated as such' (EU, 2000).

Good water quality and sufficient water in rivers, groundwater, lakes, coastal areas, wetlands and floodplains are necessary for nature to thrive. In return, healthy freshwater ecosystems provide many services essential to society, such as helping to purify water for drinking and reducing the cost of water supply and sanitation. They also provide sources of food and materials, mitigate floods and droughts, contribute to carbon storage and provide more reliable water flow for navigation and recreation.

Water also plays a key role in Europe's competitiveness and strategic autonomy and in supporting its green and digital transition. Freshwater ecosystem services are costly and often impossible to replace when aquatic systems are degraded (Baron et al., 2003).

Freshwater ecosystems face an acute biodiversity crisis globally (Albert et al., 2021). In Europe, the decline in migratory freshwater fish, such as eel, sturgeon and salmon, is among the steepest on the planet, with a collapse of 93% since 1970 (Almond et al., 2022). Despite a long history of initiatives to protect European waters, this decline in freshwater biodiversity is unresolved (Haase et al., 2023). Amphibian, freshwater fish and water-dependent bird populations continue to decline across Europe.

Risks from climate change, pollution and biodiversity loss all impact the quality and availability of water which, in turn, impact water uses, including water for the environment. Recent extreme weather events in Europe, with floods, droughts and high temperatures, have heightened our awareness of these risks (EEA, 2024a).

The European Green Deal (Box 1.1) recognises many of the ways in which we rely on water and the increasing water risks that European citizens face with climate change (EC, 2019b). Effective management of our water resources has always been important, but as we move into more uncertain times, it will become increasingly essential for the health and well-being of society and the environment. As well as addressing the issues already identified in water policy, we need to consider emerging issues and highlight potential tensions and trade-offs if effective solutions are to be found.

Box 1.1

The European Green Deal

The ambition of the European Green Deal is to enable 'a transition to a low-carbon, climate-neutral, resource-efficient and biodiverse economy in full compliance with the United Nations 2030 Agenda and the 17 Sustainable Development Goals'. Its objectives include to 'live well within planetary boundaries' and establish a 'regenerative economy' that 'gives back to the planet more than it takes'. The essential needs of European citizens — nutrition, housing and mobility — must be met in a sustainable way that leaves 'no-one behind'.

Source: EC, 2019b.

Building on earlier sectoral legislation such as the Urban Waste Water Treatment Directive (EU, 1991a) and Nitrates Directive (EU, 1991b), the WFD (EU, 2000) set the ambitious goal of achieving good status for all European waters by 2015, unless there were grounds for exemption. Only in those cases was it possible to extend the achievement of good status to 2021 or 2027 or to set less stringent targets.

Yet, as we publish in 2024, good status is not achieved for over half of European surface water bodies. European rivers, groundwater, lakes, estuaries and coastal waters continue to be under intense pressure from human activities — a situation linked to the slow implementation of the WFD and insufficient integration of environmental objectives in sectoral policies (EC, 2019a).

As Europe nears 2027, there needs to be a general reflection on the achievements to date and future challenges, considering the renewed ambitions of the Green Deal for 2030. This State of Water assessment complements the WISE WFD report (available on the WISE Freshwater WFD) and the European Commission's (EC) assessment of Member States' river basin management plans. Its scope is to:

- highlight challenges that remain to be tackled;
- identify upcoming and critical challenges for water management that call for a European response;
- present the importance of sustainable responses and solutions such as nature-based solutions (NbS), resource efficiency, societal transformations and just and fair transitions in meeting the EU's water sustainability challenges.

As a result of this broad scope, this State of Water report builds on data reported under the WFD (Box 1.2) alongside a broader set of data flows, such as from the Habitats Directive and scientific publications.

Box 1.2

Note on the use of WFD data in this assessment

This assessment accompanies the reporting required under the WFD (Art. 5). The reported data can be accessed and visualised through the WISE Freshwater WFD.

This assessment focuses on the 19 Member States (3) which had electronically reported by July 2024. It represents 85% of surface water bodies and 87% of groundwater body area in the EU-27. More specifically, the representativeness of the data presented in this report is highest for rivers (88% of river water bodies), then lakes (73% of lake water bodies), coastal waters (69% of coastal water bodies), and transitional waters at the interface between freshwater and marine water (68% of transitional water bodies).

For a more updated overview of the data reported under the WISE State of Water (SoW), please refer to the WISE Freshwater WFD. Data for Norway are also available through this website.

The overall WFD objective for all water bodies is 'good' water status. 'Good' encompasses chemical and ecological status for surface waters and chemical and quantitative status for groundwater. Each of these status assessments includes several quality elements/pollutants/determinants.

The WFD uses the 'one out, all out' principle when assessing water bodies, i.e. the lowest status of the elements used in the assessment determines the overall status of the water body, and a lack of progress in some quality elements/determinants may conceal achievements and progress in others. This assessment presents changes for both overall status and specific quality elements or pollutants to measure progress.

Caution is needed when using the results for comparing Member States. Results can depend on the state's monitoring activities, the number of quality elements used, chemicals assessed and the interpretation of those data.

1.2 Water — a resource under intense and increasing pressure

Over the 20th century, Europe has undergone profound societal and economic transformations that have significantly impacted its water environment. The continent's demographic growth, rapid industrialisation, intensification of agriculture, energy production, mining, navigation and urban development have collectively exerted mounting pressures on rivers, lakes, transitional, coastal and groundwaters. Today, climate change has increased the risk of water stress and severe floods, exacerbating existing pressures.

In 2000, the WFD represented a major overhaul of Europe's approach to water management, resulting in remarkable human, technological and scientific investments. However, slow progress and ongoing pressures from human activities, together with the increasing intensity of climate change impacts, will challenge established water management practices in all European regions. Innovations, adaptation and transformation will be needed to build water resilience.

Unless major changes occur in European lifestyles and economic development, Europe's water resources and ecosystems will continue to deteriorate, accelerated by the intensification of climate change impacts.

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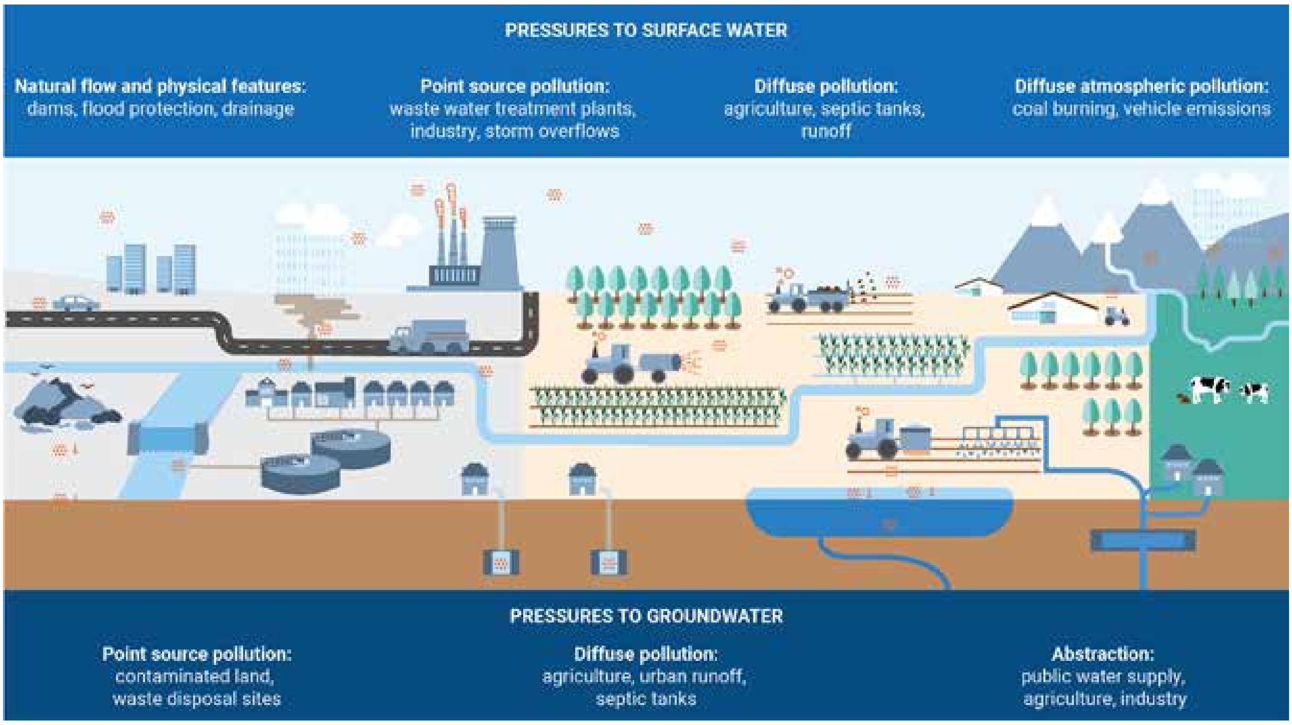
(3) The Member States included are: Austria, Belgium, Croatia, Czechia, Denmark, Estonia, Germany, France, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovakia, Spain and Sweden.

Figure 1.1 **Pressures on the water environment as in the Water Framework Directive**



Source: EEA.

The third river basin management plans (RBMPs) under the WFD, reported by EU Member States for 2021, show that Europe's surface water bodies remain under significant pressure (Figure 1.1). One of the most significant drivers impacting the quality of European surface and groundwaters is the intensive use of nutrients and pesticides in agricultural production (see also Schürings et al., 2024). Irrigated agriculture is also by far the highest net water consumer in Europe and places particular pressure on freshwater ecosystems in southern Europe. Without changes in practices, demand is likely to increase with climate change.

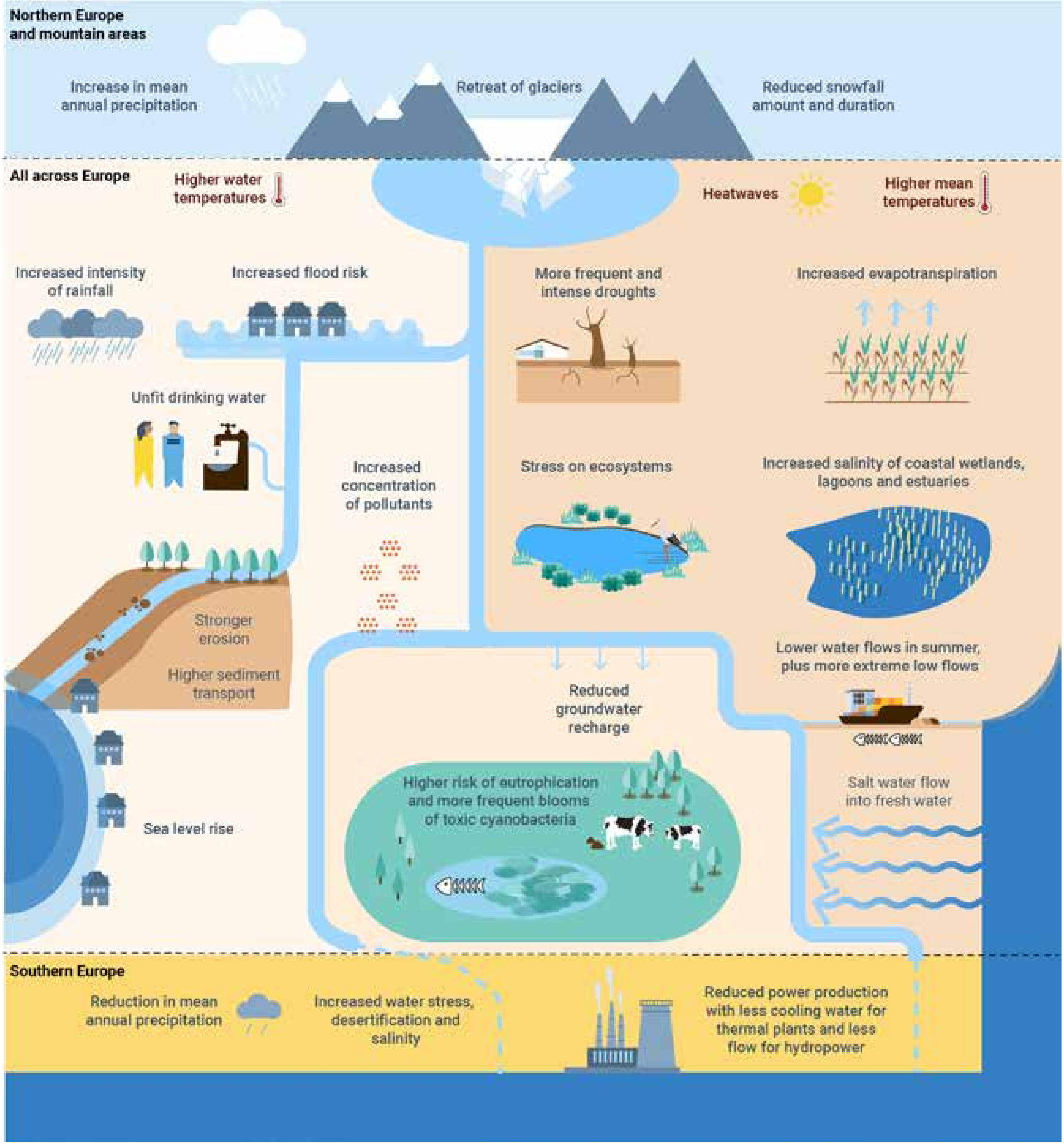
Wetlands and floodplains have been drained for agricultural use, especially in northern Europe, contributing to declines in aquatic species and the general aquatic habitat. Also, sectors such as energy production and inland navigation continue to impair the natural flow and physical features of European rivers, posing barriers to fish passage. In urban areas, flood protection has led to fragmentation of floodplain areas, altering the hydrological cycle.

Urban areas also still represent a major source of pollution, especially to surface waters, from emissions to the atmosphere which can be carried long distances before return to land, and from discharges from treatment plants and urban run-off, particularly during heavy precipitation.

According to EUCRA (EEA, 2024a), Europe is the fastest-warming continent worldwide, with climate risks of droughts and floods increasing in intensity and frequency (see also Chapter 4).

Forecasts portray a bleak picture (Figure 1.2). Climate change projections show that overall annual rainfall will reduce in southern and some western regions, leading to growing scarcity and a widening gap between demand and supply of water resources. Even in regions where projected rainfall will remain stable or increase, less precipitation will fall in summer, reducing water availability further when water is needed most, for example, by agriculture. At the same time, rainfall will fall in heavy bursts, leading to more intense floods. It may reduce groundwater recharge as intense, heavy rain does not infiltrate soils, instead reaching rivers in the form of surface run-off and aggravating soil erosion.

Figure 1.2 **Climate change impacts on water**



Source: EEA.

Longer dry periods will contribute to lower river flows, reduced groundwater recharge and aquifer depletion, affecting water quality and increasing the risk of eutrophication and harmful algal blooms. This will, in turn, affect aquatic and terrestrial ecosystems, pose significant health risks and compromise food and water security of essential sectors such as public water supply, energy cooling and navigation. This situation will be exacerbated by reductions in mountain ice cover and on the length of the snow season. Major European rivers like the Danube, Rhine, Po and Ebro that are crucial for the livelihoods and economy of Europe's largest urban centres and agricultural areas will be strongly affected.

The complex and multifaceted impacts of climate change on the freshwater environment, and the human uses that depend on it, are further explored through the report.

1.3 Finding solutions for a more sustainable future

Over the years, Europe has developed a comprehensive environmental *acquis* on water policy, including a coherent and integrative governance framework in the form of management plans for river basins and for flood and drought risk, with proposals for urban wastewater management plans currently under discussion (EC, 2022c) (Table 1.1 and Table 1.2). The WFD has contributed to raising awareness and enhancing public participation in water management. Economic and financial instruments are increasingly recognised as part of the toolbox of water managers (Lago et al., 2015; Vidaurre et al., 2017).

Thousands of measures have been implemented, with positive effects on the state of European waters. Many solutions to water management are inherently local, dependent as they are upon factors such as geography, population density, housing stock, industry and financial resources. Nature-based solutions (Box 1.3), targeted to suit the particular location, can offer cost-effective and sustainable ways to mitigate and adapt to challenges such as flooding, water scarcity and wastewater treatment. They can also present opportunities to give people access to an improved environment, with associated benefits for well-being.

Several reasons explain why the WFD's objectives have not been reached fully at the European level.

On the one hand, water bodies need time to recover. Hence, the effects of measures implemented during the first and second cycle are still being realised. Second, implementation of the WFD has been slow, suffering from insufficient funding and insufficient integration of environmental objectives in sectoral policies (EC, 2019a). Member States and sectors with a heavy impact on water, such as agriculture, energy and transport, must accelerate implementation to deliver more tangible environmental improvements.

Box 1.3

Nature-based solutions to address multiple water management challenges

There is increasing recognition of the need to work with nature and promote NbS, e.g. restoring riparian areas and floodplains (Serra-Llobet et al., 2022).

In 2021, the EU climate adaptation strategy called for the implementation of NbS on a larger scale to increase climate resilience. The Nature Restoration Law emphasises the fundamental role that NbS (including natural carbon stocks and sinks) play in securing biodiverse ecosystems and tackling climate change. They can be combined with grey infrastructure, soft governance and regulatory approaches to improve water resilience while maximising the delivery of ecosystem services.

NbS are defined as actions to protect, sustainably manage and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature (Figure 1.3). An increasing body of evidence supports the benefits of NbS and solutions that work with nature (EEA, 2021b; OECD, 2020). They are often cost-effective and help manage risks in a more variable or extreme climate. Especially in urban areas, they provide green spaces which improve living conditions and bring value to local communities.

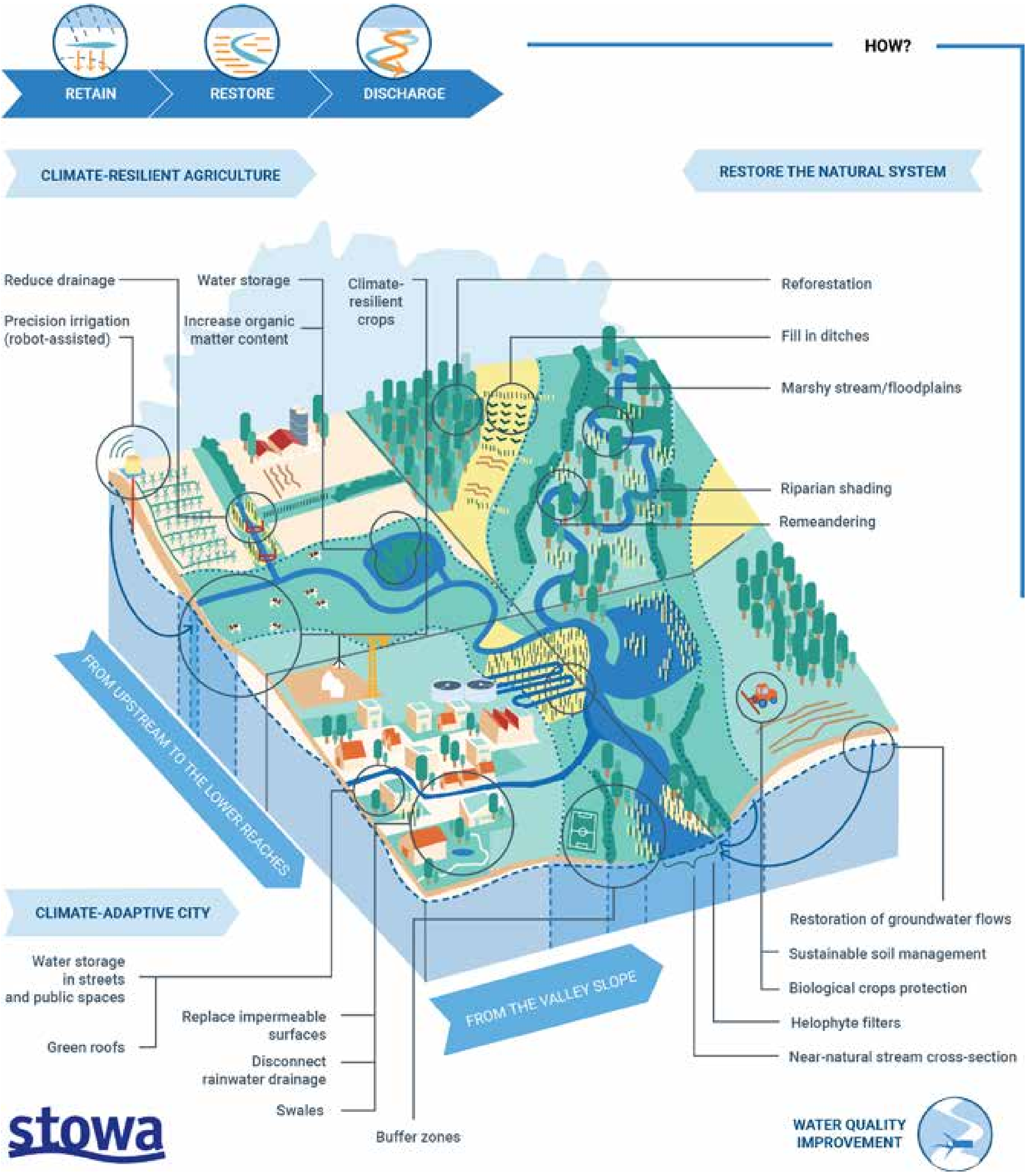
The Room for the River programme in the Netherlands is one of the largest of its kind in Europe, promoting NbS to support flood risk management and environmental improvements. Dykes were moved inland to restore a more natural floodplain and give more space for flood retention, thereby lowering flood risk to the city of Nijmegen. At the same time, a nature park was created, providing new recreational space and natural habitats.

Strategies and legislative initiatives under the European Green Deal and the Eighth Environment Action Programme aim to overcome some of these obstacles by addressing the underlying causes (Tables 1.1 and 1.2). The EU's biodiversity strategy for 2030, climate adaptation strategy, zero pollution action plan, circular economy action plan and farm to fork strategy are policies which present new opportunities to address key water challenges by setting more concrete targets for the implementation of measures. They recognise the need for multi-benefit solutions, supporting a transition towards more sustainable economic development that works for sectors and enhances policy agendas on water resources, biodiversity, climate and resource use.

Given the intertwined nature of water sustainability challenges, an attempt has been made throughout this report to present sustainable responses and solutions that provide multiple benefits for both society and nature. Solutions can work with nature, restore ecosystem functions and the delivery of ecosystem services to society and enhance their resilience to current and future stress.

Furthermore, attention has been paid to responses that support a circular economy of water and chemicals, and responses which emphasise addressing production and consumption patterns and societal use of products, for instance linked to agriculture, households, industry and energy.

Figure 1.3 **Impact of NbS on water environment pressures, leading to a more naturally functioning landscape**



Source: Adapted from STOWA, 2020.

Table 1.1 **Overview of EU environmental and climate policies relevant to surface and groundwaters**

Policy	Policy objectives for the aquatic environment	Target year
Eighth Environment Action Programme to 2030	Pursue a zero pollution ambition for air, water and soil (EU, 2022). Protect, preserve and restore biodiversity and enhance natural capital, notably air, water and soil as well as forest, freshwater, wetland and marine ecosystems. Make full use of NbS.	2030
EU biodiversity strategy for 2030	Aims to put Europe's biodiversity on a path to recovery with benefits for people, climate and the planet (EC, 2020d). Preserving natural flows and functions of rivers. Restore at least 25000km of free-flowing rivers. 30% of EU land and sea protected, one third of which is under strict protection. No deterioration in any protected habitats and species by 2030; trend to be positive for at least 30% of them. At least 10% increase in biodiverse landscape features.	2030
Farm to fork strategy	Aims to make food systems fair, healthy and environmentally friendly (EC, 2020a). Reduce nutrient losses by at least 50%. Reduce use of fertilisers by at least 20%. Reduce the overall use of and risk from chemical pesticides by 50% and reduce the use of more hazardous pesticides by 50%. At least 25% of agricultural land to be under organic farming.	2030
Water scarcity and drought communication and policy review	Addressing the challenge of water scarcity and droughts in the EU (EC, 2007).	NA
EU strategy on adaptation to climate change	Aims to contribute to a more climate-resilient Europe by enhancing the preparedness and capacity to respond to the impacts of climate change at local, regional, national and EU levels (EC, 2021b).	NA
Zero pollution action plan for air, water and soil	Aims to better prevent, remedy, monitor and report on pollution (EC, 2021c).	2030
Chemicals strategy — for sustainability, towards a toxic-free environment	Ban the most harmful chemicals. Phase out PFAS. Boost production of chemicals that are safe. Support research and development for decontamination solutions in aquatic environments (EC, 2020c).	NA
Second circular economy action plan	Has initiatives along the entire life cycle of products, aiming to ensure that the resources used are kept in the EU economy for as long as possible (EC, 2020b).	2030
Soil strategy	Ensure all EU soil ecosystems are healthy and more resilient and can therefore continue to provide their crucial services (EC, 2021e).	2050
Sustainable Development Goal 6	Ensure availability and sustainable management of water and sanitation for all (UN, 2016).	2030
Sustainable Development Goal 11.5	Reduce the adverse effects of natural disasters, including water-related disasters (UN, 2016).	2030
Sustainable Development Goal 15	Protect, restore and promote sustainable use of terrestrial and freshwater ecosystems (UN, 2016).	2030

Note: NA, not applicable.

Table 1.2 **Overview of EU environmental and climate legislation relevant to surface and groundwaters**

Legislative instrument	Objectives for the aquatic environment	Target year
Water Framework Directive	Achieve good ecological and chemical status of surface water bodies and good chemical and quantitative status of groundwater bodies (EU, 2000).	2015/2027
Habitats Directive and Birds Directive	Conservation and protection of habitats and species listed in Annexes I and II (EU, 1992, 2010a).	NA
Groundwater Directive (revision proposed 2022)	Improve groundwater quality in line with the goals of the WFD (EU, 2006b).	2015
Environmental Quality Standards Directive (revision proposed 2022)	Defines water quality standards for pollutants of EU-wide concern, i.e. priority substances (EU, 2008b).	2015
Nitrates Directive	Reduce and further prevent water pollution by nitrates from agricultural sources (EU, 1991b).	NA
Sustainable Use of Pesticides Directive	Reduce the risks and impacts of pesticide use on human health and the environment. Promote the use of integrated pest management and non-chemical alternatives to pesticides (EU, 2009a).	NA
Drinking Water Directive	Ensure that water intended for human consumption can be consumed safely, leading to a high level of health protection (EU, 2020a).	NA
Marine Strategy Framework Directive	Achieve good environmental status of marine waters in the EU (EU, 2008a)	2020
Floods Directive	Reduce the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods (EU, 2007).	NA
Urban Wastewater Treatment Directive (revision proposed 2022)	Protect the environment from the adverse effects of urban wastewater through collection and treatment of wastewater (EU, 1991a). Implementation period varies depending on year of accession.	EU-15 (by 2005) EU-13 (by 2023)
Bathing Water Directive	Preserve, protect and improve the quality of the environment and protect human health (EU, 2006a).	2015/2027
EU Climate Law	Adapt to climate change and achieve net zero greenhouse gas emissions for EU countries as a whole (EU, 2021).	2030
Sewage Sludge Directive	Encourage the use of sewage sludge in agriculture and regulate its use to prevent harmful effects on soil, vegetation, animals and humans (EU, 1986).	NA
Regulation on minimum requirements for water reuse	Sets minimum requirements for water quality and monitoring and provisions on risk management, for the safe use of reclaimed water (EU, 2020b).	NA
Nature Restoration Law	Restore ecosystems, habitats and species across the EU's land and sea areas. Has targets on river connectivity and several habitats of relevance to water (EU, 2024a).	2030/2040/2050

Note: NA, not applicable.

1.4 A guide to the report

This report is structured around three overarching challenges facing future European water management:

1. protecting and restoring aquatic ecosystems;

2. achieving the zero pollution ambition;

3. adapting to water scarcity, drought and flood risks.

These topics were selected based on current knowledge of the key drivers and pressures affecting good status as reported under the WFD, the challenges posed by climate change and the priorities in light of the ambition set at EU level, in particular under the European Green Deal. Each chapter explores current progress and remaining issues, taking drivers, pressures and climate change impacts into account, and describing current and innovative responses that the EU and Member States can adopt and implement.

Chapter 2, **Protecting and restoring aquatic ecosystems**, looks into how far Member States are towards achieving EU policy targets to prevent deterioration and improve the overall ecological status of European water bodies and the status of protected freshwater species and habitats in rivers, lakes, alluvial habitats and wetlands, including intertidal areas and groundwater-dependent ecosystems. Progress in restoring river connectivity by removing barriers and restoring floodplains and wetlands is also addressed.

Chapter 3, **Achieving the zero pollution ambition for water**, examines to what extent Member States address various nutrient and chemical pressures in the context of climate change. A focus is then put on addressing different pollution pressures, from agriculture to urban and industrial sources. Finally, a sub-chapter explores pollutants of emerging concern that are not yet effectively regulated.

Water in sufficient quantity, available at the right time of year, is essential for both the environment and many economic sectors. Chapter 4, **Adapting to water scarcity, drought and flood risks**, examines how far Member States protect and restore the natural hydrological cycle in river basins as a crucial step in climate change adaptation, to secure water availability for the environment and society and prevent damage and risk to human life from floods while giving room to ecosystems that depend on floods.

Chapter 5 briefly summarises the report and then considers the outlook for water in the context of recognised challenges and the need to ensure the sustainability of this essential resource.

2 Protecting and restoring aquatic ecosystems

Europe hosts an extremely diverse range of aquatic ecosystems, which need to be protected and managed. Resilient ecosystems provide valuable ecosystem services to people, such as water purification and flood mitigation. The Water Framework, Habitats and Birds Directives and other key EU policies such as the Nature Restoration Law — a main pillar of the European Green Deal underlining the EU's commitment to protect and restore damaged ecosystems — drive the protection and enhancement of European aquatic ecosystems.

However, the EU is far from achieving its biodiversity ambition in aquatic ecosystems, a situation that is worsening due to persistent human pressures and the increasing impact of climate change. More efforts are needed to meet EU policy targets on reaching good ecological status of surface waters, protecting Europe's unique freshwater species and habitats, restoring river and floodplain connectivity, and restoring whole catchments with a landscape perspective, including wetland ecosystems (Figure 2.1). Efforts need to be coordinated with other management tools, such as the reduction of pollution (Chapter 3) and ensuring the availability of sufficient water for nature (Chapter 4), if desired outcomes are to be realised.

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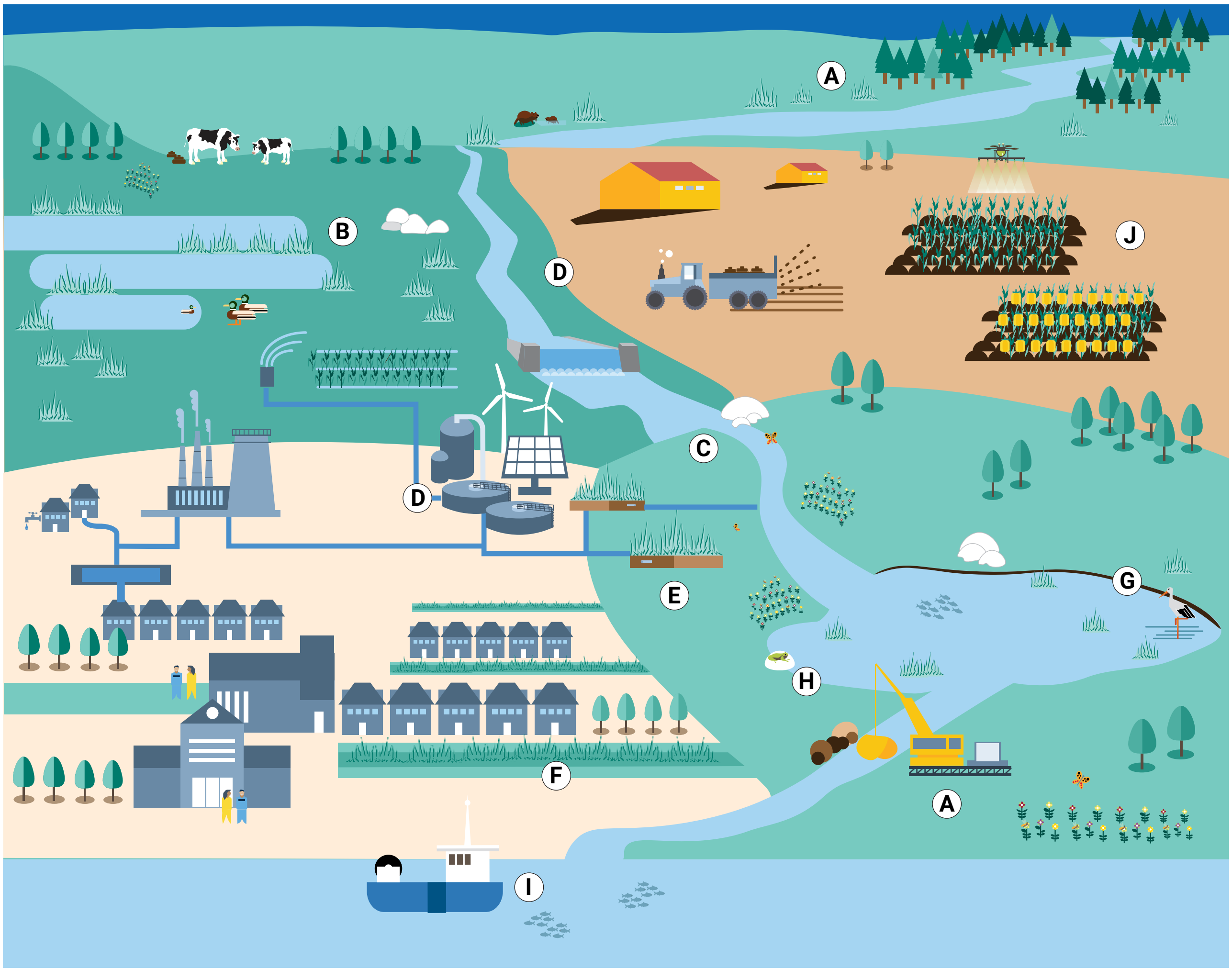
Figure 2.1 **Addressing the acute biodiversity crisis in European aquatic ecosystems**



Ⓐ Sediment management, e.g. afforestation upstream, modify dredging

Ⓑ Restore floodplains and wetlands

Ⓒ Restore river connectivity, e.g. barrier removal, fish migration aids

Ⓓ Water pollution prevention: e.g. high-tech UWWT plant, buffer strips

Ⓔ Reed filter beds for wastewater treatment

Ⓕ Flood mitigation, e.g. swales

Ⓖ Enhance and expand protected areas for aquatic habitats and species

Ⓗ Restore lakes and coastal waters

Ⓘ Prevent invasive species

Ⓙ Water scarcity/water efficiency, e.g. precision farming, different crops

Source: EEA.

2.1 The ecological status of Europe's surface waters

A central objective of the WFD is the achievement of good ecological status in rivers, lakes, transitional waters and coastal waters by 2015, or at the latest by 2027. Ecological status reflects the degree to which the ecosystems in our water bodies correspond to the original ecosystem conditions undisturbed by human activities. The closer the ecosystem is to its natural condition, the better its ecological status and, therefore, the more resilient it is. Water bodies with high and good ecological status also have all or most of their natural biodiversity intact.

2.1.1 No deterioration in ecological status and no significant improvement

According to the latest data reported by 19 Member States, less than half of EU surface waters (37%) were in good or high ecological status in 2021 (4). The proportion of surface waters failing to achieve good ecological status is uneven across Europe, being more prevalent in parts of central and western Europe, including Germany and the Netherlands, as shown in Map 2.1. Different pressures may cause such differences between Member States, but differences may also result from varying approaches to monitoring and assessment.

Overall, the proportion of surface waters in good or high ecological status has not changed significantly between 2015 and 2021. Looking only at the same water bodies across that period, there is little change in the status of rivers, lakes, transitional waters and coastal waters.

Ecological status shows the influence of multiple pressures, in particular pollution and habitat degradation, on the biological communities and other ecosystem parameters, such as the natural flow, physical features and physico-chemical quality of waters. An overall lack of improvement in ecological status for surface waters at European level reflects the continued combined pressures on surface waters across the continent.

2.1.2 Progress observed on specific biological elements

Although the share of surface waters in good ecological status has not changed significantly across cycles, progress has been made between 2015 and 2021 for individual quality elements considered in the assessment of ecological status.

The status of phytoplankton, benthic flora and invertebrates has improved in lakes, while rivers and transitional waters have seen improvements for benthic invertebrates (5). The status for fish has slightly deteriorated in rivers and lakes but has improved in transitional waters. For coastal waters, there is no change in the status of macroalgae and angiosperms, nor for phytoplankton and benthic invertebrates.

Improvement in the ecological status of some individual biological quality elements may reflect the positive effects of measures to reduce human pressures during the previous RBMP cycles. For instance, the improving condition of benthic invertebrates in rivers and the condition of phytoplankton in lakes for water bodies in poor or bad condition in 2015 (Box 2.1) (6) can be a response to a reduction of organic pollution and nutrient pressures, respectively (7).

---

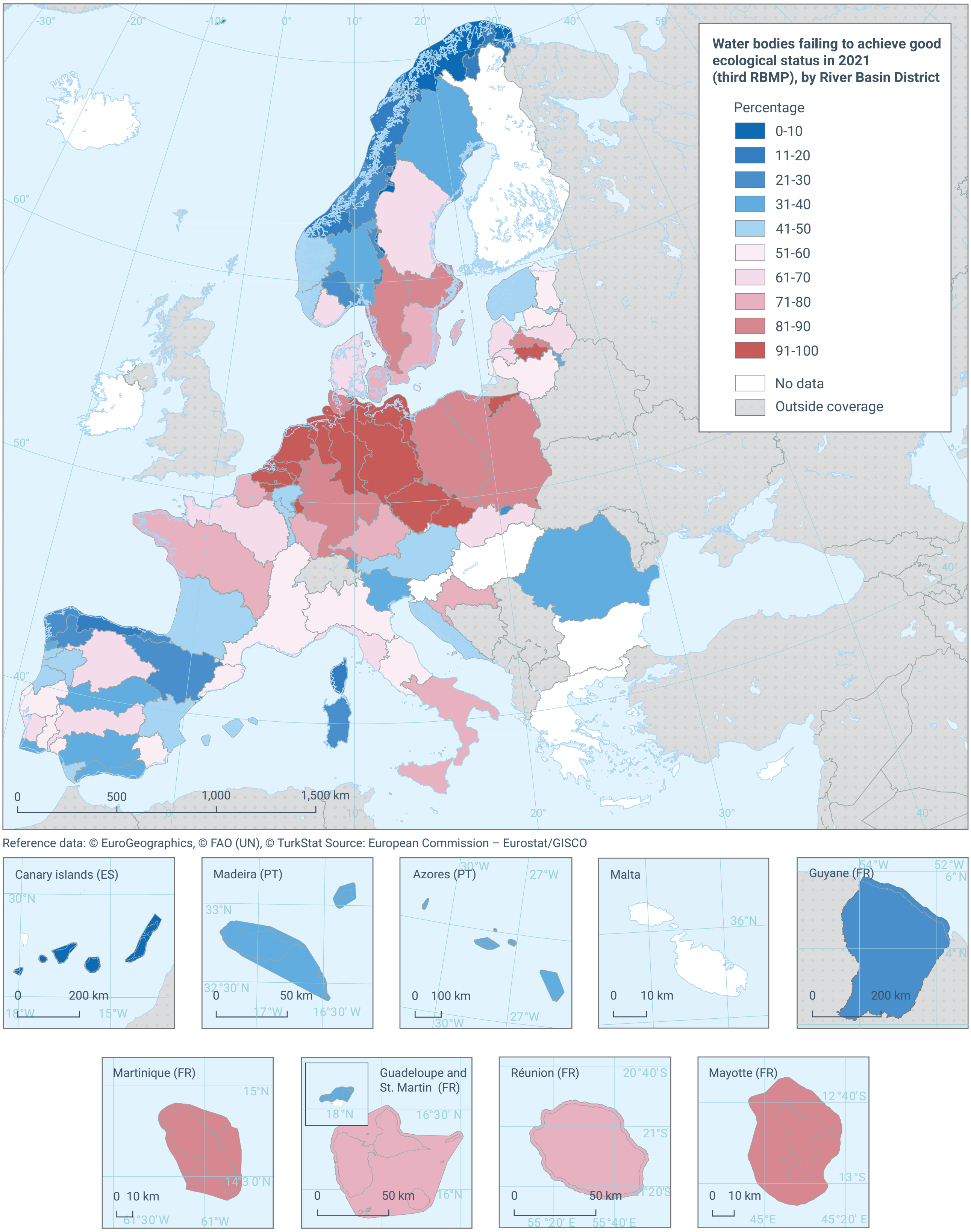
(4) In this report, no distinction is made between ecological status (natural water bodies) and ecological potential (heavily modified and artificial water bodies).

(5) Based on the share of classified water bodies reported in the second and third RBMP cycle for these biological quality elements.

(6) Trend analysis of data from Member States for the annual state of the environment reporting to WISE-2.

(7) Phytoplankton in lakes respond mainly to nutrient pollution, while benthic invertebrates respond to organic pollution decreasing the oxygen concentration in rivers, although other pressures, like metals, pesticides and hydromorphological alterations, can also be important (e.g. Hering et al., 2006; Birk et al., 2012; Poikane et al., 2015; Vitecek et al., 2021).

Map 2.1 Water bodies failing to achieve good ecological status in 2021 (third RBMP), by river basin district



Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

Notes: Map based on the WISE-SoW database, including data from 19 Member States plus Norway.

Source: https://water.europa.eu/freshwater/europe-freshwater/maps/ecological-status-map-by-rbd

Map viewer: https://www.eea.europa.eu/en/analysis/maps-and-charts/water-framework-directive-rbmp

Box 2.1

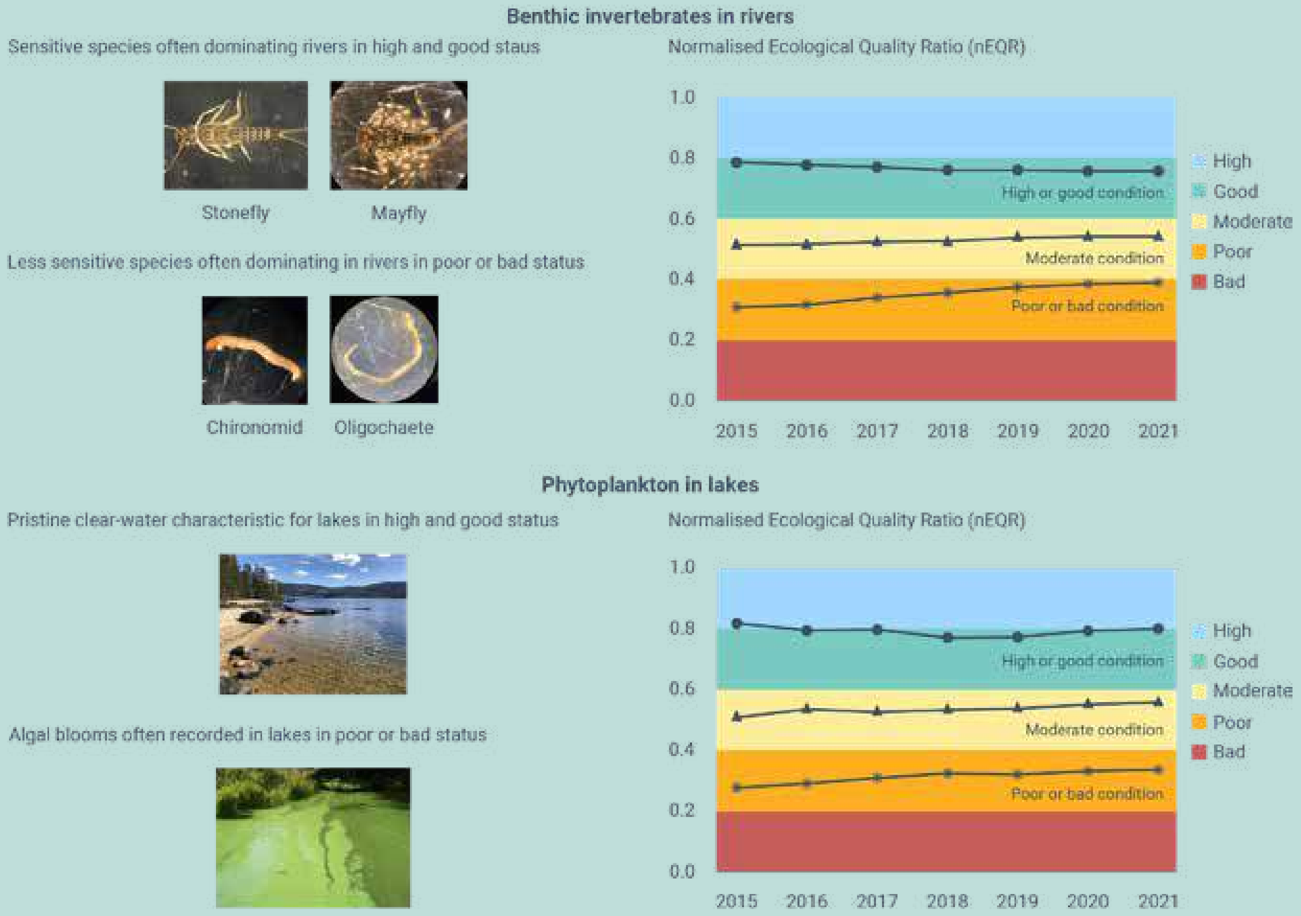
Development of ecological condition for benthic invertebrates in European rivers and phytoplankton in European lakes

Benthic invertebrates and phytoplankton are two essential biological quality elements integrated in the assessment of the ecological status of surface waters in Europe.

Benthic invertebrates are small animals, such as stoneflies and mayflies, while phytoplankton are an important food source for many crustaceans that are food for fish. Benthic invertebrates in rivers and phytoplankton in lakes are good indicators of ecological status, because they respond to human pressures.

Figure 2.2 presents how the condition of benthic invertebrates and phytoplankton has changed over time for water bodies with consistent time series between 2015 and 2021. The figure shows that water bodies in poor or bad condition (stars, red and orange chart area) present improving trends. Similar observations can be made for water bodies in moderate condition (triangles, yellow chart area). Water bodies in high or good condition (dots, blue and green chart area) present slightly degrading trends for rivers or stable trends for lakes.

Figure 2.2 **Development of ecological condition for benthic invertebrates in European rivers and phytoplankton in European lakes between 2015 and 2021**



Notes: Geographical coverage is 16 countries and 2,515 water bodies for rivers and 12 countries and 706 water bodies for lakes in the EU-27 and Norway.
Ecological Quality Ratio (EQR): These ratios represent the relationship between observed values and the values expected under the reference conditions applicable to that particular site. The ratio is expressed as a numerical value between zero and one, with 'good' ecological status being achieved at values above 0.6 (EC, 2003).

Sources: WISE-Biology, ETC BE BiologicalStatisticsData, Freshwater Community Composition — EuropaBON/EBV.

2.1.3 Continued human pressures and growing climate change impacts

The pressures that contributed to failure in achieving good ecological status in 2021 remained primarily changes in the physical features of surface water bodies and their natural flow, as well as pollution from diffuse sources from agriculture, households not connected to the sewerage network, urban run-off and atmospheric deposition (see also Section 1.2). To a lesser extent, pollution from discharge outlets (mainly from urban wastewater treatment plants) and abstractions also contributed to the failure to achieve good status.

The impacts of climate change are increasingly felt. For instance, annual maximum surface temperatures in 10 European lakes in Sweden, Austria and the UK have increased by more than 2°C over the 40 years between 1966 and 2015 (Dokulil et al., 2021). With increased warming, harmful blooms of cyanobacteria are increasing, particularly in northern European lakes in warmer summers. This impacts the entire food web, for example, by producing toxins, creating turbidity that hampers visual predators and using up oxygen when the cyanobacteria decay (Urrutia-Cordero et al., 2020; Briland et al., 2020).

A wetter climate combined with less acid rain has caused conspicuous browning of lakes, rivers and near-shore coastal waters, due to run-off of humic substances from forest and peat soils in northern Europe over the past couple of decades (de Wit et al., 2016). Browning has numerous negative impacts on surface water environments (Albrecht et al., 2023), but can also reduce the risk of harmful cyanobacteria blooms in lakes (Lyche Solheim et al., 2024).

In addition, under a changing climate, the vulnerability of sensitive freshwater species to environmental pressures increases. For example, decreased oxygen concentrations in rivers impact the early life stages of salmonid fish (Warren et al., 2015).

2.1.4 Measures for improving good ecological status

Although multiple pressures continue to impact surface waters, EU countries have made marked efforts in recent decades to improve the ecological status of surface waters (EEA, 2018b).

Some of the key measures taken in the RBMPs have had a positive effect, especially improving urban wastewater treatment, which has contributed significantly to reduced organic pollution and nutrients (see also Box 2.1). Across the whole EU, 82% of urban wastewaters are collected and treated in accordance with the Urban Wastewater Treatment Directive (EEA, 2021c).

At the same time, pollution pressures remain significant, especially from agriculture. There is growing concern about the impacts of nutrients and emerging chemical pollutants on aquatic ecosystems and the ecological status of surface waters. Pollution pressures and responses are explored further in Chapter 3.

Over time, RBMPs have included many measures to reduce pressures from changes in the physical features and natural flow of surface waters (EC, 2021h). Restoration measures such as restoring river banks, river remeandering, sediment management and restoring connectivity of rivers and their floodplains can improve the ecological condition of surface water bodies and also contribute to the recovery of habitats and species protected under EU nature policies.

Research has shown that restored rivers in Europe enhanced agricultural production, carbon sequestration and recreation, in addition to increasing flood protection, and yielded a net societal economic benefit over unrestored rivers estimated at EUR 1,400 per hectare per year (Vermaat et al., 2016). Restoration measures take longer to show positive effects on water ecosystems and biodiversity but can result in further improvements in ecological status in the longer term.

Restoration of aquatic ecosystems related to protected habitats and species, to river and floodplain connectivity and restoration of catchment-scale processes including wetlands are examined in more detail in Sections 2.2, 2.3 and 2.4.

The restoration of lakes, estuaries and coastal waters also merits further attention for achieving good ecological status. The benefits of lake restoration measures (see Box 2.2) are to reduce algal blooms, improve water quality, stimulate healthier and more biodiverse water ecosystems and improve human health. Such measures also improve the recreational value of lakes (Juutinen et al., 2022). Lake restoration can contribute to water storage and retention, thereby reducing the impacts of droughts and floods.

All in all, it is key to accompany restoration of aquatic and water-dependent ecosystems with measures to improve surface and groundwater quality, as good water quality is essential for water habitats and species populations (see Chapter 3).

Box 2.2

Case study: restoring Lake Vesijärvi, Finland

Lake Vesijärvi is a large lake (111km^2) in southern Finland and a flagship example of successful lake restoration in Europe. Vesijärvi suffered severe eutrophication in the 1960s due to receiving sewage effluent. A restoration programme began with the diversion of urban wastewater in the mid-1970s, followed by a range of measures to get rid of the algal blooms and thereby speed up the recovery (Salonen et al., 2020).

Most notably, a large-scale biomanipulation was carried out during 1989-1993 with the mass removal of planktivorous and benthivorous fish and stocking of predatory pikeperch, which led to big reductions in both nutrient concentrations and harmful algal blooms of cyanobacteria (Horppila et al., 1998).

The largest basin now achieves good ecological status and actions are ongoing to restore the remaining basins and protect the lake for the future.

The Lake Vesijärvi Foundation was established in 2007 by two municipalities, the City of Lahti, key industries and an association representing businesses in the region, to work together and promote efforts to protect and restore the lake. The foundation combines public and private resources to fund research, maintenance and management efforts. Long-term and extensive monitoring of the lake and its catchment has been critical to guide management decisions at Vesijärvi.

The restoration highlights the need to reduce external loads of nutrients from the catchment as a pre-requisite before measures are applied to tackle internal sources of nutrients from the lake sediments. Often, a combined approach is needed in lake restoration to tackle legacy pollution from the catchment that has accumulated over decades in the lake basin.

In addition, fish biomanipulation contributes to the circular 'blue' economy by using the removed fish in local food production industries (Taipale et al., 2022). Good governance and effective ecosystem monitoring are seen as important to commercial fish removal, to avoid overfishing of target species and sustainably secure the fishery (Tammeorg et al., 2024).

The work at Vesijärvi showcases four key pillars for successful lake restoration (WWQA Ecosystems, 2023):

1. a good scientific understanding of the causes of lake deterioration and effectiveness of restoration measures;
2. effective policy and governance for lake management;
3. public-private finance partnerships to sustain lake monitoring and management programmes over decades;
4. widespread local awareness of the social and economic benefits of restoration.

The restoration of Lake Vesijärvi has increased the economic value of land around the lake as well as its recreational value, stimulating the tourist sector in the local economy and the development of fishing opportunities (Kairesalo and Kuoppamäki, 2004).

Figure 2.3 View over Lake Vesijärvi

2.2 Preserving vulnerable aquatic habitats and species

Due to its ecological approach, the WFD shares many connections with nature conservation (Janauer et al., 2015).

In EU Member States, endangered aquatic and water-dependent habitats and species are protected under the Habitats Directive and the Natura 2000 network. The Habitats Directive aims to protect and restore selected priority habitats and species in the EU to a good conservation status and thus secure their long-term survival across their entire natural range within Europe.

Both the ecological status and the conservation status are important indicators for the protection and restoration of aquatic and water-dependent ecosystems. Whereas ecological status under the WFD describes the general condition of the aquatic environment, conservation status describes the condition of specific protected habitats and species. Measures according to the WFD often take place within Natura 2000 sites and, conversely, conservation measures taken for protected aquatic habitats and species, such as the freshwater pearl mussel, need to be coordinated with RBMPs.

2.2.1 The poor condition of protected habitats and species in Europe

Since early 2000, data reported under the Habitats Directive have indicated that aquatic biodiversity in the EU is declining at an alarming rate and that aquatic and water-dependent habitats are facing an acute crisis. Most of the protected EU aquatic and water-dependent habitats and species have poor or bad conservation status (latest reporting period 2013-2018). Only 17% of EU freshwater habitats have good conservation status, whereas more than three quarters (76%) have poor or bad conservation status (EC, 2022a) (see Box 2.3 and Figure 2.4).

Box 2.3

Freshwater habitats (rivers, lakes, alluvial and riparian) protected by the Habitats Directive

The Habitats Directive (Annex I) protects 32 different habitat types of rivers, lakes alluvial and riparian freshwater ecosystems.

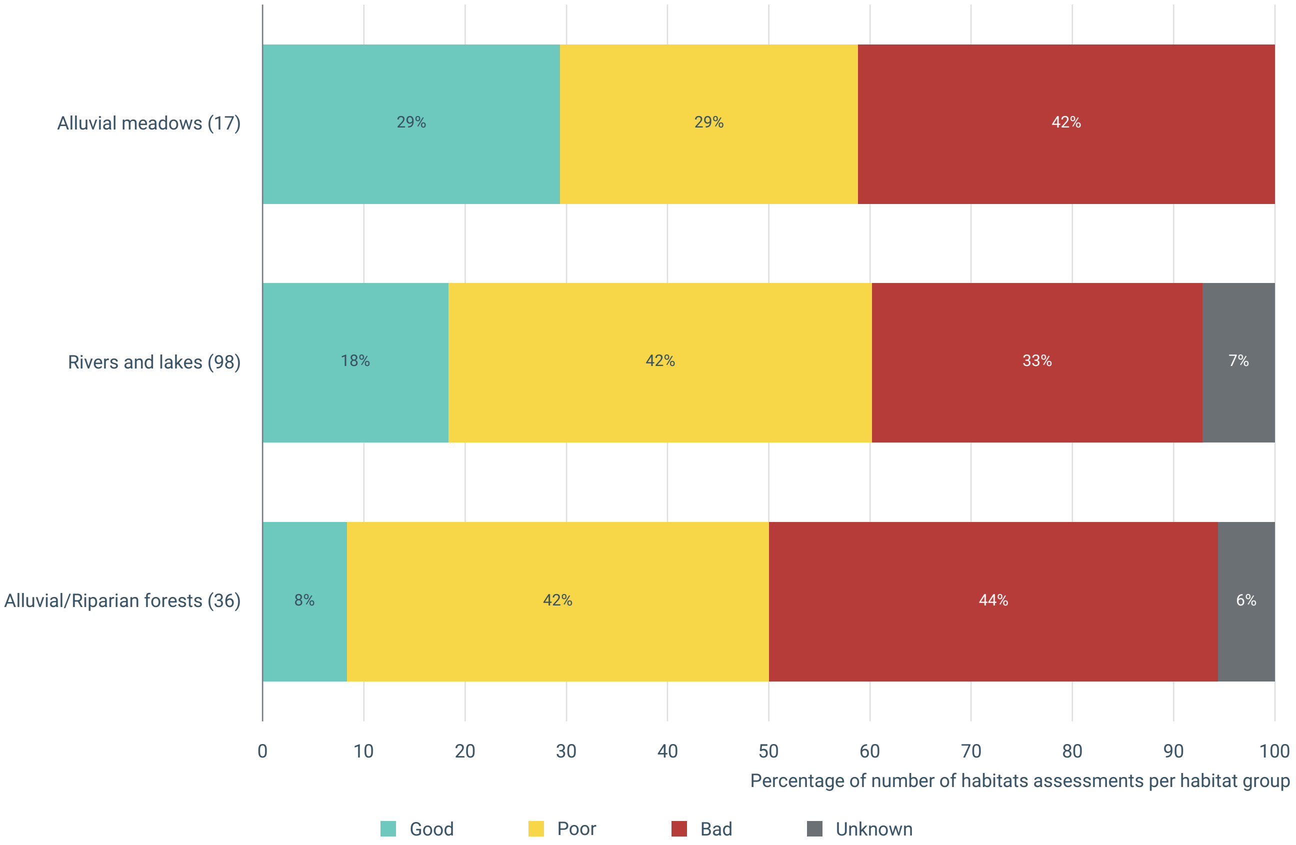
The rivers and lakes habitats include surface standing waters (lakes, ponds and pools, permanent lake ice), surface running waters (springs, upstream tidal and non-tidal rivers including temporary ones) and the littoral zone of inland surface water bodies (various vegetation types in and around freshwater).

Acknowledging that rivers are wider than the channels associated with them, riverbanks and areas next to rivers, which may be covered by water only during floods, are also considered part of the river system. Therefore, freshwater habitats in the Habitats Directive cover alluvial forests and meadows.

Floodplains acting as an interface between the catchment and the river are an important ecological part of the system and its healthy functioning and are therefore also part of the river ecosystem.

Source: EC, 2022a.

Figure 2.4 **Conservation status of freshwater habitats at EU level**



Note: Number of habitat assessments per group is shown in brackets.

Source: EEA, based on data reported by Member States under Article 17 of the Habitats Directive for the period 2013-2018.

Freshwater and marine fish have a very high proportion of their species assessments in poor or bad conservation status (around 80%) under the Habitats Directive, which is higher than any other species group.

Loss of large freshwater fish that are top predators of smaller fish may result in higher biomass of small fish, lower biomass of invertebrates and therefore more algae, impacting the ecological status of water bodies. For amphibians (such as frogs and salamanders), approximately 60% of their species assessments show a poor or bad conservation status (EEA, 2020). Habitat loss is the most common threat to amphibians, followed by disease, while the effects of climate change are emerging as a concerning threat because amphibians are particularly sensitive to changes in their environment (Re:wild et al., 2023). This indicates that the large majority of protected fish and amphibian species in the EU are in danger of becoming locally extinct or are in situations where a change in management is required for them to thrive.

Migratory freshwater fish, such as salmon, sea trout, sturgeon and eel, are particularly affected. Their populations are now at a fraction of their historical abundance, having declined by 93% since 1970 (Deinet et al., 2020) due to river barriers, water pollution, changes in river flows and loss of key habitats.

The most notable iconic European fish facing population collapse is the Beluga sturgeon (*Huso huso*), the largest freshwater fish in the world. Along with five other sturgeon species in the Danube river, Beluga sturgeon numbers have collapsed in recent decades due to overfishing and dams blocking their migration (DDBRA et al., 2020).

Freshwater habitats also host a number of mammals that are protected under the Habitats Directive, such as the Eurasian beaver, the European otter and the European mink. Although the beaver and otter are in good conservation status in most biogeographical regions, the mink is in poor or bad conservation status (EEA and ETC BE, HD Art. 17 web tool); it is one of the most endangered mammals in Europe, with its range reducing by over 97% in the last 150 years due to habitat loss and degradation, overexploitation, illegal hunting and the impact of invasive species (Global Conservation, 2024).

In addition, over 50% of wader and wildfowl bird species in the EU are experiencing population declines and are among the most threatened and fastest declining groups of birds in Europe, due to the degraded quality of their habitats. Waders are usually found in shallow water or along its muddy margins and wildfowl are birds that live close to lakes or rivers, in particular wetlands (EC, 2022f).

2.2.2 Growing threats from pressures, climate change and invasive alien species

Despite the ambitious targets of the Habitats Directive and the EU biodiversity strategy for 2030, and decades of efforts to maintain and restore ecosystems in Natura 2000 sites, protected aquatic habitats and species continue to be affected by the key pressures which impact Europe's surface waters (pollution, physical and hydrological alterations, and invasive non-native species) (EC, 2022a).

In particular, freshwater invasive non-native species have increased seven-fold in number over the last 100 years (Cid and Cardoso, 2013), introduced and spread from hotspots through fishing, aquaculture, inland canals or shipping (for example, via ballast water) and high levels of tourism and recreational activity.

The biodiversity crisis of EU aquatic and water-dependent ecosystems is expected to intensify due to climate change. This is drastically affecting biodiversity by modifying aquatic habitats and putting some habitats at risk of disappearing (intertidal habitats are affected by sea level rise, for example). Climate change alters the geographic distributions and seasonal dynamics of aquatic species.

Scientists have also recognised a discrepancy between the location of areas currently designated as protected and the predicted areas of suitable habitat under climate change. Fostering climate resilience of aquatic habitats within protected areas, restoring stream connectivity among such areas, preserving groundwater flows, and assisted migration to newly suitable protected areas where natural dispersal is not possible are key actions to overcome this potential future conservation gap (Basen et al., 2022).

Due to increases in temperature, climate change also provides opportunities for colonisation by invasive non-native species. As such species are very difficult and expensive to control once they are established in the water environment, management should be focused on measures to prevent establishment that include early detection, rapid response planning and raising public awareness of water users (IPBES, 2023).

2.2.3 *Exploiting synergies of water management and conservation*

There are many examples of synergies between WFD implementation and conservation measures in the water environment across Europe. Protecting aquatic ecosystems requires implementation of river basin management. As such, the WFD and other water legislation already contribute to reducing pollution, abstraction, drainage, barrier construction and flow regulation, but more work is needed to conserve protected aquatic habitats and species. Experience shows that strong, concerted action can reverse declining trends, as seen in the comeback of the salmon on many European rivers (see Box 2.4).

Box 2.4

Case study: successful restoration of salmon population in northern Sweden

Norrbotten County in northern Sweden is often called 'the salmon country' because it is home to the few remaining salmon rivers in the Baltic area. But for many decades, salmon populations have been in decline, almost to the verge of extinction. The main reasons for this in Sweden were hydropower dams, habitat degradation and poor management of fisheries.

However, a salmon rebuilding project in Norrbotten County has returned the fish to local rivers, successfully rebuilding salmon stocks. Key aspects of its success were:

- the high priority given to the project to sustain the regional economy;
- river restoration measures;
- legislative changes on fisheries management at the international level (restriction on salmon fishing in the Baltic);
- poaching control (Interreg Europe, 2022).

Figure 2.5 Fish leaping upstream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Forward-looking solutions to enhance the protection of aquatic habitats and species involve clearer recognition of their specific conservation needs and the main threats they face, both inside and outside Natura 2000 protected areas.

To date, protected areas have often been designated for terrestrial or, more recently, for marine biodiversity, but rarely for freshwater biodiversity (Szabolcs et al., 2022). As a result, the few assessments made of Natura 2000's effectiveness on the conservation of freshwater biodiversity show that current Natura 2000 sites and the management measures applied do not guarantee fewer anthropogenic impacts and higher species richness (Gavioli et al., 2023) and may fail to adequately cover key species in the network of protected areas (Hermoso et al., 2015).

Further management actions to recover freshwater biodiversity should align conservation measures more tightly with water management strategies and target sites at greater risk of biodiversity decline, such as those downstream of urban areas, cropland and dams, while maintaining and strengthening protection of the least impacted systems that are refuges of biodiversity (Haase et al., 2023).

The dynamic nature of water and sediment needs to be recognised and managed in a way that is favourable to aquatic and water-dependent ecosystems. This requires recognising the need to address pressures not only in protected areas but also upstream and downstream, and in the land surrounding protected areas, including the interaction of groundwater flows with freshwater and terrestrial ecosystems.

In particular, protected areas should take into account the key role of small water bodies (8) in preserving freshwater biodiversity and connectivity between freshwater habitats. Taking a landscape approach to restoration that includes wetland conservation, river-floodplain connectivity and surface-groundwater interaction are essential strategies, both for achieving better ecological status of EU surface waters and for the effective conservation of protected species and habitats (see also Sections 2.3 and 2.4).

2.3 Restoring connectivity of rivers and floodplains

Healthy rivers require a high degree of connectivity between river sections and between rivers and their floodplains. Such connectivity supports the complex life cycles of many aquatic species and delivers water to water-dependent ecosystems. A natural flow of water and sediments in rivers supports populations of migratory fish such as salmon and eel with recreational and economic value.

Natural and restored floodplains increase the capacity of ecosystems to provide valuable ecosystem services, such as increased buffer capacity for nutrients and other pollutants, drinking water purification, carbon storage, reduced flood risk (by improving natural water retention in the landscape, soils and groundwater) and recreation opportunities (EEA, 2019).

2.3.1 An important legacy of barriers

At least 1.2 million transversal barriers currently affect river connectivity in the EU, with the highest density of barriers in the heavily modified rivers of central Europe (Belletti et al., 2020).

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(8) Lakes and ponds of less than 0.5km^2 that are not explicitly managed under the WFD.

In 2021, barriers were identified as a significant pressure on 31% of EU river water bodies. Transversal barriers include dams, weirs and sluices used for various purposes, such as hydropower or water storage for drinking water supply, flood protection and irrigation. They profoundly alter rivers' longitudinal continuity, i.e. the upstream and downstream movement of water, species and sediments. Migratory fish species are particularly affected by the fragmentation of their habitats. In some cases, there is even a total change in fish species composition when a river is converted to a lake because of a dam.

In addition, a large number of artificial barriers interrupt lateral river connectivity in the EU. Examples include bank protection works, embankments, levees and flood protection dykes. Such interruptions are often associated with other major modifications, such as river straightening, disconnection of floodplain wetlands and drainage ditches.

To date, an estimated 70-90% of European floodplains have been environmentally degraded (EEA, 2019). In many cases, this degradation has occurred over centuries of urban, agricultural and infrastructure development. Heavily developed and straightened rivers that are decoupled from their floodplains should have more space to permit lateral erosion and to allow the development of vegetation and natural structures along the rivers.

2.3.2 Restoring free-flowing rivers

Given the high degree of river fragmentation in the EU and the urgent need to restore connectivity, the EU biodiversity strategy for 2030 sets a target of restoring at least 25,000km of rivers into free-flowing rivers, through the removal of barriers to longitudinal and lateral river connectivity and the restoration of floodplains (EC, 2021i) (Box 2.5).

Box 2.5

What are free-flowing rivers?

A free-flowing river supports connectivity of water, sediment, nutrients, organic matter and organisms within the river system and with surrounding landscapes in four dimensions:

1. longitudinal (connectivity between up- and downstream);
2. lateral (connectivity to floodplain and riparian areas);
3. vertical (connectivity to groundwater and atmosphere);
4. temporal (connectivity based on seasonality of fluxes).

A free-flowing river is not impaired by artificial barriers and is not disconnected from its floodplain, when one is present (EC, 2022e). Free-flowing rivers help limit and control flooding, carry nutrients and sediments, conserve biodiversity, provide recreational services such as fishing and are often economically important for tourism.

Restoring rivers to a free-flowing state is designed to help achieve WFD objectives, as well as boost broader river restoration efforts for the benefit of habitats and species. Typical measures to restore free-flowing rivers include the removal of barriers, restoring degraded EU floodplains and re-establishing the connectivity of rivers to their floodplain. This includes, for instance, removing dykes, reconnecting the river with its old reaches and giving space to the water body for river remeandering.

Figure 2.6 **A free-flowing river**


© Muhammet Azlak

Several European countries have implemented restoration measures to improve the ecological condition and connectivity of their rivers and floodplains, with substantial benefits achieved in some areas, such as the large rivers Elbe and Isar in Germany WMLM, 2011; Serra-Llobet et al., 2022). In Estonia, the Pärnu River underwent the largest river restoration initiative in this country based on dam removal (see Box 2.6).

Box 2.6

Case Study: restoration of the Pärnu River basin for migratory fish, Estonia

The restoration of the Pärnu River basin, part of the Natura 2000 network, is Estonia's largest river restoration initiative in recent years.

The Pärnu is the country's second longest river and most important salmon river. The restoration project focused on migratory fish and particularly targeted barriers to salmon migration.

Until recently, dams had made about 90% of the suitable habitats and spawning sites in the river basin inaccessible to migratory fish. The first and most significant migration barrier on the river was the Sindi Dam, located 14km from the estuary. In 2015, the Estonian government bought the land and the dam from private owners for EUR 1.3 million and the Sindi Dam was demolished in 2019. Local communities are expected to benefit from the return of the salmon through angling and other nature-based tourism opportunities. The river restoration will also enable swimming, the creation of riverbank pathways and kayaking (Rewilding Europe, 2019).

The project helped restore a historical salmon migration route and riverine habitats in the Pärnu River basin through the removal of two other dams on the Pärnu and five dams on its tributaries. This restoration action was part of a larger EUR 15 million project funded by the EU Cohesion Fund and the Estonian state budget. Overall, 3,300km of interconnected river system, including the Pärnu and its tributaries, were restored and ecological conditions improved. Removing fish barriers has improved the conservation status of 32 species living in the river.

Source: EC, 2024b.

Figure 2.7 **Aerial view of the Sindi Dam before removal**

© Estonian Environment Agency

For an EU-wide assessment of the free-flowing status of rivers, the development of targeted methodologies and detailed inventories of artificial barriers are needed. However, it is expected that only a few EU rivers are at present free flowing, as required by the EU biodiversity strategy for 2030 and the Nature Restoration Law. Rivers with no or very few transversal barriers can still be found in the Balkans, the Baltic states and parts of Scandinavia and southern Europe (Belletti et al., 2020). Recognising the value of preserving the free-flowing nature of some of the last such rivers in Europe, some Balkan countries are starting to protect their natural heritage, such as the Vjosa River between Albania and Greece (IUCN, 2023).

River and floodplain restoration measures are complex to implement as they can restrain or even prevent the continuation of certain land and water uses. They require careful dialogue with multiple users of rivers and floodplains, such as farmers, energy companies and municipalities, plus an assessment of trade-offs when deciding which barrier removals to prioritise. A significant number of river barriers could be removed as they are no longer useful for their original purpose (obsolete barriers). However, they may be part of the cultural heritage of certain regions, such as historical water mills dating back centuries. Human health aspects must also be considered, due to the risk of restored floodplains generating more habitats for disease vectors, e.g. mosquitoes (EEA, 2024d).

Across Europe, 1,152 transversal river barriers were removed between 2020 and 2023. In 2023 alone, at least 487 barriers were removed in 15 countries, showing a 50% increase compared to the number of river barriers removed in 2022. Most of the removed barriers were weirs and culverts, with the largest numbers removed in France, Spain, Sweden and Denmark (Mouchlianitis, 2024).

At the same time, there are plans to build new river barriers that will increase river fragmentation. With climate change, periods of drought are becoming more extreme and widespread; the construction of more barriers to store water in reservoirs is being considered as a potential coping strategy. Climate change will further increase flood risk in flood-prone areas in the EU, which may lead to the construction of more flood protection barriers. Further, almost 9,000 new barriers and dams for hydropower production are planned or already in construction in parts of Europe, of which the large majority are small hydropower plants. Half of these new barriers for hydropower are in the Balkans and eastern Mediterranean (WWF et al., 2019). The planning and construction of new hydropower plants is driven by policies such as the revised Renewable Energy Directive which aims to increase the share of energy from renewable sources (to a minimum of 42.5% by 2030).

2.4 Restoring at a landscape scale, including wetlands

Restoration of aquatic ecosystems in the EU takes place in landscapes with a long history of human intervention and intensive land uses. Most restoration measures focus on single water bodies or groups of water bodies, aiming to restore ecosystem functions at a limited scale. But restoration at the catchment scale, with a landscape perspective, is emerging as a key tool for climate change mitigation and adaptation and for enhancing ecosystem services such as improved natural water retention, water quality and biodiversity.

Restoring the functionality of water catchments and resilient landscapes involves restoring natural hydrological processes and morphological patterns to replenish groundwater and surface water, reduce run-off and soil erosion, and build a sustainable clean water supply. This landscape approach to restoration involves forestry and agricultural practices that consider water availability and hydrological flows, as well as the strategic restoration of streams, floodplains, wetlands and ponds to re-establish natural hydrological and morphological processes at the catchment scale over time (Box 2.7).

Box 2.7

Catchment-scale restoration of Eddleston Water, Scotland

The Eddleston Water project, now in its 13th year, is a long-term pilot set up by the Scottish government to study the effect of catchment-scale restoration on flood risk reduction by temporarily storing water and slowing down water flow and through habitat improvement. The project aims to restore lost hydrological and ecological processes within both river reaches and the broader landscape.

A range of restoration measures have now been implemented in the 69km^2 catchment, including 3.5km of channel remeandering, the removal of embankments on the floodplain, the creation of 38 ponds and wetland storage areas, the installation of 116 engineered log structures in the headwaters and the planting of more than 330,000 trees across the catchment.

The pilot project underwent detailed hydrological and ecological monitoring and high-resolution modelling before and after restoration. Empirical results show that the restoration has reduced flood risk by 30% in the upper catchment and by 8% in the lower catchment for a 2-year return flood.

It is estimated that the restoration implemented so far results in a positive net present value of nearly GBP 1 million of damage avoided. Although natural water retention alone cannot fully protect the downstream town of Peebles, the project shows that the restoration complements engineered flood protection while contributing to mitigating future climate-induced flood risk.

The impact of measures extends beyond flood risk reduction. Restoration at both the riparian and landscape scales has increased the availability of habitats for various freshwater, riparian and terrestrial species.

The project also provides an estimated GBP 4 million in co-benefits to society. These include water quality improvements, carbon management, recreational opportunities, biodiversity enhancement and support for fisheries.

The project estimated the benefits of expanding restoration further to reduce future flood risk. An enhanced restoration scenario in the catchment — involving 25% more afforestation, doubling the length of channel work and increasing the number of flow restrictors five-fold, log jams and run-off attenuation features and ponds — could deliver an additional GBP 2.9 million of avoided flood damage and GBP 18 million in co-benefits.

The project is now examining further flood damage reduction, climate change resilience and the potential to attract private finance to pay for catchment-wide restoration measures.

Sources: Black et al., 2021; Spray et al., 2022.

Figure 2.8 **Eddlestone Water restoration measures**

Pond creation

Floodplain restoration

Reforestation

Log jam

2.4.1 A closer look at wetlands and their condition in the water landscape

Wetlands and peatlands provide multiple, critical ecosystem services and must be protected. They can act as sponges in the landscape during wet periods, storing water and giving natural aquifers time to recharge, regulating the water cycle and acting as a damper against droughts, floods, heatwaves and wildfires (Trémolet et al., 2019). Wetlands are also biodiversity hotspots for many endemic species of fauna and flora, holding up to 40% of species globally (UNFCC, 2018).

Wetlands can act as riparian buffers between polluting land uses such as agriculture and freshwater ecosystems, helping to remove nitrogen, phosphorus and pesticides, as well as reduce sediment erosion and delivery before entering water bodies (Lange et al., 2021).

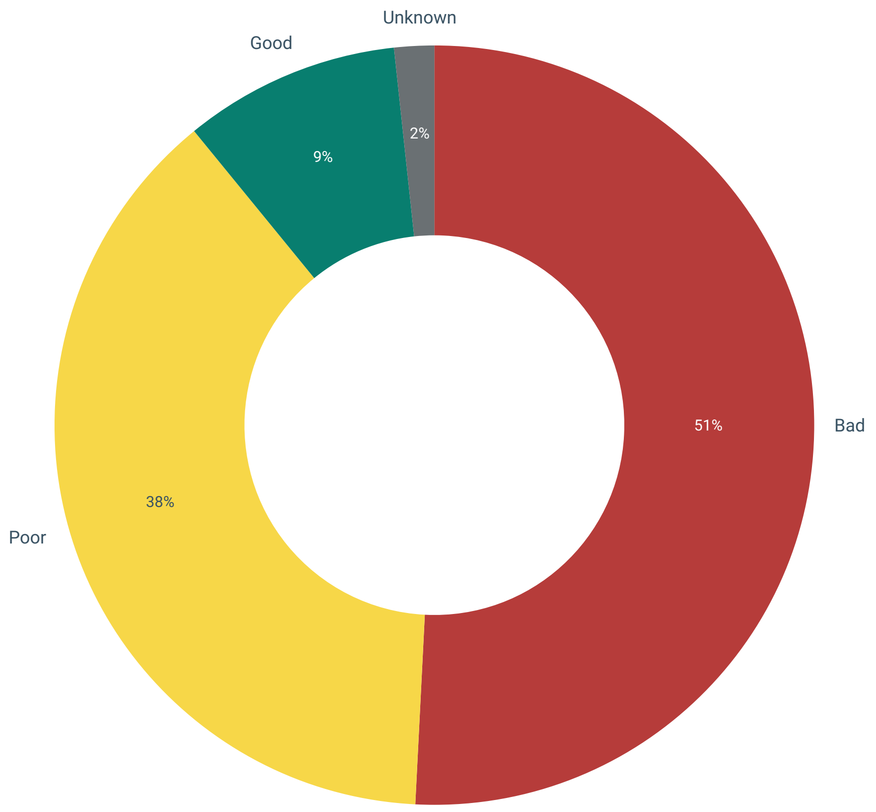
Further, carbon-rich wetland ecosystems (peatlands, coastal wetlands, halophytic (salt) habitats, wet heaths and wet forests) also hold great potential to safeguard carbon stocks and increase carbon sequestration (Malak et al., 2021; EEA, 2022b).

Despite their crucial role in providing key ecosystem services for human well-being, about 80% of wetland areas (such as large bogs and marshes, small or shallow lakes) in Europe have been lost in the past millennium and the trend continues, albeit more slowly (Verhoeven, 2014).

Certain European countries have some of the highest percentages of wetland loss globally. For instance, since 1700 Ireland has lost more than 90% of its wetlands, Germany, Lithuania and Hungary more than 80%, and the UK, Netherlands and Italy have lost more than 75% (Fluet-Chouinard et al., 2023). And wetland loss has increased the vulnerability of many water catchments to negative impacts.

The vast majority of protected wetland habitats in Europe have poor or bad conservation status (89% of habitat assessments at EU level, Figure 2.9). The outlook remains negative, with wetlands still suffering from multiple pressures (including land drainage, habitat conversion and agricultural intensification) (EC, 2022a). Moreover, climate change-related pressures such as changes in precipitation, rising temperatures and rising sea levels are exacerbating the condition and biodiversity of many wetland habitats and consequently compromising their long-term ecological functioning, which, in turn, will impact the climate system (Maes et al., 2020).

Figure 2.9 **EU wetlands: conservation status, importance for biodiversity and the carbon cycle**



Ecological importance of wetlands	Importance of wetlands in the carbon cycle
Host up to 40% of global biodiversity	Restoration of peatland and wetlands to good condition could achieve additional net greenhouse gas mitigation benefits: • 7.8-22.8Mt CO_2eq/year to 2030 • 26.7-62.9Mt CO_2eq/year to 2050

Notes: EU wetlands cover the following habitat types: coastal and salt habitats (11 types), wet heath and peat grassland (3 types), mires, bogs and fens (12 types) and wet forests (2 types).
Mt CO_2e, million tonnes of CO_2 equivalent.

Source: EEA, based on data reported by Member States under Article 17 of the Habitats Directive for the period 2013-2018.

2.4.2 Restoring wetlands and peatlands

The EU biodiversity strategy for 2030 recognises the importance of strengthening the protection of wetlands and peatlands. It aims to strictly protect significant areas of carbon-rich ecosystems. The Nature Restoration Law sets targets to protect and restore wetland habitats and species of conservation value and to restore drained peatlands under agricultural use by 2030, and more ambitious targets in terms of the area to be restored by 2040 and by 2050. Meeting these targets will help increase biodiversity and reduce greenhouse gas emissions.

As shown in Figure 2.9, the restoration of peatland and wetland habitats to good condition could achieve additional net greenhouse gas (GHG) mitigation benefits between 7.8 and 22.8 million tonnes of CO_2 equivalent (Mt CO_2eq) per year to 2030 and 26.7-62.9Mt CO_2eq/year to 2050 (EC, 2021a). Restored wetlands emit less CO_2 and rewetting 35% of the total area of peatlands used for agriculture in the EU could reduce their emissions by 25% (around 45Mt CO_2eq) (Greifswald Mire Centre and Wetlands International, 2022). At the same time, rewetting drained peatlands can lead to increased methane emissions (Couwenberg and Jurasinski, 2022) but increased emissions can be prevented and minimised with appropriate management techniques (Evans and Gauci, 2023).

To date, 41% of wetland area in the EU are protected under the Natura 2000 network (Maes et al., 2020). Further significant efforts have been made over the last decades to preserve and restore wetlands and peatlands under the LIFE programme and in the context of wetland conservation programmes at the national level.

In particular, the success of restoration and conservation initiatives for mires habitats developed at a local scale in the last 30 years — mainly in northern European countries such as Sweden, Finland and Scotland — have effectively contributed to reducing the loss of wetlands in Europe (Maes et al., 2020). Relevant measures have included the restoration of raised bogs and blanket peat bogs, halting commercial forestry to restore the original habitats, removing trees, blocking drainage and restoring natural flow conditions in surface waters and groundwater.

Despite these efforts, however, tangible improvements in the condition of wetlands and the re-establishment of their functions are far from being met (Maes et al., 2020). Successful restoration of degraded wetlands needs to account for trade-offs and minimise potential negative consequences on sectors and users most affected, in particular farming, forestry, fisheries and other economic activities of local communities. Win-win wetland restoration measures should ensure that benefits are distributed across multiple sectors of society, for instance, nature tourism depending on the recreational values of preserved and restored wetlands.

In the case of peatlands, low-input paludiculture is considered a win-win option for the future agricultural use of peatlands. Paludiculture is the practice of farming on wet peatlands and can include cultivation of various types of reeds, certain forms of timber, blueberry and cranberry cultivation, sphagnum farming and grazing with water buffalo. It allows productive land use under conditions that maintain the peat body, sustain peatland ecosystem services and encourage carbon accumulation.

This chapter has considered the many challenges facing biodiversity in Europe's freshwater ecosystems. Chapter 3 focuses on pollution, a pressure that directly impacts species and natural communities.

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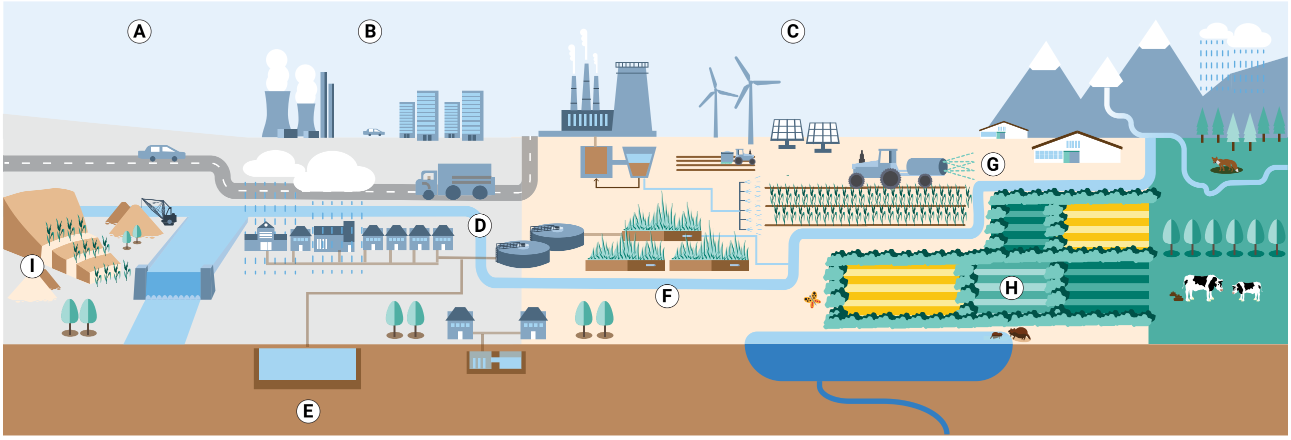
3 Achieving the zero pollution ambition for water

The zero pollution action plan aims to reduce pollution in air, water and soil to levels no longer considered harmful to health and natural ecosystems by 2050, with the ambition to reduce nutrient losses and use of chemical pesticides by 50% by 2030. Given current pollution trends, reaching these goals will be challenging.

Reporting of water pollution under the Water Framework Directive is extensive, recognising the impacts on biodiversity (see Chapter 2) and also on human health where pollutants may harm people, such as through food. Impacts of climate change affecting the quality of water resources are causing increasing concern, with lower volumes of water leading to increased pollutant concentration and salinisation of groundwater (see Chapter 4).

Further actions are needed to transform the European economy into a circular model for chemicals, supported by strong consumer demand for sustainable products (Figure 3.1).

Figure 3.1 Addressing pollution pressures on European waters



Ⓐ Prevent pollution: use environmentally-friendly alternatives to chemicals

Ⓑ Reduce harmful emissions to air

Ⓒ Use cleaner energy sources

Ⓓ Ensure urban waste water is treated effectively, using treatment plants or systems for non-connected dwellings

Ⓔ Storage and treatment of storm waters to reduce overflows

Ⓕ Use nature based solutions, e.g. reedbeds for water treatment

Ⓖ Balance nutrients and pesticides with environmental protection

Ⓗ Shift to organic and sustainable farming

Ⓘ Treat mine wastes and remediate discharges from abandoned mines and contaminated land

3.1 Europe's water quality

Under the WFD, EU Member States are required to preserve and restore good water quality so that European waters are free from excessive nutrient pollution and harmful chemical substances. To monitor these objectives, chemical status is assessed in both surface and groundwaters, while ecological status also includes the assessment of nutrients and chemicals as physico-chemical quality elements and river basin specific pollutants (RBSPs).

Once released into the aquatic environment, pollutants can be difficult to remove. Both nutrients and persistent substances can be transported downstream across boundaries and into the coastal and marine environment. For this reason, the WFD emphasises an integrated and holistic approach to water management, taking into account the entire river basin or catchment area from its source to its outlet into the sea.

In 2021, 29% of surface water bodies achieved good chemical status (see Map 3.1, left). This is a slight reduction compared to 2015, potentially due to a combination of factors including new and revised quality standards, changes in methodology and chemical pressures. Mercury and brominated flame retardants are the main cause of failure of chemical status, while 18% of surface waters failed ecological status for nutrients and 7% for RBSPs.

Priority substances under the WFD are those which present a significant risk to or via the aquatic environment. Standards protect the most sensitive species, which range from simple plants to more complex species, including humans. Exceeding one threshold leads to failure of chemical status in the surface water body.

A subset of the priority substances, including mercury and brominated flame retardants, are identified as ubiquitous, persistent, bioaccumulative and toxic substances (uPBTs) (9) and are found in many water bodies where they are likely to remain. They frequently cause water bodies to fail to achieve good chemical status. Once they are in the water, little can be done to remediate these chemicals, masking improvements in chemical status achieved for other priority substances (EC, 2022b). Without the uPBTs, good chemical status was achieved in 80% of surface waters in 2021 (see Map 3.1, right).

Knowledge about chemical status in surface waters has slightly improved, with 14% in unknown status in 2021, while 18% were unknown in 2015.

Overall, 77% of groundwater body areas were in good chemical status in 2021 (Map 3.2), similar to 2015. Nitrates and pesticides are the main cause of failure to achieve good chemical status. Groundwater is a valuable natural resource and, as such, should be protected from deterioration and chemical pollution, as set under the Groundwater Directive (EU, 2006b). Groundwater provides a major source of drinking water for many EU citizens and is the base flow for rivers and lakes. Pollutants can infiltrate groundwater and feed back into surface water and wetlands. Keeping groundwater free of pollution is therefore vital for humans and river and wetland ecosystems.

Once pollutants are in groundwater, recovery can take years or even many decades because of residence times and the slow degradation of pollutants (Box 3.1). Besides, as groundwater discharges to surface water (rivers and lakes), contaminants present in one compartment can be transferred to the other. We need a better understanding of the interactions between surface water and groundwater and their implications on contaminant transport.

No clear improvement in the overall chemical status in ground waters is evident over time, while a slight decrease occurs in surface waters. Indeed, more comprehensive monitoring, including increasing the range of chemicals as RBSPs or groundwater pollutants measured, can increase the number of harmful substances found and lead to increased failure to achieve good status. For example, the Netherlands has identified many RBSPs and reported failure of at least one in most surface water bodies, leading to an overall failure of ecological status.

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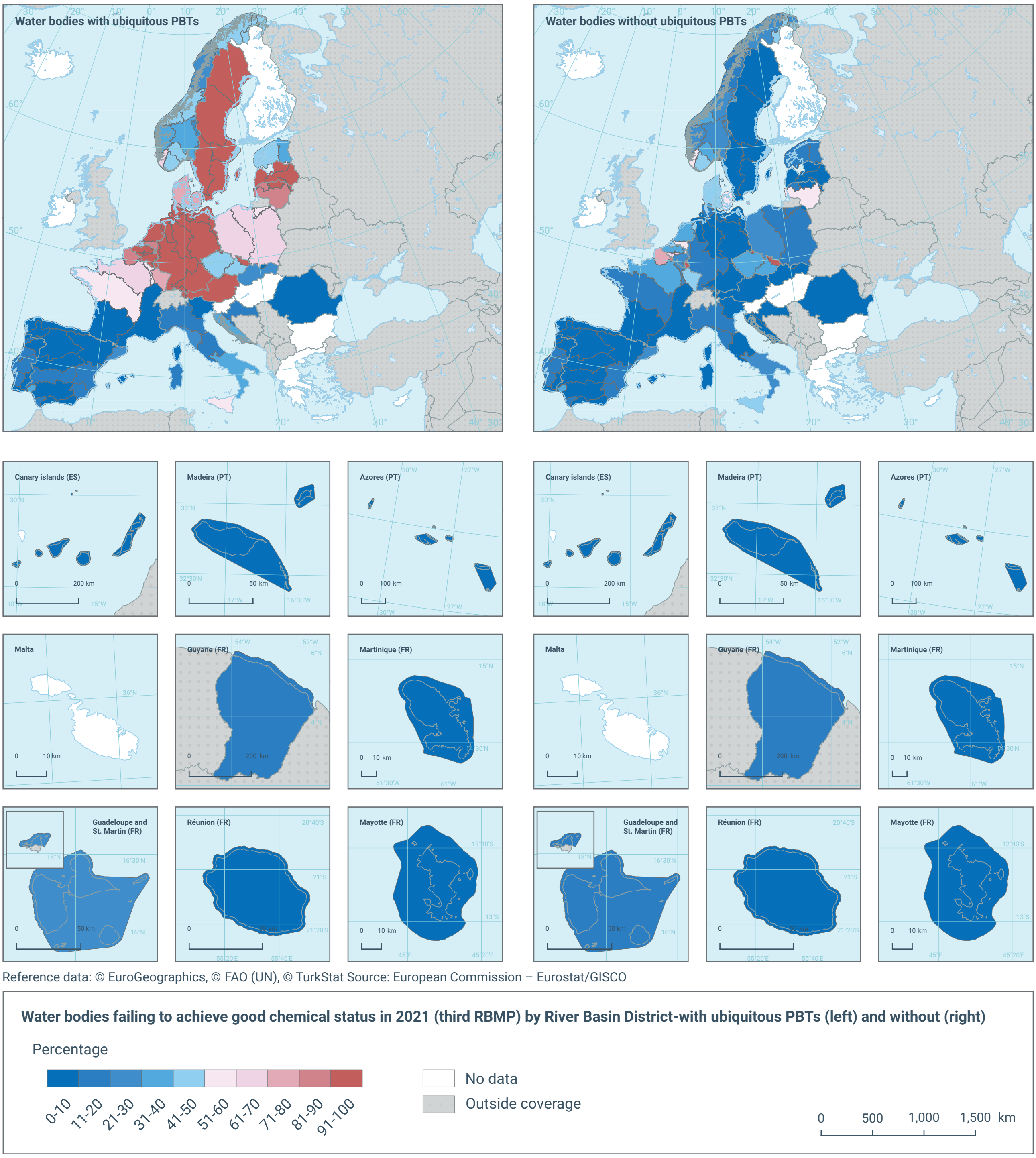
(9) uPBTs (EC, 2013) can be found for years in the aquatic environment at levels posing a significant risk, even if extensive measures to reduce or eliminate emissions of such substances have already been taken.

Map 3.1 **Water bodies failing to achieve good chemical status in 2021 (third RBMP) by river basin district – with ubiquitous PBTs (left) and without (right)**

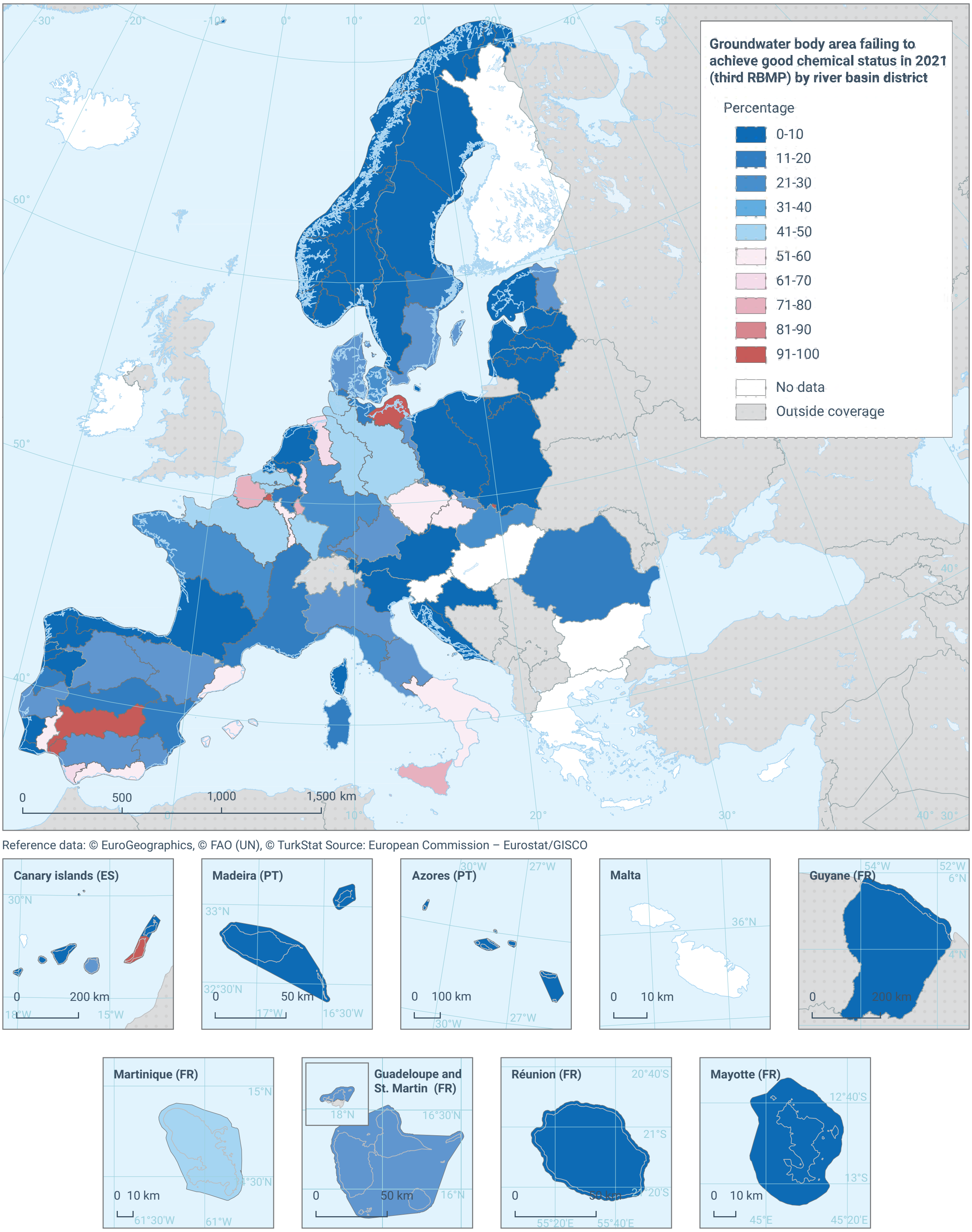


Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

Note: Maps based on WISE-SoW database, including data from 19 Member States plus Norway.

Source: https://water.europa.eu/freshwater/europe-freshwater/water-framework-directive/surface-water-chemical-status

Map 3.2 Groundwater body area failing to achieve good chemical status in 2021 (third RBMP) by river basin district



Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

Note: Map based on the WISE-SoW database, including data from 19 Member States plus Norway.

Source: https://water.europa.eu/freshwater/europe-freshwater/water-framework-directive/groundwater-bodies-chemical-status

3.1.1 Nutrients and oxygen-consuming substances

Despite decades of legislation and the zero pollution target to reduce nutrient losses by 50%, high concentrations of nitrogen and phosphorus, and contamination by organic substances from manure and sewage, continue to have serious ecological effects in Europe. These include toxic algal blooms and oxygen depletion, leading to fish die-off and loss of other freshwater fauna.

In 2021, 18% of surface waters failed for nutrients and 10% for oxygen consuming substances. Under the Nitrates Directive, 50% of all monitoring sites in surface waters are still classified as eutrophic or could become eutrophic. Although nutrient conditions have improved in recent decades, thanks to measures on urban wastewater treatment, detergents and agricultural inputs, recent years have seen a tendency for concentrations to level off (EEA, 2023e).

High nitrogen concentrations have also been identified in the coastal areas of the North Sea and the Baltic Sea (EEA, 2024b). If ambitious efforts were made to address agricultural practices, atmospheric emissions and urban wastewater treatment, modelling suggests that it would be possible to reduce nitrogen inputs to marine ecosystems by 32% and phosphorus inputs by 17% (JRC, 2022). Even in this scenario, where all measures are implemented, the zero pollution target of 50% reduction would only be achieved in 4 in 10 marine regions for nitrogen and 2 out of 10 for phosphorus (JRC, 2022).

In groundwater, nitrates are reported as affecting 14% of groundwater area. Nitrate concentrations reported under the Nitrates Directive show that the quality standard of 50mg/l is exceeded in 14% of the groundwater monitoring sites across Europe (EC, 2021g). The average nitrate concentration in EU groundwaters has not changed significantly since 2000 (EEA, 2023d).

The vast majority of nutrients reaching freshwaters in the EU are from agriculture through diffuse leaching of nitrogen and erosion of phosphorus attached to soil particles. Agriculture releases more than four times the amount of nitrogen released by wastewater and more than twice the amount of phosphorus (JRC, 2022).

3.1.2 Pesticides

Pesticides encompass plant protection products and biocides (10). In the context of this chapter, the term 'pesticide' mainly refers to substances used as herbicides, fungicides or insecticides in agriculture. Pesticides are of high concern in many Member States (Box 3.1).

Reducing the use and risk presented by chemical pesticides by 50% is a target under the zero pollution ambition (EC, 2021c).

Pesticides mainly enter freshwaters after application in the field, through surface run-off after rainfall, aerial drift and leaching into soils and groundwater. They can also enter via discharges from urban wastewater treatment, following inputs from gardens and municipal use. There is increasing evidence showing links between pesticide exposure in freshwaters and population declines of various species, biodiversity loss, ecosystem function disruptions and chronic diseases in humans (e.g. Liess et al., 2021; EEA, 2023c). Use of pesticides ultimately causes a risk to food security due to increased pesticide-resistant pests and diseases and large-scale loss of pollinators (EEA, 2023c; EFSA et al., 2020).

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(10) Pesticides encompass plant protection products designed to protect crops or desirable or useful plants from pests and diseases (EU 1107/2009) and biocides used 'for the control of organisms that are harmful to human or animal health and for the control of organisms that cause damage to natural or manufactured material' (BPR EU 528/2012).

Few surface waters fail to achieve good chemical status due to pesticides (EEA, 2018a), but 10% of groundwater body area was affected by them in 2021.

Heptachlor, a highly persistent insecticide, non-authorised since the 1990s, was the main pesticide causing failure in EU surface waters in 2021 (2% of surface water bodies). Failure caused by older pesticides such as isoproturon and diuron tended to reduce between 2015 and 2021, likely as a consequence of restrictions on their use. Pesticides newly added to the list of priority substances, such as the insecticides cypermethrin and dichlorvos, lead to a comparatively higher number of water bodies failing to achieve good status, although still limited (below 1%).

The difference between limited failure owing to pesticides in surface water and the widespread concern over their effect partly owes to the limited number (20) of mostly old and heavily restricted pesticides included in surface water chemical status, and partly to the selection of sampling sites from larger rivers, which overlooks contamination from agricultural pesticides found mainly in smaller rivers and streams. Timing of sample taking may also play a part: pesticides used on a crop can have a short-term acute effect on surface waters, which is missed in monthly or longer sampling, while, in groundwaters, transport and dilution are much slower (Weisner et al., 2022).

Both pesticides themselves and their degradation products may be of concern. AMPA, the main metabolite of the herbicide glyphosate, causes more failures than glyphosate itself (both substances are monitored as RBSPs by two countries). So-called non-relevant metabolites of plant protection products, which are breakdown products of lower toxicity than the parent compound, are a particular risk to groundwater quality (EC, 2022b). Non-relevant metabolites of pesticides require more attention in monitoring and regulation in groundwater and drinking water (see also Box 3.1).

Focusing on concentration data reported to the EEA, one or more pesticides was detected above its effect threshold at 10% to 25% of all surface water monitoring sites in each year of assessment (2013-2021), while exceedances of one or more pesticides were detected at between 4% and 11% of groundwater monitoring sites (EEA, 2024c). New pesticides on the market tend to show more efficacy and, conversely, more toxicity to wildlife (Schulz et al., 2021).

Current assessment of water quality does not account for potential mixture toxicity effects when pesticides and other substances are present in a water body concurrently (see Section 3.3). The proposed revision of the Environmental Quality Standards Directive would include a total pesticide standard for surface waters and introduce effect-based monitoring for estrogenic hormones (EC, 2022b), paving the way for such monitoring to be used for other groups of substances in future.

3.1.3 Ubiquitous, persistent, bioaccumulative and toxic priority substances – uPBTs

Some priority substances such as mercury, polycyclic aromatic hydrocarbons (PAHs), brominated flame retardants (BFRs) and perfluorooctane sulfonic acid (PFOS) are particularly difficult to address once released into the aquatic environment. Due to their widespread use and chemical behaviour, they can be found for decades at levels posing a significant risk, even if extensive measures to reduce or eliminate emissions of such substances have already been taken (EU, 2013).

Mercury and PAHs mainly enter the aquatic environment following unintentional atmospheric emissions resulting from combustion. Concentrations in water in part arise from background concentrations, being naturally occurring substances and with possible historic pollution. However, mercury can also enter surface waters through atmospheric

Box 3.1

Drinking water protection

Contaminated raw water needs additional treatment to reduce unsafe levels of substances such as nutrients, pathogens, pesticides, nitrates and metals before it can be supplied as drinking water.

Where treatment or recovery is not possible, sources may have to be abandoned, which can jeopardise the supply of drinking water. This is a particular concern for groundwater, a major source of drinking water. Once polluted, aquifers can take decades to recover.

Since 1980, the EU has set minimum requirements for nutrients and chemicals in drinking water through its Drinking Water Directive. The latest revision in 2020 reinforces protection standards and broadens the scope of the directive to include consideration of pesticides and emerging pollutants such as PFAS, endocrine-disrupting compounds such as nonylphenol and beta-oestradiol, and microplastics (EU, 2020a). In particular, the revision considers the emerging concern for 'non-relevant metabolites', providing the possibility to reduce the risk at its source and to prohibit pesticides in vulnerable areas.

Pesticides in drinking water are becoming a major concern for many Member States. Several national monitoring studies have recently detected pesticides in drinking water.

For example, seven recently approved pesticides not part of routine monitoring exceeded the quality standard of Dutch drinking water (Sjerps et al., 2019). In 2021, an Irish study estimated that 4.5% of drinking water supplies were above the quality standard (EPA, 2021). Up to 41% of Danish households were potentially exposed to pesticides in drinking water between 2015 and 2019 (Voutchkova et al., 2021). In Germany, certain pesticides were detected in 60% of measurements, although only a few are part of the monitoring (LAWA, 2019).

Aside from pesticides, other substances may threaten the quality of our drinking water. This includes persistent, mobile chemicals in the aquatic environment, such as PFAS, certain pharmaceuticals or very soluble substances like caffeine or trifluoracetic acid, which can breach natural and artificial barriers (filters) and migrate unhindered into our groundwater reserves. They do not adsorb to any substrate and make water treatment difficult and expensive.

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deposition of emissions from the burning of fossil fuels (e.g. coal). As an example, in Ireland, the combined emission from solid waste disposal on land and waste incineration accounted for a 10.4% share of total emissions (Hyde et al., 2023), advocating for the use of appropriate waste management practices. Overall, atmospheric deposition contributes to widespread mercury contamination. 49% of surface waters are affected by mercury. Other inorganic compounds such as cadmium, lead and nickel contribute to impairing the quality of European water (1% of surface waters).

PAHs can enter surface waters through atmospheric deposition, surface run-off or direct discharge, following the burning of materials such as wood, coal, oil or plastics. Many PAHs are persistent, accumulate in food webs and are also carcinogenic, mutagenic and toxic to reproduction for humans and animals. Benzo(a)pyrene and fluoranthene are the main PAHs causing failure to achieve good status.

BFRs and PFOS are internationally recognised as persistent organic pollutants (EU, 2019). Their manufacture and use have ceased, so ongoing releases are due to their persistence and presence in existing products. Knowledge about emissions and pathways to water is relatively poor, hampering efforts to reduce pollution.

- BFRs cause widespread failure to achieve good chemical status in surface waters, with 49% of surface waters failing for this pollutant. They were added to many products as flame retardants to improve safety, such as plastics, textiles and electronic equipment. The standard for BFRs under the WFD is set to protect human health from these pollutants in fish (11).

- PFOS belongs to the large group of PFAS, which are used, for example, in cooking utensils, clothing and furniture, fire-fighting foam and personal care products (see Section 3.3). PFOS has been reported in the third RBMPs for the first time, with 2% of surface waters failing for this substance. The revised Drinking Water Directive (EU, 2020a), in effect since January 2021, establishes limits for 20 individual PFAS and limits for total PFAS concentration.

3.1.4 Climate change

Climate change is causing increasing concern with regard to water quality. More frequent droughts can indirectly alter water quality when low flow in rivers leads to increased pollutant concentrations, or in lakes by decreasing the water level via increasing evaporation and lower river inflows.

Groundwater quality can be affected by climate change through interdependencies between pollution and over-abstraction. For example, if an aquifer is over-abstracted, the concentrations of nutrients and chemicals may increase because pollutants will be less diluted. Over-abstraction in water-stressed areas can also cause groundwater pollution if saline or polluted waters are drawn into the aquifer (EEA, 2022d).

More frequent extreme rain events can lead to increased nutrient run-off to rivers and lakes from agricultural areas and urban wastewater overflows. Urban wastewater overflow due to heavy rainfall can result in temporary hazardous conditions for bathers due to the presence of *Escherichia coli* and enterococci (EEA, 2022a).

Heavy rain events can also cause drastic erosion of phosphorus-rich agricultural soils and loss of manure from animal husbandry, resulting in additional phosphorus inputs into surface waters. Increasing nutrient concentrations can, in turn, stimulate toxic algal blooms, which are harmful to both other aquatic organisms and bathers. Such blooms

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(11) The marked increase in water bodies failing for this substance in comparison to the second RBMPs owes to a change from measuring them in water to fish.

contribute to reduced oxygen concentration in water owing to bacterial degradation of the algal biomass after bloom collapse. Reduced oxygen concentration also results from urban wastewater discharges and higher water temperatures.

Low flow due to drought combined with nutrient and salt pollution unexpectedly caused anoxia and a toxic algal bloom, leading to an ecological catastrophe with massive fish die-off in the Oder River in 2022 (Box 3.2). The incident highlights how climate change-related factors can exacerbate the effects of pollution on sensitive habitats such as rivers and their diverse aquatic life. This underlines the importance of integrated measures to adapt to climate change in combination with other goals, like reducing pollution.

Box 3.2

Catastrophic fish die-off in the Oder River

In August 2022, a catastrophic fish die-off occurred in the Oder River (JRC, 2023a), with fish mortality recently estimated at 1,025 tonnes (Szlauer-Łukaszewska et al., 2024). Other aquatic organisms such as snails, crayfish and mussels also died.

Overall, it had an ecological impact on more than 500km of the river. The mass mortality of fish and other aquatic fauna was caused by an algal bloom of the harmful species *Prymnesium parvum*, typically adapted to brackish waters. This species produces toxins deadly to fish and other aquatic organisms.

The algal bloom was mainly caused by salt pollution discharged from salt mines combined with nutrient pollution (especially phosphorus and nitrogen) from urban wastewater. Moreover, drought and low flow together with high water temperature were important components that additionally favoured the bloom. Similar blooms may occur in future, as observed in other rivers and lakes worldwide.

Following this event, experts stressed the importance of developing adaptive river basin management practices to allow for climate change impacts. Other recommendations included improving transboundary monitoring, communication and risk management, as well as strengthening enforcement to prevent future ecological disasters in the Oder River and other European waters (Schulte et al., 2022; JRC, 2023a).

Figure 3.2 The Oder River catastrophe, 2022

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3.2 Addressing the main sources of pollution

The main sources of nutrient and organic pollution are agriculture and urban wastewater, sewage from non-connected dwellings, animal manure and farm and food-processing wastes. For chemicals, the major remaining pathway is for diffuse emissions such as atmospheric releases from energy production, which return to land and water far from the source (e.g. mercury and PAHs). Those chemicals reaching the water environment through direct discharges, urban wastewater and run-off can arise from emissions and losses across their entire life cycle, including industrial processes, consumer products and disposal.

3.2.1 Agriculture as a major source of pollution to surface and groundwaters

Diffuse pollution pressures from agriculture affect 32% of groundwaters and 29% of surface waters. Groundwater pollution from agriculture leading to poor chemical status is particularly widespread, especially in western and central Europe (Map 3.3). The main diffuse pollutants from agriculture affecting water are nutrients and pesticides.

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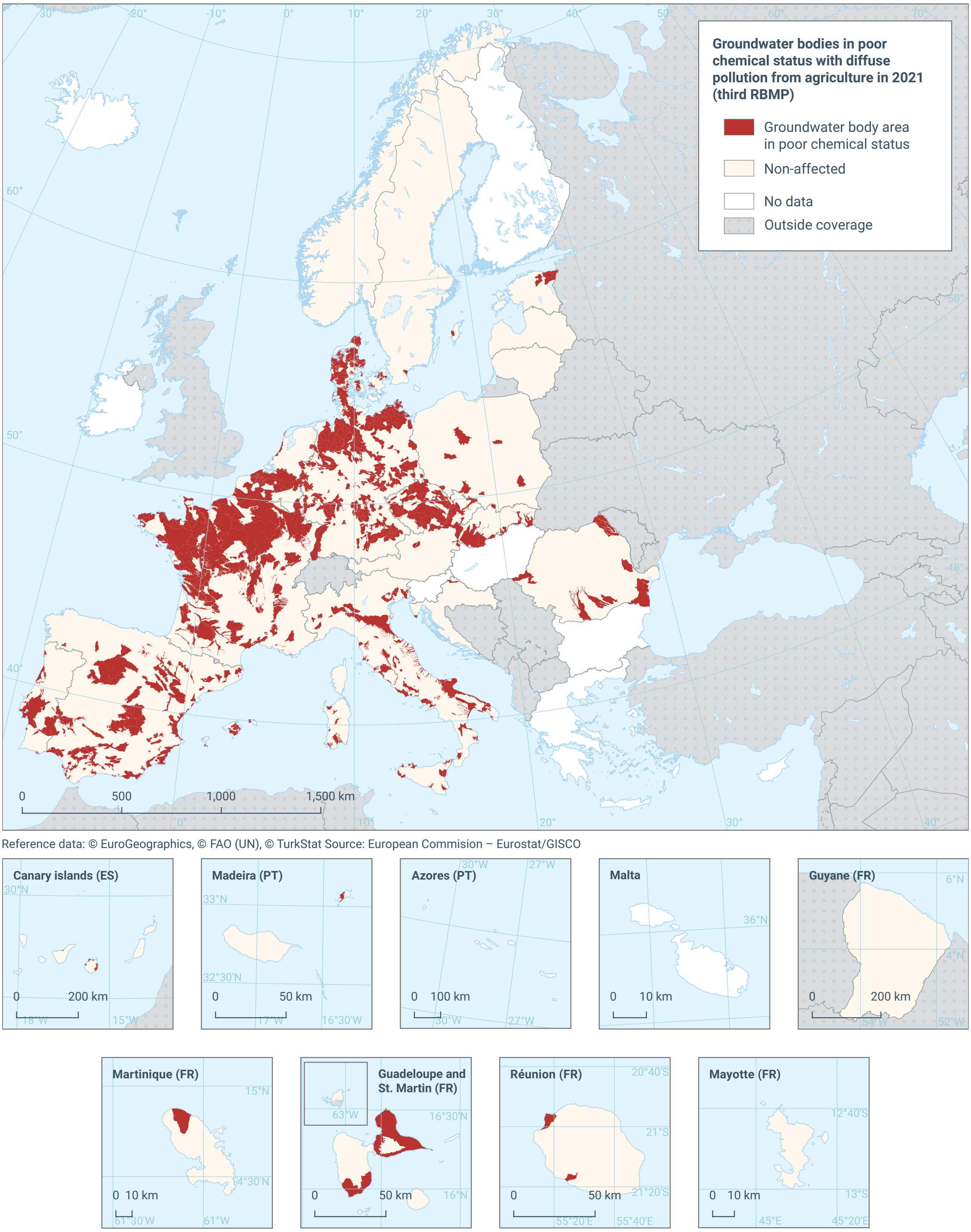
Map 3.3 Diffuse source pollution from agriculture in groundwater bodies in 2021 (third RBMP)



Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commision – Eurostat/GISCO

Notes: Map based on the WISE-SoW database, including data from 19 Member States plus Norway.

Source: Adapted from the EEA dashboard for groundwater significant pressures. https://water.europa.eu/freshwater/resources/metadata/wfd-dashboards/groundwater-bodies-significant-pressures-table

Nitrogen emissions from agriculture surged three-fold between the 1960s and 1980s (Lassaletta et al., 2016; EEA, 2021a). Nitrogen surpluses in agricultural soils still exist across much of Europe, such as Belgium, Germany, Ireland, the Netherlands and parts of most other EU-27 countries (EEA, 2021a). As much as 81% of agricultural nitrogen inputs to aquatic systems are due to intensive livestock farming (EC, 2021g).

No overview of the amounts of pesticides used and their emissions from agriculture is available at the European level. A commonly used proxy, pesticide sales, shows that volumes have remained stable at around 350,000 tonnes sold each year from 2011 to 2020 (Eurostat, 2024). It should be noted, however, that several of the more recent pesticides have a higher specific toxicity, i.e. higher toxicity per unit weight (see Section 3.1), and therefore sales volume trends may be misleading.

Modelling suggests that most pressure and impact from pesticides on aquatic species occur in regions dominated by intensive arable and permanent crop farming of Belgium, Bulgaria, Cyprus, western and northern France, north-western parts of Germany, Italy, Malta, the Netherlands, Romania, and Spain (van Gils et al., 2019; EEA, 2021a). Some coastal countries, such as Norway, are particularly affected by pressures from the aquaculture sector (Box 3.3).

Box 3.3

Iceland and Norway reporting under the WFD

Although Iceland and Norway are not in the EU, they report under the WFD. Many of the water management challenges they face are similar to those experienced by EU Member States. They have only recently started reporting (Norway starting with the second cycle and Iceland for the first time with the third cycle) and consequently may have significant unknown status. For instance, Norway reports that of 32,399 surface water bodies, 71% achieve good or high ecological status, but 92% have unknown chemical status.

A pressure of particular significance to these northern countries is aquaculture. In Norway, diffuse pollution from aquaculture is significant in 25% of the area of coastal waters. Pollutants include nutrients, copper and pharmaceuticals used to treat the fish.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Source: https://water.europa.eu/freshwater/europe-freshwater/water-framework-directive

With climate change, concerns are rising in relation to changing crop pests and disease distributions, which may increase the application of pesticides in areas without uptake of alternative plant protection methods (Mentzel et al., 2022).

Several options are available to achieve the European Green Deal targets for reducing nutrients and chemical pollution (Table 1.1), such as organic farming and more sustainable farm practices. These may include soil conservation practices, soil cover, mixed cropping, diversification of crop rotation, biological pest control, biodiversity-rich landscape features, agroforestry and nature-based solutions (EEA, 2021a).

The EU common agricultural policy (CAP) can support the transition from conventional farming practices towards multi-functional and diverse agroecosystems. Other incentive structures need to be considered, such as the tax regime for businesses producing organic and sustainable biobased goods, making such products more economically competitive. Development and implementation of government-led green procurement policies and initiatives that would limit water pollution are examples of other areas where the transition to more sustainable practice can be supported.

The EU organic action plan (EC, 2021d) is an essential avenue to facilitate the expansion of organic farming by stimulating demand, reinforcing the value chain and supporting conversion through research and training. Yet, the 25% target of agricultural land under organic production is unlikely to be achieved given current conversion rates (EEA, 2023a), calling for a strengthening of national organic action plans and CAP support.

In addition, addressing diffuse pollution from agriculture requires better implementation of existing legislation such as the Nitrates Directive and the Sustainable Use of Pesticides Directive. Further regulatory actions may be needed to strengthen and align provisions with WFD objectives and the Green Deal ambitions.

Tradable permits have been explored as a market-based mechanism to address water pollution. The WFD encourages the use of tradable pollution permits to limit nutrient discharges into water bodies. By setting a cap on total nutrient emissions and allowing industries to buy and sell permits, this approach could provide a flexible and economically efficient way to achieve water quality objectives. To avoid adverse outcomes, strong institutions and careful planning are needed to avoid localised increases in pressures and manage social impacts.

The scale of the agricultural pressures in Europe is enormous, not only on water but also on climate, biodiversity, soils and air quality. To address those challenges, not only must more sustainable agricultural practices be stimulated but also consumer demand for sustainable agricultural products. This requires attention to trade and marketing, as well as diet, health and lifestyle.

Reducing meat consumption and stimulating consumer demand for plant-based alternatives can be an important lever to reduce pressures on water resources (Leip et al., 2022). Studies suggest that halving meat, egg and dairy consumption in the EU could achieve a 40% reduction in reactive nitrogen emissions into water and the air and a 25-40% reduction in GHG emissions (Westhoek et al., 2014; Rega et al., 2019; Billen et al., 2021).

A systemic approach is essential, involving farmers, food chain operators, authorities, consumers and citizens. Box 3.4 *Case study: collaboration between water suppliers and farmers in Rennes, France*, is an example of schemes where water suppliers and farmers increasingly collaborate through a variety of mechanisms, such as financial support schemes, public food procurement, certification schemes and market conditions, to support a transition towards more sustainable farm practices. Integrating water, agriculture, food and energy systems will pave the way for a more effective and coherent response.

Box 3.4

Case study: collaboration between water suppliers and farmers in Rennes, France

With only 3% of the surface water bodies of its watershed area in good or high ecological status in 2018 — largely due to nutrient and pesticide pollution from agriculture — the city of Rennes faces significant challenges in supplying good quality drinking water to its citizens. To address these challenges, the city and its water utility company have implemented various initiatives since the 1980s.

The immediate surroundings of drinking water abstraction points are subject to strict regulations, including on the use of fertilisers and chemical pesticides. In these areas, the water utility has a programme to buy or swap farmland, allowing direct management to safeguard water quality. In 2021, the utility owned 10% (i.e. 518 hectares (ha)) of the land in drinking water protected areas.

Beyond these protection zones, broader initiatives have been in place since the 1990s to influence farming practices across the 150,000ha of land in the catchments feeding into the drinking water abstraction points. However, reaching the 2,500 farms currently operating in these catchments is a significant financial and administrative challenge.

Starting in the 2000s, the water utility and city of Rennes decided to initiate the Terre de Source programme, an innovative approach to open up contracts to supply food to the city's public canteens to farmers situated in the city's drinking water catchments, on the condition that they improved their agricultural practices to reduce pressures on the city's drinking water supply.

Following approval by the European competition regulator, the city of Rennes is now in its third cycle of public service contracts requiring such service delivery from food suppliers, representing EUR 1.5 million worth of contracts, with 18 food processing companies and 88 farms covering 6,452ha.

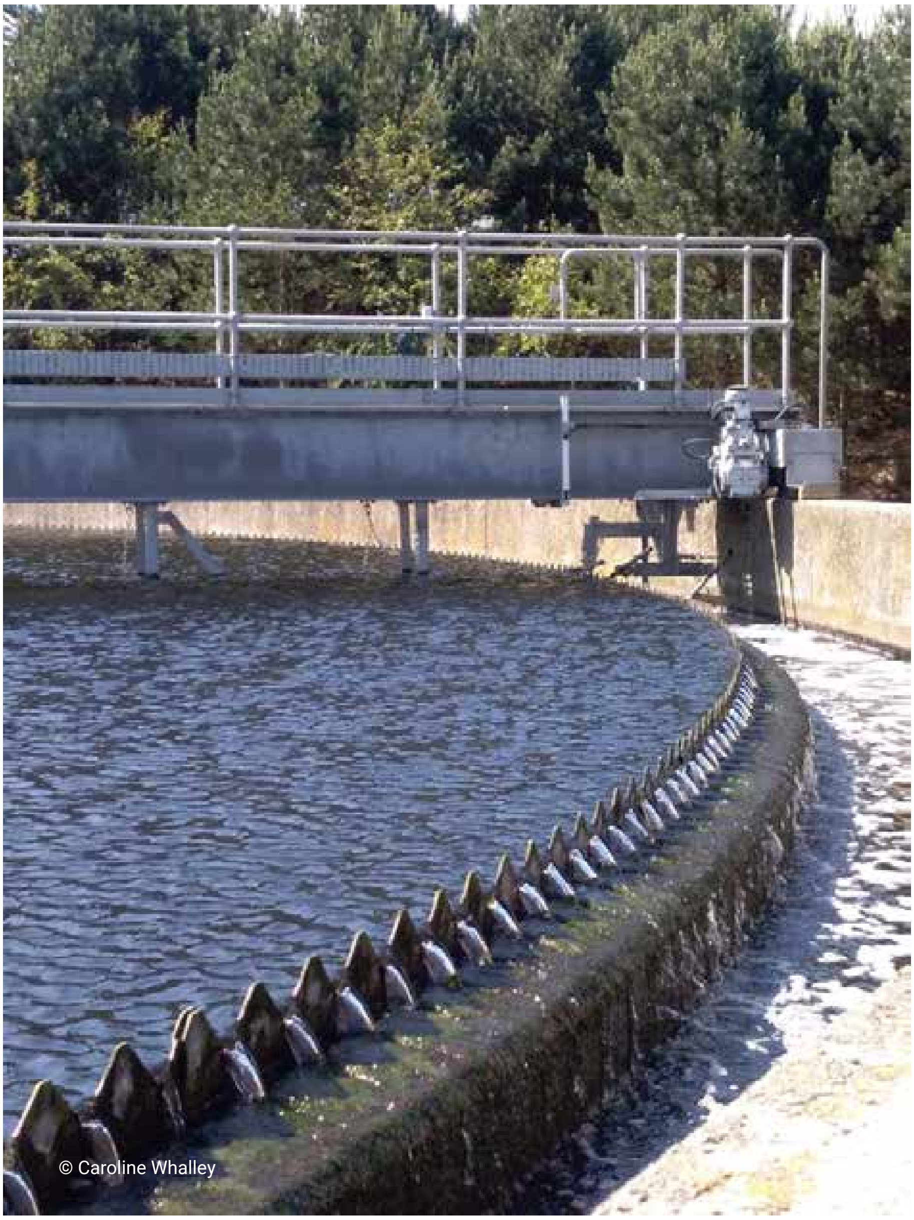
Sources: Zeggoud, 2020; Eau du Bassin Rennais Collectivité, 2023.

3.2.2 Urban wastewater treatment

Owing to large-scale investments in wastewater treatment, nutrient and organic pollution decreased in European surface waters from 1992 to 2010, especially with regards to phosphorus and oxygen-consuming substances. However, concentrations of nutrients and organic pollution are still too high to support good ecological status in many areas (EEA, 2018b).

The recent proposal for a revision of the Urban Wastewater Treatment Directive (UWWTD), adopted in 2022, introduces new provisions to further reduce nutrient pollution of the aquatic environment by urban wastewaters (EC, 2022c). It would enlarge the scope of the previous directive to cover all agglomerations of 1,000 population equivalents or above. The proposal also considers scattered and non-connected dwellings by establishing specific requirements for individual wastewater treatment systems, which should help to decrease concentrations of nutrients and organic pollutants further.

Figure 3.4 **Aeration in urban waste water treatment**



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Urban wastewater treatment has focused on addressing nutrient pollution, albeit other chemicals could also be removed. A large range of micropollutants, such as metals, biocides (Fuchs et al., 2020) and pharmaceuticals, can be found in urban wastewater (Comber et al., 2015; Fuchs et al., 2020; Pistocchi et al., 2022), with 92% of the residual toxicity in urban wastewater coming from the pharmaceutical and cosmetics sectors (EC, 2022c). The proposed revision of the UWWTD would require more intensive treatment at large plants to remove more micropollutants.

Run-off of rainwater in urban areas is a pathway for metals, oils, biocides, pathogens, plastics and various other substances into water. Intense rainfall can cause stormwater overflows, particularly in districts with combined sewer systems, where urban wastewater mixes with urban run-off. With climate change, managing the impact of more frequent heavy rainfall on stormwater overflows and polluted run-off from urban areas will become increasingly necessary.

The proposed new rules of the UWWTD would require an integrated approach to rainwater collection and treatment by establishing and implementing integrated wastewater management plans in large agglomerations.

The combination of urban development leading to more impervious surfaces, and pollution with more climate extremes, requires European cities to take new approaches to tackling the water quantity and quality challenges they are facing, and to become more resilient to environmental risks.

Some of these problems can be addressed simultaneously with NbS (Oral et al., 2020). Furthermore, it is necessary to move towards a circular economy of water and chemicals that promotes pollution avoidance, water and waste treatment, and recovery and reuse of remaining pollution loads (EEA, 2022a) (Box 3.5). While sewage sludge has been exploited for centuries (Box 3.6), water reuse is now receiving significant attention, particularly as water stress is becoming more widespread (see Chapter 4).

Box 3.5

Case study: innovation and business opportunities from minimising nutrient emissions from urban wastewater treatment plants

Transformation of nutrients in treated urban wastewater into algae-based products is an innovative, cost-effective way to reduce nutrient emissions to aquatic ecosystems. The gains from such a transformation are:

- to achieve the zero pollution vision for unwanted emissions from urban wastewater treatment plants (UWWTPs);
- to take care of the wastewater resources for net value creation;
- to develop and demonstrate circular economy solutions for sustainable development.

The technology links urban wastewater treatment with the circular economy, while increasing the acceptance of wastewater as a resource through awareness raising and capacity building. It can facilitate the emergence of a scalable, sustainable and efficient algae-based bioeconomy for wastewater treatment plants. The algal biomass product may be used as a green fertiliser to supply nutrients to agriculture, thereby partly substituting artificial fertilisers.

Another algal product is biochar, which can be used for applications such as soil improvement and fertiliser, alongside reducing GHG emissions. This technology is implemented on a pilot scale in collaboration with the major UWWTP in Oslo, Norway, (800,000 population equivalents) and will also be further developed in other countries through a new Horizon Europe innovation project, LOCALITY.

Source: NIVA, 2021.

Box 3.6

Opportunities and limitations in the use of sewage sludge

One byproduct of wastewater treatment is sewage sludge, the organic material produced by bacteria during secondary biological treatment.

Instead of being incinerated or landfilled, sewage sludge can be used beneficially for its nutrients and organic matter content (EEA, 2022e). Similarly, manure from livestock rearing can be recovered. Common uses include land application as a soil conditioner or fertiliser and, in some cases, for energy recovery through biogas production or incineration.

Recycling nutrients from sewage sludge and manure, such as phosphorus as a non-renewable resource, increases food security while simultaneously reducing nutrient enrichment of natural water bodies and risks of eutrophication.

Benefits include better water quality and ecosystem health, reduced treatment costs and improved bathing water quality. In 2021, over 11.1 million tonnes of wastewater sludge were generated in the EU, with about 61% being reused in agriculture or elsewhere (EEA, 2022a).

However, if chemically polluted sludge is spread on land, to return organic matter and nutrients to the soil, this may represent a form of diffuse pollution. Preferably, that situation would be prevented by avoiding the chemical contamination of urban wastewater, as under the Swedish Revaq certification system.

Where that is not possible, mono-incineration can be used to recover phosphorus from the sludge (EEA, 2022a). The 1986 Sewage Sludge Directive has recently been evaluated, noting that further review is needed of the chemical behaviour of sludge contaminants when sludge is reused in agriculture (EEA, 2022a).

3.2.3 Industrial emissions

Industrial emissions of pollutants are extremely varied and reach the water environment via various pathways, including wastewater treatment plants, run-off from impermeable surfaces (such as roads) and atmospheric deposition (Box 3.7). The Industrial Emissions Directive (IED) (EU, 2010b) is the key instrument for reducing harmful industrial emissions across the EU. The directive was recently revised (EU, 2024b), updating requirements for emissions and permitting.

Box 3.7

Atmospheric pollutants

Deposition of air pollution, including particulate matter, is a leading source of pollutants to the water environment. Emissions of sulphur dioxide, mostly from energy supply, contribute to acid rain. Emissions of nitrogen oxide from transport and ammonia from agriculture contribute to nitrogen accumulation on land and water (EEA, 2022c). Air pollution from manufacturing, the extractive industry and coal-fired power generation are major sources of metals and persistent organic pollutants in water (EEA, 2018a, 2022c).

The EU is a party to the international Convention on Long-Range Transboundary Air Pollution (CLRTAP), which, through the Gothenburg Protocol, has aimed to abate acidification, eutrophication and ground-level ozone since 1992. This concerns mainly nitrogen in freshwaters, although a strategy is under construction to bridge assessments for marine waters between the CLRTAP and the OSPAR and Helsinki conventions.

The focus on reducing industrial emissions should not overshadow the need to explore alternative solutions for curbing pollution. Specifically, attention must be given to addressing emissions throughout the entire life cycle of industrial chemicals. The EU's circular economy action plan (EC, 2020b) aims to standardise the production of sustainable products and eliminate the use of hazardous substances through safe-by-design approaches. It calls for revisions of relevant EU rules on the authorisation of hazardous chemicals on the EU market — for example, the Regulation on the registration, evaluation, authorisation and restriction of chemicals (REACH) — their use in specific products such as textiles and electronic and electrical equipment (EU, 2011), and the design of sustainable products (e.g. the Ecodesign for Sustainable Products Regulation) (EC, 2022d).

Improved waste management is particularly crucial, especially in the electrical and electronic equipment sectors (Ryan-Fogarty et al., 2023). With 80% of a product's environmental impacts determined at the design phase, the production and use of biodegradable, recyclable and less hazardous materials and products can be very influential (EC, 2012). Implementing ambitious ecodesign principles with stringent chemical regulations — i.e. setting high standards for their production, use and disposal — would reduce the risk of hazardous chemicals leaching or being discharged into the water environment.

3.3 Tackling emerging concerns in water pollution

In Europe, legislative initiatives have been adopted over time to tackle major pollutants such as organic matter and nutrients. The 1991 UWWTD and Nitrates Directive were followed by the WFD and its daughter directives, which set quality standards for chemicals in surface and groundwaters. The WFD relies heavily on source control legislation for chemicals, e.g. legislation regulating the authorisation, use and emissions of chemicals, in particular REACH (EU, 2006c), the Plant Protection Products Regulation (EU, 2009b), the Biocidal Products Regulation (EU, 2012) and the Industrial Emissions Directive (EU, 2010b).

The main mechanism providing feedback on the efficacy of source control legislation in protecting the aquatic environment is chemical monitoring and emissions inventories under the WFD. However, legislation can be slow to recognise and respond to new risks.

'Emerging pollutants' is a broad term referring to substances of increasing concern which are not yet included in routine monitoring programmes. They could pose a risk because of properties such as high toxicity, persistence, bioaccumulation (i.e. concentrations build up in an organism) and/or mobility (where substances can be transported over long distances, e.g. in the atmosphere or aquatic environment and through soil).

Three topics that are receiving increasing attention are PFAS, microplastics and antimicrobial resistance; they are addressed in several EU policies and initiatives to reduce pollution sources (for example, the plastics strategy).

- **Perfluorinated substances** (e.g. PFAS), also described as 'forever pollutants', are very persistent and are being found widely in the aquatic environment and organisms across Europe (Ahrens and Bundschuh, 2014). Their chemical nature and structure prevent them from degrading and can make them bioaccumulate. They are carcinogenic and are suspected hormone disrupters, affecting human and animal health (e.g. Yuan et al., 2020; Singh and Hsieh, 2021; Mokra, 2021). In addition to the long-chain rather bioaccumulative PFAS with known toxic effects (Anderson et al., 2022), short-chain PFAS have specific inherent risks. However, quantitative data are currently lacking on sources and environmental pathways. A general PFAS restriction under REACH is under discussion (ECHA, 2021).

- **Plastics and microplastics** include chemical additives and pollutants which can be harmful to human health and ecosystems. Some cause cancer and change hormone activity (WHO, 2019). There are limited data on microplastics in tap water because of a lack of harmonised monitoring methods, though they are widely dispersed in natural aquatic environments (WHO, 2019; Alfaro-Núñez et al., 2021). It is estimated that 2 trillion microplastic particles are transported annually by the River Danube to the Black Sea (UNEP, 2023).

- **Antimicrobial resistance** is a major public health concern, estimated to kill more than 35,000 people per year in the EU, Iceland and Norway (ECDC, 2022). Until now, the focus of efforts has been on the healthcare and food sectors. However, the potential role of the environment in transmitting resistance genes is increasingly being recognised, with a Council recommendation calling for further action in a One Health approach (EU, 2023). The EU has adopted a target to reduce the sale of antimicrobials for farmed animals and aquaculture by 50% (EEA, 2022g). Resistance genes are found in wastewater treatment plant effluents and their receiving water bodies (Cacace et al., 2019), as well as in other freshwater ecosystems such as lakes (Spänig et al., 2021).

In response to such concerns, the proposed revisions to the Groundwater and Environmental Quality Standards Directives (EC, 2022b) include adding a range of new thresholds for substances including PFAS, pesticides, several medicines and antibiotics in surface and groundwaters (EC, 2022b). The proposals would also include microplastics and antimicrobial resistance genes in monitoring for emerging pollutants (watch lists) once suitable monitoring methods become available.

A further concern is that the risks of chemical pollution in the environment are currently assessed on a substance-by-substance basis. This does not reflect the reality that organisms (including humans) are exposed to mixtures of chemicals. A growing number of effects-based methods are available which can help investigate the impact of mixtures on water quality. Tools can provide measures of cumulative toxicity, integrating the effect of substances acting in a similar way on the organism. If effects are detected, effects-directed analysis can be used to identify the major drivers of the mixture toxicity (Brack et al., 2019). The proposed revisions to the Environmental Quality Standards Directive (EC, 2022b) introduce their use for estrogenic hormones. These tools could complement existing approaches, to better assess the chemical status of water bodies although standardised protocols will be needed to facilitate their use in regulation.

Attempting to manage harmful chemicals once they reach the environment is not a sustainable approach. The European Green Deal recognises that a profound change in the production and use of chemicals is required.

In the chemicals strategy (EC, 2020c), the EU aims to ban the most harmful chemicals in consumer products — allowing those chemicals only where their use is essential. The pharmaceutical strategy for Europe (EC, 2020e) aims to address the environmental implications of all phases of the life cycle of pharmaceuticals (human and veterinary), from design and production to use and disposal. These policy signals need to be strengthened by further promoting corporate social responsibility and setting regulatory requirements to enforce circularity and safe-by-design principles.

Underlying these efforts is the goal to shift from the current unsustainable linear model of 'take, make, consume and waste', to create a sustainable loop where product life cycles are made intrinsically safer from the start, to avoid pollution, by ensuring producer responsibility, based on the concept of safe and circular by design.

This 'circular economy for chemicals' would reduce the overall cost to society of treatment and remedial measures.

This chapter has provided an overview of the pollution pressures facing Europe's rivers, lakes, transitional waters and groundwaters, focusing on nutrients and chemicals. Climate change impacts, especially lower water volumes, present new challenges to water quality. Such issues are considered further in Chapter 4.

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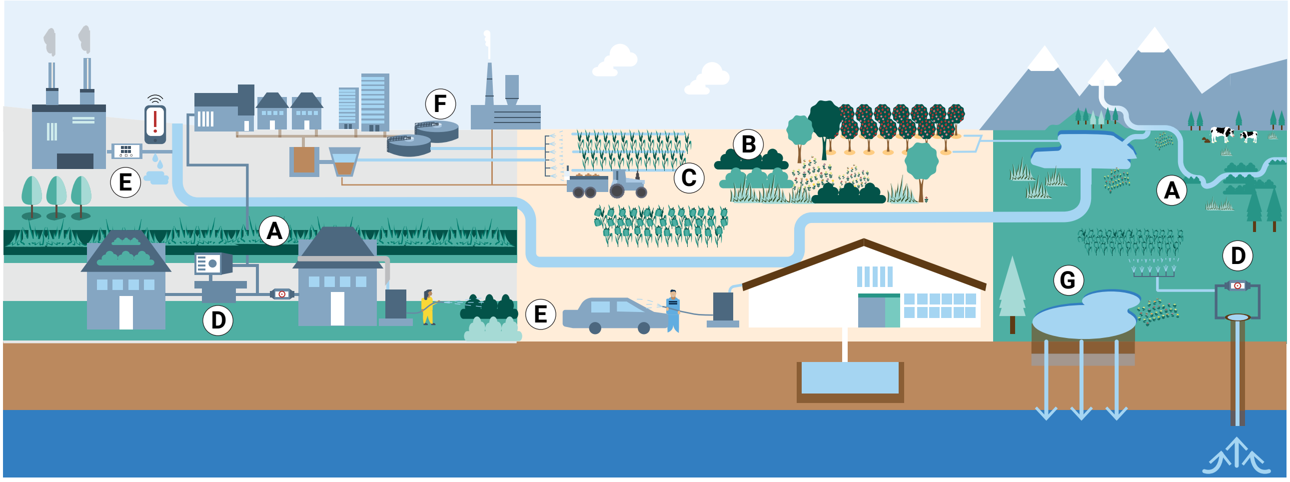
4 Adapting to water scarcity, drought and flood risks

Water is a vital resource. It is essential for human and environmental health and supports economic activities, including agriculture, industry and energy production. It creates diverse recreational and economic opportunities such as bathing, tourism and fisheries. Environmental well-being and social equity rely upon it.

Water stress is already prominent in Europe and is likely to increase due to climate change. Water scarcity already affects 20% of European territory and 30% of the population each year. Prolonged drought, extreme heat and large-scale flooding will increase throughout the continent, damaging ecosystems and human health and leading to major disruption to economic activities (EEA, 2024a). With climate change, preserving water resources and the natural flow of rivers (see Chapter 2) while supplying sufficient water of good quality (see Chapter 3) for society and ecosystems is becoming a major challenge (Figure 4.1).

Figure 4.1 **Addressing water scarcity, drought and flood pressures in Europe**



Ⓐ Natural water retention measures: green infrastructure, swales, floodplain restoration

Ⓑ Sustainable farming: restoring soil carbon which holds water, riparian buffers, woody features

Ⓒ Changing crops for less water-intensive species

Ⓓ Metering, abstraction control and enforcement

Ⓔ Water saving and demand reduction: leakage control, water use efficiency, economic incentives

Ⓕ Water re-use, rainwater harvesting, desalination if using sustainable energy and preventing pollution by brine

Ⓖ Groundwater recharge

Source: EEA.

4.1 Groundwater quantitative status and flow regimes

Groundwater supplies 65% of water for drinking and 25% of that for agricultural irrigation in the EU. It is a finite resource that needs to be protected from pollution and over-exploitation, to ensure the long-term sustainability of its use for human activities and natural ecosystems (EEA, 2022d). Groundwater is important to maintain steady river baseflows and ensure reliable water availability for ecosystems and for other uses, even in dry periods.

Flow regimes influence the functioning of aquatic ecosystems through habitats, water quality, temperature, nutrient cycling, sediment flows and geomorphological processes. In healthy aquatic ecosystems, water flows freely between groundwater and lakes, rivers and their floodplains and finally to the sea, without artificial barriers. Restoring natural flows is essential to preserve the ecological integrity of rivers. However, this can come at the expense of human uses that depend on storing, diverting and abstracting water. Collaborative approaches will be necessary to achieve sustainable flow regimes.

4.1.1 Groundwater status and hydrological regimes of surface waters

In the Water Framework Directive, groundwaters must achieve good quantitative status, meaning that:

- groundwater recharge is balanced with abstraction;
- there is no sustained saline or other intrusion;
- there are no negative impacts on surface water linked with groundwater or ecosystems fed by groundwater (e.g. ponds).

In 2021, 91% of groundwaters were reported to be in good quantitative status, unchanged from 2015. Overall, there are now few knowledge gaps on quantitative groundwater status in Europe, but the high levels of good quantitative status reported under the WFD contrasts with our wider understanding of the challenges facing groundwater resources discussed throughout this chapter. Guidance on groundwater status and trend assessment needs revisiting, not least in the context of climate change.

Failure to achieve good quantitative status of groundwater bodies is more frequent in certain river basin districts of Belgium, France, Italy and Spain (Map 4.1). Although not shown on Map 4.1 due to data availability (12), the failure to achieve good quantitative status of groundwater bodies was also frequent in Cyprus, Hungary, Greece and Malta in 2015 (EEA, 2018b).

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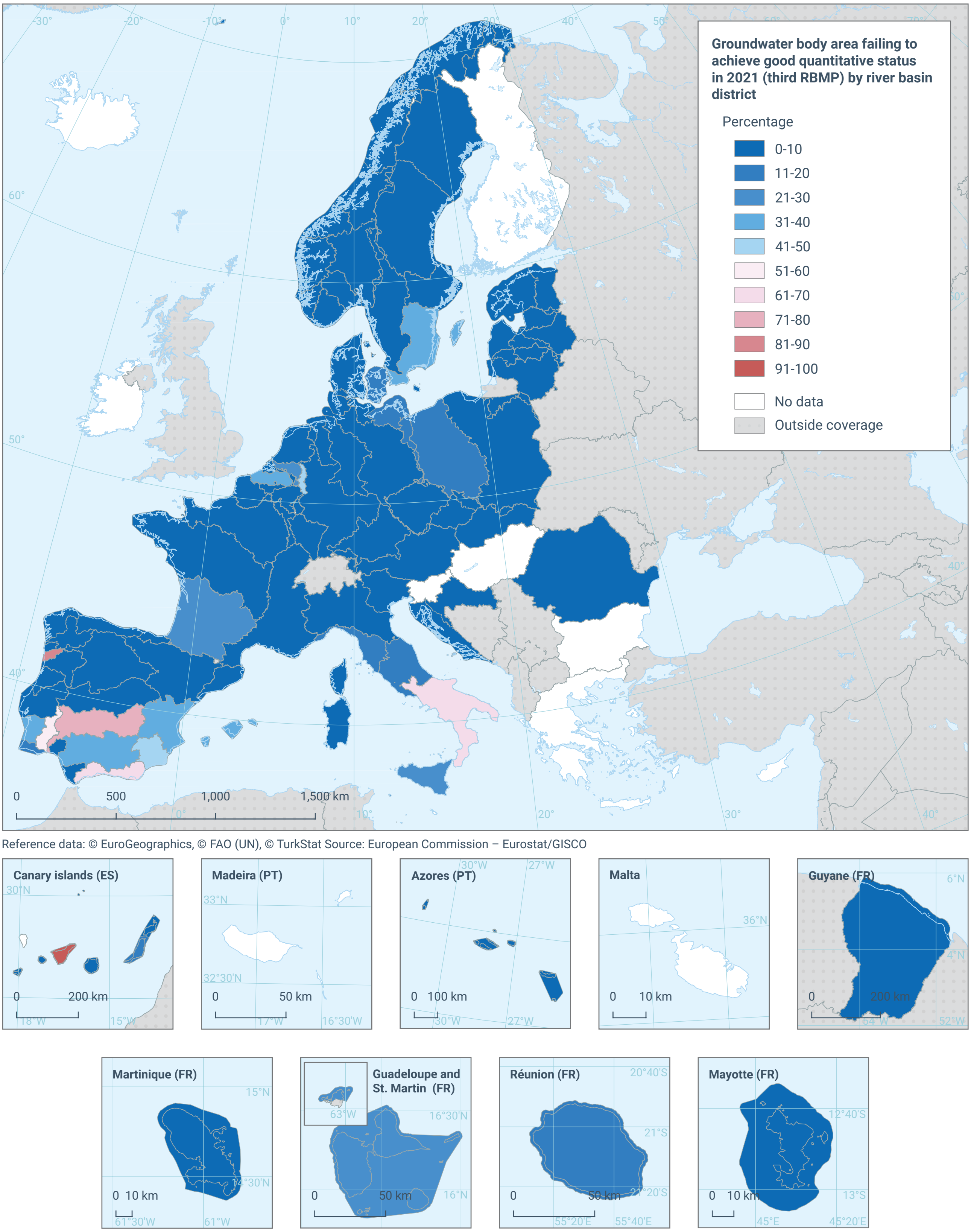
(12) By July 2024, 19 Member States and Norway had reported electronically to the EEA for groundwater quantitative status.

Map 4.1 Percentage of groundwater body area failing to achieve good quantitative status in 2021 (third RBMP) by river basin district



Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

Note: Map based on the WISE-SoW database, including data from 19 Member States plus Norway.

Source: https://water.europa.eu/freshwater/europe-freshwater/maps/groundwater-quantitative-status-map

Failure of good quantitative status is linked to the sustained decline of groundwater levels, compared to the average conditions, due to groundwater being abstracted from the aquifer at a higher rate than its recharge (7% of groundwater body area failing). Other reasons for failure include negative impacts on surface waters and related freshwater and terrestrial ecosystems due to changes in groundwater flow conditions, and seawater (salt) or other polluting sources.

Surface waters are not assessed for quantitative status under the WFD. Instead, ecological status (see Chapter 2) includes hydrological and flow parameters, but many countries do not fully report nor assess them (13). Based on available data, in 2021, 21% of surface waters fail good ecological status for river continuity, 15% for hydrological conditions and 17% for morphological conditions.

4.1.2 Human and climate pressures impact natural water flow

Pressures leading to changes in the natural flow and physical features have been reported as the most common pressure on EU rivers, affecting 51% of surface waters (see Section 2.3).

Various human activities cause these alterations, such as operation of dams and reservoirs, navigation infrastructure, flood protection and drainage altering floodplains and wetlands, as well as abstraction for economic activities such as irrigated agriculture, energy production, industry and public water supply.

As water scarcity and drought frequency increase with climate change, mitigating the impact of hydrological alterations from human activities is becoming increasingly challenging. In 2022, the annual average river discharge across Europe was the second lowest in records dating back to 1991 (Copernicus, 2022). It was also the sixth consecutive year of discharge below the average for the 1991-2020 reference period and the driest on record in terms of the area affected, with 63% of rivers having below-average discharge.

Alterations to the natural flow regimes of rivers and groundwater, combined with the impacts of climate change, pose a particular threat to transitional and coastal habitats such as estuaries and coastal lakes.

Reduced freshwater inflows can cause shifts in salinity gradients, impacting the distribution of aquatic species and endangering breeding grounds, feeding areas and nurseries. Concurrently, other pressures exacerbate these challenges, such as pollution, the spread of invasive species and rising sea levels. These processes are observed throughout Europe, for instance in Mediterranean lagoons (Lacoste et al., 2023), where the balance between freshwater and saltwater has already been significantly disrupted, compromising the integrity of these unique ecosystems.

4.1.3 Restoring natural flow regimes in surface waters and groundwaters

Restoring a more natural water cycle across whole catchments and river basins is a priority, because it is a precondition for habitat restoration (see Chapter 2). Efforts are needed to integrate river flow, groundwater levels and soil water storage. Ecological flows, a key measure under the WFD, represent a natural flow regime in terms of low flows, flood regime and their timing throughout the year.

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(13) In 2021, 47% of surface waters were classified for river continuity, 40% for hydrological conditions and 51% for morphological conditions.

In the third RBMPs, 18 Member States now use ecological flow methods, but challenges persist, especially in their implementation and enforcement (Kampa and Schmidt, 2023). To secure ecological flows, operational measures, such as modified hydropower operations and restrictions on abstraction, should be accommodated to ensure these flows are met in different meteorological circumstances (e.g. droughts).

Other measures can contribute to restoring a more natural water cycle, such as removing barriers and restoring connectivity (see Section 2.3), controlling abstraction (see Section 4.2) and implementing natural water retention measures. Natural water retention measures are nature-based solutions that aim to store water in natural, agricultural, forested and urban landscapes (see Section 1.3). They include improved agricultural soil management, river and landscape-wide restoration, green roofs and measures to reduce soil sealing. Planned appropriately, such solutions have the potential to restore groundwater levels and support ecological flows while reducing water-related risks from water scarcity, floods and droughts.

4.2 Addressing water scarcity and abstraction pressures

Water stress is of increasing concern across Europe, with growing water scarcity in southern regions and more frequent and intense drought conditions across the continent. This will impact water ecosystems (see Section 2.1), pose significant challenges to public water supply and economic activities such as agriculture and industry, and impair people's enjoyment of the water environment.

4.2.1 Water stress and scarcity increasing across Europe

Water stress is a widespread problem across Europe, with water-stressed basins affecting around 20% of European territory and 30% of the population each year (EEA, 2023h).

Water stress is a major concern in southern Europe, where the combined effect of agricultural irrigation, energy production and public water supply, including tourism, can put intense pressure on water resources (EEA, 2021b). Many river basins in western and eastern Europe are also affected by water stress conditions and it can even affect northern regions, especially small catchments (Map 4.2).

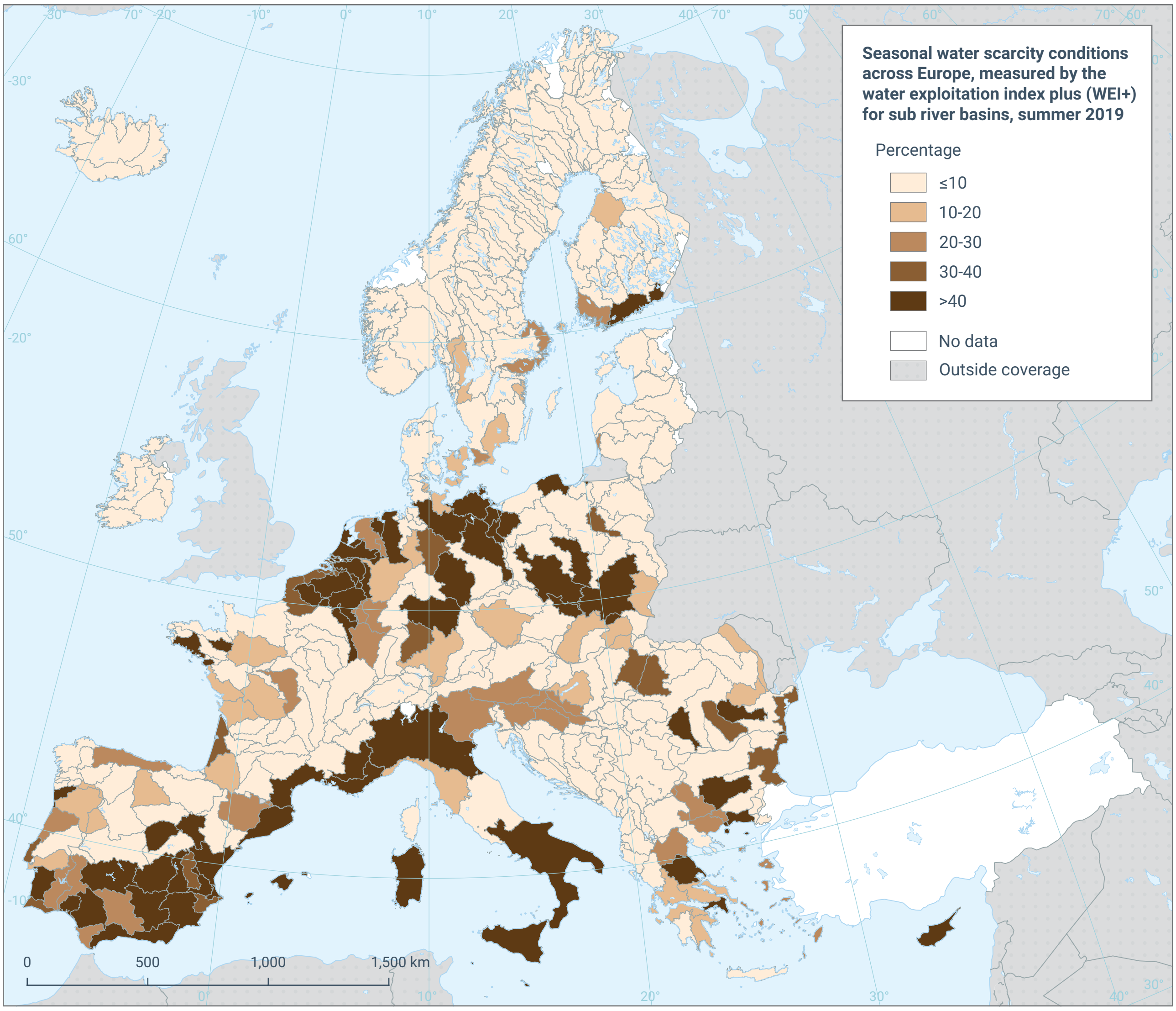
Although total water abstraction at the EU-27 level appeared to decrease by 15% between 2000 and 2019 (EEA, 2022f), trends and projections point to an increase in water stress due to growing scarcity and drought conditions (EEA, 2021b). Water scarcity conditions arise from the overuse of water resources and are characterised by a long-term imbalance between consumption and available water resources (Schmidt et al., 2012).

Increasing water scarcity is the result of a combination of factors, including increasing water abstraction in these regions, and climate change leading to changes in rainfall patterns, reduced snow cover, the loss of glaciers, increased evapotranspiration and drought conditions.

Pollution can also aggravate water scarcity, impacting the suitability of water for different water uses. For instance, since 2000, drinking water companies in the south and east of the Netherlands have closed 12 groundwater abstraction wells and modified five due to quality problems caused by leaching fertilisers and/or to prevent long-term lowering of groundwater tables (van Loon and Fraters, 2016). No European overview is available quantifying the significance of pollution as a factor of water scarcity. However, in 2015, 30% of groundwaters in the EU-27 failed to achieve good status, due to chemical pollution or depletion of groundwater resources (Psomas et al., 2021), posing challenges to their sustainable use.

Water scarcity conditions are currently prevalent in southern Europe, but, with climate change, conditions of significant water scarcity will extend into and intensify in other parts of Europe, including areas in Belgium, Bulgaria, France, Germany, Poland and Romania (JRC, 2020a). This will translate into more widespread limitations to the development of European society and economies. It emphasises the need to manage competition for water between the economy and the environment, and between the various water-using sectors.

Map 4.2 **Water exploitation index plus in European river sub-basins, summer 2019**



Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

Notes: WEI+, water exploitation index plus.
Levels above 20% indicate water stress, while levels above 40% indicate severe water stress. If these levels are exceeded in the long term, then water scarcity conditions have a structural nature. It is noted that central and eastern Europe were affected by drought in the summer of 2019, whereas in southern Europe water scarcity conditions are prevalent nearly all year round.

ISPRA and ISTAT provided data for Italian river basins (2015-2019).

Assessments of the sustainability of water abstraction at the European level can be limited by varying data availability across different spatial scales and the estimation approach of water returns. This may lead to discrepancies in the WEI+ calculated at the European level by the EEA, compared to national calculations based on more detailed datasets. An example of this occurs in the little Brittany sub-basin in France.

Source: Adapted from EEA, 2023g.

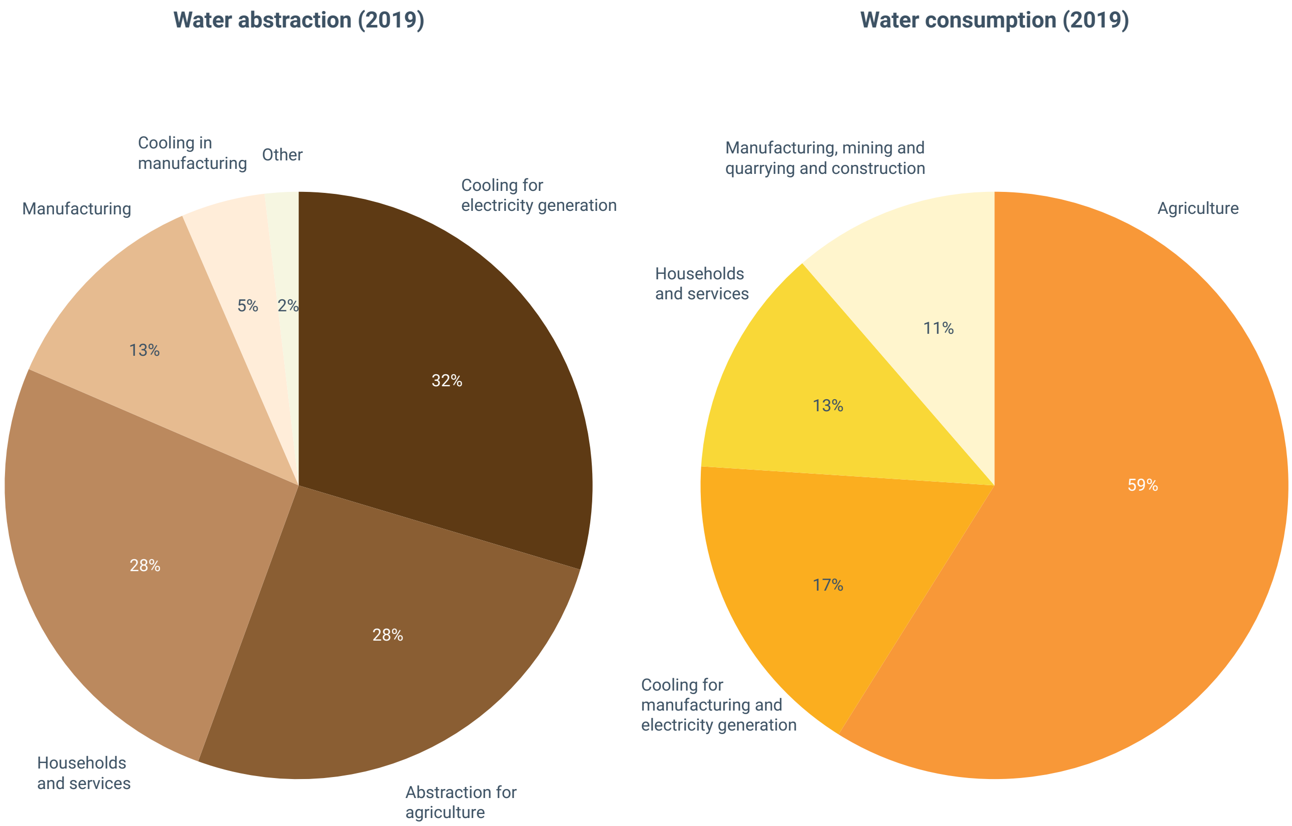
4.2.2 Abstraction: a driver of increasing water stress

In 2021, water abstraction was reported as a significant pressure in 18% of groundwaters and 8% of surface waters. Abstraction can affect both quantitative and chemical status, illustrating the significant risk it presents. The situation in groundwater thus appears worse than the overall quantitative status would suggest (see Section 4.1).

Some countries are experiencing high levels of abstraction pressure, not limited to southern Europe. In 2021, abstraction pressures were the highest in Portugal, Belgium and Estonia, where 87%, 71% and 53% of groundwaters were affected, respectively. For surface waters, France, Italy and Spain reported the highest number of affected surface waters.

Agriculture is the leading abstraction pressure on surface waters reported under the WFD in 2021. For groundwaters, pressures from agriculture and public water supply are highest. Overall, agriculture is the highest net water-consuming sector at the EU level, as most of the water is consumed by the crop or evaporates and so is not returned to the environment (Figure 4.2). Electricity production is the largest water-abstracting sector, but most of the water is returned to the environment after cooling or turbine propulsion. Other uses, such as industry and water utilities, abstract and consume comparatively less water, but they can represent locally significant pressures, especially on groundwater.

Figure 4.2 **Annual water and abstraction by economic sector in the EU27**



Source: Adapted from EEA, 2022f.

There have been some positive trends in certain sectors, such as energy production and various water-intensive industrial uses where water abstraction has reduced by approximately 30% (EEA, 2022f).This happened without legislative or policy instruments at EU level for water saving or for reducing water demand.The revised industrial emissions Directive (IED 2.0) (EU, 2024d) has new requirements for competent authorities to set limits for environmental performance including water, raw materials and energy use Data should be reported under the recently adopted industrial emissions portal regulation (EU, 2024c),which requires reporting on water use from 2028 for all already regulated sectors and additional activities such as aquaculture or medium combustion plants.

There are worrying trends. Despite already high water use and investments in reducing water losses, demand for irrigation water in southern Europe has continued to increase in recent years (+8% since 2010) (EEA, 2022f). Abstraction for public water supply increased by 10% between 2010 and 2019, while losses in public water infrastructures remain significant (around 30%) (ETC BE, forthcoming).

With climate change, and without significantly adapting current practices, demand in several sectors, such as agriculture and public water supply, will likely increase. At the same time, the push for renewable energy through additional hydropower and water-intensive forms of energy production, such as hydrogen and biofuels, as well as new demands from emerging industries like the digital sector, may lead to additional pressure on rivers and groundwaters.

4.2.3 Responding to water scarcity

Increasing water use efficiency in homes and sectors such as irrigated agriculture, industry and cooling systems for energy production can help address water scarcity (ETC BE, forthcoming). Driving behavioural change of water users and large-scale adoption of technological innovations and best practices can boost impacts. For example, adopting techniques such as precision farming and sub-irrigation can reduce evaporation losses in agriculture.

Despite their benefits, the gains from water efficiency measures have limitations. In some cases, a narrow focus on efficiency might have unintended consequences, such as the rebound effect, where saved water is redirected to new, consumptive uses which does not lead to the expected return flows to the environment. This is of particular concern in transitioning to more efficient irrigated agriculture (EEA, 2021a).

Additionally, such measures can require significant investment, technical expertise and behavioural change, which can be challenging to implement more widely and rapidly across all sectors and communities. For instance, investments in precision farming can entail significant costs to small-scale farms (EIP-AGRI, 2015). A holistic approach based on sound governance, community engagement and consideration of environmental implications is essential.

Circularity in water use is now a priority at EU level. In the water sector, the EU has adopted the Water Reuse Regulation to incentivise the use of reclaimed water in crop irrigation. The proposed revisions to the Urban Wastewater Treatment Directive would also promote the reuse of treated urban wastewater.

Used appropriately, water reuse can help address water scarcity while reducing the application of synthetic fertilisers (Box 4.1 *Case study: wastewater reuse for irrigation in southern Europe*). However, to achieve these benefits, good practices must be strictly followed (Box 4.2). In the industrial sector, water reuse can reduce demand for freshwater abstraction, reduce costs and enhance regulatory with discharge standards.

Box 4.1

Case study: wastewater reuse for irrigation in southern Europe

The Puglia region in south-eastern Italy supports horticulture, olive trees and vineyards. However, as the region lacks permanent rivers or lakes, the seasonal demand for irrigation water is met with groundwater abstractions. Over the past decades, the local groundwater has been exploited intensively, causing the groundwater table to drop significantly and sea water to intrude via the coast and mix with groundwater. Increased salinity levels impact local crops, natural vegetation and wetlands.

The local urban wastewater treatment plant of the municipality of Fasano treats about 10,000m^3 of urban wastewater per day. Before 2005, the wastewater received biological treatment and was discharged to the sea. However, in 2006 a private operator was commissioned to apply more advanced biological treatment with nutrient removal and disinfection to the effluent wastewater, making it suitable for reuse in irrigated agriculture.

The operator was also commissioned to distribute the reclaimed water to farmers. Local farmers enter into contracts to use the reclaimed water instead of groundwater, paying a fee to the operator for the distribution costs which varies based on volume supplied, distance and frequency of use.

In periods of lower water demand, storage overflow is redirected to an infiltration pond, where it recharges the groundwater directly. Groundwater recharge contributes to limiting seawater intrusion.

The first treatment system operated for 10 years and was upgraded in 2016. The irrigated area with reclaimed water increased from 350ha to about 1,000ha. Reused water mainly irrigates fields previously irrigated with groundwater. The valves and pumps in the distribution system are automatically managed, using sensor data across the network to adjust the flow rate and pressure in the network branches. The constructed infiltration pond and reduced pollution loads support the growth of regional biodiversity.

Sources: Water Reuse Europe, 2018; Aquasoil, 2023.

Box 4.2

Water reuse in agriculture: opportunities and limitations

Reusing treated urban wastewater in irrigated agriculture offers the possibility to reduce agricultural abstraction and synthetic fertiliser use.

The benefits of water reuse in agriculture largely depend on where and how it is implemented. Reused water should replace abstraction from rivers, lakes and groundwater for irrigated agriculture. It needs to avoid diverting wastewater discharges that contribute to maintaining baseflows and minimum water levels during dry periods (EC, 2017). Many water reuse projects will cause the least impact when using coastal wastewater discharges. Similarly, nutrient budgeting needs particular attention so that the nutrients included in reclaimed water are used effectively as substitutes for synthetic fertilisers.

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Beyond water efficiency measures, managing water demand will be increasingly needed as water resource availability becomes more volatile. A renewed focus is needed on implementing the user pays principle, the polluter pays principle and pricing policies to manage water demand (Box 4.3).

Box 4.3

Water demand management – crucial for sustainable water use

Efficient water use and reducing demand should be central to any strategies to tackle water scarcity.

Pricing measures can strengthen the implementation of measures such as leakage reduction, water-saving devices and public awareness campaigns. Water pricing involves setting tariffs or charges that water users pay for the provision of water and sanitation services and the use of water resources. Pricing can play a signalling role in prompting households and sectors such as industry, agriculture and commerce to reduce consumption. It can also consolidate financing in the water sector and ensure that water users effectively participate in recovering the costs of water services.

These benefits are recognised by the WFD (Article 9), which requires Member States to account for the recovery of the costs of water services and ensure that water-pricing policies provide adequate incentives for users to use water resources efficiently. While pricing policies play an important role in sustainable water use, their effectiveness in water demand management depends on several factors (EEA, 2017).

Furthermore, pricing policies should consider affordability for households and other sectors (EEA, forthcoming). For example, some municipalities in Germany have adopted tariff policies in which households consuming more water face progressively higher prices for each additional drop used. This tiered pricing structure aims to discourage excessive water use and promote conservation, while maintaining affordability for essential household uses (EEA, 2013).

Increased funding and investments necessary to meet the WFD's objectives and strengthen resilience to climate change should exploit all sources of financing, from EU funds to private investment through the EU Taxonomy.

A key measure also relates to controls over water use. In this regard, European countries have now established permitting and licensing regimes to control the access to and use of water resources. However, lack of compliance with permit conditions is a major issue in several Member States, partly due to poor monitoring and enforcement and inadequate fines (Schmidt et al., 2020).

Illegal abstraction from agriculture is a particularly significant issue in several southern European countries, with national and local initiatives trying to address the issue (Box 4.4). The proposal for a directive on the protection of the environment through criminal law offers an opportunity for Member States to take criminal cases against non-compliance with permit requirements (EC, 2021f).

Further work is needed to make effective use of permitting regimes to match water demand with available resources and better guide economic investments according to the long-term availability of local water resources.

Current trends in climate change and economic development indicate that decisions must be made about which water-dependent activities can be sustainably maintained. Strategic decisions regarding who uses water, how much, when and where will be needed as part of river basin and territorial planning.

Box 4.4

Case study: improved control on agricultural water use – the case of the Junta Central de Regantes de Mancha Oriental, Spain

In Spain, when a groundwater body is declared overexploited, river basin authorities have the power to restrict water abstraction. All licence holders exploiting that groundwater must also form an independent public administration in the form of a water user association, whose main role is to ensure the collective management of the aquifer and its conservation. In addition, the user association represents the interests of local users in the decision-making bodies of the river basin authority.

The Junta Central de Regantes de Mancha Oriental (JCRMO) was formed in 1994 to sustainably manage the aquifer of the Mancha Oriental in central Spain. The managed area covers over 10,000km^2, thousands of irrigators and abstractors in three provinces and seven groundwater bodies. The aquifer was not declared overexploited at the time but was at risk due to heavy abstraction by agriculture, cities and industries. The users of the aquifer proactively self-organised to control abstraction.

The Jucar River Basin Authority (RBA) retains regulatory control over individual permits. In contrast, the JCRMO collects water demand by each user (e.g. based on planned crops and rotation on each parcel for agricultural users) and ensures the coherence of the cumulative demand with the agreed abstraction cap. When needed, it proposes a reduction in the authorised volumes in permits, resulting in legal restrictions from the RBA. The JCRMO also encourages measures for more efficient water use, such as a shift towards micro-irrigation and adjustments in cropping patterns.

To control abstraction, the JCRMO employs a satellite imagery system developed and applied by the University of Castilla-La Mancha. An algorithm assesses water use and a computer program identifies situations of possible over-pumping compared to the annual authorisation. Enforcement is carried out with a site visit and administrative procedure if the over-pumping is confirmed. Penalties include a reduction in the next year's allocation. All data are shared between the JCRMO and RBA. Transparency is an essential element of the way the system performs.

Thanks to the improved monitoring and compliance check, abstraction levels have stabilised. However, abstraction levels are still high and can impact the Jucar River and downstream users. Furthermore, use in tree crop areas has not yet been monitored and these irrigated areas are expanding.

Sources: Castaño et al., 2010; Ortega-Reig et al., 2019; Cassiraga et al., 2019.

Water is a shared and common resource across Europe, so priorities will need to take into account various environmental, social and economic criteria such as upstream-downstream relationships, old water rights and new uses, needs of sectors and the environment, water productivity, water security, social access and affordability. All measures should be implemented in an integrated way to ensure the sustainable management of water resources. Long term, water allocations should be tied to river basin management planning to ensure coherence with river basin priorities and ecosystem integrity. Decision-making over water allocation will need to become more knowledge-based, transparent and flexible, to offer long-term perspectives for water uses while supporting a robust approach during drought crises.

4.3 Living with more frequent and extreme floods and droughts

With a changing climate, all European regions will face more hydrological extremes. Rainfall will fall more heavily in intense bursts, leading to more floods, and coastal regions will face sea level rise. Seasonal and prolonged droughts will become more common across Europe, exacerbating water stress. Europe must urgently adapt to growing uncertainties on water resources.

4.3.1 More extreme droughts: a major challenge for society and economic sectors

Droughts are natural phenomena involving a temporary but severe deviation of rainfall, but they can be exacerbated by human-induced climate change (Schmidt et al., 2012). Droughts lead to a more irregular water supply, causing severe environmental and economic damage. Droughts cause harm to ecosystems, often in combination with other stressors such as permanently lower groundwater levels, lower water quality, high temperatures or wildfires.

In 2022, Europe experienced its hottest summer and the second warmest year on record, leading to drought impacting over 15% of EU territory. The average annual economic loss caused by droughts in the EU in 1981-2010 was estimated at around EUR 9 billion/year (JRC, 2020b). Extreme droughts in western and central Europe between 2018 and 2022 caused considerable damage. Of the economic sectors, droughts mostly affect agriculture, the energy sector and the public water supply, as well as navigation in some regions (EEA, 2023b). Cascading impacts within and across production chains may even surpass the direct damage.

Rain-fed agriculture depends purely on rainfall as a water source and is among the first to be affected by a meteorological drought. That affects 83% of the EU agricultural area. Irrigated agriculture thrives well as long as its water sources (rivers, reservoirs, groundwater) can provide the required volumes of water. However, it is very vulnerable to prolonged and multi-year droughts. Both in irrigated and rain-fed agriculture, droughts can increase soil degradation through wind erosion or salinisation.

Some 60% of the EU's electricity production relies on the availability of water for cooling (ETC BE, forthcoming). Climate change is expected to induce higher water temperatures and more frequent and extreme low-flow situations. This will have a large impact on the sector (Ecofys et al., 2014). Countries in the west and south of Europe, such as France, Germany and Spain, have already experienced these low-flow situations and interruptions in power production during recent summers.

Drinking water production from surface water also faces problems with low river flows and, in addition, suffers from deteriorating water quality during such periods (RIWA-Meuse, 2023). This forces drinking water companies to invest in buffer capacity and reservoirs, to bridge periods when the water intake is interrupted and in additional investments for advanced treatment methods. Measures such as enhanced coordination, enforcement, legal measures and cross-border cooperation are also needed (RIWA-Meuse, 2023), together with enhanced network interconnections and NbS (APE, 2023).

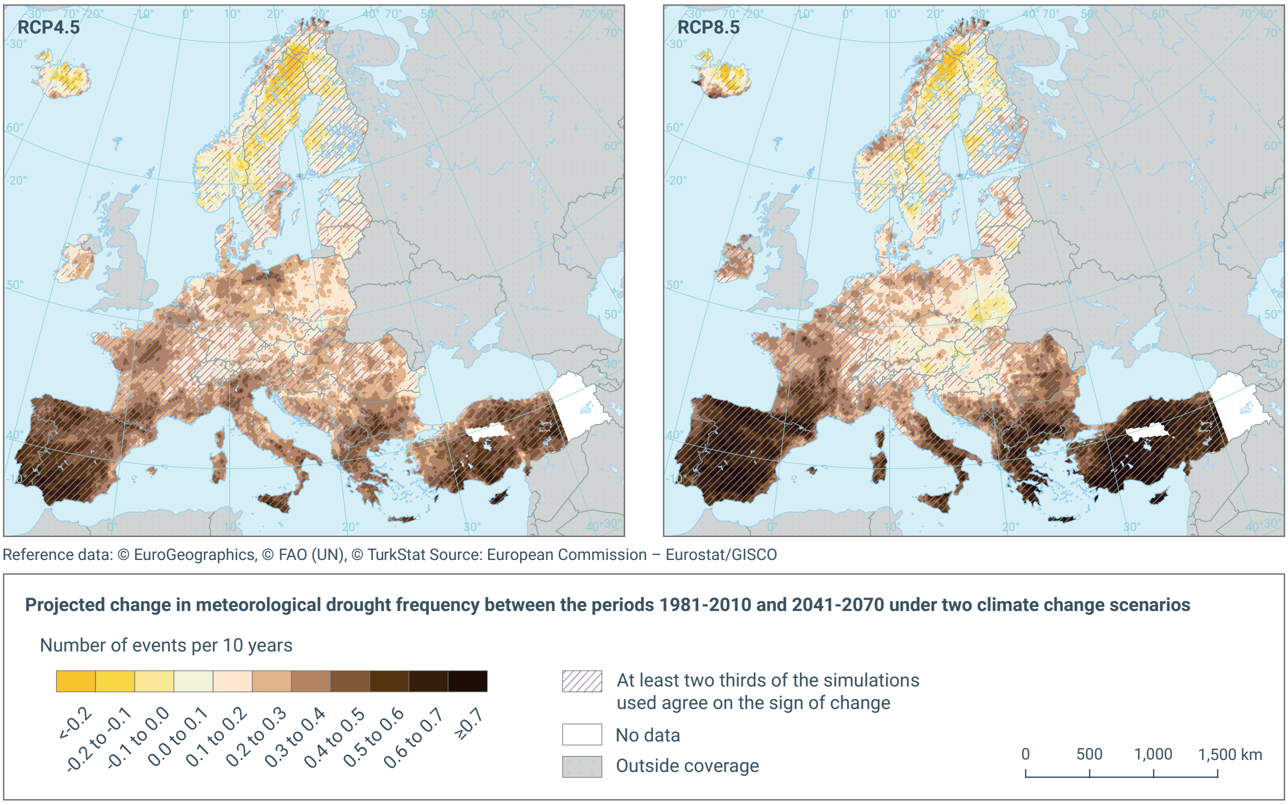
Some sectors are highly dependent on water availability. Inland navigation uses waterways for the transport of goods and is rather concentrated geographically, in particular in Germany and the Netherlands where it represents over 30% of inland goods transport, but also in Belgium, France and Romania (CCNR, 2021). When water levels are low, ships must be loaded at less-than-full capacity, wait longer at locks or sail in convoy.

In the dry summer of 2018, this caused damage estimated at EUR 140-345 million in Germany and the Netherlands (Ecorys, 2019). Inland water transport is seen as an alternative to road transport in the energy transition. However, with climate change, more frequent (prolonged) low-flow events pose challenges in maintaining waterways functional for navigation.

While water scarcity and droughts are distinct phenomena, they are interconnected. Not every drought event leads to water scarcity. However, in areas susceptible to water scarcity or prolonged droughts, these conditions can trigger or exacerbate water scarcity issues. Droughts are projected to increasingly affect every region in Europe (Map 4.3), leading to increased competition for water among economic sectors dependent upon it. Global warming of 3°C could double the frequency of droughts in many regions.

With no adaptation measures, it was estimated that annual drought losses in Europe and the UK could increase to EUR 45 billion/year up to 2100 with warming of 3°C (JRC, 2020b). Even at a 1.5°C increase, drought impacts could reach EUR 25 billion/year, with the Mediterranean and the Atlantic regions most severely impacted (JRC, 2020b).

Map 4.3 **Projected change in meteorological drought frequency between the periods 1981-2010 and 2041-2070 under two climate change scenarios**



Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

Notes: A drought event is defined as a continuous period of at least 2 months in which the Standard Precipitation Index-3 is below -1 (JRC, 2023b).Trends are expressed in number of events per decade squared. For example, a trend of +1 means that a location will experience each decade, on average, one drought event more than in the previous decade.

RCP 4.5 represents an intermediate greenhouse case emissions scenario, RCP 8.5 a high greenhouse gas emissions scenario.

Source: Adapted from JRC, 2017; EEA, 2023f.

Droughts have usually lasted a few months in Europe. In recent years, however, several multi-year droughts have occurred, such as the 2018-2020 drought in central Europe (van der Wiel et al., 2023) and the 2022-2023 drought in northern Italy (Box 4.5), France, Portugal and Spain (JRC, 2021). Prolonged droughts with dry winters between two consecutive dry summers are projected to happen more frequently in the future in Europe (Rakovec et al., 2022), posing additional challenges to drought management.

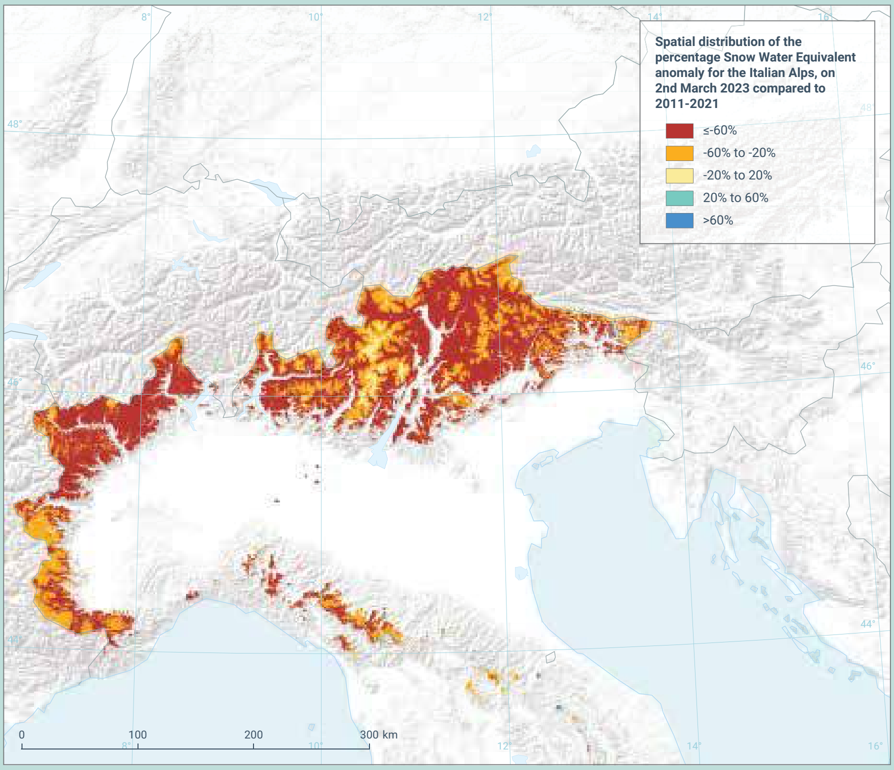
Box 4.5

The 2022-2023 drought and floods in northern Italy

The summer of 2022 in northern Italy was extremely dry, jeopardising water supplies for households, agriculture and hydropower. The drought continued during the winter season of 2022/2023, with a deficit in snowfall in the Alps of up to 63% (JRC, 2023b) (Map 4.4). The water level of Lake Garda was 70cm lower than usual and the canals in Venice were drying up. The entire agricultural and food sector in the Veneto was considered in peril (JRC, 2023b). In May 2023, almost half the average annual precipitation fell in northern Italy over 21 days (up to 350mm), an estimated 1-in-200-year event (Barnes et al., 2023). The rainfall caused widespread and devastating floods, with 17 fatalities and 50,000 people evacuated; the economic damage is estimated in the order of billions of euros.

No trend in the May precipitation attributable to climate change was identified, in contrast to the drought of 2022/2023 (Barnes et al., 2023). However, this series of events illustrates the need to be prepared for more extreme climate conditions in Europe.

Map 4.4 **Spatial distribution of the percentage Snow Water Equivalent (SWE) anomaly for the Italian Alps, on 2 March 2023 compared to 2011-2021**



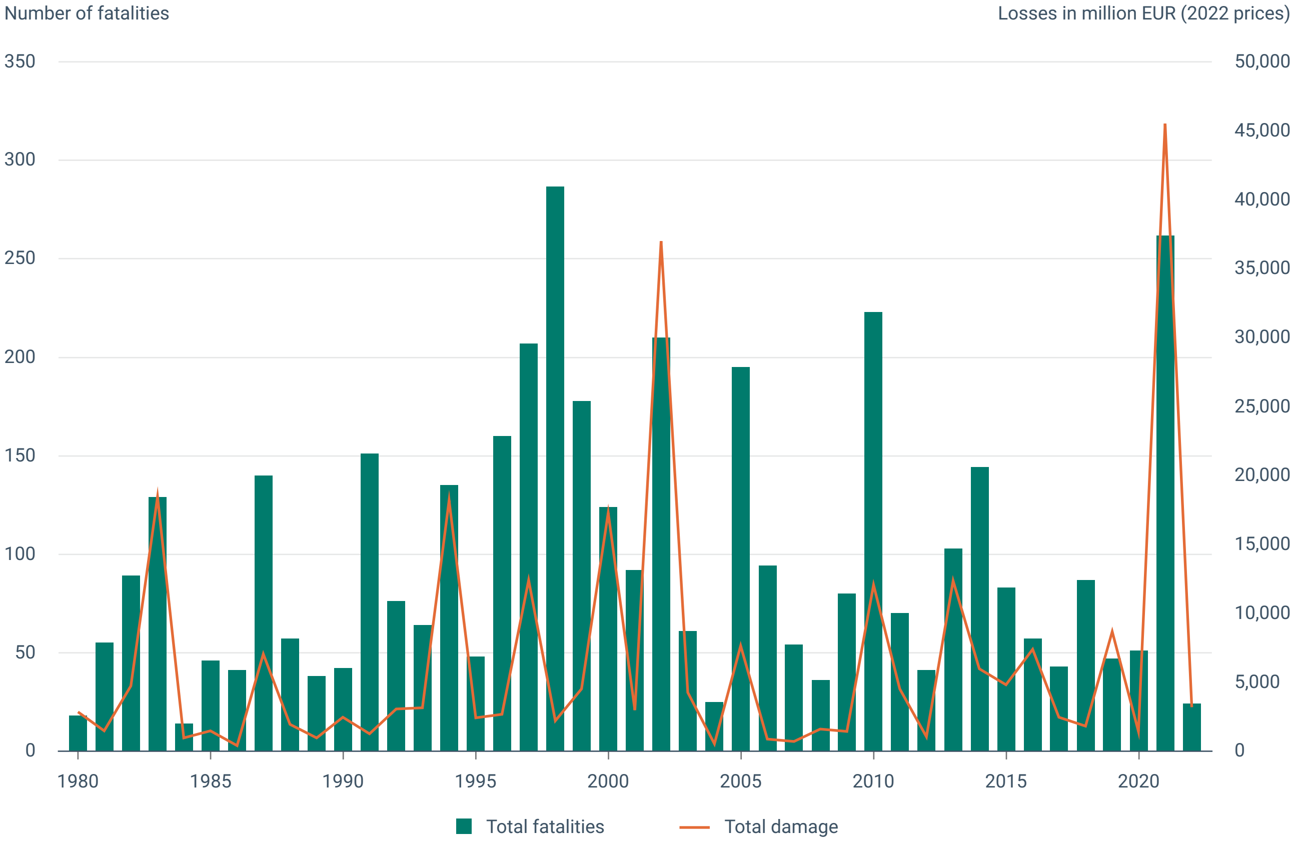
Reference data: © ESRI, USGS, NOAA and © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

Source: Adapted from the CIMA Research Foundation, in JRC, 2023b.

4.3.2 A growing risk of floods due to climate change and land use choices

In the period 1998-2020, floods comprised 43% of all disaster events in Europe (EEA, 2023b) (see also Figure 4.4 for 1980-2021). During this period, Europe suffered about 100 major damaging floods, causing some 700 fatalities, the displacement of about half a million people and nearly EUR 280 billion in insured economic losses.

Figure 4.4 Fatalities and economic damage (EUR million) attributable to floods in the EU-27, 1980-2021



Note: Riverine and coastal floods combined.

Source: EEA, 2023b

Climate change impacts and socio-economic developments are leading to more frequent flooding, affecting an increasing number of people and causing increasing damage (EEA, 2023b). 12% of Europe's population lives in floodplains (EEA, 2019) and trends show that more housing and industry are still being developed in flood-prone areas (EEA, 2024a). In addition, changes in land use significantly reduce catchments' water retention capacity, such as soil sealing in urban areas and agricultural intensification (e.g. tillage, drainage, removal of hedgerows, soil compaction by machinery).

As a result of climate change, extreme rainfall events are becoming more intense and frequent. Furthermore, their known temporal and spatial patterns are changing, as they may occur beyond the expected seasons and on a wider scale than before. They may lead to flash floods, which, although local, cause disproportionate numbers of casualties because of their sudden onset, while causing severe damage to the economy and environment at the local scale (see Figure 4.5).

Indirect negative impacts often occur as a result of pollution from surface run-off or sewage overflows. There is currently particular interest in addressing stormwater overflows and urban run-off as part of the proposed revision of the Urban Wastewater Treatment Directive (EC, 2022c) and sharing best practices for preventing water pollution through industrial accidents caused by flooding and droughts.

Rising sea levels and increased risk of coastal floods will impact an increasing number of people in coastal areas. Over the past 50 years, the population living in European coastal municipalities has more than doubled, thereby increasing the vulnerability of the European population to coastal flooding. With climate change, impacts from coastal flooding can become a major challenge for Europe. Annual economic losses could climb to EUR 239 billion/year (a 170-fold increase) with a high emission scenario and no adaptation (JRC, 2020b). For river flooding, losses could increase to EUR 47 billion/year by the end of the century (six-fold compared to current losses).

Figure 4.5 **Impact of a flash flood in Austria, summer 2024**

©Thomas Dworak

4.3.3 Responding to growing flood and drought risks

As re-emphasised by the EU climate adaptation strategy, Europe urgently needs to better manage flood and drought risks. With climate change impacts becoming more persistent, flood and drought management must fully integrate the risks arising from climate change (EC, 2019a). A combination of preparedness, emergency and recovery responses on the one hand, and adapting societal and economic activities on the other, will be essential to reduce vulnerability and increase resilience.

Drought and flood management plans exist in the EU. The Floods Directive (EU, 2007) aims to reduce and manage the risks of floods to human health, the environment, cultural heritage and economic activity through shifting the approach from flood defence to flood risk management. It covers river floods, flash floods, urban floods, sewer floods and coastal floods. The directive requires Member States to set objectives for flood risk management and to draw up measures to achieve them. Flood risk management plans have been developed in all Member States.

With increasing drought risks across Europe, more river basins would benefit from developing drought management plans. At EU level, there is no legal obligation to develop drought management plans (DMPs) and they are being prepared only in 18 of the 27 EU Member States (EC, 2023c). However, DMPs can support proactive risk management. As well as mitigating economic impacts, such plans can regulate competition for water between sectors. The provision of information, indicators and criteria, together with a negotiated set of priority and allocation rules, can provide clarity for stakeholders and thus contribute to societal resilience.

Early warning is key to reducing the impact of floods and droughts. Since 2012, the European Flood Awareness System (EFAS) has provided a wide range of early flood forecasting information, and complements national approaches to support national and regional authorities responsible for flood risk management in arranging preparatory measures before an event strikes. Additionally, EFAS provides an overview on currently observed and forecasted flood events. The service also estimates and maps the potential socio-economic impact of those events. For flash floods, EFAS provides different indicators, with lead times ranging from 6 hours to 5 days (EFAS, 2024).

With early warning of drought events, authorities and users can take action to delay the onset of the strictest restrictive measures. Complementing national schemes, the European Drought Observatory (JRC, 2021), including the recently published EDORA Drought Impact Database and Drought Risk Atlas (JRC, 2023c), provides drought forecasting, detection and monitoring at European level.

In many European countries, dikes, levees and reservoirs have been constructed for flood management. At the same time, reservoirs are promoted to address water scarcity and droughts. However, these infrastructures are among the main causes of alteration and ecological impairment of rivers (see Chapter 2). Dykes and levees may even be counter-productive at a river basin and catchment scale, as they reduce the area available to absorb and convey floods (EEA, 2019). Floods are an essential phenomenon in healthy river systems. Measures should aim at working towards flood regimes that resemble the natural ones more closely, rather than simply restraining floods.

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Synergies should be sought across adaptation plans, RBMPs, flood risk management plans and drought management plans.

For instance, NbS (see Box 1.3, Section 3.2) have the potential to both reduce flood risk and increase drought resilience, while delivering multiple benefits for nature and society such as water purification. NbS are increasingly popular and used at multiple scales to slow the flow, store water in the landscape and infiltrate water into soils and groundwater.

Careful planning is necessary, as the effectiveness of NbS is context-specific and must be adapted to the local situation. This means that a 'one solution that fits all' does not exist (Trémolet et al., 2019; Black et al., 2021). In flood management, NbS cannot usually fully replace existing solutions and may not be effective for the most extreme events (Dadson et al., 2017; Black et al., 2021). However, NbS can enhance the effectiveness and operable life of grey infrastructure by increasing water absorption capacity, reducing water velocity and regulating peak flows (OECD, 2020). NbS and grey infrastructure can be implemented in an integrated way to reduce flood risk and provide other benefits, for instance in an urban context (Box 4.6).

There is still very limited field experience with the application of NbS in drought management (Sahani et al., 2019; Trémolet et al., 2019). However, using landscapes and catchments as sponges to maximise water retention in soils and groundwater hold potential to increase resilience to droughts. In particular, soil water storage on agricultural land could be maximised to buffer the need for abstraction (see Section 4.1).

Box 4.6

Case study: swales in a new housing area in the city of Enschede, the Netherlands

Urban drainage systems can cause problems, such as peak discharges into surface water, combined sewer overflows, shortage of water during summer and high ground water tables in the winter period. To prevent these problems, the Dutch municipality of Enschede designed a new drainage system with swales for a new housing estate. Implemented in 1999, the system was then monitored on hydraulic performance, social impact, water quality and environmental impact from 1999 to 2005, with additional hydraulic monitoring in 2022 and 2023.

All run-off is guided through gutters along the streets. In this way, it is kept visible on the surface. The gutters guide the rainwater to a series of swales. From there, gullies transport the surplus water to a subsoil infiltration body, made of expanded clay grains wrapped in a geo-textile. Above a certain water level in the swale, the water is discharged into the next swale and ultimately into the surface water. At the bottom of the infiltration device, underneath the swale, drainpipes are installed. They spread the water through the infiltration body when groundwater tables are low and they drain the area when groundwater tables are high.

The swale system thus combines drainage in wet (winter) periods with storage and infiltration during dry (summer) periods (Figure 4.6).

Monitoring data indicate that almost all run-off (about 99%) infiltrated into the soil and groundwater instead of being discharged to surface water or the wastewater treatment plant. Residents confirm that the swales are mostly emptied within 24 hours. Analysis of times to empty with infiltration capacity tests shows no loss of infiltration capacity at the site of the monitoring programme. The costs of construction of a swale system per unit discharging area are slightly less than the costs of a traditional sewer system. Costs for maintenance though are slightly higher compared to a traditional rainwater system.

Early stakeholder involvement has proven key for the success of the project. It helped develop support (overcoming initial objections, resulting in spontaneous sharing of field observations) and offered opportunities for the residents to exchange experiences and propose improvements.

Source: Boogaard, 2022.

Figure 4.6 **Swale in a housing area**

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The intentional recharge of groundwater, either through natural retention and infiltration across the landscape or through managed aquifer recharge (EC, 2023a) can also help recover groundwater levels after droughts and enhance overall resilience. Careful site selection and monitoring is needed to avoid possible leaching of surface water pollutants into aquifers, and to avoid competition between water users in recharge areas, such as agriculture, forestry, industry and drinking water supply.

There is scope to use different water supply sources in more coordinated ways. Water supplies can be diversified through rainwater harvesting, reused or recycled water, or desalinisation of seawater. Although these can have benefits in particular settings, they also have drawbacks. For instance, desalinisation is usually energy intensive and can create significant salt (brine) waste which can be toxic to the marine environment.

Better coordination between the use of surface water and groundwater resources is needed. For instance, groundwater can be preserved as a strategic resource to draw upon in emergency situations or for future generations, as with some aquifers critical for drinking water supply in France (Herivaux and Rinaudo, 2015). In other cases, it may call for greater use of groundwater resources to preserve important surface water reserves and flows for society and the environment. This coordinated management in the use of surface water and groundwater is still rare in the EU.

This chapter has considered the pressing challenges for water resources, particularly those associated with climate change. Water scarcity is increasing, especially in southern regions of Europe, while more frequent and intense droughts and rainfall will occur across the continent. Floods and water scarcity compromise food and water security and the health of the general population, in turn affecting social cohesion and stability (EEA, 2024a).

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5 Summary and outlook

5.1 Summary

This report has presented the state of water based on Member States' reporting under the Water Framework Directive and other water-related directives, focusing on three overarching challenges facing European water management:

1. protecting and restoring aquatic ecosystems;

2. achieving the zero pollution ambition;

3. adapting to water scarcity, drought and flood risks.

Surface waters across the continent reflect continued combined pressures, in particular diffuse pollution and the degradation of their natural flow and physical features. Pollution by nutrients and persistent priority substances continues, which, together with substances newly emerging as pollutants, represent ongoing risks to human and aquatic health. Groundwaters are also affected by diffuse pollution, especially from agriculture, and are also impacted by abstraction for agriculture, public water supply and industry. To improve Europe's water status and build resilience, pressures need to be reduced.

Climate change represents an unrelenting threat to water resources and aquatic ecosystems, increasing the vulnerability of freshwater species to pressures from human activity and competition from non-native species. Water stress affects 20% of European territory and 30% of the population on average every year and this will increase. Lack of water security can affect social cohesion and stability, disrupt critical infrastructure and undermine the EU's internal cohesion (EEA, 2024a).

Water stress also impacts aquatic and water-dependent ecosystems and the services they deliver. Current trends indicate that decisions must be made on what water-dependent activities can be sustainably maintained, where, and under what conditions. Tools for managing water use and balancing water demand and supply are insufficient to ensure enough water remains in rivers, lakes and groundwater to sustain aquatic ecosystems and downstream uses.

In an era dominated by the growing impact of climate change and increasing water stress, water security for all European citizens is an essential goal for water management. Water is a fundamental need, as recognised in Sustainable Development Goal 6, to ensure the availability and sustainable management of water and sanitation for all (UN, 2016).

5.2 Outlook

5.2.1 A fresh impetus for restoring aquatic ecosystems

This report has highlighted how EU aquatic and water-dependent ecosystems and biodiversity are facing a crisis: widespread diffuse sources of pollution and changes in the physical features and natural flow of water bodies lead to loss of key habitats and species decline.

Despite efforts with measures under the WFD and the Habitats Directive, freshwater ecosystems are still among the most degraded in Europe, with their decline expected to intensify due to climate change.

More than half of the world's total GDP is estimated to be moderately or highly dependent on nature and biodiversity. Healthy ecosystems are self-balancing, but ecosystems can also rapidly collapse if critical thresholds are crossed. The most immediate detrimental effect will be to food security, local communities and those economic sectors that are most dependent on healthy nature. To maintain and restore the resilience of ecosystems and the services they provide, approximately 30-50% of Earth's land, freshwater and oceans will need to be effectively and equitably preserved (EC, 2024a).

The EU Nature Restoration Law can spark large-scale nature recovery and restoration of the health of freshwaters. Targets to restore freshwater, coastal and wetland ecosystems and to remove river barriers should be carefully coordinated with ongoing restoration efforts under the WFD. Improved monitoring systems combined with remote sensing technologies (such as Copernicus) can support better-informed decisions for aquatic ecosystem restoration at different scales.

Seizing new opportunities for the recovery of freshwater ecosystems and biodiversity will require good assessment and consideration of the specific restoration needs of aquatic habitats and species, inside and outside Natura 2000 areas, addressing connectivity issues and tackling new challenges such as emerging chemical pollutants and climate change.

Investing in nature-based solutions that support water retention and purification in the landscape and the soil will not only help restore the water cycle, but also benefit biodiversity and climate change mitigation. Water management should upscale from traditional restoration approaches focusing on specific river stretches or water bodies to larger-scale restoration programmes. These can include restoring key wetland ecosystems and floodplains, rewetting peatlands, and adopting forestry and agricultural practices that avoid soil compaction and help replenish groundwater and surface water reserves.

5.2.2 Managing growing uncertainties on water resources with climate change

As the effects of climate change become more pervasive, river basin management plans must be strengthened to accommodate water scarcity, droughts and floods. NbS have the potential to provide multiple benefits for nature and society by mitigating these risks and increasing resilience. They can lower adaptation costs and provide alternatives to, or complement, grey infrastructure. To achieve this, there needs to be better joined-up action and promotion of innovation in sectors and policies that can become more water-smart, such as energy, agriculture and industry.

Water scarcity and water quality are closely intertwined. Reduced water resources can lower water quality, while poorer quality can reduce water availability for all users, including aquatic life. Taken to an extreme, tipping points may emerge that significantly threaten water availability in some regions. The fundamental need for water may drive changes in societal behaviour: the extent to which people can afford to and are willing to adapt their behaviour to match the available water, together with changes to the natural and built environment, will determine the level of resilience.

With the risk of intense rainfall and flooding increasing and drinking water resources reducing, urban areas have major challenges ahead. More emphasis must be given to the large-scale adoption of NbS to enhance water retention and 'slow the flow' of intense rain. These include, for example, green infrastructure in cities to collect, retain and treat stormwater, agroforestry practices in agriculture, restoration of drained peatlands and wetlands, and reforestation of biodiverse forests. Such methods can contribute to mitigating the impacts of floods while storing water in soils and groundwater through NbS. Nature-based solutions can also contribute to nutrient recycling, carbon storage, improved water quality and more biodiversity.

Agriculture and hence food security faces severe challenges from climate change. Increased water scarcity and droughts in many parts of Europe will put current agricultural practices under pressure, threatening crop yields and livelihoods. Building resilience in agroecosystems is a priority, adapting soil and crop management techniques, diversifying production and landscapes and promoting technological innovation. Increased efforts are urgently needed to manage the risk of prolonged drought, including in Member States' CAP strategic plans. This could include supporting drought-resilient crops or varieties and favouring less water-intensive crops (EEA, 2024a).

New and existing energy infrastructure should incorporate hydrological forecasting and monitoring systems to manage risk from prolonged droughts and water scarcity. New energy infrastructure in water-scarce regions should be as water-efficient as possible and planned in the light of climate projections and demands from other sectors (EEA, 2024a).

Management, planning, monitoring and enforcement are needed to match the demand for water with the available resources, now and into the future. Users should be treated equitably, while decisions may need to prioritise users such as the public water supply, freshwater ecosystems and agricultural irrigation. Pricing can play a signalling role in encouraging efficient water use while raising financing needed for water investments. Currently, none of the legislative or policy instruments at the EU level set quantitative targets for water saving or water demand reduction.

Extreme weather events pose increasing risks to the built environment and infrastructure in Europe, as well as the services they provide. Such events can disrupt essential services, including energy supply, water supply and transport networks (EEA, 2024a).

While this report has noted impacts of current water demand on water scarcity due to, for instance, irrigated agriculture and cooling at energy plants, others have identified challenges owing to the energy transition (EC, forthcoming). These include the potential further expansion of hydropower (e.g. small-scale hydropower), with its associated potential for impacting river connectivity and degrading natural habitats. Such examples, where objectives between climate neutrality and ecosystem protection may collide, need to be strategically addressed and mitigated. Other challenges include the use of reservoirs for energy and water storage and the expansion of new energy technologies (such as hydrogen) with water demands that could intensify existing water scarcity.

Increasing interest in the value of 'blue health', particularly its role in improving people's well-being (BlueHealth, 2020), can be combined with NbS and other restoration approaches. Studies have shown that adults with better mental health were more likely to report having spent time playing in and around coastal and inland waters (Vitale et al., 2022). An improved understanding of the health benefits of access to blue space is needed to better assess the value of such interventions.

5.2.3 Securing a transition to a circular economy

The European Green Deal set out ambitious plans for a circular economy. Integrating water resilience into the transition will be necessary and is already becoming a factor in sectors heavily reliant on water. Water reuse should be pursued more widely, in line with the Water Reuse Regulation (EU, 2020b). Further applications for water reuse (for example, in industry and amenities) should also be explored while ensuring its safety through appropriate standards and practices.

Changes in production and consumption systems associated with technological change and new living standards and habits also need to be strategically managed to avoid adverse outcomes for water.

Digitisation offers the opportunity to better manage water through rapid data gathering and forecasting. However, challenges may arise from new technology, such as from water use in mining for critical minerals and in recycling electrical products for rare metals, as well as in new industrial water demands for semiconductors and batteries (Water Europe, 2023). Locally, developing new industrial sites, such as for chip manufacturing or storing data, may become sources of conflict owing to their water demand for cooling. For the digital transition to adequately manage water availability, water use must be considered at an early stage of development.

Achieving the zero pollution targets set out under the Green Deal requires ambitious measures to reduce nitrogen and phosphorus inputs to aquatic ecosystems (EC, 2019b). This needs to include further efforts from the agricultural and urban wastewater treatment sectors, as well as reducing nitrogen from atmospheric deposition.

The widespread and intense pressure posed by intensive agricultural practices calls for a major transformation of European agriculture towards more sustainable practices to preserve our water resources and sustain the multiple uses attached to good quality, sufficient water.

New technologies, such as precision agriculture for inputs of water, nutrients and pesticides, offer ways for farmers to become more efficient while protecting the environment. A full agricultural transition needs to be accompanied by a change in food systems, adapting consumer choices and food value chain policies to more environmentally and socially acceptable and resilient agriculture.

Widespread pollution of surface waters, by harmful and persistent pollutants released to air which later return with rainfall to the earth's surface, presents a major challenge. Further efforts are needed to reduce emissions of mercury, such as from coal burning for energy production. Improved knowledge of the pathways taken by brominated flame retardants is needed to establish effective measures.

Improving urban wastewater treatment to reduce chemical and nutrient discharges is one aim of the proposed revision to the Urban Wastewater Treatment Directive (EC, 2022c). Typically, efforts to achieve this can involve high levels of investment and carbon-intensive infrastructure. New technologies and improved practices to reduce emissions and improve efficiency are under development. Further innovations to meet the ambitions of the proposed revision, for instance towards reduced release of micropollutants, are urgently needed.

While large urban wastewater treatment plants can deliver considerable efficiencies of scale, local, decentralised facilities, ranging in scale from individual buildings up to small towns, can also deliver effective sewage treatment (EEA, 2022a).

Technologies like separated wastewater systems enable safe treatment of sewage while recovering both energy and nutrients. Wastewater from washing and cooking can be reused for applications where lower-quality water will suffice, such as irrigating parks and gardens.

With the widespread use of increasing numbers of chemicals, reducing chemical pollution to ensure sufficient, good quality water for people and the environment requires effort from many stakeholders beyond the water sector. The emerging issue of water pollution by PFAS will be difficult and expensive to ameliorate. The early warning and action system of chemical risks, proposed in the draft regulation on establishing a common data platform on chemicals (EC, 2023b), aims to prevent pollution before it becomes widespread.

Proposed revisions to the WFD set out in 2022 (EC, 2022b) would extend the scope of monitoring to antibiotic-resistant genes and microplastics, underlining the essential role of the WFD in monitoring the environmental impact of many activities undertaken across Europe. Guidance and common assessment grounds are needed. Progress in the analysis of emerging pollutants, combined with monitoring for chemical mixture effects, could help improve understanding of water quality and identify further measures to prevent pollution.

Water is not an option. It underpins society and the natural environment as we know it. The status of waters reported by Member States highlights the urgent need for more decisive action.

Current trends indicate that decisions must be made between competing needs, such as the public water supply, agriculture, nature, industry. For long-term water security, Europe needs to restore surface waters' natural flow and physical features, reduce pollution and better manage water resources. This requires renewed effort, innovation and recognition of the roles needed at all levels of management, from local land management through to European strategic policy.


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List of abbreviations

Abbreviation	Name
BFRs	Brominated flame retardants
CAP	Common agricultural policy
CLRTAP	Convention on Long-Range Transboundary Air Pollution
EC	European Commission
EUCRA	European Climate Risk Assessment
EEA	European Environment Agency
EU	European Union
EU-27	27 EU Member States
GDP	Gross domestic product
GHG	Greenhouse gas
ha	Hectares
IED	Industrial Emissions Directive
IED 2.0	Industrial and Livestock Rearing Emissions Directive
Mt CO_2e	Million tonnes of CO_2 equivalent
NbS	Nature-based solutions
PAHs	Polycyclic aromatic hydrocarbons
PFAS	Per- and polyfluoroalkyl substances
PFOS	Perfluorooctane sulfonic acid
REACH	Registration, evaluation, authorisation and restriction of chemicals
RBMP	River basin management plan
RBSPs	River basin specific pollutants
uPBTs	Ubiquitous, persistent, bioaccumulative and toxic substances
UWWTD	Urban Wastewater Treatment Directive
WFD	Water Framework Directive

References

Ahrens, L. and Bundschuh, M., 2014, 'Fate and effects of poly- and perfluoroalkyl substances in the aquatic environment: A review', *Environmental Toxicology and Chemistry* 33(9), pp. 1921-1929 (DOI: 10.1002/etc.2663).

Albert, J. S., et al., 2021, 'Scientists' warning to humanity on the freshwater biodiversity crisis', *Ambio* 50(1), pp. 85-94 (DOI: 10.1007/s13280-020-01318-8).

Albrecht, E., et al., 2023, 'Browning of boreal lakes: Do public perceptions and governance align with the biological foundations?', *Ecological Applications* 33(5), p. e2856 (DOI: 10.1002/eap.2856).

Alfaro-Núñez, A., et al., 2021, 'Microplastic pollution in seawater and marine organisms across the Tropical Eastern Pacific and Galápagos', *Scientific Reports* 11(1), p. 6424 (DOI: 10.1038/s41598-021-85939-3).

Almond, R. E. A., et al. (eds), 2022, *Living Planet Report 2022 – Building a nature-positive society*, WWF, Gland, Switzerland.

Anderson, J. K., et al., 2022, 'Grouping of PFAS for human health risk assessment: Findings from an independent panel of experts', *Regulatory Toxicology and Pharmacology* 134, p. 105226 (DOI: 10.1016/j.yrtph.2022.105226).

APE, 2023, *RESILIENCE IN ACTION Public Water Operators' Strategies to Tackle Water Scarcity and Drought*, Aqua Publica Europea, The European Association of Public Water Operators (https://www.aquapublica.eu/sites/default/files/document/file/APE%20publication%20-%20Resilence%20in%20action.pdf) accessed 21 June 2024.

Aquasoil, 2023 (https://www.aquasoil.it/en) accessed 12 October 2023.

Barnes, C., et al., 2023, *Limited net role for climate change in heavy spring rainfall in Emilia-Romagna* (http://spiral.imperial.ac.uk/handle/10044/1/104550) accessed 26 March 2024.

Baron, J. S., et al., 2003, 'Sustaining Healthy Freshwater Ecosystems', *Issues in Ecology* 10.

Basen, T., et al., 2022, 'Suitability of Natura 2000 sites for threatened freshwater species under projected climate change', *Aquatic Conservation: Marine and Freshwater Ecosystems* 32(12), pp. 1872-1887 (DOI: 10.1002/aqc.3899).

Belletti, B., et al., 2020, 'More than one million barriers fragment Europe's rivers', *Nature* 588(7838), pp. 436-441 (DOI: 10.1038/s41586-020-3005-2).

Billen, G., et al., 2021, 'Reshaping the European agro-food system and closing its nitrogen cycle: The potential of combining dietary change, agroecology, and circularity', *One Earth* 4(6), pp. 839-850 (DOI: 10.1016/j.oneear.2021.05.008).

Birk, S., et al., 2012, 'Three hundred ways to assess Europe's surface waters: An almost complete overview of biological methods to implement the Water Framework Directive', *Ecological Indicators* 18, pp. 31-41 (DOI: 10.1016/j.ecolind.2011.10.009).

Black, A., et al., 2021, 'Natural flood management, lag time and catchment scale: Results from an empirical nested catchment study', *Journal of Flood Risk Management* 14(3), p. e12717 (DOI: 10.1111/jfr3.12717).

BlueHealth, 2020, 'About BlueHealth' (https://bluehealth2020.eu/about) accessed 22 March 2024.

Boogaard, F. C., 2022, 'Spatial and Time Variable Long Term Infiltration Rates of Green Infrastructure under Extreme Climate Conditions, Drought and Highly Intensive Rainfall', *Water* 14(6), p. 840 (DOI: 10.3390/w14060840).

Brack, W., et al., 2019, 'Effect-based methods are key. The European Collaborative Project SOLUTIONS recommends integrating effect-based methods for diagnosis and monitoring of water quality', *Environmental Sciences Europe* 31(1), p. 10 (DOI: 10.1186/s12302-019-0192-2).

Briland, R. D., et al., 2020, 'Cyanobacterial blooms modify food web structure and interactions in western Lake Erie', *Harmful Algae* 92, p. 101586 (DOI: 10.1016/j.hal.2019.03.004).

Cacace, D., et al., 2019, 'Antibiotic resistance genes in treated wastewater and in the receiving water bodies: A pan-European survey of urban settings', *Water Research* 162, pp. 320-330 (DOI: 10.1016/j.watres.2019.06.039).

Cassiraga, E., et al., 2019, 'Groundwater management in Spain: The case of the Eastern Mancha Aquifer System', *Hydrolink, International Association for Hydro-Environment Engineering and Research (IAHR)*, pp. 81-83.

Castaño, S., et al., 2010, 'Methodology for Quantifying Groundwater Abstractions for Agriculture via Remote Sensing and GIS', *Water Resources Management* 24(4), pp. 795-814 (DOI: 10.1007/s11269-009-9473-7).

CCNR, 2021, *Annual report 2021. Inland navigation in Europe. Market observation. Central Commission for the Navigation of the Rhine (CCNR)*, European Commission (https://inland-navigation-market.org/wp-content/uploads/2021/09/CCNR_annual_report_EN_2021_WEB.pdf) accessed 21 June 2024.

Cid, N. and Cardoso, A. C., 2013, European freshwater alien species, 'Global Freshwater Biodiversity Atlas' (atlas.freshwaterbiodiversity.eu) accessed 3 March 2020.

Comber, S., et al., 2015, 'Source apportionment of trace contaminants in urban sewer catchments', *Environmental Technology* 36(5), pp. 573-587 (DOI: 10.1080/09593330.2014.953599).

Copernicus, 2022, 'River discharge' (https://climate.copernicus.eu/esotc/2022/river-discharge) accessed 12 March 2024.

Couwenberg, J. and Jurasinski, G., 2022, Fact sheet: The role of methane in peatland rewetting, Greifswald Mire Centre, University of Rostock (https://www.greifswaldmoor.de/files/dokumente/Infopapiere_Briefings/202211_Fact%20sheet_GMCUR_Methan_English.pdf) accessed 21 June 2024.

Dadson, S. J., et al., 2017, 'A restatement of the natural science evidence concerning catchment-based “natural” flood management in the UK', *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 473(2199), p. 20160706 (DOI: 10.1098/rspa.2016.0706).

DDBRA et al., 2020, 'Danube Sturgeons' (https://danube-sturgeons.org/danube-sturgeons/) accessed 20 March 2024.

Deinet, S., et al., 2020, *The Living Planet Index (LPI) for migratory freshwater fish — Technical Report*, World Fish Migration Foundation, the Netherlands (https://worldfishmigrationfoundation.com/wp-content/uploads/2020/07/LPI_report_2020.pdf) accessed 21 June 2024.

de Wit, H. A., et al., 2016, 'Current Browning of Surface Waters Will Be Further Promoted by Wetter Climate', *Environmental Science & Technology Letters* 3(12), pp. 430-435 (DOI: 10.1021/acs.estlett.6b00396).

Dokulil, M. T., et al., 2021, 'Increasing maximum lake surface temperature under climate change', *Climatic Change* 165(3-4), p. 56 (DOI: 10.1007/s10584-021-03085-1).

Eau du Bassin Rennais Collectivité, 2023, 'La Collectivité en charge du service public - d'eau potable sur le bassin rennais', Eau du Bassin Rennais Collectivité (https://www.eaudubassinrennais-collectivite.fr) accessed 1 December 2023.

EC, 2003, *Monitoring under the Water Framework Directive*, Office for Official Publications of the European Communities, Luxembourg

EC, 2007, Communication from the Commission to the European Parliament and the Council 'Addressing the challenge of water scarcity and droughts in the European Union' (COM(2007) 414 final).

EC, 2012, *Ecodesign your future: how ecodesign can help the environment by making products smarter*, Publications Office of the European Union, Luxembourg (https://data.europa.eu/doi/10.2769/38512) accessed 21 June 2024.

EC, 2017, *Characterization of unplanned water reuse in the EU: final report*, Publications Office of the European Union, Luxembourg (http://dx.publications.europa.eu/10.2779/597701) accessed 7 July 2020.

EC, 2019a, Commission Staff Working Document Fitness Check of the Water Framework Directive, Groundwater Directive, Environmental Quality Standards Directive and Floods Directive, Brussels (SWD(2019) 439 final).

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

EC, 2020a, Communication from the Commission to the European Parliament, the European 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, 2020b, Communication from the Commission to the European Parliament, the European 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, 2020c, Communication from the Commission to the European Parliament, the European Council, the European Economic and Social Committee and the Committee of the Regions, 'Chemicals Strategy for Sustainability Towards a Toxic-Free Environment' (COM(2020) 667 final).

EC, 2020d, Communication from the Commission to the European Parliament, the European 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).

EC, 2020e, Communication from the Commission to the European Parliament, the European Council, the European Economic and Social Committee and the Committee of the Regions, 'Pharmaceutical Strategy for Europe' (COM(2020) 761 final).

EC, 2021a, Commission Staff Working Document - Impact Assessment Report Accompanying the document 'Proposal for a Regulation of the European Parliament and the Council amending Regulations (EU) 2018/841 as regards the scope, simplifying the compliance rules, setting out the targets of the Member States for 2030 and committing to the collective achievement of climate neutrality by 2035 in the land use, forestry and agriculture sector, and (EU) 2018/1999 as regards improvement in monitoring, reporting, tracking of progress and review', No SWD(2021) 609 final, European Commission, Brussels (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD:2021:0609:FIN) accessed 28 March 2024.

EC, 2021b, Communication from the Commission to the European Parliament, the European Council, the European Economic and Social Committee and the Committee of the Regions, 'Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change' (COM/2021/82 final).

EC, 2021c, Communication from the Commission to the European Parliament, the European Council, the European Economic and Social Committee and the Committee of the Regions, 'Pathway to a Healthy Planet for All EU Action Plan: "Towards Zero Pollution for Air, Water and Soil' (COM/2021/400 final).

EC, 2021d, Communication from the Commission to the European Parliament, the European Council, the European Economic and Social Committee and the Committee of the Regions, 'Action Plan for the development of organic production' (COM(2021)141).

EC, 2021e, Communication from the Commission to the European Parliament, the European Council, the European Economic and Social Committee and the Committee of the Regions, 'EU Soil Strategy for 2030 - Reaping the benefits of healthy soils for people, food, nature and climate' (COM(2021)699).

EC, 2021f, Proposal for a Directive of the European Parliament and of the Council on the protection of the environment through criminal law and replacing Directive 2008/99/EC (COM/2021/851 final).

EC, 2021g, Report from the Commission to the Council and the European Parliament on the implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources based on Member State reports for the period 2016-2019 (COM/2021/1000 final), European Commission (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A1000%3AFIN) accessed 21 June 2024.

EC, 2021h, Report from the Commission to the Council and the European Parliament on the implementation of the Water Framework Directive (2000/60/EC), the Environmental Quality Standards Directive (2008/105/EC amended by Directive 2013/39/EU) and the Floods Directive (2007/60/EC) Implementation of planned Programmes of Measures New Priority Substances Preliminary Flood Risk Assessments and Areas of Potential Significant Flood Risk (COM(2021) 970 final).

EC, 2021i, *EU biodiversity strategy for 2030: bringing nature back into our lives*, Publications Office of the European Union, Luxembourg.

EC, 2022a, Commission Staff Working Document Impact Assessment, 'Accompanying the proposal for a Regulation of the European Parliament and of the Council on nature restoration' (SWD/2022/167 final).

EC, 2022b, Proposal for a Directive of the European Parliament and of the Council amending Directive 2000/60/EC establishing a framework for Community action in the field of water policy, Directive 2006/118/EC on the protection of groundwater against pollution and deterioration and Directive 2008/105/EC on environmental quality standards in the field of water policy (COM/2022/540 final).

EC, 2022c, Proposal for a Directive of the European Parliament and of the Council concerning urban wastewater treatment (recast) (COM(2022)541).

EC, 2022d, Proposal for a Regulation of the European Parliament and of the Council establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC (COM(2022) 142 final).

EC, 2022e, *Biodiversity strategy for 2030: barrier removal for river restoration*, Publications Office of the European Union, Luxembourg.

EC, 2022f, *European Red List of Birds 2021*, Publications Office of the European Union, Luxembourg.

EC, 2023a, Common Implementation Strategy for the Water Framework Directive and the Floods Directive: Managed Aquifer Recharge (MAR) under the Water Framework Directive, European Commission (https://circabc.europa.eu/ui/group/9ab5926d-bed4-4322-9aa7-9964bbe8312d/library/cd3e9234-6fe0-4069-8b2f-f87131d8bf2a/details) accessed 21 June 2024.

EC, 2023b, Proposal for a Regulation of the European Parliament and of the Council establishing a common data platform on chemicals, laying down rules to ensure that the data contained in it are findable, accessible, interoperable and reusable and establishing a monitoring and outlook framework for chemicals (COM(2023) 779 final), (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2023%3A779%3AFIN) accessed 4 March 2024.

EC, 2023c, *Stock-taking analysis and outlook of drought policies, planning and management in EU Member States: final report*, Publications Office of the European Union, Luxembourg.

EC, 2024a, Communication from the Commission to the European Parliament, the European Council, the European Economic and Social Committee and the Committee of the Regions, 'Managing climate risks - protecting people and prosperity' (COM/2024/91 final).

EC, 2024b, 'Natura 2000 Award - Improving the Pärnu river basin for its migratory fish' (https://environment.ec.europa.eu/topics/nature-and-biodiversity/natura-2000-award/meet-natura-2000-heroes/improving-parnu-river-basin-its-migratory-fish_en) accessed 19 March 2024.

EC, forthcoming, 'FORENV Cycle 5: Emerging environmental and other issues impacting our ability to achieve a water-resilient Europe by 2050'.

ECDC, 2022, 'Antibiotic resistance: a growing threat to human health' (https://www.ecdc.europa.eu/en/publications-data/antibiotic-resistance-growing-threat-human-health) accessed 19 March 2024.

ECHA, 2021, 'Registry of restriction intentions until outcome' (https://echa.europa.eu/de/registry-of-restriction-intentions/-/dislist/details/0b0236e18663449b) accessed 25 March 2024.

Ecofys et al., 2014, *Pilot project on availability, use and sustainability of water production of nuclear and fossil energy – Geo-localised inventory of water use in cooling processes, assessment of vulnerability and of water use management measures End Report*, ENV.D1/SER/2013/0004 (https://wayback.archive-it.org/12090/20230308040711/https://ec.europa.eu/environment/archives/water/adaptation/pdf/InventoryCoolingWaterUse.pdf) accessed 25 March 2024.

Ecorys, 2019, 'Economische schade door droogte in 2018', Ministerie van Infrastructuur en Waterstaat, Rotterdam (https://www.ecorys.com/app/uploads/files/2019-10/20190221%20Rapport%20Economische%20schade%20door%20droogte%20in%202018.pdf) accessed 21 June 2024.

EEA, 2013, *Assessment of cost recovery through water pricing*, EEA Technical Report No 16/2013, European Environment Agency (https://www.eea.europa.eu/publications/assessment-of-full-cost-recovery) accessed 21 March 2024.

EEA, 2017, 'Water management in Europe: price and non-price approaches to water conservation', European Environment Agency (https://www.eea.europa.eu/publications/water-management-in-europe-price) accessed 19 March 2024.

EEA, 2018a, *Chemicals in European waters*, EEA Report No 18/2018, European Environment Agency (https://www.eea.europa.eu/publications/chemicals-in-european-waters) accessed 18 March 2024.

EEA, 2018b, *European waters — Assessment of status and pressures 2018*, EEA Report No 7/2018, European Environment Agency (https://www.eea.europa.eu/publications/state-of-water) accessed 6 December 2018.

EEA, 2019, *Floodplains: A natural system to preserve and restore*, EEA Report No 24/2019, European Environment Agency (https://www.eea.europa.eu/publications/floodplains-a-natural-system-to-preserve-and-restore) accessed 21 June 2024.

EEA, 2020, *State of nature in the EU — Results from reporting under the nature directives 2013-2018*, EEA Report No 10/2020, European Environment Agency (https://www.eea.europa.eu/publications/state-of-nature-in-the-eu-2020) accessed 11 April 2023.

EEA, 2021a, *Water and agriculture: towards sustainable solutions*, EEA Report No 17/2020, European Environment Agency (https://www.eea.europa.eu/publications/water-and-agriculture-towards-sustainable-solutions) accessed 19 January 2023.

EEA, 2021b, *Water resources across Europe — Confronting water stress: An updated assessment*, EEA Report No 12/2021, European Environment Agency (https://www.eea.europa.eu/publications/water-resources-across-europe-confronting) accessed 2 July 2022.

EEA, 2021c, 'WISE FRESHWATER INFORMATION SYSTEM FOR EUROPE Country profiles on urban wastewater treatment — European Union', European Environment Agency (https://water.europa.eu/freshwater/countries/uwwt/european-union) accessed 12 January 2023.

EEA, 2022a, *Beyond water quality - Sewage treatment in a circular economy*, EEA Report No 05/2022, European Environment Agency (https://www.eea.europa.eu/publications/beyond-water-quality-sewage-treatment) accessed 19 March 2024.

EEA, 2022b, 'Carbon stocks and sequestration in terrestrial and marine ecosystems: a lever for nature restoration?', European Environment Agency (https://www.eea.europa.eu/publications/carbon-stocks-and-sequestration-rates/carbon-stocks-and-sequestration-in) accessed 8 March 2023.

EEA, 2022c, 'Cross-cutting story 5: Co-benefits of addressing climate change and pollution', Health: Cross-cutting stories, European Environment Agency (https://www.eea.europa.eu/publications/zero-pollution/cross-cutting-stories/cross-cutting-story-5-co) accessed 21 December 2022.

EEA, 2022d, 'Europe's groundwater — a key resource under pressure', European Environment Agency (https://www.eea.europa.eu/publications/europes-groundwater/europes-groundwater) accessed 19 March 2024.

EEA, 2022e, 'Soil signals', European Environment Agency (https://www.eea.europa.eu/publications/zero-pollution/health/signals/soil) accessed 19 March 2024.

EEA, 2022f, 'Water abstraction by source and economic sector in Europe', European Environment Agency (https://www.eea.europa.eu/ims/water-abstraction-by-source-and) accessed 26 March 2024.

EEA, 2022g, 'Water signals', European Environment Agency (https://www.eea.europa.eu/publications/zero-pollution/health/signals/water) accessed 13 December 2023.

EEA, 2023a, 'Agricultural area under organic farming in Europe', European Environment Agency (https://www.eea.europa.eu/ims/agricultural-area-used-for-organic) accessed 23 March 2023.

EEA, 2023b, 'Economic losses from weather- and climate-related extremes in Europe', European Environment Agency (https://www.eea.europa.eu/en/analysis/indicators/economic-losses-from-climate-related?activeAccordion=309c5ef9-de09-4759-bc02-802370dfa366) accessed 14 November 2023.

EEA, 2023c, 'How pesticides impact human health and ecosystems in Europe', European Environment Agency (https://www.eea.europa.eu/publications/how-pesticides-impact-human-health/how-pesticides-impact-human-health) accessed 22 March 2024.

EEA, 2023d, 'Nitrate in groundwater', European Environment Agency (https://www.eea.europa.eu/en/analysis/indicators/nitrate-in-groundwater-8th-eap) accessed 20 March 2024.

EEA, 2023e, 'Nutrients in freshwater in Europe', European Environment Agency (https://www.eea.europa.eu/en/analysis/indicators/nutrients-in-freshwater-in-europe) accessed 20 March 2024.

EEA, 2023f, 'Projected change in meteorological drought frequency between the periods 1981-2010 and 2041-2070 under two climate change scenarios', European Environment Agency (https://www.eea.europa.eu/data-and-maps/figures/projected-change-in-meteorological-drought-1) accessed 22 March 2024.

EEA, 2023g, 'Seasonal water scarcity conditions across Europe, measured by the water exploitation index plus (WEI+) for sub river basins, 2019', European Environment Agency (https://www.eea.europa.eu/data-and-maps/figures/seasonal-water-exploitation-index-plus-4) accessed 20 March 2024.

EEA, 2023h, 'Water scarcity conditions in Europe (Water exploitation index plus)', European Environment Agency (https://www.eea.europa.eu/en/analysis/indicators/use-of-freshwater-resources-in-europe-1) accessed 28 November 2023.

EEA, 2024a, *European climate risk assessment*, EEA report No 01/2024, Europe Environment Agency (https://www.eea.europa.eu/publications/european-climate-risk-assessment) accessed 12 March 2024.

EEA, 2024b, 'Nutrients in transitional, coastal and marine waters in Europe', European Environment Agency (https://www.eea.europa.eu/en/analysis/indicators/nutrients-in-transitional-coastal-and) accessed 19 March 2024.

EEA, 2024c, 'Pesticides in rivers, lakes and groundwater in Europe', European Environment Agency (https://www.eea.europa.eu/en/analysis/indicators/pesticides-in-rivers-lakes-and) accessed 29 February 2024.

EEA, 2024d, 'Responding to climate change impacts on human health in Europe: focus on floods, droughts and water quality' European Environment Agency (https://www.eea.europa.eu/publications/responding-to-climate-change-impacts) accessed 23 August 2024

EEA and ETC-BD, undated, 'Article 17 web tool – Species assessments at EU biogeographical level', Eionet Europa (https://nature-art17.eionet.europa.eu/article17) accessed on 24 June 2024

EFAS, 2024, 'Flash flood indicators' (https://www.efas.eu/en/flash-flood-indicators) accessed 20 March 2024.

EFSA et al., 2020, 'Climate change as a driver of emerging risks for food and feed safety, plant, animal health and nutritional quality', *EFSA Supporting Publications* 17(6).

EIP-AGRI, 2015, *Precision Farming-Final Report*, EIP-AGRI (https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_focus_group_on_precision_farming_final_report_2015.pdf) accessed 22 March 2024.

EPA, 2021, *Drinking water quality in public supplies*, Environmental Protection Agency, Ireland (https://www.epa.ie/publications/compliance--enforcement/drinking-water/annual-drinking-water-reports/87838-EPA-Public-Report-2020-full-File-revised.pdf) accessed 27 March 2023.

ETC BE, forthcoming, *Water saving measures*.

EU, 1986, Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (OJ L 181, 4.7.1986, pp. 6-12).

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

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, pp. 1-8).

EU, 1992, Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (OJ L 206, 22.7.1992, pp. 7-50).

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 (OJ L 327, 22.12.2000, pp. 1-73).

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, pp. 37-51).

EU, 2006b, Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration (OJ L 372, 27.12.2006, pp. 19-3).

EU, 2006c, 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, pp. 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, pp. 27-34).

EU, 2008a, 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) (Text with EEA relevance) (OJ L 164, 25.6.2008, pp. 19-40).

EU, 2008b, Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council (OJ L 348, 24.12.2008, pp. 84-97).

EU, 2009a, 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 (Text with EEA relevance) (OJ L 309, 24.11.2009, pp. 71-86).

EU, 2009b, Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC (OJ L 309, 24.11.2009, pp. 1-50).

EU, 2010a, Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (codified version) (OJ L20, 26.1.2010, pp. 7-25).

EU, 2010b, Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) Text with EEA relevance (OJ l 334, 17.12.2010, pp. 17-119).

EU, 2011, Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast) (OJ L 174, 1.7.2011, pp. 88-110).

EU, 2012, Regulation (EU) No 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products (text with EEA relevance) (OJ L 167, 27.6.2012, pp. 1-123).

EU, 2013, Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy (Text with EEA relevance) (OJ L 226, 24.8.2013, pp. 1-17).

EU, 2019, Regulation (EU) 2019/1021 of the European Parliament and of the Council of 20 June 2019 on persistent organic pollutants (recast) (Text with EEA relevance.) (OJ L 169, 25.6.2019, pp. 45-77).

EU, 2020a, Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast) (OJ L 435, 23.12.2020, pp. 1-62).

EU, 2020b, Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse (OJ L 177, 5.6.2020, pp. 32-55).

EU, 2021, Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law') (OJ L 243, 9.7.2021, pp. 1-17).

EU, 2022, Decision (EU) 2022/591 of the European Parliament and of the Council of 6 April 2022 on a general Union Environment Action Programme to 2030 (OJ L 114, 12.4.2022, p. 22-36).

EU, 2023, Council Recommendation on stepping up EU actions to combat antimicrobial resistance in a One Health approach 2023/C 220/01 (ST/9581/2023/INIT OJ C 220, 22.6.2023, pp. 1-20).

EU, 2024a, Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) EU, 2024d, Directive (EU) 2024/1785 of the European Parliament and of the Council of 24 April 2024 amending Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control) and Council Directive 1999/31/EC on the landfill of waste. http://data.europa.eu/eli/dir/2024/1785/oj (OJ L, 2024/1991, 29.7.2024).

EU, 2024b, Directive (EU) 2024/1785 of the European Parliament and of the Council of 24 April 2024 amending Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control) and Council Directive 1999/31/EC on the landfill of waste (OJ L, 2024/1785, 15.7.2024).

EU, 2024c, Regulation (EU) 2024/1244 of the European Parliament and of the Council of 24 April 2024 on reporting of environmental data from industrial installations, establishing an Industrial Emissions Portal and repealing Regulation (EC) No 166/2006 (OJ L, 2024/1244 , 2 May 2024).

EU, 2024d, Directive (EU) 2024/1785 of the European Parliament and of the Council of 24 April 2024 amending Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control) and Council Directive 1999/31/EC on the landfill of waste.http://data.europa.eu/eli/dir/2024/1785/oj

Eurostat, 2024, 'Pesticide sales' (https://ec.europa.eu/eurostat/databrowser/view/AEI_FM_SALPEST09__custom_5813112/bookmark/table?lang=en&bookmarkId=b424969f-cccd-4a52-b89e-5f04473f3da2) accessed 22 March 2024.

Evans, C. and Gauci, V., 2023, *Wetlands and Methane (Technical Report)*, Wetlands International (https://www.wetlands.org/publication/wetlands-and-methane-technical-report/) accessed 20 March 2024.

Fluet-Chouinard, E., et al., 2023, 'Extensive global wetland loss over the past three centuries', *Nature* 614(7947), pp. 281-286 (DOI: 10.1038/s41586-022-05572-6).

Fuchs, S., et al., 2020, *TEXTE 169/2020: Ressortforschungsplan des Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit: Forschungskennzahl 3717634040 FB000306 Belastung der Umwelt mit Bioziden realistischer erfassen - Schwerpunkt Einträge über Kläranlagen: Abschlussbericht*, Abschlussbericht No 169/2020, Umweltbundesamt, Dessau-Roßlau (https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/texte_169-2020_belastung_der_umwelt_mit_bioziden_realistischer_erfassen_-_schwerpunkt_eintraege_ueber_klaeranlagen.pdf) accessed 21 June 2024.

Gavioli, A., et al., 2023, 'Effectiveness of the Natura 2000 network for freshwater fish conservation in a Mediterranean region', *Frontiers in Environmental Science* 11 (DOI: 10.3389/fenvs.2023.1122464).

Global Conservation, 2024, 'European Mink | Species Facing Extinction' (https://globalconservation.org/species-facing-extinction/european-mink/) accessed 14 March 2024.

Greifswald Mire Centre and Wetlands International, 2022, 'Higher ambition for Peatlands in the EU Nature Restoration Law Proposal — Policy Briefing' (https://europe.wetlands.org/download/6860/?tmstv=1710946280) accessed 20 March 2024.

Haase, P., et al., 2023, 'The recovery of European freshwater biodiversity has come to a halt', *Nature* 620(7974), pp. 582-588 (DOI: 10.1038/s41586-023-06400-1).

Hering, D., et al., 2006, 'Assessment of European streams with diatoms, macrophytes, macroinvertebrates and fish: a comparative metric-based analysis of organism response to stress', *Freshwater Biology* 51(9), pp. 1757-1785 (DOI: 10.1111/j.1365-2427.2006.01610.x).

Herivaux, C. and Rinaudo, J., 2015, *Pourquoi et comment préserver les eaux souterraines pour leur rôle d'assurance? Tour d'horizon de l'expérience française*, Rapport final No BRGM/RP-65631-FR, BRGM.

Hermoso, V., et al., 2015, 'Effectiveness of a large reserve network in protecting freshwater biodiversity: a test for the Iberian Peninsula', *Freshwater Biology* 60(4), pp. 698-710 (DOI: 10.1111/fwb.12519).

Horppila, J., et al., 1998, 'Top-down or Bottom-up Effects by Fish: Issues of Concern in Biomanipulation of Lakes', *Restoration Ecology* 6(1), pp. 20-28 (DOI: 10.1046/j.1526-100x.1998.00613.x).

Hyde, B., et al., 2023, 'Ireland Informative Inventory Report 2023 Air Pollutant Emissions in Ireland 1990–2021 reported to the Secretariat of the UNECE Convention on Long-Range Transboundary Air Pollution and to the European Union', EPA (https://www.epa.ie/publications/monitoring--assessment/climate-change/air-emissions/Ireland-IIR-2023-finalv2.1.pdf) accessed 21 June 2024.

Interreg Europe, 2022, 'The return of wild salmon' (https://www.interregeurope.eu/find-policy-solutions/stories/the-return-of-wild-salmon) accessed 20 March 2024.

IPBES, 2023, Summary for Policymakers of the Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Roy, H. E. et al. (eds.), IPBES Secretariat, Bonn, Germany (https://zenodo.org/doi/10.5281/zenodo.7430692) accessed 14 March 2024.

IUCN, 2023, 'Vjosa, one of our last wild rivers, becomes Europe's first Wild River National Park - Press release' (https://www.iucn.org/press-release/202303/vjosa-one-our-last-wild-rivers-becomes-europes-first-wild-river-national-park) accessed 21 March 2024.

Janauer, G. A., et al., 2015, 'Synergies and Conflicts Between Water Framework Directive and Natura 2000: Legal Requirements, Technical Guidance and Experiences from Practice', in: Ignar, S. and Grygoruk, M. (eds), *Wetlands and Water Framework Directive: Protection, Management and Climate Change*, Springer International Publishing, Cham, pp. 9-29.

JRC, 2017, *Science for disaster risk management 2017: knowing better and losing less*, Publications Office of the European Union, Luxembourg.

JRC, 2020a, *Climate change and Europe's water resources*, Publications Office of the European Union, Luxembourg (https://data.europa.eu/doi/10.2760/15553) accessed 12 March 2024.

JRC, 2020b, *Global warming and drought impacts in the EU*, Technical Report No EUR 29956 EN JRC118585, Publications Office of the European Union, Luxembourg (https://joint-research-centre.ec.europa.eu/system/files/2020-05/pesetaiv_task_7_drought_final_report.pdf) accessed 21 June 2024.

JRC, 2021, 'EDO Home - European Drought Observatory' (https://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000) accessed 22 March 2024.

JRC, 2022, *Zero pollution: outlook 2022*, JRC129655 No EUR 31248 EN, Publications Office of the European Union, Luxembourg (https://data.europa.eu/doi/10.2760/778012) accessed 14 March 2024.

JRC, 2023a, *An EU analysis of the ecological disaster in the Oder River of 2022*, Publications Office of the European Union, Luxembourg (https://data.europa.eu/doi/10.2760/536489) accessed 14 March 2024.

JRC, 2023b, *Drought in Europe: March 2023: GDO analytical report*, Publications Office of the European Union, Luxembourg.

JRC, 2023c, *European Drought Risk Atlas*, No JRC135215, Publications Office of the European Union, Luxembourg (https://doi.org/10.2760/608737) accessed 14 February 2024.

Juutinen, A., et al., 2022, 'A comparative analysis of the value of recreation in six contrasting Nordic landscapes using the travel cost method', *Journal of Outdoor Recreation and Tourism* 39, p. 100528 (DOI: 10.1016/j.jort.2022.100528).

Kairesalo, T. and Kuoppamäki, K., 2004, 'Lake Vesijärvi and the city of Lahti (southern Finland) comprehensive interactions between the lake and the coupled human community', *SILnews* 41.

Kampa, E. and Schmidt, G., 2023, *Implementation of e-flows in the EU. Developed under the Framework Contract 'Water for the Green Deal' - Implementation and development of the EU water and marine policies (09020200/2022/869340/SFRA/ENV.C.1). Specific Contract 'Support to the Commission on water quantity management – follow up to the Fitness Check of EU water law conclusions, EU Strategy on Adaptation to Climate Change and Common Implementation Strategy Work Programme for the water directives (2022-2024)'*, Ecologic Institute, Fresh Throughts Consulting GmbH, Milieu Consulting.

Lacoste, É., et al., 2023, 'A Review of Knowledge on the Impacts of Multiple Anthropogenic Pressures on the Soft-Bottom Benthic Ecosystem in Mediterranean Coastal Lagoons', *Estuaries and Coasts* 46(8), pp. 2190-2207 (DOI: 10.1007/s12237-023-01188-9).

Lago, M., et al. (eds), 2015, *Use of Economic Instruments in Water Policy: Insights from International Experience*, Springer International Publishing, Cham.

Lange, J., et al., 2021, 'Wetland buffer zones for nutrients retention and cleaner waters', Greifswald Mire Centre (https://www.moorwissen.de/files/doc/Projekte%20und%20Praxis/desire/GMC-factsheet-WBZ-Engl.pdf) accessed 21 June 2024.

Lassaletta, L., et al., 2016, 'Nitrogen use in the global food system: past trends and future trajectories of agronomic performance, pollution, trade, and dietary demand', *Environmental Research Letters* 11(9), p. 095007 (DOI: 10.1088/1748-9326/11/9/095007).

LAWA, 2019, 'Bericht zur Grundwasserbeschaffenheit - Pflanzenschutzmittel. Berichtszeitraum 2013-2016', Bund/Länder-Arbeitsgemeinschaft Wasser (LAWA) (https://www.lawa.de/documents/lawa-bericht-zur-gw-beschaffenheit--psm_2_1558355266.pdf) accessed 21 June 2024.

Leip, A., et al., 2022, 'Halving nitrogen waste in the European Union food systems requires both dietary shifts and farm level actions', *Global Food Security* 35, p. 100648 (DOI: 10.1016/j.gfs.2022.100648).

Liess, M., et al., 2021, 'Pesticides are the dominant stressors for vulnerable insects in lowland streams', *Water Research* 201, p. 117262 (DOI: 10.1016/j.watres.2021.117262).

Lyche Solheim, A., et al., 2024, 'Lake browning counteracts cyanobacteria responses to nutrients: Evidence from phytoplankton dynamics in large enclosure experiments and comprehensive observational data', *Global Change Biology* 30(1), p. e17013 (DOI: 10.1111/gcb.17013).

Maes, J., et al., 2020, *Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment*, No EUR 30161, JRC120383, Publications Office of the European Union, Luxembourg (https://policycommons.net/artifacts/2162494/mapping-and-assessment-of-ecosystems-and-their-services/2918034/) accessed 18 March 2024.

Malak, D., et al., 2021, *Carbon pools and sequestration potential of wetlands in the European Union*, ETC/ULS Report No 10/2021, European Topic Centre on Urban, Land and Soil Systems (https://www.eionet.europa.eu/etcs/etc-uls/products/etc-uls-reports/etc-uls-report-10-2021-carbon-pools-and-sequestration-potential-of-wetlands-in-the-european-union) accessed 4 July 2023.

Mentzel, S., et al., 2022, 'Probabilistic risk assessment of pesticides under future agricultural and climate scenarios using a bayesian network', *Frontiers in Environmental Science* 10, p. 957926 (DOI: 10.3389/fenvs.2022.957926).

Mokra, K., 2021, 'Endocrine Disruptor Potential of Short- and Long-Chain Perfluoroalkyl Substances (PFASs) — A Synthesis of Current Knowledge with Proposal of Molecular Mechanism', *International Journal of Molecular Sciences* 22(4), p. 2148 (DOI: 10.3390/ijms22042148).

Mouchlianitis, F. A., 2024, 'Dam Removal Progress 2023', World Fish Migration Foundation (https://damremoval.eu/wp-content/uploads/2024/04/Web-version_DRE-Report-2023.pdf) accessed 19 July 2024.

NIVA, 2021, 'ALGECO | Cost-effective algae technology | Norway', ALGECO (https://www.alg.eco) accessed 18 March 2024.

OECD, 2020, 'Nature-based solutions for adapting to water-related climate risks', OECD Environment Policy Papers No 21 (https://www.oecd-ilibrary.org/environment/nature-based-solutions-for-adapting-to-water-related-climate-risks_2257873d-en) accessed 20 March 2024.

Oral, H. V., et al., 2020, 'A review of nature-based solutions for urban water management in European circular cities: a critical assessment based on case studies and literature', *Blue-Green Systems* 2(1), pp. 112-136 (DOI: 10.2166/bgs.2020.932).

Ortega-Reig, M., et al., 2019, 'Adaptación de la agricultura a escenarios de cambio global. Aplicación de métodos participativos en la cuenca del río Júcar (España)', *Economía Agraria y Recursos Naturales* 18(2), p. 29 (DOI: 10.7201/earn.2018.02.02).

Pistocchi, A., et al., 2022, 'Impacts of Urban Wastewater Treatment on Aquatic Micropollutant Emissions in Europe', *SSRN Electronic Journal* (DOI: 10.2139/ssrn.4052484).

Poikane, S., et al., 2015, 'A hitchhiker's guide to European lake ecological assessment and intercalibration', *Ecological Indicators* 52, pp. 533-544 (DOI: 10.1016/j.ecolind.2015.01.005).

Psomas, A., et al., 2021, *Comparative study on quantitative and chemical status of groundwater bodies: Study of the impacts of pressures on groundwater in Europe*, Service Contract No 3415/B2020/EEA.58185, European Environment Agency.

Rakovec, O., et al., 2022, 'The 2018-2020 Multi-Year Drought Sets a New Benchmark in Europe', *Earth's Future* 10(3), p. e2021EF002394 (DOI: 10.1029/2021EF002394).

Rega, C., et al., 2019, 'Environmentalism and localism in agricultural and land-use policies can maintain food production while supporting biodiversity. Findings from simulations of contrasting scenarios in the EU', *Land Use Policy* 87, p. 103986
(DOI: 10.1016/j.landusepol.2019.05.005).

Re:wild et al., 2023, 'State of the World's Amphibians: The Second Global Amphibian Assessment', Re:wild (https://www.iucn-amphibians.org/wp-content/uploads/2023/10/SOTWA-final-10.4.23.pdf) accessed 21 June 2024.

Rewilding Europe, 2019, 'Estonia's massive dam removal efforts highlight benefits of river restoration', Rewilding Europe (https://rewildingeurope.com/news/estonias-massive-dam-removal-efforts-highlight-benefits-of-river-restoration/) accessed 21 March 2024.

RIWA-Meuse, 2023, 'Annual Report 2022 - The Meuse: Protect the source of drinking water for 7 million people!' (https://www.riwa-maas.org/wp-content/uploads/2023/09/IDF3064-RIWA-MAAS-Jaarrapport-UK-2022-digitaal.pdf) accessed 21 June 2024.

Ryan-Fogarty, Y., et al., 2023, 'Uncaptured mercury lost to the environment from waste electrical and electronic equipment (WEEE) in scrap metal and municipal wastes', *Resources, Conservation and Recycling* 191, p. 106881 (DOI: 10.1016/j.resconrec.2023.106881).

Sahani, J., et al., 2019, 'Hydro-meteorological risk assessment methods and management by nature-based solutions', *Science of The Total Environment* 696, p. 133936 (DOI: 10.1016/j.scitotenv.2019.133936).

Salonen, K., et al., 2020, 'Development of Lake Vesijärvi through four decades of remediation efforts', *Hydrobiologia* 847(21), pp. 4601-4619 (DOI: 10.1007/s10750-020-04338-3).

Schmidt, G., et al., 2012, *Working definitions of Water scarcity and Drought*, Expert Group on Water Scarcity and Droughts of the Common Implementation Strategy for the Water Framework Directive, European Commission (https://www.gwp.org/globalassets/global/gwp-cee_images/idmp-working-definitions.doc) accessed 21 June 2024.

Schmidt, G., et al., 2020, *How to tackle illegal water abstractions? Taking stock from experiences, Lessons learned*, Project Report, Fundacion Botin (https://www.fundacionbotin.org/89dguuytdfr276ed_uploads/Observatorio%20Tendencias/How%20to...ok_enlaces.pdf) accessed 28 March 2024.

Schulte, C., et al., 2022, *Fish die-off in the Oder River, August 2022*, Status Report, German expert group on the fish die-off in the Oder River headed up by the German Environment Agency (UBA).

Schulz, R., et al., 2021, 'Applied pesticide toxicity shifts toward plants and invertebrates, even in GM crops', *Science* 372(6537), pp. 81-84 (DOI: 10.1126/science.abe1148).

Schürings, C., et al., 2024, 'River ecological status is shaped by agricultural land use intensity across Europe', *Water Research* 251, p. 121136 (DOI: 10.1016/j.watres.2024.121136).

Serra-Llobet, A., et al., 2022, 'Restoring Rivers and Floodplains for Habitat and Flood Risk Reduction: Experiences in Multi-Benefit Floodplain Management From California and Germany', *Frontiers in Environmental Science* 9, p. 778568. (DOI: 10.3389/fenvs.2021.778568).

Singh, N. and Hsieh, C. Y. J., 2021, 'Exploring Potential Carcinogenic Activity of Per- and Polyfluorinated Alkyl Substances Utilizing High-Throughput Toxicity Screening Data', *International Journal of Toxicology* 40(4), pp. 355-366 (DOI: 10.1177/10915818211010490).

Sjerps, R. M. A., et al., 2019, 'Occurrence of pesticides in Dutch drinking water sources', *Chemosphere* 235, pp. 510-518 (DOI: 10.1016/j.chemosphere.2019.06.207).

Spänig, S., et al., 2021, 'A multi-omics study on quantifying antimicrobial resistance in European freshwater lakes', *Environment International* 157, p. 106821 (DOI: 10.1016/j.envint.2021.106821).

Spray, C., et al., 2022, 'Eddleston Water 2021 Report', Tweed Forum (https://tweedforum.org/wp-content/uploads/2023/02/Eddleston-Water-2021-Report.pdf) accessed 21 June 2024.

STOWA, 2020, 'Praatplaat Naar een klimaatbestendig beekdallandschap' (https://www.stowa.nl/publicaties/praatplaat-naar-een-klimaatbestendig-beekdallandschap) accessed 20 March 2024.

Szabolcs, M., et al., 2022, 'Spatial priorities for freshwater biodiversity conservation in light of catchment protection and connectivity in Europe', Martin, C. W. (ed.), *PLOS ONE* 17(5), p. e0267801 (DOI: 10.1371/journal.pone.0267801).

Szlauer-Łukaszewska, A., et al., 2024, 'Quantifying a mass mortality event in freshwater wildlife within the Lower Odra River: Insights from a large European river', *Science of The Total Environment* 907, p. 167898 (DOI: 10.1016/j.scitotenv.2023.167898).

Taipale, S. J., et al., 2022, 'Poor nutritional quality of primary producers and zooplankton driven by eutrophication is mitigated at upper trophic levels', *Ecology and Evolution* 12(3), p. e8687 (DOI: 10.1002/ece3.8687).

Tammeorg, O., et al., 2024, 'Sustainable lake restoration: From challenges to solutions', *WIREs Water* 11(2), p. e1689 (DOI: 10.1002/wat2.1689).

Trémolet, S., et al., 2019, 'Investing in Nature for European Water Security', The Nature Conservancy, Ecologic Institute and ICLEI, London, United Kingdom (https://www.nature.org/content/dam/tnc/nature/en/documents/Investing_in_Nature_for_European_Water_Security_02.pdf) accessed 12 June 2024.

UN, 2016, 'The Sustainable Development Goals Report 2016', United Nations Publications issued by the Department of Economic and Social Affairs (DESA), New York (https://unstats.un.org/sdgs/report/2016/The%20Sustainable%20Development%20Goals%20Report%202016.pdf) accessed 22 March 2024.

UNEP, 2023, 'Visual Feature | Beat Plastic Pollution' (http://unep.org/interactive/beat-plastic-pollution/) accessed 20 March 2024.

UNFCC, 2018, 'Wetlands Disappearing Three Times Faster than Forests' (https://unfccc.int/news/wetlands-disappearing-three-times-faster-than-forests) accessed 20 March 2024.

Urrutia-Cordero, P., et al., 2020, 'Climate warming and heat waves alter harmful cyanobacterial blooms along the benthic-pelagic interface', *Ecology* 101(7), p. e03025 (DOI: 10.1002/ecy.3025).

van der Wiel, K., et al., 2023, 'Large increases of multi-year droughts in north-western Europe in a warmer climate', *Climate Dynamics* 60(5-6), pp. 1781-1800 (DOI: 10.1007/s00382-022-06373-3).

van Gils, J., et al., 2019, 'The European Collaborative Project SOLUTIONS developed models to provide diagnostic and prognostic capacity and fill data gaps for chemicals of emerging concern', *Environmental Sciences Europe* 31(1), p. 72 (DOI: 10.1186/s12302-019-0248-3).

van Loon, Dr. Ir. A. and Fraters, Ir. D., 2016, *De gevolgen van mestgebruik voor drinkwaterwinning: Een tussenbalans*, Technical Report No 2016.023b, KWR Watercycle Research Institute, the Netherlands (http://api.kwrwater.nl/uploads/2018/10/KWR-2016.023b-De-gevolgen-van-mestgebruik-voor-drinkwaterwinning.-Een-tussenbalans.pdf) accessed 21 June 2024.

Verhoeven, J. T. A., 2014, 'Wetlands in Europe: Perspectives for restoration of a lost paradise', *Ecological Engineering* 66, pp. 6-9 (DOI: 10.1016/j.ecoleng.2013.03.006).

Vermaat, J. E., et al., 2016, 'Assessing the societal benefits of river restoration using the ecosystem services approach', *Hydrobiologia* 769(1), pp. 121-135 (DOI: 10.1007/s10750-015-2482-z).

Vidaurre, R., et al., 2017, 'Implementing Redistributive Financial Mechanisms in River Basin Management' (https://www.ecologic.eu/sites/default/files/publication/2018/2266-ecocuencas_en_final-v2.pdf) accessed 21 June 2024.

Vitale, V., et al., 2022, 'Mechanisms underlying childhood exposure to blue spaces and adult subjective well-being: An 18-country analysis', *Journal of Environmental Psychology* 84, p. 101876 (DOI: 10.1016/j.jenvp.2022.101876).

Vitecek, S., et al., 2021, 'Assessing the Ecological Status of European Rivers and Lakes Using Benthic Invertebrate Communities: A Practical Catalogue of Metrics and Methods', *Water* 13(3), p. 346 (DOI: 10.3390/w13030346).

Voutchkova, D. D., et al., 2021, 'Estimating pesticides in public drinking water at the household level in Denmark', *GEUS Bulletin* 47, pp. 1695-1717 (DOI: 10.34194/geusb.v47.6090).

Warren, M., et al., 2015, 'River flow as a determinant of salmonid distribution and abundance: a review', *Environmental Biology of Fishes* 98(6), pp. 1695-1717
(DOI: 10.1007/s10641-015-0376-6).

WMLM (Wasserwirtschaftsamt München and Landeshauptstadt München), 2011, 'A new lease of life for the Isar River' (https://climate-adapt.eea.europa.eu/en/metadata/case-studies/isar-plan-2013-water-management-plan-and-restoration-of-the-isar-river-munich-germany/munich_document-2.pdf) accessed 20 March 2024.

Water Europe, 2023, 'MANIFESTO The European Union needs an ambitious Water-Smart Strategy' (https://watereurope.eu/wp-content/uploads/Manifesto-EU-Water-Strategy.pdf) accessed 20 March 2024.

Water Reuse Europe, 2018, 'Water Reuse Europe Review 2018' (https://water-reuse-europe.org/wp-content/uploads/2018/08/wre_review2018_final.pdf) accessed 20 March 2024.

Weisner, O., et al., 2022, 'Three reasons why the Water Framework Directive (WFD) fails to identify pesticide risks', *Water Research* 208, p. 117848 (DOI: 10.1016/j.watres.2021.117848).

Westhoek, H., et al., 2014, 'Food choices, health and environment: Effects of cutting Europe's meat and dairy intake', *Global Environmental Change* 26, pp. 196-205 (DOI: 10.1016/j.gloenvcha.2014.02.004).

WHO, 2019, 'Microplastics in drinking-water', World Health Organization, Geneva (https://www.who.int/water_sanitation_health/publications/information-sheet190822.pdf) accessed 26 November 2021.

WWF et al., 2019, 'Hydropower pressure on European rivers: the story in numbers' (https://www.wwf.eu/wwf_news/publications/?uNewsID=356638) accessed 15 June 2021.

WWQA Ecosystems, 2023, *White Paper – Embedding Lakes into the Global Sustainability Agenda*, UK Centre for Ecology & Hydrology on behalf of the United Nations Environment Programme coordinated World Water Quality Alliance Ecosystems Workstream (https://zenodo.org/record/7752982) accessed 20 March 2024.

Yuan, Y., et al., 2020, 'PFOA evokes extracellular Ca2+ influx and compromises progesterone-induced response in human sperm', *Chemosphere* 241, p. 125074 (DOI: 10.1016/j.chemosphere.2019.125074).

Zeggoud, A., 2020, 'Terres de Sources, de la ville à la campagne – accompagner la transition agroécologique au-delà de son territoire grâce à la protection de l'eau' (https://www.chaireunesco-adm.com/Amale-Zeggoud) accessed 20 March 2024.

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