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EurAqua's Strategic Research and Innovation Agenda

The European Network of Freshwater Research Organisations | euraqua.org | December 2023

Abstract

EurAqua is the European Network of Freshwater Research Organisations. It aims to substantially contribute to the development and dissemination of European freshwater science and technology, thus having a significant input to the development of the scientific and economic basis of European water management. EurAqua consists of 26 predominantly public research institutes, representing the European Countries.

This document provides EurAqua's Strategic Research and Innovation Agenda on freshwater. The development of this agenda responds to EurAqua's vision to provide European freshwater research, management, and policy development with the capacity to restore, protect and develop European freshwaters for the benefits of biodiversity, society and sustainable economies. This agenda creates a foundation for the network to establish common and high-priority activities**.** Additionally, it aims to set out water RDI areas where enhanced collaboration amongst EurAqua partners will be sought in order to address current and emerging water challenges.

This agenda will be reviewed each year at the annual EurAqua management board meetings to ensure it remains relevant to the EurAqua network.

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EurAqua's Strategic Research and Innovation Agenda (SRIA) outlines water Research, Development and Innovation (RDI) areas for which enhanced collaboration will be sought. It is built upon the RDI priorities of EurAqua's members, and it is meant to be the guiding action plan for EurAqua in the coming years. This agenda is a living document as it will be continuously updated accounting for EurAqua members' changing priorities whilst taking into account emerging water challenges and latest scientific developments.

Contents

Abbreviations

HMWB	Heavily Modified Water Bodies
PoM/PoMs	Programme(s) of Measures
RBMP	River Basin Management Plans
RDI	Research, Development and Innovation
SDGs	Sustainable Development Goals
SRIA	Strategic Research and Innovation Agenda
WFD	Water Framework Directive

Introduction to the European Network of Freshwater Research Organisations (EurAqua)

Established in 1992, EurAqua consists today of 26 research institutes and universities, representing 26 European Countries. EurAqua seeks to contribute substantially to the development of European freshwater science and technology and its dissemination. **EurAqua's Vision is to provide European freshwater research, management and policy development with the capacity, knowledge and understanding to restore, protect and develop European freshwaters for the benefits of biodiversity, society, and sustainable economies**.

As the European network of freshwater research organisations, EurAqua's Mission is to promote freshwater sustainability by:

(i) providing leadership in coordinating efforts to understand European freshwater challenges;
(ii) helping to understand the impacts of climate change on freshwater systems and the steps needed to develop solutions to combat those impacts;
(iii) building a scientific platform for freshwater policy development and decision making; and
(iv) facilitating dialogue between the scientific community and regulatory bodies for the sustainable management of freshwater resources.

Since its establishment, over 100 European co-funded collaborative research projects carry EurAqua's signature, either through the strong involvement of EurAqua members' in consortia, or where EurAqua has explicitly been an initiator of proposals. Topics typically address freshwater resources management, both surface water and groundwater, floods and droughts forecasting and risk management, hydrological modelling and monitoring, hydrological data services, climate change impacts, freshwater biodiversity and ecological assessment, ecotoxicology, restoration of ecosystems and the services they provide.

1. **AUSTRIA** – The Federal Agency for Water Management
2. **BELGIUM** – Interuniversity Programme in Wat. Resources Engineering
3. **CROATIA** – University of Zagreb Faculty of Civil Engineering
4. **CZECH REPUBLIC** – T.G. Masaryk Water Research Institute
5. **DENMARK** – Danish Centre for Environment and Energy
6. **ESTONIA** – Technical University of Tallinn
7. **FINLAND** – The Finnish Environment Institute
8. **FRANCE** – Nat. Res. Inst. of S&T for Environment and Agriculture
9. **GERMANY** – The Federal Institute of Hydrology
10. **GREECE** – The National Technical University of Athens
11. **IRELAND** – Environmental Sustainability & Health Inst., TU Dublin
12. **ICELAND** – Icelandic Met Office
13. **ITALY** – Water Research Institute
14. **LATVIA** – University of Latvia – Faculty of Geographical and Earth Sciences
15. **LITHUANIA** – Lithuanian Energy Institute
16. **MALTA** – The Energy & Water Agency
17. **NORWAY** – The Norwegian Institute for Water Research
18. **POLAND** – Institute of Meteorology and Water Management
19. **PORTUGAL** – Laboratório Nacional de Engenharia Civil
20. **ROMANIA** – Nat. Res. & Dev. Inst. for Marine Geology and Geoecology
21. **SLOVAK REPUBLIC** – Slovak Hydrometeorological Institute
22. **SLOVENIA** – University of Ljubljana
23. **SPAIN** – The Spanish Center for Public Works Research and Studies
24. **SWEDEN** – IVL Swedish Environmental Research Institute
25. **THE NETHERLANDS** – Deltares
26. **UNITED KINGDOM** – UK Centre for Ecology & Hydrology

EurAqua's members are present in several European flagship initiatives and projects. This expertise has allowed the network to contribute ideas to European programming, to provide cutting-edge knowledge in strategic water management areas in the face of local, regional and global challenges, and to become a real promoter of policy-oriented, innovative solutions for freshwater ecosystem restoration and flood and drought management. EurAqua is an observer to the Common Implementation Strategy of the Water Framework Directive, to the International Commission of the protection of the Rhine and to the Baltic Marine Environment Protection Commission (Helcom).

EurAqua is also a member of the Stakeholders Advisory Group of the Water4All Partnership, has a Memorandum of Understanding with Water Europe, and several of its members are also in the Partnership for European Environmental Research (https://www.peer.eu/). Informally, EurAqua collaborates with the Partnership for Research and Innovation in the Mediterranean Area (PRIMA) and the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE).

Several EurAqua partners are also part of the technical advisory boards, expert working groups or management teams of international organisations and networks, such as the IPCC, IPBES, WMO, the High Expert and Leaders Panel on Water and Disasters (HELP), the International Panel on Deltas and Coastal areas (IPDC), Alliance for Global Water Adaptation (AGWA), the UNEP World Water Quality Alliance, UNECE water convention, International Network of Basin Organizations (INBO) amongst others. EurAqua members are leading partners in several EU initiatives, such as the development of The International Centre for Advanced Studies on River-Sea Systems 'Danubius' which is developing a Roadmap of the European Strategy Forum on Research Infrastructures (ESFRI).

EurAqua partners are also quite involved in projects providing pan-European access to research facilities such as the hydraulic research infrastructures network Hydralab, European Long-Term Ecosystem and socio-ecological Research Infrastructure (eLTER), the Network of Leading European AQUAtic MesoCOSM Facilities (Aquacosm). EurAqua members also operate a large number of research infrastructures, several of which are unique. The facilities are clustered as follows:

- Experimental Basins
- Earth observation facilities
- Field laboratory equipment and test sites
- Flumes
- Laboratory facilities
- Facilities for computational sciences and data science
- Miscellaneous

These research infrastructures are essential to develop our understanding and test solutions for overcoming the challenges identified in the following chapters. Exploitation and coordinated awareness of existing facilities not only increases research quality and efficacy but also leads to better use, and more strategic development, of new investments across our network.


Image: Laura Härkönen, Finnish Environment Institute

Aims of the Strategic Research and Innovation Agenda (SRIA)

This document outlines EurAqua's Strategic Research and Innovation Agenda (SRIA) on freshwater. The development of this agenda responds to EurAqua's Vision and **creates a foundation for the network to establish common and high-priority activities** where enhanced collaboration amongst EurAqua partners will be sought to address current and emerging water challenges. Such collaboration is intended to translate into the development of collaborative RDI projects, training networks, lobbying activities, knowledge, and infrastructure sharing, and/or mobility actions.

This document is not simply a compilation of members' Research, Development, and Innovation (RDI) priorities; on the contrary, **EurAqua's SRIA describes water RDI areas where joint activities are envisaged** through either external or internal funding. Six main RDI areas are identified based on EurAqua member's in-house investments and research priorities. Within each of these areas, several research ambitions are elaborated upon in the following chapters.

Over recent years, funding for research has become increasingly competitive and does not usually facilitate broad collaboration across EurAqua partners. Complementarity of research is a key requirement in collaborative projects, especially within the framework of the Horizon Europe programme for example, where multidisciplinary research is a possibility, but also a challenge. By choosing an approach based on existing research investments plans, we are optimistic that research alignment and joint projects can be identified which require limited additional resources.

Water RDI areas for enhanced collaboration

Increasing water resilience to changing climate

Water resources are currently under pressure worldwide, which is expected to further exacerbate in the next decades, driven by climate change and growing water demands due to demographic developments but also due to societal transitions. For example, some (new) low-carbon energy sources, such as biofuels and hydrogen production will require significant water resources[1]. Climate change is widespread, rapid and intensifying, also in Europe (IPCC 2022). Consequently, it brings more intense rainfall and associated flooding, more intense droughts, as well as the occurrence of more intense compound events. Further global warming will amplify permafrost thawing, the loss of seasonal snow cover, melting of glaciers and accelerating sea level rise. Europe will face exceptionally hot and dry summers, mild winters and heavy rainfall leading to river flooding and flash floods. The flood and drought events in the last decades have illustrated Europe's vulnerability to hydrological extremes. Aquatic and groundwater-dependent ecosystems are under pressure and biodiversity is under threat from rapid climate change. Agricultural production systems will be at risk due to an increase in water shortages, especially in Southern and Eastern Europe. This may lead to increased production to regions experiencing less water stress. The hydrological changes are also impacting other economic activities such as renewable energy through hydropower and inland water transport. Water scarcity conditions are also impacting the drinking water supply. The EU Strategy on Adaptation to Climate Change[2] calls for smarter, more systemic, and faster adaptation. A cornerstone of this is implementing pathways with targeted actions to ensure the availability and sustainability of freshwater resources. EurAqua partners are contributing to the development of knowledge, approaches, modelling and monitoring tools and solutions to support decision-making on climate-resilient water management strategies and actions.

Ensuring water resources availability and sharing water resources

Hydrological processes and cycles are impacted by a changing climate, not only resulting in extreme hydrological events such as floods and droughts, but also changing the river flows patterns, groundwater aquifers due to changes in rainfall, snow, glacier melt and increased evapotranspiration due to higher temperatures. This will also impact the water resources availability for ecosystems, society, and economic activities. For example, it is expected that summer river flow of the river Rhine will decline up to 20% by 2050. Even if in some parts of the world water resources are expected to increase in the next decades, the global water demand will increase, including Europe, and will put more pressure on the available water resources. Nexus-approaches may support finding a balance between available water resources in river basins, ecological hydrological requirements, water demands for society and economy under changing climate and socio-economic developments. Currently, many river basin management plans are not based on climate risk-informed, sustainable, equitable and efficient sharing of water resources. Inadequate sharing of water resources is leading to a) high water use inefficiency in sectors receiving abundant water or inadequate signals capturing water scarcity, (b) insufficient water allocated to the environment to support aquatic ecosystem functioning and biodiversity, and (c) rigidity in

water allocation mechanisms unable to account for short and long-term changes including climate variability and change and socio-economic development. Current water allocation regimes are largely shaped by historical preferences, water use rights and usage patterns (OECD, 2015).[3] They are therefore usually not well equipped to deal with the growing water demands and intensifying competition among different water use sectors, the impacts of climate changes, especially water scarcity and/or shifts in societal preferences, such as the increasing value placed on water-related ecological services.

Increasing water resilience to changing climate – EurAqua's Research and innovation priorities

- To develop stakeholder-driven data-services and modelling tools to enhance the understanding of hydrological processes in surface and groundwater systems and their interactions to better assess and provide advice for adaptation of water resources availability, management, and water use.
- To develop water **scenarios on the water resources availability and water use in catchments and aquifers under future climate change conditions, technological and socio-economic developments**.
- To assess the operational space for climate-resilient, sustainable and inclusive water resources management and to design pathways of transitions to enhance natural water retention to increase water resilience and restore depleting groundwater resources.
- To develop new approaches to better **operationalise ecological flows** to define the solution space for balancing water demands while meeting the hydrological requirements of ecosystems and its ecosystem services.
- To analyse the impacts of melting glaciers, decline of permafrost and changes in snowfall patterns on the hydrological regimes of rivers.
- To improve the understanding of the **role of groundwater in base flow of streams**.
- To analyse and assess **transitions in land use management and develop catchment wide spatial management options** to foster water retention, groundwater level rise and stabilisation of catchments to enhance water resilience to changing climate.

Managing flood risk

According to the OECD, 'Today, 100-200 million people per year are victims of floods, droughts, and other water-related disasters (affected or killed); almost two-thirds are attributed to floods. The number of people at risk from floods is projected to rise from 1.2 billion today to around 1.6 billion in 2050 (nearly 20% of the world's population). The economic value of assets at risk is expected to be around USD 45 trillion by 2050, a growth of over 340% from 2010[4]. In Europe, the Floods Directive is considered fit for purpose. *Reducing flood risk where and when it matters most is, however, a matter of scrupulous and consistent implementation that requires sustained attention over a long period and cooperation across borders. The dramatic events of summer 2021 in Europe show that much remains to be done to reduce flood risk effectively*[5]. The same report stresses the lack of cost estimated due to flood damages, reducing the ability to prioritise flood mitigation measures. Several major flood events in Europe and worldwide have also indicated either a lack of an early warning system or a failure of its efficient communication (Figure 1).

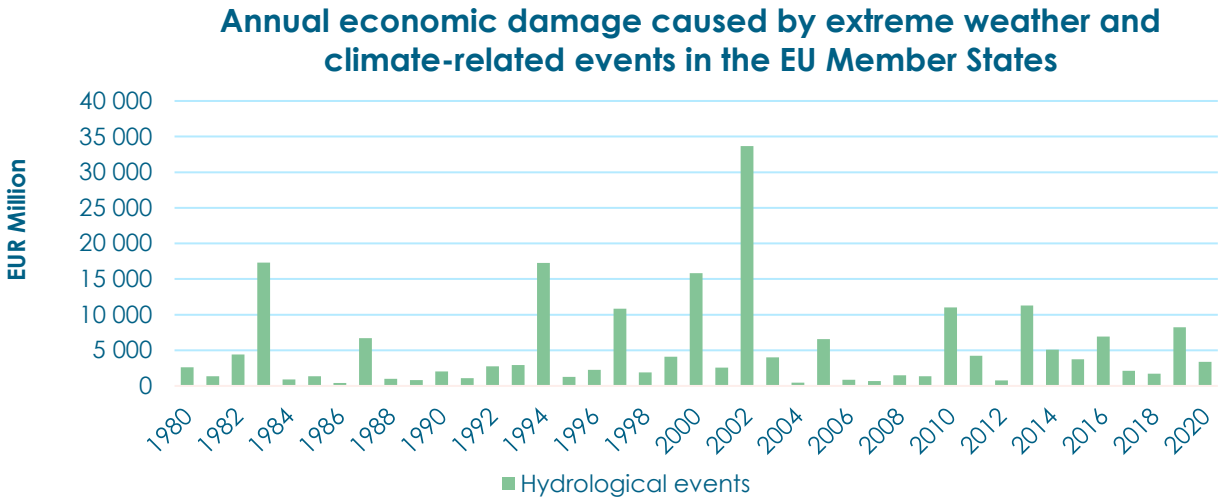

Figure 1. Economic damage caused by weather and climate-related, hydrological events (floods, mass movements). Source EEA[6]

To make things more challenging, current flood infrastructure needs to be replaced or refurbished due to a variety of reasons, such as ageing, public demands for higher flood protection levels, increasing asset values that require protection, and climate change. In addition, uncertainty in the rate of climate change adds significant uncertainty to the infrastructure renewing process. Based on a perception survey, failure to mitigate climate change, failure to adapt to climate change and extreme weather events and natural hazards are the three highest ranked risks in terms of likelihood and impact on a 10-year perspective[7]. Finally, in line with climate and biodiversity policy, infrastructure renewal should be more and more climate neutral or positive, based on circularity principles or transferred to nature-based infrastructure.

Also, urban areas are subjected to hydrological extreme events whose impacts can be large due to the concentration of citizens and economic activities leading to increased transport of pollutants and nutrients and thus degrading water bodies downstream from urban areas.

In the light of the challenges ahead, research is required in the entire disaster management cycle: mitigation of, preparedness for, response to and recovery from (flood and drought) hazards.

Managing flood risk – EurAqua's research and innovation priorities:

- Improvement of impact based hydrological modelling.
- Development of **flood mitigation measures, with special emphasis on floodplain management exploring nature-based solutions and landscape approaches to flood attenuation**.
- Improvement of the understanding of impacts of short duration high intensity (extreme) rainfall events/storms and compound events
- Improvement of hydrological forecasts considering compound events and feedback of mitigation measures on forecasts.
- Efficiency of **communicating early warning, spanning several days, including effects on society and water use sectors**.

Managing the risks on droughts and water scarcity

Droughts start with a period of lower-than-average precipitation, which then, depending on its duration, intensity, and timing, may propagate through the hydrological cycle and lead to such effects as low soil moisture content, decreasing groundwater levels, saltwater intrusion, deteriorating water quality and reduced river discharges. Following these propagation phases, drought is often categorised in four ways: meteorological drought, agricultural or soil moisture drought, hydrological drought, and socio-economic drought (Figure 2). Water stress is a condition when the water demands for economic sectors and society is regularly exceeding the sustainable supply capacity of the natural system in river basins and groundwater aquifers.

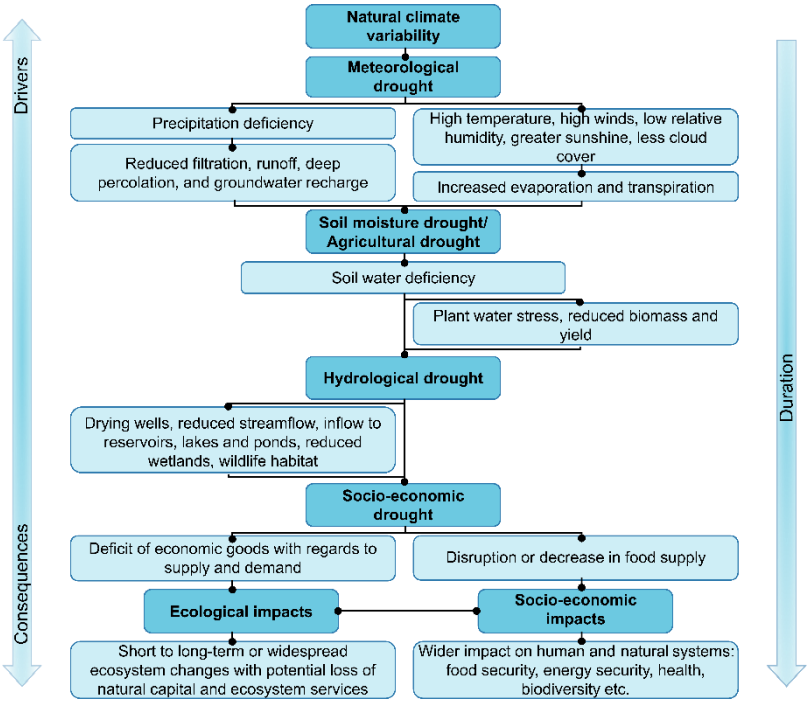

Figure 2. Categories of drought and their impacts. Adapted and modified from: Van Loon et al. (2016).

The intense drought events of 2018 and 2022-23 in Europe have demonstrated society's vulnerability to drought and freshwater shortages (Figure 3). While effects such as wildfires, reduced crop yields and inland shipping volumes are well known, it is less well known what the impacts resulting from such direct effects are on ecosystems, society and economic sectors. For example, the recent drought events in the Netherlands has caused subsidence in the peatlands and as a consequence damages to infrastructure and buildings. Research on the 2018 drought showed a decrease in carbon uptake: "Carbon sinks decreased in general by 18% according to a study covering 56 sites"[8].

Recent HELP report[9] on drought risk management has indicated topics that need attention to improve informed decision making in developing drought risk management strategies and implementation of actions and solutions. In the words of[4] "*the unsustainable patterns of water use across Europe are compounded by climate change, generating higher levels of evaporation and longer periods of extreme droughts which add to already existing water scarcity in increasingly large parts of Europe. A multifaceted water resilience agenda has to be part of the response, in the context of global climate, health, biodiversity and pollution challenges.*"

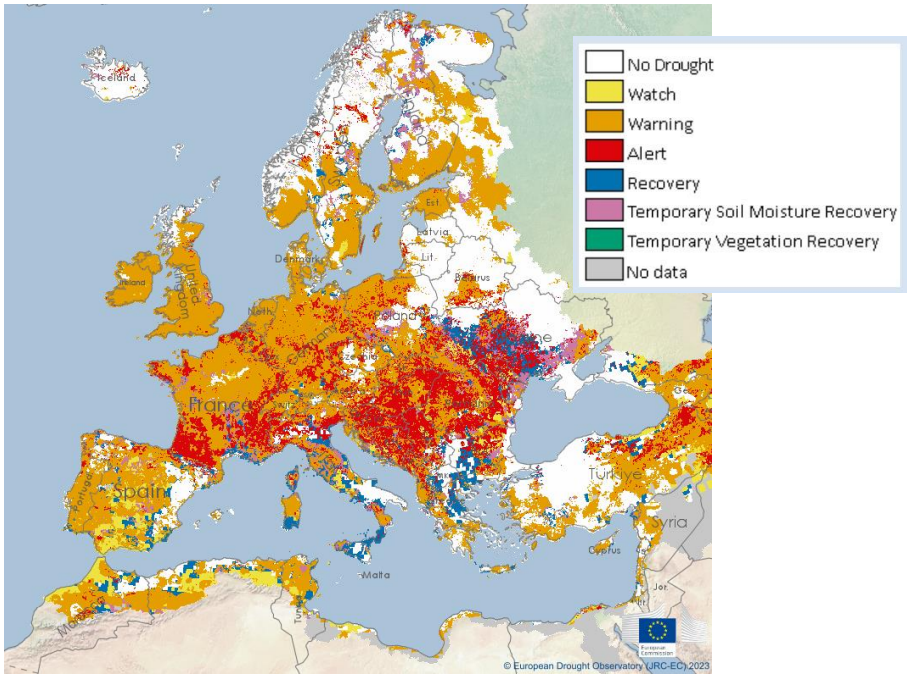

Figure 3. Combined Drought Indicator at 2nd 10-day period in August 2022 (EDO[10]).

Depending on our ability to mitigate climate change, droughts in Europe are projected to increase and intensify[11]. In the light of this research and innovation can help society to cope with severe droughts. Action is required in the entire drought management cycle: mitigation of, preparedness for, response to and recovery from drought hazards. EurAqua priorities are mainly focussed on mitigation and preparedness and, to some extent, response.

Managing the risks on droughts and water scarcity – EurAqua's research and innovation priorities:

- Improvement of the **understanding on how drought events will change in magnitude and intensity due to climate change, considered drought exposure, vulnerability and resilience**.
- Improvement of the **forecasting of meteorological drought events and the consequences for hydrological droughts and its impacts on ecosystems, carbon sequestration and economic sectors**.
- Development of innovative methods for rational, supported decision making during hydrological droughts, accounting for all stakes, including nature (minimum environmental flows).
- Development of methods to climate/drought-proof and fair water allocation strategies, both from surface and groundwater systems.
- Development and impact assessment of mitigation measures, such as water saving, natural water retention measures and other nature-based solutions, managed aquifer recharge, circular use, risk-free water re-use, etc.
- Enhanced assessment of **synergetic impacts of hydrological droughts and pollution on water quality (ecological status) and biodiversity**.
- Increase stakeholder engagement in decision-making processes and communication during drought events, and development of tools to support this.

Protecting and restoring freshwater ecosystems

Freshwater ecosystems are highly valued due to their importance for biodiversity and the ecosystem services they provide, such as food security (irrigation and fisheries), provision of clean drinking water, recreation and tourism, carbon sequestration, energy production and navigation. Access to 'blue spaces' is also increasingly recognised for mental health and improving well-being. Despite these recognised values, degradation of freshwater ecosystems across Europe is severe.

The WFD set a target to restore surface and ground waters to good ecological and chemical status by 2027. According to EEA's European Waters Assessment of Status and Pressures 2018 report[12], only 40 % of surface waters (rivers, lakes, and transitional and coastal waters) are in good ecological status or potential, and only 38 % are in good chemical status. Under the WFD River Basin Management Plans (RBMPs), thousands of measures have been undertaken across Europe to restore waters in the first and second RBMPs, but there has been little overall change compared to the first reporting cycle of the WFD. **Time lags are expected in restoring good ecological status, but the scale of restoration measures is still considered to be insufficient and there remains uncertainty of the effectiveness of many measures, in terms of if, when and to what extent they will result in good ecological status or potential, particularly in the light of climate change**.

In relation to biodiversity, the latest WWF Living Planet Report[13] indicates that freshwater species populations have seen the greatest overall global decline (83%) between 1970 and 2018, with 19% of wetland and freshwater species in Europe classified by the IUCN as endangered and an additional 7% classified as Near Threatened. Urgent action is needed to reverse the decline of biodiversity and safeguard the vital ecosystem services freshwaters provide, including support to the development of the blue economy.

Pollution (especially nutrients), over-abstraction, hydrological and morphological alterations, as well as the impacts of invasive species and climate change are some of the major pressures affecting freshwater habitats and species. The EU Biodiversity Strategy has set a target to legally protect 30% of the EU's land areas, including freshwaters, in Protected Areas by 2030. Implementation of the proposed Nature Restoration law will increase the policy drive for enhanced restoration plans to reverse the loss of biodiversity, with a target that restoration measures cover 20% of the EU's land and sea area by 2030.

Image: Riku Lumiaro, Finnish Environment Institute

Protection and restoration approaches need to tackle external pollution pressures and restore more natural hydrological regimes and geomorphological functioning of freshwater ecosystems. Waters impacted by organic pollution also emit more methane, which is a strong greenhouse gas[14]. Nature-based solutions are widely seen as a cost-effective landscape approach that provide biodiversity benefits at the same time as addressing societal challenges, such as carbon sequestration and climate adaptation (e.g., Natural Flood Management Measures). Developing circular solutions for water reuse and nutrient recovery is also a major policy topic within the EU Green Deal, to transform to a more sustainable economy (see Section 3.3). As eutrophication increases GHG emissions from freshwaters, their restoration (re-oligotrophication) not only supports WFD and Biodiversity policy but contributes to emission reductions, potentially supporting the achievement of the EU Green Deal's net zero GHG emissions target if comprehensive emission accounting is in place.

While the cost of protection and restoration measures can be estimated well through available techniques, **the full ecological effects and associated economic and social benefits of programmes of measures are poorly understood**. In other cases, system understanding is insufficient to set restoration targets. For example, our knowledge on ephemeral streams is insufficient to devise dedicated programmes of measures (PoMs), despite such streams occurring all over Europe and being dominant in the Mediterranean basin.

The effectiveness of complex PoMs is difficult to assess, in particular in the light of new pressures such as climate change and emerging substances. Lack of robust and long-term evaluations following implementation of measures hampers our ability to provide scientifically underpinned insight in effectiveness.

Protecting and restoring freshwater ecosystems – EurAqua's research and innovation priorities:

- **Developing scientifically-grounded PoMs that are climate-responsive and robust.**
- Evaluating the **impact of restoration measures on biodiversity, natural capital and ecosystem service provision**, particularly the impact of combinations of measures over the long-term and across large landscapes to basin scales.
- Understanding the **role of connectivity in protection and restoration of surface waters, particularly in relation to transfer of pollutants and dispersal of species (native and invasive)**.
- Research on biodiversity and functioning of poorly studied freshwater ecosystems, such as ephemeral streams, ponds, urban waters and transitional waters bodies
- Developing **nature-based and circular economy solutions to protect and restore water quality and biodiversity**, including the management of invasive species

Increasing circularity of water resources

Circularity in the water sector is a powerful tool for locally and globally tackling climate change impacts and implementing smart adaptation strategies. In particular, circularity shall be favoured by promoting actions aimed at: (i) limiting the use of natural water resources, (ii) enhancing their recovery and conservation (rainwater harvesting, infiltration), (iii) upgrade existing infrastructures (e.g. to limit losses form distribution networks), (iv) decreasing the consumption of water and water-intensive goods, (v) developing nutrient-, energy-, and water-efficient agriculture (precision irrigation, smart farming systems), (vi) accepting that water quality should be fit-for-purpose, (vii) adopting water- and energy-saving technologies and industrial processes, etc.

Water use

A new consciousness needs to be developed around the concept of "one water", recognizing the value of water independent of its origin, and rather focusing on its potential applications. The increasing public awareness about water scarcity, with the effects of climate change, growing world population, and uneven distribution, calls for urgent responses from the scientific community. A possible pathway for tackling this challenge starts from reconsidering the water use cycle as a whole and recognizing that the linear pattern "withdraw-use-waste" is no longer sustainable. Water reuse and recycling ideally should be maximised through actions focused on promoting multiple cascades of uses. This can be achieved through various technical and non-technical solutions, including education and financial incentives (e.g. tariffs, financial tools, fiscal measures). A common level of understanding and adoption of these measures should be pursued across Europe, also by considering the different needs and sensitivities of the various areas (e.g. Mediterranean, Central and Northern regions).

Resource recovery

The recovery of resources within water has obvious and immediate benefits in terms of both environmental and economic sustainability. For example, nutrients can be recovered from municipal wastewater treatment and reused in cultivation (or agriculture) reducing the need for chemical fertilisers. Energy savings and recoveries (e.g. biogas production, microbubble air blowing) can have a significant role in reducing energy impacts of wastewater treatment plants, as these can become not only energy-neutral, but net energy producers. Indeed, wastewater treatment plants are being revisioned as sites for resource recovery. Rather than aiming at water disposal under environmental and hygienically safe conditions (as traditionally intended), they can be considered as "factories" using wastewater as a raw material for producing water, nutrients, and energy. Similarly, reservoirs are more commonly becoming sites for the installation of floating solar power systems, thus exploiting their ample surface area, and possibly limiting evaporation and algal growth. A wide variety of additional benefits can be derived through appropriate management of water-related resources, including ecosystem services such as landscape and environmental preservation, sports, leisure and human wellbeing, navigation, fishing, and aquaculture. All these need to be considered and preserved in a context of sustainable and circular integrated water resources management.

Increasing circularity of water resources – EurAqua's research and innovation priorities:

- Research and **innovation in water/wastewater treatment processes and technologies** (including nature-based solutions) to efficiently remove and recover pollutants from wastewater, including microplastics and pharmaceuticals
- New **approaches to water reuse and recycling** that are safe, cost-effective, and can reduce reliance on freshwater resources
- **Tools and innovative methods for optimising water (and nutrient) utilisation in farming activities, including irrigation techniques, crop planning, AI support tools**.
- Development of low-cost, effective, methods to promote domestic water harvesting and reuse.
- Water efficiency of industrial processes, especially those sectors which are bulk consumers.
- New approaches for improving the appeal of water sustainability practices should be created and tested, in the areas of education, information and motivation, and in terms of economic measures.
- Developing methodologies for sediment management, recovery and reuse

Addressing water quality challenges

Several pressures increasingly threaten freshwater quality in Europe's rivers and lakes and are leading to decreased biodiversity, reduced fish populations, and reduced availability of clean water for human and animal consumption. The use of fertilisers, pesticides and other chemicals in agriculture can lead to contamination of water bodies through runoff, leaching, and erosion, while livestock farming can also contribute to nutrient pollution and to the spread of antibiotics and antibiotic resistance. Population growth, particularly in areas with high population density or rapid urbanisation, can significantly affect freshwater quality through increased demand for water resources, increased pollution from sewage, and the destruction of natural habitats, including riparian ecosystems, that ameliorate pollutants. Industrial activities, such as mining, manufacturing, and energy production, often release pollutants such as heavy metals, chemicals, and organic compounds, into water bodies.

Meanwhile, climate change threatens to exacerbate the situation, with changes in precipitation patterns and temperature likely to affect water quality; changes in droughts will increase the concentration of pollutants in water bodies, while increased flooding may result in more pollutants washing into rivers and lakes. Coastal zones are often heavily affected by seawater intrusion into groundwater reservoirs, due to overexploitation of these resources and insufficient natural recharge.

Pollutants that cause the greatest freshwater quality problems include: nutrients, such as nitrogen and phosphorus, which cause algal blooms, leading to oxygen depletion and the death of fish and other aquatic organisms; microplastics, that can come from a variety of sources, including wastewater treatment plants, plastics industries, and urban runoff and can be ingested by aquatic organisms and accumulate through the food chain; a wide range of chemicals including pesticides, herbicides, pharmaceuticals (e.g. antibiotics, endocrine disruptors, personal care products), and industrial chemicals; heavy metals such as lead, cadmium, and mercury can be toxic to aquatic organisms; and pathogens such as bacteria, viruses, and parasites contaminate freshwater systems and cause waterborne diseases in humans and animals. All these impacts can be further exacerbated with climate change.

The European Union has enacted several pieces of legislation to protect freshwater quality in Europe. Arguably, the most significant is the Water Framework Directive (WFD). It requires member states to establish river basin management plans, monitor water quality, and take measures to reduce pollution. Other legislation includes the Urban Wastewater Treatment Directive and the Nitrates Directive.

While legislation has helped to improve freshwater quality in Europe, there are limitations to their effectiveness, such as with their implementation and enforcement, data availability - there are still gaps in knowledge and data about the state of freshwater quality in Europe, which can make it challenging to make informed decisions about management measures, and the existing legislation is largely focused on traditional pollutants and currently does not adequately address emerging contaminants, such as microplastics and pharmaceuticals. On the other hand, the recent update of the UWWTD and the new Regulation 2020/741 on minimum quality requirements for water reuse introduce the risk management approach as a prevalent tool to facilitate case-by-case application of the regulations, considering local specificities and possible variabilities over time. This approach seems more dynamic than those based on checklists of compounds to be monitored, whose updates are often not timely enough to meet with changing environmental needs.

Addressing problems of water quality is essential to maintain healthy and thriving aquatic ecosystems and to ensure the availability of clean and safe water resources for human use. There is a need for sustainable water management practices that consider the needs of both human populations and the environment. While legislation is an important tool in protecting freshwater quality, it is not sufficient on its own. The EU Zero Pollution Action Plan recognises that additional measures such as public education, research and development, and stakeholder involvement are necessary to address the limitations and enhance the effectiveness of legislation in protecting freshwater quality in Europe.

Addressing water quality challenges - EurAqua's research and innovation priorities:

- Innovation in treatment of legacy waste (e.g mine water), contaminated water resources and sediments due to activities in the past.
- Improved methods for detecting/apportioning diffuse/point sources of pollutants
- Evaluation of **effects of emerging contaminants, contaminant mixtures, toxins and waterborne pathogens on humans and ecosystem.**
- **Effects of climate change on water quality and the biogeochemistry of rivers & lakes.**
- Improved methods for **modelling/predicting the transport and fate of pollutants** in freshwater (rivers, lakes, deltas, coastal/transitional waters)

Towards integrated water governance

Water governance is a topic that spans a range of challenges in the management of freshwater systems (Figure 4), both groundwater and surface water including[17]:

- Managing water resources sustainably, fairly balancing the needs of different stakeholders (domestic use, agriculture, industry) with the needs of freshwater biodiversity.
- Ensuring water sources and ecosystems are protected from pollution and other threats, such as invasive species or over-fishing.
- Establishing systems to increase effectiveness and accountability in water management, including developing institutional and stakeholder capacity to manage water resources sustainably.
- Promoting cooperation across catchments, between sectors, regions and countries. Large, transboundary catchments offer particular challenges.
- Ensuring policy integration and coherence related to water governance
- Facilitating effective collaboration between water agencies during flood and drought events

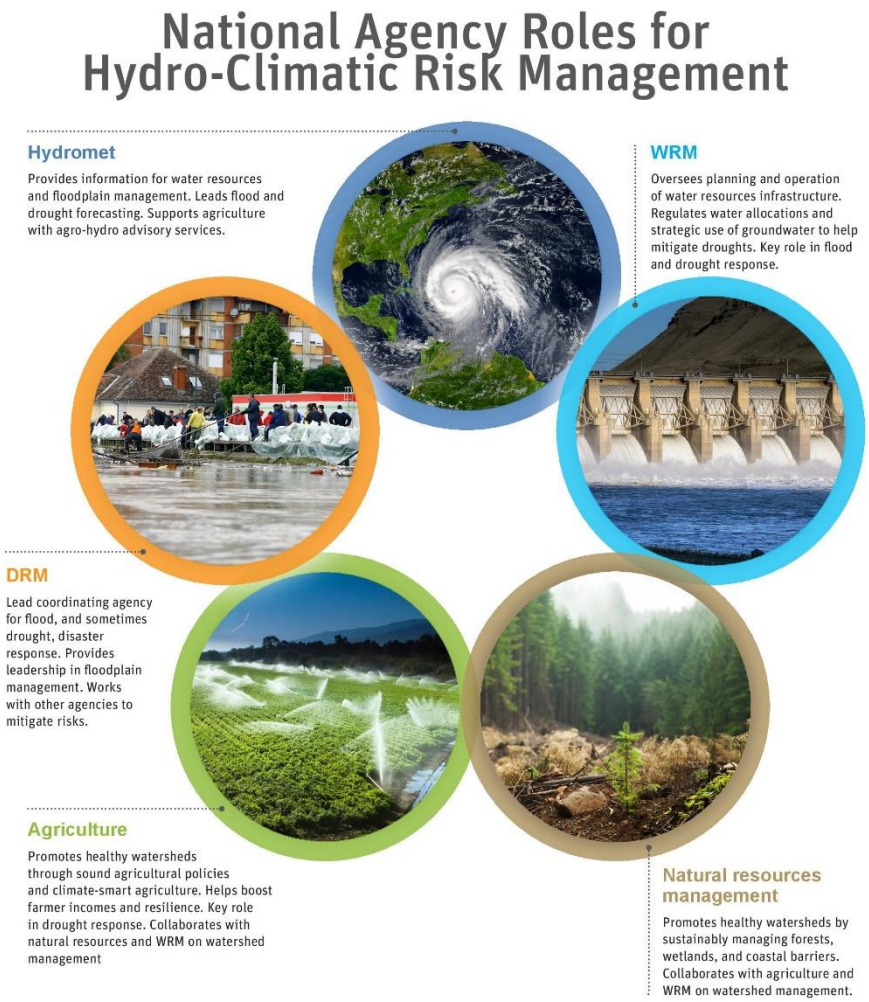

Figure 4. The EPIC Framework for inter-agency collaboration to have an effective governance with respect to floods and droughts risk management. DRM=Disaster Risk Management and WRM=Water Resources Management. Adopted from[17] (© World Bank, Washington, DC).

"Water has conventionally been managed within administrative units rather than natural boundaries, in a fragmented rather than holistic manner, and in a technocratic rather than participatory way"[15]. The introduction of the WFD should have shifted towards a water management approach based upon broad stakeholder and sector participation as well as institutional adaptation and procedural innovation. It is, however, now evident that EU water policy (the WFD) has only been partially integrated into sectoral policies[16]. Despite the efforts of many Member States, there is still a significant number of Heavily Modified Water Bodies (HMWB) with lower environmental objectives in Europe. HMWB are not often properly addressed in Europe due to the costs associated with their restoration and the insufficient knowledge on best possible measures not causing significant harm to the use of these water bodies (e.g. hydropower, flood protection, waterborne traffic).

EurAqua advocates for the development and implementation of innovative tools and integrated, adaptive and participatory approaches to river basin management. (transboundary) catchments, rivers, groundwater aquifers and deltas management approaches need to link ecological, social and economic systems: This should include research and innovation in policy, economy, social challenges, and understanding how the socio-hydrological, biogeographical and policy contexts of the catchments influence the governance system. This integration is particularly important in managing climate-associated risks (Figure 4).

Towards integrated water governance – EurAqua's research and innovation priorities:

- Development of tools and **mechanisms for multi-actor engagement in water management** at all scales, from local communities to international, transboundary river basins.
- Development of **citizen approaches for monitoring and restoring freshwaters** and engagement in water management
- Evaluating **policy integration and coherence** to support policy objectives, such as coherence between the WFD, the SDGs and other sectoral policies (agriculture, energy, water industry).
- New approaches **for economic instruments and financing mechanisms for ecologically sustainable and inclusive sharing of water resources, such as incentive water pricing, economic valuation and payment for ecosystem services** across catchments between beneficiaries and service providers.
- Developing natural capital concepts and ecosystem accounting approaches
- Development of **tools and methods for more informed sustainable catchment management**, for example development of eFlow tools, **digital twins**, Water Oriented Living Labs (https://watereurope.eu/water-oriented-living-labs/) etc. to support innovation, decision-making and scenario planning in response to climate and land-use change.
- Development of advanced instruments enabling new regulatory and economic conditions that drive, and give incentives to, individual and collective decisions and practices resulting in climate resilient, sustainable, equitable and efficient sharing of water resources

Innovation in monitoring and assessment

EU Member States and EEA countries perform chemical and biological monitoring and assessment for groundwater, rivers, and lakes on a regular basis. Following the adoption of the WFD, robust and comparable methods for ecological and chemical status monitoring and assessment have been developed. The analysis of the second round of RBMPs indicated that investments in new or better ecological and chemical monitoring programmes have been conducted, with subsequent incorporation and inclusion of a greater number of monitoring sites and quality elements[18]. The existence of more than 130 000 monitoring sites across Europe has allowed for a comprehensive assessment of ecological and chemical status in many areas.

Image: Laura Härkönen, Finnish Environment Institute

However, monitoring does not cover all European freshwater ecosystems and smaller water bodies, important for biodiversity, are overlooked. Additionally, not all the relevant biological and chemical quality elements are included in freshwater monitoring activities[16, 19]. The uncertainty of chemical and ecological status assessment needs to be evaluated and assessments further developed for some pressures (e.g., browning, hydromorphology) across different types of water bodies and relevant sensitive quality elements.

Understanding on species distribution and prevalence also needs to be expanded with more consistent agreement between European countries on Essential Biodiversity Variables and approaches for monitoring the status and trends of habitats and species. Collaboration between countries on sharing biodiversity monitoring data would also enable improved knowledge, understanding and prediction of responses to environmental change and restoration measures. In relation to the IUCN Red List of Threatened Species assessment, nearly 7% of freshwater and wetland species have the status Data Deficient (DD), since their risk of extinction cannot be assessed due to a lack of information.

Monitoring water quality and biodiversity is of fundamental importance in preserving ecosystem integrity and functioning. Advanced technologies for improved frequency and spatial coverage of monitoring activities are needed to fill in knowledge gaps both in water quality and in species prevalence to provide capacity in evaluating impacts of multiple pressures on aquatic ecosystems. These pressures (climate change, agricultural production, changes in hydromorphology, invasive species i.a.) and the increasing presence of emerging pollutants (including plastics) call for the development of cost-efficient, advanced-technology monitoring systems

that are able to reliably monitor a large number of parameters at regular intervals[20].

Technologies such as digital sensors, passive samplers, earth observation (EO), and utilisation of drones offer great opportunities and support for cost-efficient improval of monitoring both the natural environment and industrial activities, such as water use and wastewater treatment. Citizen science further supports the monitoring of changes in water quality and species distribution and also adds valuable information on water use, supporting environmental compliance and the valuation of ecosystem services. Environmental DNA (eDNA) is another area of innovation enhancing biomonitoring by enabling comprehensive analysis of taxonomic groups from a single sample. The potential of these innovations for enhanced coverage, frequency and quality of monitoring needs further research and evaluation in practice. To enhance innovation in monitoring, full advantage should also be taken of Water-Oriented Living Labs (https://watereurope.eu/water-oriented-living-labs/) that are networks of infrastructures and services with multi-stakeholder commitment.

Innovation in monitoring and assessment – EurAqua's research and innovation priorities:

- Development and application of **innovative, automated and continuous monitoring techniques and methodologies** for water quality and biodiversity, especially microplastics, emerging contaminants, and environmental DNA (eDNA).
- Design and optimisation of monitoring networks and use of AI in data analytics
- Developing **monitoring practices and techniques to fulfil knowledge gaps** related to freshwater species and habitat indicators, as required by the EU Biodiversity Strategy and proposed EU Nature Restoration law
- Improving our understanding and assessing system functioning, connectivity, resilience, and vulnerability in response to multiple pressures.
- Development of algorithms and tools to support the uptake and better use of remotely-sensed data sources by water resources managers, river basin managers and policy-makers
- Comparison of the cost-efficiency and effectiveness of new monitoring approaches and their integration with existing practices
- Further elaboration of indicators and assessment schemes for policy implementation (WFD, EBVs, SDGs)

Implementation of the SRIA Action Plan

EurAqua's ambition is to "substantially contribute to the development and dissemination of European freshwater science and technology…" and "…to the development of the scientific and economic basis of European water management". Through its evaluation of the research and innovation needs identified in this document (the SRIA), EurAqua further aims to create "a foundation for the network to establish common and high-priority activities where enhanced collaboration amongst EurAqua partners [that] will… address current and emerging water challenges". EurAqua members therefore are encouraged to support such ambitions by working together on activities in each of the following four key areas.

Influencing the European RDI agenda and seizing the opportunities that arise

EurAqua endeavours to play a key role in RDI European agenda setting. It will continue to represent the research priorities and ambitions of its members through active involvement on influential panels, working groups and committees of the European Commission and associated initiatives (e.g. the Water4All Partnership; the WFD CIS working groups) as well as in international bodies, such as the WHO and UNEP. EurAqua will communicate and engage with key officers/representatives of research funders, advising them on the development of priority research calls and RDI missions. It will contribute to European programming initiatives through the identification and validation of research needs. This action has been carried out since the creation of the network more than 25 years ago and it will be progressed forward through such activities as follows:

- Writing a Position paper on water issues within the future Horizon Europe in order to contribute to reflections on Horizon Europe;
- Preparation of position papers putting forward recommendations for the preparation of calls for projects within the framework of the Water4All, Climate JPI, FACCE and the JPI Urban Europe;
- Involvement in the Stakeholders Advisory Group of the Water4All Partnership and FACCE JPIs;
- Reinforcement of the presence of EurAqua in the working groups of Water Europe;
- Strengthening of the participation of EurAqua in the WFD CIS working groups.


Image: Riku Lumiaro, Finnish Environment Institute

EurAqua will keep on developing contacts with decision-making bodies as a way to bridge the science-policy interface of its activities. EurAqua will continue to develop contacts with the following bodies:

- European Commission Directorates-General (DG)- DG Research and Innovation, DG Environment, DG Agriculture, DG Region, DG Connect and DG Move;
- European Parliament and, in particular, with intergroups dealing with freshwater issues;
- International River Basin Commissions, IPCC, IPBES and the World Water Quality Alliance

To seize the resulting opportunities presented by European calls for RDI, EurAqua strongly encourages its members to consider other fellow members first when forming consortia. Such opportunities may arise within Horizon Europe and its associated Missions, but also within Joint Programming Initiatives (e.g. Water4All, Biodiversa+) and Article 185 initiatives (e.g. PRIMA, BONUS) and their successor partnerships, *inter alia*.

Alignment of EurAqua members' projects and programmes

Many of the projects or programmes EurAqua members undertake, at national-level or internationally, singularly or in collaboration with others, have aspects that are common with those of other EurAqua members. On the premise that "the whole is greater than the sum of its parts", where possible, all members are asked to share information on their projects and programmes to help identify specific elements where joint action or alignment of activity could be mutually beneficial. However, as it is unlikely that 'new money' will be available, added value must be evident early in discussions and there should be recognition that any participation in joint activities necessarily will be voluntary and will be in varying degrees. Ideally, only those who can contribute significantly should be involved, yet results should be made broadly available. To enable alignment on projects, members should consider making use, where possible, of existing research mobility programmes. Further opportunities for collaboration may also be realised through the sharing of the research infrastructures that exist across the EurAqua network (e.g. experimental facilities, laboratories, etc.).

Building capacity and knowledge exchange within EurAqua

Alignment or collaboration of projects will inevitably provide opportunities for the EurAqua members to learn from each other, share knowledge and expertise, and thus enhance their respective capacity to conduct research. More explicitly, EurAqua will seek to enhance capacity by convening various knowledge exchange meetings, webinars and networking events, including:

- Maintaining a regular series of webinars;
- Annual in-person discussion events, to develop action plans for specific parts of the SRIA;
- Increase EurAqua presence and involvement at European conferences (e.g. convening special sessions at EGU or SEFS);
- Inviting EurAqua partners to final project meetings and other dissemination events of large R&I projects.

EurAqua will encourage participation of all members and their staff, particularly supporting equality, diversity and inclusion at all such events, especially development opportunities for early-career scientists.

Establishing external links and collaborations

The ambitious RDI needs and objectives set out in the SRIA cannot be tackled and resolved by EurAqua and its members alone. However, through working in partnership with other international organisations, initiatives and networks and co-aligning activities, much more is likely to be achieved. To this end, EurAqua will actively seek to engage with and establish strong working relationships with the likes of WMO, IUCN, PEER, UNEP, WWQA, ALTER-net, HELP, etc.

Of course, Non-EurAqua organisations within countries are also likely to run research programmes that are relevant to this EurAqua agenda. Where this is the case, EurAqua welcomes their involvement in the alignment activities (point 2 above).

Awareness of Emerging Research Needs

Working on the understanding that existing long-term research investment plans of EurAqua members bares a risk that emerging topics may be overlooked, this research agenda will be discussed annually with two key questions:

- Have EurAqua members launched new research programmes, and if so, what update to the strategic R&I agenda needs to be initiated?
- What topics have not yet been included in EurAqua's priority topics but may receive more attention within the foreseeable future?

EurAqua's Management Board agrees upon a flexible activity plan on a two-yearly basis. Progress will be reviewed during the annual Management Board meetings, at which the action plan may be modified to integrate new insights. The plan will consider, besides the research topics itself, the contributing role of mobility, research infrastructures and networking, and priority position papers as well as other advocacy actions.


Image: Riku Lumiaro, Finnish Environment Institute

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