EurAqua

The European Network of Freshwater Research Organisations

EurAqua's strategic research and innovation agenda

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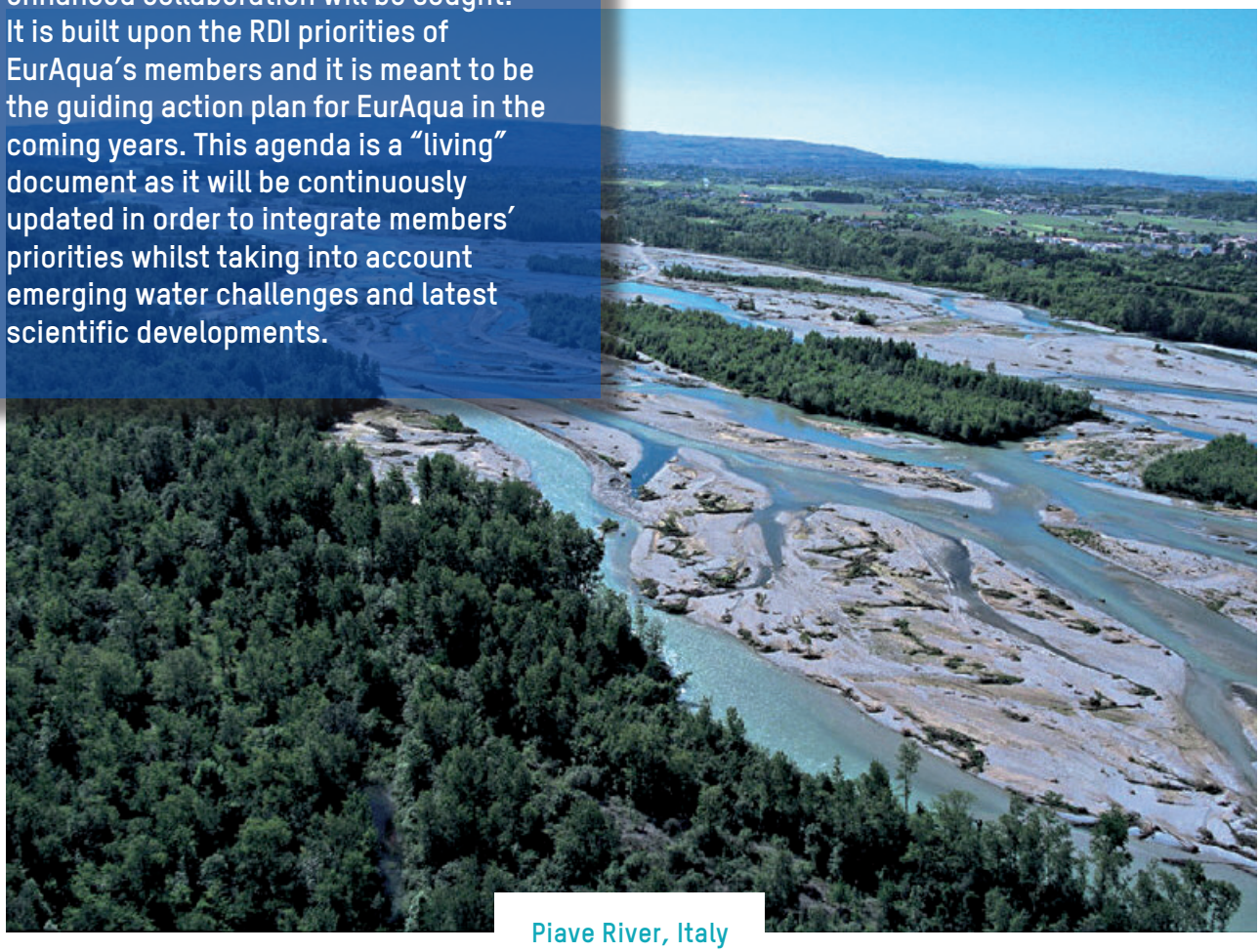
This paper contains EurAqua's strategic research and innovation agenda (SRIA).

It 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 in order to integrate members' priorities whilst taking into account emerging water challenges and latest scientific developments.



Piave River, Italy

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Abbreviations

HMWB Heavily Modified Water Bodies
POM Programmes 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

Table of contents

Contacts / Abbreviations 2

About EurAqua 5

1 Introduction 7

2 Water RDI areas for enhanced collaboration 9

2.1 Environmental quality and human well-being under climate change 9

2.1.1 System Understanding: Monitoring and assessment 9

2.1.2 Solutions: Combinations of technical restoration measures 11

2.1.3 Solutions: Catchments, rivers and deltas management and governance 13

2.2 Climate Change and natural hazards 14

2.2.1 Flood Research 14

2.2.2 Drought and water scarcity 15

2.3 Cross-cutting issues 17

2.3.1 Digital technologies and (big) data 17

2.3.2 Experimental facilities 17

About EurAqua

EurAqua is the European Network of Freshwater Research Organisations. The aim of EurAqua is to contribute substantially to the development of European freshwater science and technology and its dissemination on a European scale, thus having a significant input on the development of the scientific and economic basis of European water management. Established in 1993, EurAqua consists today of 26 predominantly (semi-)public research institutes, representing the same number of European Union Member States and European Economic Area Countries. These institutes extensively support national policies as well as businesses, enhancing the translation of science into policy and application.
Since its establishment, at least 80 European co-funded collaborative research projects carry EurAqua's signature, either by a strong EurAqua members' involvement in consortia, or by having EurAqua as an initiator of proposals, for example in the areas of ecotoxicology, ecosystem services, flood and droughts and water resources monitoring and modelling.

EurAqua is present in a number of European flagship initiatives and projects. This presence has allowed the network to play a role in European programming, to provide cutting-edge knowledge in strategic water management areas in the face of local, regional challenges, and to become a real promoter of policy-oriented, innovative solutions for water ecosystems 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 a member of the Stakeholders Advisory Group of the Water JPI 'Water challenges for a changing world' and has Memoranda of Understanding with The Water supply and sanitation Technology Platform (WssTP) and the Partnership for European Environmental Research (PEER). 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).

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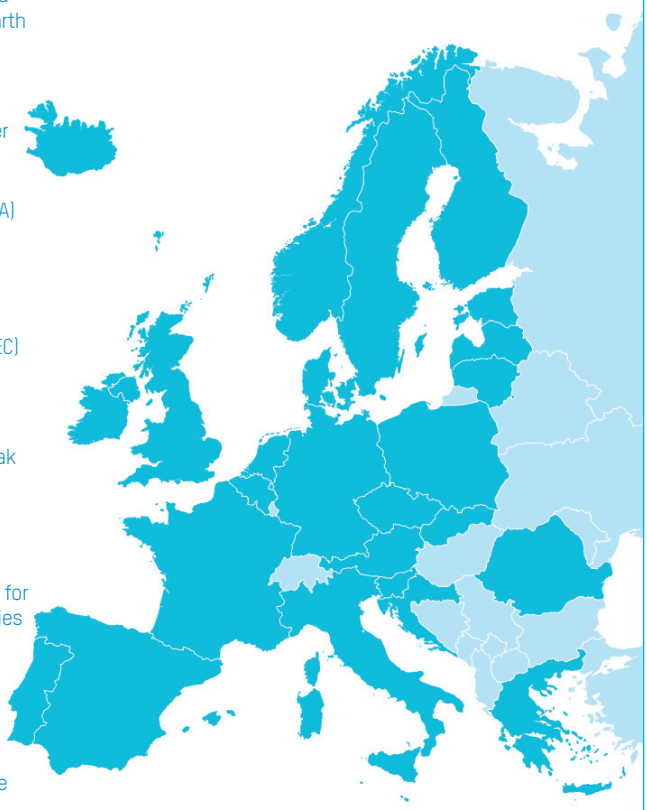
1. **AUSTRIA** – The Federal Agency for Water Management (BAW)
2. **BELGIUM** – Interuniversity Programme in Wat. Resources Engineering (IUPWARE)
3. **CROATIA** – University of Zagreb Faculty of Civil Engineering (UNIZG-FCE)
4. **CZECH REPUBLIC** – T.G. Masaryk Water Research Institute (VUV)
5. **DENMARK**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



Introduction

1

This document provides the Strategic Research and Innovation Agenda on freshwater of the EurAqua network. The development of this strategic agenda responds to one of the objectives identified in EurAqua's vision ("**to facilitate coordinated water research**" amongst its members so as to "**support knowledge-based water management and policy**"). This agenda intends **to create a foundation for the establishment of common and high-priority activities for the network**.

This is an innovative agenda. As, it is to our knowledge, the first in its kind that is built on demonstrable multi-annual research investments of the EurAqua members institutes – as stated in their own strategies. However, this document is not a compilation of members' RDI priorities; on the contrary, **EurAqua's strategic research and innovation agenda describes water RDI areas where joint activities are envisaged** through either external or internal funding (in-kind contribution).

The ultimate aim of this agenda is 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 collaboration will translate into the development of collaborative RDI projects, training networks, lobbying activities, knowledge and infrastructure sharing, and/or mobility actions.

Recent years have shown that funding has become even more competitive and, moreover, does not facilitate broad collaboration within EurAqua: complementarity of research areas is a key requirement in collaborative projects, especially within the framework of the Horizon 2020 programme where multidisciplinarity is a must. By choosing an approach based on actual existing research investments plans, we are confident that some research alignment and joint projects can be identified which require limited additional resources.

To define this agenda, we collected almost 60 research programs in which EurAqua's members invest. These have been classified resulting in the main headers depicted in **Figure 1**.

Within each of the lower branches several research ambitions have been identified and are elaborated in the following chapters.

For the implementation of this agenda, three further strategies will be deployed:

- 1. Stimulating alignment projects with in-kind contributions amongst the members;
- 2. Discussions with research funders, advising them on the development of priority research calls and RDI missions;
- 3.Seizing opportunities presented by European calls for RDI, such as opportunities in Horizon 2020, Horizon Europe, Joint Programming Initiatives such as JPI-Water and Article 185 initiatives such as PRIMA, etc.

Regarding strategy (1), EurAqua's Management Board will seek to stimulate discussions between programme leaders running similar programs. They will be encouraged to identify those specific elements where joint action will result in more than the sum of parts. As there is no 'new money' involved, added value must be evident early on in the discussions. Participation in joint activities will be voluntary and in varying geometries, as only those who can contribute should be involved to be most efficient. Results shall of course be made broadly available.

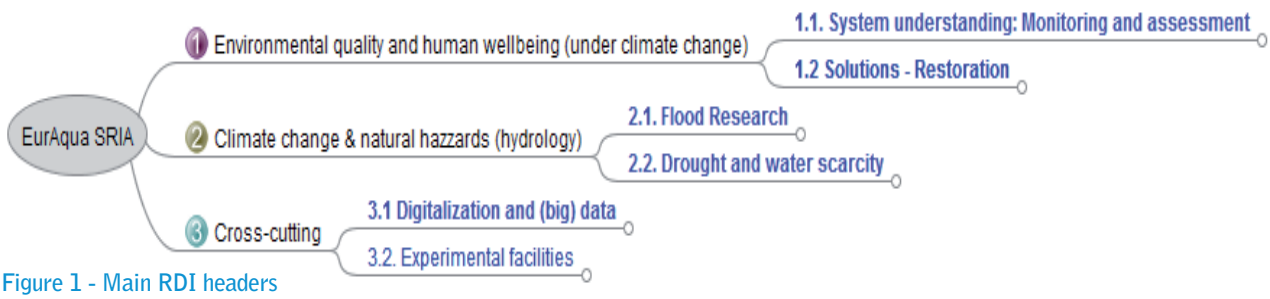


Figure 1 - Main RDI headers

Alignment projects shall also consider making use of existing research mobility programmes and research infrastructures:

- i. Science collaboration will be accompanied by a **reinforcement of mobility actions** of both scientists and other staff (laboratory technicians, project managers, European policy managers, etc.), the purpose of this action being the enhancement of collaborations between members as well as knowledge sharing and knowledge transfer.
- ii. EurAqua gathers today a strong research and innovation capacity from all over Europe. Some of EurAqua's members support cutting-edge technologies and infrastructures. Experimental facilities available within EurAqua include Earth observation facilities, long-term monitoring programmes of lakes and rivers, test sites, flumes, and extensive field and laboratory facilities and equipment. **Infrastructure sharing** will be further promoted over the next few years, which will allow resource efficiency and knowledge sharing.

As to the discussions with research funding organizations (2), EurAqua will endeavour to play a key role in RDI European agenda setting. The agenda will be used to consistently bring research needs to the attention of funding agencies and networks.

EurAqua aims to actively 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 the following activities:

- Preparation of a Position paper on water issues within the future Horizon Europe in order to contribute to reflections on Horizon Europe;
- Water research and innovation recommendations paper prior to the publication of Horizon Europe's work programmes;
- Preparation of position papers putting forward recommendations for the preparation of calls for projects within the frame of the Water JPI, Climate JPI, FACCE and the JPI Urban Europe;
- Involvement in the Stakeholders Advisory Group of the Water and FACCE JPIs;
- Finalisation of a position paper on a future "water mission" and a "water partnership" in Horizon Europe;
- Reinforcement of the presence of EurAqua in the working groups of WssTP;
- Strengthening of the participation of EurAqua in the CIS working groups.

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 – 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.
- (River) Basin Commissions

Emerging research needs

Working on the basis of existing long-term research investment plans of the EurAqua members bares a risk that emerging topics may be overlooked. To address this risk, this research agenda will be discussed regularly with two main questions:

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

Involvement of non-EurAqua partners

Non-EurAqua partners are likely to run research programmes that are relevant to this EurAqua agenda, too. Other institutes may engage in the alignment activities (point 1 above) providing for their own resources, added value and upon agreement with the already participating institutes.

Water RDI areas for enhanced collaboration

2

Detailed implementation and action plan

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

2.1 Environmental quality and human well-being under climate change

2.1.1 System Understanding: Monitoring and assessment

Context and challenges

EU Member States and EEA countries perform water quality 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 indicate that "many Member States and river basin districts have invested in new or better ecological and chemical monitoring programmes, with a greater number of monitoring sites and the inclusion of more chemicals and quality elements"[1]. The existence of more than 130 000 monitoring sites across Europe has allowed a comprehensive assessment of water quality status in many areas where little or no data existed as well as providing a better understanding of the pressures affecting Europe's water resources.

Despite the progress made in the last few decades, **progress in water quality monitoring is still needed**. The impact of multiple pressures (climate change, agricultural production, changes in hydromorphology, etc.) and the increasing presence of emerging pollutants (including plastics) call for the development and roll out of "water quality monitoring systems that are able to monitor reliably a large number of water quality parameters at regular intervals. There is a need for the development of cost-effective instrumentation using advanced technology and shifting to automation to reduce overall analytical costs"[2]. Improvements in water quality monitoring will provide a number of benefits, such as:

- a more accurate assessment of the impact of multiple pressures on the quality of freshwater and related ecosystems over time;
- a better understanding of (local) water quality status, issues and trends;
- more reliable information and evidence for decision makers to target water quality investments to reduce pressures; and,
- an assessment of the success of pollution prevention and mitigation strategies (including an evaluation of the effectiveness of POMS.

RDI areas to be addressed on this theme, as proposed by EurAqua, are:

- **Development and application of innovative water quality monitoring techniques**. The list of monitoring techniques to be addressed include liquid chromatography and gas chromatography-mass spectrometry non-target screening methods, model and information systems, sensor technologies, earth observation, passive sampling techniques, effect-based monitoring, metabarcoding and DNA techniques, and citizen science.
- **Optimisation in monitoring network design** for

1-European waters assessment of status and pressures 2018. EEA, July 2018. Page: 7

2-In-situ and real-time measurements in water monitoring. Gruiz, K., Fenyvesi, É. (2017). Engineering Tools for Environmental Risk Management -3: Site Assessment and Monitoring Tools. pp. 181-244"

3-Carvalho et al., 2018. Protecting and restoring Europe's waters: An analysis of the future development needs of the Water Framework Directive. Science of the Total Environment, 658, 1228-1238. www.doi.org/10.1016/j.scitotenv.2018.12.255

different WFD purposes, such as status assessment, trend detection, and diagnostics for causes of degradation[3]. Research on these areas should enhance CIS guidance on water quality monitoring and assessment.

- **Better understanding of system functioning** (thresholds, resilience, vulnerability, and relationships between ecological status, ecosystem functioning and the sustainable delivery of ecosystem services) **in response to multiple pressures**. RDI in this area should contribute to providing a better understanding of, for example, the effects of multiple pressures on soils and freshwater ecosystems dynamics. Specific topics to be covered include carbon sinks and sources, the adaptation capacity of biotic communities to different pressure factors (changes in temperature/ nutrients, presence of invasive species, harmful microbiological species and toxins...), as well as the assessment of the toxicity, cumulative risk and potential environmental impact of multiple stressors on aquatic biotic communities. The opportunities provided by big data, computing power, artificial intelligence, innovative molecular methods and biosensors should be further seized by Europe in the delivery of system understanding.
- **Assessment of the state, vulnerability and adaptation capacity of aquatic ecosystems and water** assets in response to natural and anthropogenic risks.
- **Comparability of new approaches to existing practice approaches**. Comparison will be based upon the added value of new approaches (e.g. eDNA, EO), their cost-effectiveness in the delivery of data in interpretable products, acceptability, integrability in current monitoring and assessment structures, and usability with historical data sets.
- **Cumulative impacts**. There is still a weak scientific foundation for some specific features of cumulative impacts, as in the case of (for instance) the interrelationship between land use and water quality of upland tributaries. We need to understand the cumulative contributions of different land uses as they change downstream if we are to develop meaningful water quality regulations. EurAqua aims to direct more attention to the following aspects:
  - 1. Characterisation of cumulative impacts by innovative and cost-effective tools based upon modelling, GIS, trends analysis, indicators, etc.
  - 2. Analyses of the causes, pathways and consequences. Attention should be paid to uncertainties and the costs involved in the assessment of cumulative impacts. Research must expand our knowledge on the connection between PoMs and their effect on ecological indicators (fish, plants, and fauna) as well as on the combined effect of multiple stressors on the ecological status of water bodies.

Expected impacts

- **Capacity building:** Improved water quality monitoring and modelling instruments; better understanding of the quantity, variety, regional differences, trends and possible adverse effects of contaminants in aquatic ecosystems; enabled identification and evaluation of (unknown) sources of contamination; identification and evaluation of the effectiveness of innovative techniques as early warning tools of contamination occurrence.
- **Policy implementation:** Outputs will better support decision making and water resources planning through the provision of near real time data; enabled improved evaluation of the effectiveness of mitigation measures; enabled continuous revision and prioritisation of the list of contaminants to be monitored; provision of an evidence base to pinpoint non-compliance to specific polluters and to apply the polluter pays principle; increased ability to develop more effective Programmes of Measures (PoM) within the frame of the WFD.
- **Social and health benefits:** Enhanced ecosystem services, biodiversity, land-use planning, etc.; enhanced public awareness of water quality issues through the application of citizen science principles.
- **Economic benefits:** Increased competitiveness of European monitoring and assessment companies; increased cost efficiency of monitoring

by increasing the information amount obtained per euro spent.

EurAqua investments

Several EurAqua partners run research programmes that significantly contribute to the aforementioned issues:

1. BfG: Modern screening techniques for surveillance of chemical water quality
2. CEH: Advancing monitoring and assessment of water resources & aquatic ecosystems
3. CEH: Land Ocean Carbon Transfer
4. CEH: Resilience of freshwaters to climate change
5. DCE: Lake models
6. DCE: Mapping of phosphorus risk areas
7. Deltares: Ecosystem Monitoring and Modelling
8. Deltares: Understanding System Dynamics Programme
9. ESHI-DIT: Water Quality, Ecosystem Monitoring & Modelling
10. ESHI-DIT: Health and Water in the landscape under Climate Change
11. IRSA: Environmental-DNA technologies (E-DNA) in water management and treating
12. IRSA: Microplastics and emerging compounds (monitoring, treating, preventing)
13. Irstea: Analysis of multiple stressors, cumulative impacts, vulnerability of ecosystems, adaptation capacity
14. IVL: Emerging substances
15. LEI: Climate Change Impact on Aquatic Ecosystems
16. NIVA: Ecosystem based management
17. NIVA: Hazard, risk and environmental impact assessment of multiple stressors
18. NIVA: Innovative technology for micro- and nanoplastic detection and data interpretation
19. VUV: Advanced tools for monitoring and assessment of anthropogenic impacts on aquatic ecosystems

2.1.2 Solutions: Combinations of technical restoration measures

Context and challenges

According to EEA's European waters Assessment of status and pressures 2018 report[4], around 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, showing little overall change compared to the first cycle report. In the report the EEA recognizes that measures will take time to show effect. EEA's report states that 'by the time the third RBMPs are drafted (2019-2021), some of the several thousand individual measures undertaken in the first and second RBMPs should have had a positive effect in terms of achieving good status'. **This statement illustrates the uncertainty of the effectiveness of measures, in terms of if, when and to what extent measures will result in good ecological status or potential**.

The achievement of good ecological and chemical status relies on the implementation of the most cost-efficient measures at the basin level, whilst considering all interconnectivity effects. While the cost of measures can be estimated well through available techniques, **the full ecological effect of programmes of measures is typically poorly understood, in particular quantitatively**. In other cases, system understanding is insufficient to set targets, let alone to devise measures to reach them. For example, our knowledge on ephemeral streams is insufficient to device dedicated PoMs, while such stream occur all over Europe and are dominant in the Mediterranean basin.

4-EEA Report No 7/2018

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 dedicated evaluations after implementing measures hamper our ability to provide scientifically underpinned insight in effectiveness.

RDI areas to be addressed on this theme, as proposed by EurAqua:

- **Development of climate sensitive, smart responsive, scientifically grounded PoMs and research to determine the temporal and spatial cumulative effects of measures**. There is a need to **better understand how restoration trajectories are impacted** by individual and combined measures:
  - The upstream-downstream connectivity is somehow overlooked in the WFD as a result of which the introduction of upstream measures is highly recommended. Research and innovation actions should help discern adequate upstream measures, including measures concerning sediments and basin wide sediment management. The concept of "water body connectivity" and a whole-basin approach needs to be further developed.
  - Research needs to encompass the full spectrum of water bodies, such as ephemeral streams, transitional waters bodies, urban waters and heavily Modified Water Bodies
  - Improved decision framework for selecting dedicated PoMs for Heavily Modified Water Bodies and for Intermittent Rivers.
- Research must expand our **knowledge on the connection between PoMs and their effect on ecological indicators** (fish, plants, and fauna) **as well as on the combined effect of multiple stressors on the ecological status of water bodies**.

Expected impacts

- Improved, science-based and hence cost-effective development of PoMs, resulting from an increased understanding of status and multi-stressors;
- Operationalized decision framework for deciding on the necessity of complementary measures to be taken.
- New management practices to reach the WFD objectives.
- Advanced multiresolution modelling tools.
- European leadership in water management and restoration. Increased competitiveness of European monitoring and assessment companies.

EurAqua investments

Several EurAqua partners run research programmes that significantly contribute to the aforementioned issues:

1. BfG: Invasive alien species
2. DCE: Measures to reduce the impact from agriculture
3. Deltares: Solutions for Impacted Environment
4. Irstea: Ecosystems restoration measures
5. SYKE: Effects of agriculture and forestry and urban areas on the state of waters and methods to reduce the pollution and restoration of the freshwaters
6. Uni-Lj: Sustainable Sediment Management Tools
7. Uni-Lj: Water Science and Technology: Tools and Methods for Process Analyses & Simulations, and Development of Technologies
8. VUV: Technological processes of water purification, water treatment and water reuse

5-Integrated river basin management, ICT and DSS: Challenges and needs. Gourbesville, P. (2008).

6-Protecting and restoring Europe's waters: An analysis of the future development needs of the Water Framework Directive. Carvalho et al., 2018. Science of the Total Environment, 658, 1228-1238. www.doi.org/10.1016/j.scitotenv.2018.12.255

2.1.3 Solutions: Catchments, rivers and deltas management and governance

Context and challenges

"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"[5]. The introduction of the WFD should have shifted towards a water management approach based upon stakeholder participation as well as institutional adaptation and procedural innovation. It is now evident however that "the WFD has driven a highly uneven shift to river basin-level planning" across Member States and that the objectives of EU water policy have only been partially integrated into sectorial policies[6]. Despite the efforts of many Member States, there is still a significant number of HMWB in Europe. HMWB are not properly tackled in Europe due to the costs associated with their restoration and the insufficient knowledge on best possible measures.

EurAqua advocates for the development and implementation of innovative, integrated, adaptive and participatory (transnational) catchments, rivers and deltas management approaches that link ecological and social systems (including policy, economy, social challenges, and the socio-hydrological and bio-geographical dimensions of the catchment system).

RDI areas to be addressed on this theme, as proposed by EurAqua:

- Development of **innovative mechanisms of social engagement** in water management at all scales, from local communities to international and transboundary ones.
- Strengthening **policy integration, coherence and water policy coordination** in order to exert a real change in society, in line with the objectives set out by the WFD and the SDGs.
- **Understanding and acting upon the links between ecological and social systems** for the establishment of a knowledge base for water management planning. In particular, there is a need to address the links between behavioural systems, governance and management technologies. This will require collaborative input from contributors in the arts, humanities and social sciences coupled with those in the science, technology and mathematics communities.
- Development of **tools and methods for better sustainable catchment, river and delta management**. These tools and methods should play a role both in the monitoring of the responses of socio-ecological systems to global changes and in decision making support (i.e. tools useful in the design of measures and in the development of plans to balance water demand and availability). For the development of these tools, the participation of end users will be promoted.

Expected impacts

- **Capacity building:** Improved knowledge of processes at the river basin scale; better ability to identify and suggest governance and stakeholder informed solutions in order to resolve freshwater issues of concern; support the transition from aquatic diagnosis to societal solutions; public and sectorial buy-in, empowerment and joint responsibilities in implementing environmental policies in general and the WFD in particular.
- **Policy implementation:** Development of more informed procedures for the development of PoMs within the frame of the WFD; improved ability to reach the objectives of the WFD and the SDGs due to the development of a new water management paradigm.
- **Social and health benefits:** Enhanced environmental services provided to citizens, and advanced societal well-being.

EurAqua in-house investments

Several EurAqua partners run research programmes that significantly contribute to the aforementioned issues:

1. BfG: Sociohydrological Change
2. BfG: Common Reference Scenarios
3. CEH: Sustainable Catchment Management & Restoration

7-OECD Environmental Outlook to 2050: The Consequences of Inaction - ISBN 978-92-64-122161 © OECD 2012
8-EEA - Economic losses from climate-related extremes

4. Deltares: Delta Governance

5. NIVA: Catchment governance and stakeholder engagement

6. IRSA: WFD implementation (TMDL, management practices, soil management, e-flow)

7. Irstea: Integrated and adaptive water management research area

2.2 Climate Change and natural hazards

2.2.2 Flood Research

Context and challenges

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. '[7].

Figure 2 provides insight in the damages due to hydrological events (floods, mass movements); Source EEA[8].

To make things more challenging current flood infrastructure needs to be replaced or refurbished

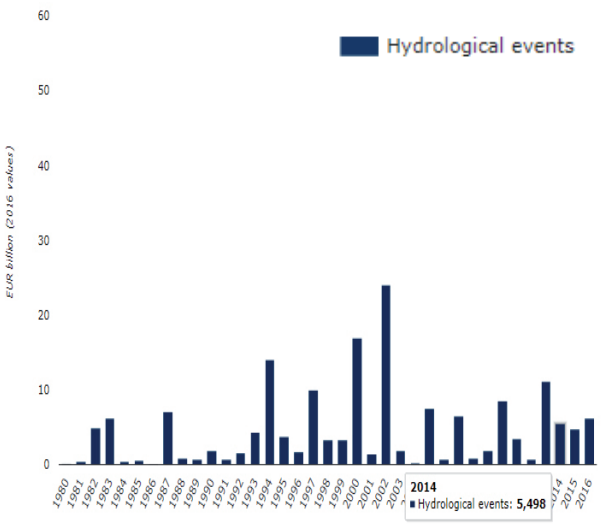


Figure 2 - Economic damage caused by weather and climate-related extreme events

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. Uncertainty in the rate of climate change adds significant uncertainty. Based on a perception survey, extreme weather events and natural hazards rank highest in terms of likelihood and impact[9].

Intermittent or ephemeral streams are very common fluvial systems not only in the Mediterranean area. These rivers show a high rate of change in streamflow, high peak discharges, and low baseflow. A large part of their annual volume flows in a few days, delivering a great part of their sediment and nutrient loads downstream, often in reservoirs used for drinking water. While they occur naturally, they are often 'men-made', and have profound effect on the wider (downstream) system. Typical Indicators of hydrological alteration fail to accommodate such kind of streams. Urban areas are subjected to hydrological extreme events, causing substantial environmental and socioeconomic impacts.

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. EurAqua priorities are mainly within the mitigation and

9-World Economic Forum, Global Risks Report 2018 *http://www3.weforum.org/docs/WEF_GRR18_Report.pdf*

preparedness sections, and to some extent in the response:

1. Integrated benchmarked **Flood risk assessment models and tools**, encompassing all flood types and different climate change and socio-economic scenarios;

2. **Development of, and advice on mitigation measures**, with special emphasis on nature based solutions and asset management;

3. **Operational forecasting and early warning**, spanning several days, including effects on society and water use sectors, and feedback of mitigation measures on forecasts.

Expected impacts

- Improved modelling and assessment tools, including tools dedicated to the public and decision makers, will allow us to better target investments to mitigate flood risks, but also support spatial planners to take flood risk into account.
- Likewise, improved operational forecasting and early warning tools will allow better preparedness and response, but more importantly, will reduce damage, disruption and recovery effort.
- New flood mitigation measures, such as nature based solutions will add societal value in terms of biodiversity, aesthetics, public health and societal resilience.
- The strong focus of this subject in the development of innovative models and policy support tools will strengthen Europe's international scientifically leading positioning on the subject and may provide commercial business to European companies.
- Actions will support the objectives of the EU Adaptation Strategy on adaptation to climate change, COM (2013) 216

EurAqua in-house investments

Several EurAqua partners run research programmes that significantly contribute to the aforementioned issues:

1. CEH: Prediction of water availability over multiple scales (covers flood & drought)

2. Deltares: Climate Adaptation (covers Flood & drought)

3. Deltares: Nature Based Flood Defenses

4. Deltares: Quantifying Flood Hazards and Impacts

5. IMO: Assessment of flood hazards and impacts

6. IMO: Operational river-flow forecasting

7. IRSA: Modeling and management of intermittent rivers

8. Irstea: Supporting decision making in a context of climate change: assessing the impacts of natural risks in hydrosystems (covers Flood & drought)

9. SYKE: Climate change and management of water resources (covers Flood & drought)

10. Uni-Lj: More room for water (covers Flood & drought)

11. VUV: Water management for sustainable development during hydrological extreme periods (covers Flood & drought)

2.2.2 Drought and water scarcity

Context and challenges

The 2018 drought in Europe has demonstrated society's vulnerability to drought and fresh water shortages. A long list of records and measures is easily available in wikipedia[10]. While effects such as wild fires, reduced crop yields and inland shipping volumes are well known, it is less well known what the impacts resulting from such direct effects are. In several Member States, dairy cattle was sold and/or sent to slaughter as a result of lack of fodder [10,11]. Car fuel became scarce in the lower Rhine region as fuel ships were only partially loaded [12]. The 2nd ten-day period of December 2018 still showed that large areas of Europe show water deficits **(Figure 3)**.

10-https://en.wikipedia.org/wiki/2018_European_heat_wave
11-https://www.euronews.com/2018/09/06/how-drought-plunged-europe-s-farmers-into-despair
12-https://www.waz.de/region/niederrhein/wegen-ebbe-im-rhein-kein-sprit-an-duisburger-tankstellen-id215725667.html

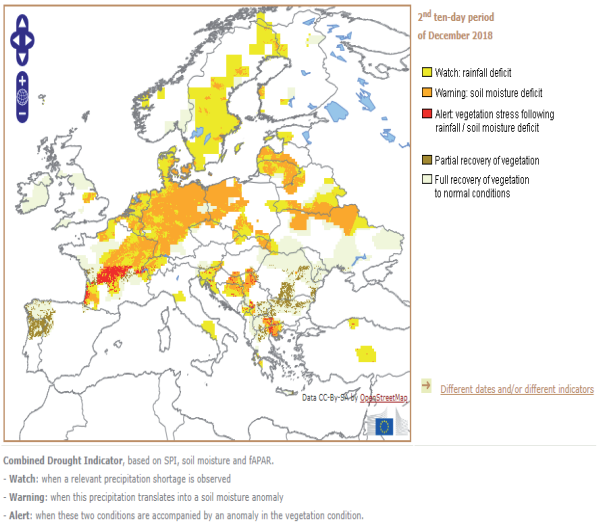


Figure 3 - Combined Drought Indicator (EDO[13]).

Depending on our ability to curve climate change droughts in Europe will increase and intensify [14].

In the light of these developments research and innovation can help society to cope with severe droughts. Action is required in the entire disaster management cycle: Mitigation of, preparedness for, response to and recovery from drought hazards. EurAqua priorities are mainly within the mitigation and preparedness sections, and to some extent in the response area:

1. **Improved understanding of and ability to predict water availability**, deepening our knowledge on land-atmosphere feedbacks, on water use (socio-economic impacts on the water cycle). Better, more reliable knowledge about the impact of climate change: How big is the heat and drought challenge in 2050? ;

2. Development of **innovative methods for rational, supported decision making during droughts**, accounting for all stakes, including nature (minimum environmental flows).

3. Development of **methods to climate/drought-proof abstraction permits**.

4. Development of **mitigation measures**, including water saving, nature based solutions, circular use, risk-free water re-use, etc.

5. **Enhanced assessment of impacts of droughts on water quality** (ecological status) **and biodiversity**.

Expected impacts

- Improved modelling and assessment tools, including tools dedicated to the public and decision makers, will allow us to better target investments to mitigate drought risks.
- Likewise, improved operational forecasting and early warning tools will allow better preparedness and response, but more importantly, will reduce damage, disruption and recovery effort.
- Large scale implementation of new drought mitigation measures, such as efficient irrigation systems, water re-use systems will significantly reduce Europe's vulnerability to droughts.
- The strong focus of this subject in the development of innovative models and technologies will strengthen Europe's international scientifically leading positioning on the subject and may provide commercial business to European companies.
- Actions will support the objectives of the EU Adaptation Strategy on adaptation to climate change, COM (2013) 216.

EurAqua in-house investments

Several EurAqua partners run research programmes that significantly contribute to the aforementioned issues:

1. CEH: Drought monitoring, prediction and mitigation

2. CEH: Prediction of water availability over multiple scales (covers flood & drought)

3. DCE: Impact of water abstraction from ground water on the ecological status of rivers

4. Deltares: Climate Adaptation (covers flood & drought)

5. Deltares: Information Systems for Water Security

6. IRSA: Waste Water reuse

7. Irstea: Supporting decision making in a context of climate change: assessing the impacts of natural risks in hydrosystems (covers flood & drought)

13- European Drought Observatory http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000

14-L. Samaniego, S. Thober, R. Kumar, N. Wanders, O. Rakovec, M. Pan, M. Zink, J. Sheffield, E. F. Wood, and A. Marx (2018): Anthropogenic warming exacerbates European soil moisture droughts. Nature Climate Change http://dx.doi.org/10.1038/s41558-018-0138-5

8. IVL: Water reuse

9. LEI: Ecological flow estimation

10. SYKE: Climate change and management of water resources (covers flood & drought)

11. Uni-Lj: More room for water (covers flood & drought)

12. VUV: Water management for sustainable development during hydrological extreme periods (covers flood & drought)

2.3 Cross-cutting issues

2.3.1 Digital technologies and (big) data

Context and challenges

Major progress is made in fields such as digital sensors, communications, virtual reality, artificial intelligence and data driven modelling. The general impression is that the potential of these new technologies for water management is not fully recognized and dedicated applications only slowly emerge and get adopted in practice. The challenge is to much faster assess the potential uses of emerging digital technologies and demonstrate their added value in one or more of the research and innovation areas developed in chapters *2.1 Environmental quality and human well-being under climate change* and *2.2. Climate Change* and *natural hazards.*

Expected impacts

- Faster adoption of innovative technologies in water management
- Novel European products entering the market, providing global commercial business opportunities to European companies.

EurAqua in-house investments

Several EurAqua partners run research programmes that significantly contribute to the aforementioned issues:

1. CEH: Data management tools and information systems for water resources

2. Deltares: Enabling Technologies

3. IVL: Digitalization

4. VUV: Hydroinformatics and data in water management

2.3.2 Experimental facilities

Context and challenges

EurAqua partners operate a large number of research infrastructures, several of which are unique. The EurAqua website (http://www.euraqua.org/content/researchinfrastructures) presents an overview along the following clusters

- Experimental Basins
- Earth observation facilities
- Field laboratory equipment and test sites
- Flumes
- Laboratory facilities
- Miscellaneous

EurAqua partners are also heavily engaged in several EU initiatives, such as the development of The International Centre for Advanced Studies on River-Sea Systems 'Danubius' whithin the 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).

These research infrastructures are essential to develop our understanding and test solutions for

the challenges developed in chapters *2.1 Environmental quality and human well-being under climate change* and *2.2. Climate Change and natural hazards i.r.t. hydrology*.

Some efforts have also been made in digital and computational research infrastructures, but this field remains rather un-aligned.

Further action and research are required to

- Improve facilities to meet the demands for experimental research.
- Connect physical and digital facilities
- Further increase the use of facilities and align investment decisions.

Expected impacts

- Increased awareness of existing facilities leading to better use and more strategic development investments.
- Increased research quality and efficiency

More information on EurAqua and its Strategic Agenda on the following Website:

http://www.euraqua.org/

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