Science of the Total Environment 658 (2019) 1228–1238

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Protecting and restoring Europe's waters: An analysis of the future development needs of the Water Framework Directive

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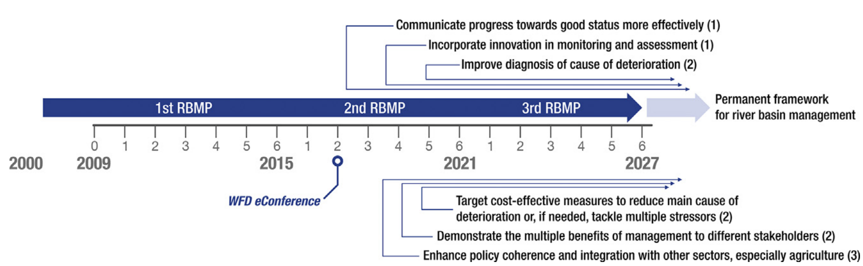
HIGHLIGHTS

- Monitoring and assessment needs to better reflect improvement in ecological status
- Management actions must account for the effects of multiple stressors
- WFD management targets need to acknowledge long-term recovery time-scales
- Water resource protection must be mainstreamed into other policy instruments
- WFD implementation must acknowledge management needs beyond 2027

GRAPHICAL ABSTRACT



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https://doi.org/10.1016/j.scitotenv.2018.12.255

ARTICLE INFO

Article history:
Received 16 September 2018
Received in revised form 16 December 2018
Accepted 16 December 2018
Available online 18 December 2018

Editor: Damia Barcelo

Keywords:
Water policy
WFD
Assessment
Monitoring
Management
Governance

ABSTRACT

The Water Framework Directive (WFD) is a pioneering piece of legislation that aims to protect and enhance aquatic ecosystems and promote sustainable water use across Europe. There is growing concern that the objective of good status, or higher, in all EU waters by 2027 is a long way from being achieved in many countries. Through questionnaire analysis of almost 100 experts, we provide recommendations to enhance WFD monitoring and assessment systems, improve programmes of measures and further integrate with other sectoral policies. Our analysis highlights that there is great potential to enhance assessment schemes through strategic design of monitoring networks and innovation, such as earth observation. New diagnostic tools that use existing WFD monitoring data, but incorporate novel statistical and trait-based approaches could be used more widely to diagnose the cause of deterioration under conditions of multiple pressures and deliver a hierarchy of solutions for more evidence-driven decisions in river basin management. There is also a growing recognition that measures undertaken in river basin management should deliver multiple benefits across sectors, such as reduced flood risk, and there needs to be robust demonstration studies that evaluate these. Continued efforts in 'mainstreaming' water policy into other policy sectors is clearly needed to deliver wider success with WFD goals, particularly with agricultural policy. Other key policy areas where a need for stronger integration with water policy was recognised included urban planning (waste water treatment), flooding, climate and energy (hydropower). Having a deadline for attaining the policy objective of good status is important, but even more essential is to have a permanent framework for river basin management that addresses the delays in implementation of measures. This requires a long-term perspective, far beyond the current deadline of 2027.

1. Introduction

The Water Framework Directive (WFD) (2000/60/EC) is the cornerstone of European Union water policy. Its main objective is to protect and enhance the status of aquatic ecosystems and promote sustainable water use (European Commission, 2000). The objective applies to all surface waters (rivers, lakes, transitional and coastal waters) as well as groundwater. The immense value of water and the need for it to be managed responsibly, is clear in the WFD where it is stated early on that "Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such" (European Commission, 2000).

The Directive has stimulated an enormous portfolio of new and comparable ecological assessment methods (Birk et al., 2012), which have greatly improved monitoring and assessment of ecological status of water bodies, thereby providing a better basis for a multitude of restoration measures (Voulvoulis et al., 2017). These assessment and monitoring methods have also greatly improved our knowledge of the status of European waters (European Environment Agency, 2012, 2018). At the same time, the member states have not succeeded in achieving the WFD primary objective: achieving good status of Europe's waters. Based on WFD data on status and pressures from EU member states delivered with the 2nd River Basin Management Plans (RBMP), the European Environment Agency (EEA) reported that around 60% of surface water bodies were failing good ecological status (European Environment Agency, 2018). The end of the 1st six-year RBMP cycle in 2015 was initially set as the deadline for achieving good ecological status in all surface waters, although extended deadlines are possible for two further cycles up to 2027. If natural conditions do not allow timely improvement in the status even further extensions are possible.

The WFD implementation process is currently in the middle of the 2nd 6-year cycle of river basin management. It has already been through a fitness check, whilst a second consultation on the WFD as well as the Floods Directive is underway (https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2017-5128184/public-consultation_en). The first fitness check, the 'Blueprint to Safeguard Europe's Water Resources' (European Commission, 2012) highlighted the need for better implementation and increased integration of WFD objectives into sectoral policy areas, such as the Common Agriculture Policy (CAP), the Cohesion and Structural funds and the policies on renewable energy, and transport and integrated management of floods and droughts. A more formal evaluation mechanism is written into the Directive, stipulating a review by 2019 at the latest. The WFD implementation is regularly assessed by official processes led by the European Commission and the EEA during every RBMP cycle (European Commission, 2012, 2015a; European Environment Agency, 2012, 2018). Independent evaluations covering a number of specific topics have also been undertaken (Borja et al., 2010a; Brack et al., 2017; Hering et al., 2010; Reyjol et al., 2014; Rouillard et al., 2017; Voulvoulis et al., 2017).

Since the WFD was formally adopted in December 2000, various developments potentially affecting its implementation have occurred:

a) increased recognition of the importance of specific pressures, including climate change and associated flood and drought risks (Quevauviller, 2011), invasive species (Cardoso and Free, 2008) and a wide range of emerging pollutants (von der Ohe et al., 2011).
b) new perspectives on environmental management have been developed, including ecosystem services, nature-based solutions and adaptive and resilience-based approaches (Blackstock et al., 2015; Grizzetti et al., 2016b; Spears et al., 2015).
c) the UN Sustainable Development Goals have been set, in which many targets are related to water, or affect waters in positive and negative ways (Shepherd et al., 2016).
d) other EU policies on biodiversity, renewable energy and floods management have been developed, influencing how we manage aquatic systems.

In the context of these changes and the upcoming WFD evaluation in 2019, there is a need to: (i) evaluate the strengths and weaknesses of current WFD implementation, (ii) identify where innovation offers new opportunities for monitoring and management, and (iii) address potential conflicts and synergies between the WFD and the new policies. Hence, two questions emerge in this context: Is the WFD fit-for-purpose after 18 years and what improvements should be made in future implementation or revision?

This paper conducts a broad and independent analysis that reflects on how water policy can incorporate innovation and adapt to the newly identified challenges facing European waters. Through questionnaire analysis and expert opinion, we consider priorities for WFD monitoring and assessment systems, improving programmes of measures for managing water resources and further integration with other sectoral policies, in particular agriculture, that are needed to deliver wider success in achieving the challenging target of good status in all surface and groundwaters. This analysis is intended to provide constructive and practical suggestions for improved monitoring, management and governance of waters across Europe, but many of the recommendations are generalisable to future development of sustainable water management and policy globally.

2. Methods

The analysis and recommendations in this study are based upon material from a 3-day eConference on 'The Future of Water Management in Europe', held 19-21st September 2017, and a follow up questionnaire survey. More details of the e-Conference structure is provided in Appendix A. The talks and panel discussions are available to view online: https://www.ceh.ac.uk/get-involved/events/future-water-management-europe-econference.

After the eConference, a questionnaire survey (Appendix B) was circulated to all 249 attendees, plus the wider MARS project (www.mars-project.eu) distribution list. The content and design were based on soliciting and prioritising questions with our expert chairs and speakers. Questions were selected that would address the key challenges and gaps in WFD implementation from their knowledge of the literature under the three themes of the eConference: (1) monitoring and assessment, (2) management measures and (3) policy integration. The purpose of the questionnaire was to ascertain where there was agreement or divergence on the topics within a broad community of water experts that spanned researchers, practitioners and policy makers. There was a 31% response rate, with 95 responses to the questionnaire over the period 24th September–1st November 2017. When asked to rate their knowledge of the WFD implementation, 78% of questionnaire respondents stated to be either good or high, suggesting the questionnaire responses were largely based on a thorough understanding of the WFD implementation. The questionnaire data were descriptively analysed with totals and ranks presented in the tables to illustrate the relative strength of opinions and the distribution of opinions between options. More sophisticated statistical analyses were not employed as the data are mainly nominal; and the sample size and composition were not suitable for statistical correlations (de Vaus, 1986). The paper builds on the existing analysis of the 'state-of-the art' reflected in the conference programme and questionnaire design. This combination of 'state-of-the-art' review and expert evaluation of strengths, weaknesses and gaps is an emerging methodology in environmental science (e.g. Sutherland et al., 2011).

3. Monitoring and assessment systems

There has been great effort and success in developing robust and comparable methods for ecological status assessment across EU member states (Birk et al., 2012). This work has been supported through a comprehensive cross-comparison of status class boundaries, known as "Intercalibration" (Birk et al., 2013). The intercalibrated methods allow extensive, comparable and robust assessments of the ecological status of Europe's waters and were viewed by eConference attendees as one of the greatest strengths of the WFD (Table 1). Another perceived strength of the WFD is that it has led to an expansion of monitoring schemes to cover all water categories, i.e. rivers, lakes, coastal, transitional waters, and groundwater (Table 1).

One of the major weaknesses of WFD monitoring and assessment was perceived as the poor linkage between pressures and effects on the ecosystem (Table 1). It has to be acknowledged that there is redundancy in WFD assessment schemes (Kelly et al., 2016), with many representing the impact of nutrient or organic pollution, albeit across different "biological quality elements" (BQEs: phytoplankton, macrophytes and phytobenthos, benthic invertebrates and fish) with differing response times. In contrast, there are few schemes developed that assess the impacts of hydrological or morphological pressures (Hellsten and Mjelde, 2009; Schinegger et al., 2018), or multiple pressure situations (Nõges et al., 2016). Intermittent waters, such as temporary rivers, which are a natural characteristic of the Mediterranean region, cannot be considered simply as degraded versions of formerly perennial water bodies and require more targeted assessment (Cid et al., 2016, see also SMIRES (Science and Management of Intermittent Rivers and Ephemeral Streams) www.smires.eu and the LIFE project TRivers on temporary rivers and the WFD http://www.lifetrivers.eu). Other criticisms of WFD monitoring and assessment include the poor representation of impacts on ecosystem functions (Moss, 2008) and overly strict criteria in the overall assessment (Table 1) due to the "one-out-all-out principle" (Borja and Rodríguez, 2010).

3.1. One-out-all-out principle

The "one-out-all-out principle" means that the lowest score of any of the BQEs, and the supporting physico-chemical and hydromorphological quality elements, determines the overall ecological status of a waterbody (WFD Annex V, 1.4.2 (i)). This is a well-suited and justifiable combination rule if different stressors are responsible for the degradation of the individual BQEs. However, it can be a problem if BQEs are sensitive to the same stressors because uncertainty associated with individual BQEs assessments can be compounded (Caroni et al., 2013), leading to over-precautionary results with more sites failing than should. However, this problem will mainly occur if quality elements with high uncertainty are included in the assessment. Assessments including several BQEs sensitive to the same pressure can be justified or even necessary if the individual BQEs 1) have very different response times, 2) represent different habitats (e.g. littoral versus pelagic) or 3) if other stressors mask the impact of the main stressor. As the risk for false downgrading a water body has been a widely voiced criticism in WFD assessment (Borja and Rodríguez, 2010; Moe et al., 2015), conference attendees were asked to answer a specific question on *How the 'one out all out' rule should be implemented to track progress* (Table 2). The most frequent recommendation was to put greater emphasis in reporting progress in individual BQEs and supporting

Table 1
Summary of the most frequent responses in the eConference questionnaire on the strengths and weaknesses of the Water Framework Directive and reasons for failure by 2027. PoMs = Programmes of Measures.

	Monitoring and assessment systems	Management measures	Policy integration
Strengths	Putting ecosystems at the centre of objectives (34%); Common Monitoring and Assessment Schemes across Europe (19%)	Increased investment in restoration measures (14%)	Consideration of all surface fresh waters, groundwater, transitional and coastal waters together (16%)
Weaknesses	Poor linkage between pressures and effects on the ecosystem (23%); Overly strict criteria to define success (8%)	Poor investment in restoration measures (15%)	Too short-term and too high expectations for the goals of improvement (31%);
Main causes of not achieving good status by 2027	Insufficient monitoring to identify the cause of degradation (9%);	Limited progress in reducing nutrient loads sufficiently (19%); Lack of investment in restoration measures (13%); Difficulty in managing PoMs at the watershed scale (9%)	Lack of cross-sector involvement in implementation of PoMs (18%); Too high expectations for the short-term (16%)

Table 2
Summary of the responses in the eConference questionnaire as to how the one-out-all-out rule should be best implemented to track progress. BQE: Biological Quality Elements.

How should the one-out-all-out rule be best implemented to track progress?	No. respondents	% respondents
Greater emphasis in reporting progress in individual quality elements	42	36%
Reporting pressure-specific weight of evidence assessment across BQEs	35	30%
Down-weighting, or exclusion, of uncertain quality elements from assessment	31	26%
No amendments to implementation are needed	6	5%

elements. Some respondents commented further that WFD reporting could present ecological status results for each pressure separately (e.g. eutrophication, morphological pressures), in addition to the overall ecological status that reflects all pressures. There was also strong support for using a pressure-specific weight of evidence approach, i.e. weighting by the uncertainty, or confidence, of all individual classification results that assess the same pressure; an approach used practically in the UK to ensure management decisions are based on the strongest evidence. Others supported the option where quality elements with high uncertainty (low confidence) should be completely excluded from the overall assessment of ecological status (Table 2). In conclusion, there are a variety of implementation options available to track progress and communicate success, whilst maintaining the more holistic, albeit precautionary, one-out-all-out principle.

3.2. Innovation in monitoring

The large expansion in monitoring required by the WFD has created pressure from governments on their regulatory agencies to reduce the costs of monitoring whilst maintaining coverage and effectiveness (Borja and Elliott, 2013). Many researchers and river basin managers agree that change is needed in WFD monitoring to provide sufficient spatial and temporal resolution and in some cases to make it more cost-effective. A large amount of monitoring in the WFD is termed "surveillance monitoring" and has two mains aims: firstly, to assess the overall surface water status within each catchment or sub-catchment, and secondly, to detect long-term trends in status. These aims require different frequencies of monitoring, with the latter generally requiring much more frequent monitoring over many years to provide the power needed to detect trends (Carvalho et al., 2012; Borja et al., 2016), whilst the former may only require monitoring in one or two years of the six-year river basin management cycle (Carvalho et al., 2013). A possible solution here can be to select fewer representative water bodies for trend detection having more frequent monitoring (e.g. every year) than the majority of water bodies included in the surveillance monitoring networks. WFD "Operational Monitoring" to measure the impact of pressures and subsequent management measures should be designed starting from the assessment of pressures, selecting only those quality elements that are sensitive to each of the significant pressures/stressors, and having sufficient frequency of monitoring, typically every year, to enable trend detection before and after the implementation of measures. "Investigative Monitoring" to diagnose the cause of degradation should take a more exploratory approach to the monitoring design, ideally with consideration of paired control and intervention sites to evaluate effectiveness of management measures (Conner et al., 2016). We recommend further WFD implementation guidance is developed on strategic design of monitoring networks to harmonise best practice in addressing these different aims.

New monitoring tools have also become available in recent years, including Earth Observation, genomics and citizen science (Danovaro et al., 2016; Tyler et al., 2016). The use of satellite data for surveillance and operational monitoring has great potential to better standardise measures across Europe and enhance confidence in WFD classification through enhancing both spatial coverage and frequency of monitoring of variables such as water colour, chlorophyll-*a*, cyanobacteria and emergent macrophyte coverage (Tyler et al., 2016). There are several active projects developing satellite products for WFD monitoring from ESA's Copernicus programme (EOMORES www.eomores-h2020.eu; CYMONS https://business.esa.int/projects/cymons; CHLO4MSFD http://chlo4msfd.azti.es/; EUNOSAT: Joint Monitoring Programme of the EUtrophication of the NOrth-Sea with SATellite data). Near real time remotely sensed observations on water quality and land-use change, in combination with machine learning, could support managers where to focus cost intensive in-situ monitoring. There is also growing support for the use of citizens and smartphone applications (e.g. www.brc.ac.uk/app/bloomin-algae-app; www.ub.edu/fem/index.php/en/inici-riunet-en) in enhancing monitoring as this can not only provide greater coverage and potentially reduced costs, it can also deliver greater public understanding and engagement in water management (Hadj-Hammou et al., 2017; Pocock et al., 2017; EU Project groundtruth2.0 http://gt20.eu/). Careful quality assurance of citizen data needs to be considered to ensure it offers evidence of sufficient quality to support decision-making (Kosmala et al., 2016). Great synergistic benefits can be achieved by combining and exploiting big data from these two new areas of innovation. Significant progress has also been made with the use of meta-barcoding and environmental DNA (eDNA) (Hering et al., 2018; Pawlowski et al., 2018) as a complementary tool for monitoring, as well as on automated sensor technologies and flying, floating and submerged drones equipped with multisensors (Duffy et al., 2018).

Adopting new approaches does raise some challenges for WFD implementation. Firstly, new approaches require checks on comparability with the existing nationally-approved and intercalibrated assessment methods. Secondly, they will need equal scrutiny of their cost-effectiveness if they are to replace existing tools: the cost of delivering data in interpretable products and effectiveness in terms of pressure-response relationships and confidence in classification. Finally, it is essential to maintain ecological and taxonomic skills and knowledge, as these often underpin the design and robustness of assessment schemes. Expert ecological knowledge and understanding is also widely called upon when making large investment decisions on what management measures should be prioritised. It is important to stress that the cost of monitoring is minor compared to the cost of mitigation and restoration measures; the correct targeting of measures requires an accurate assessment of waterbody status and the pressures causing deterioration.

4. Improving water management measures

The RBMP process outlines a Programme of Measures (PoM) to bring about the required improvements in status. The whole river basin is considered and incorporates partnership working with other sectors, such as agriculture, flood protection, hydropower, navigation and fisheries. The most commonly reported actions undertaken by member states include "basic measures" that are covered under other water legislation (Urban Waste Water Treatment Directive, Bathing Water Directive, Nitrates Directive, Drinking Water Directive, Habitats Directives). These are accompanied by "supplementary measures", such as removal of barriers to improve fish migration and natural flood retention measures, such as restoring river meanders and floodplain function (European Commission, 2015a, 2015b). The use of economic instruments, such as water pricing, are also part of the "basic measures" in the WFD (Balana et al., 2011). Member states reported substantial delays in implementing many of the measures planned. Only around 20% of WFD basic measures were reported as completed by 2015, and only 10% of supplementary measures to tackle hydromorphological and diffuse sources have been completed (75% are ongoing, 15% have not yet started). Implementation delays are also significant for water abstraction mitigation measures and the establishment of ecological flows in relation to abstraction and hydropower. These statistics reflect our questionnaire results: even though 14% of respondents felt the WFD had led to increased investment in restoration measures, 15% believed that there was a poor investment in restoration measures (Table 1). More specifically, an additional 19% believed that there has been limited progress in reducing nutrient loads sufficiently and 9% believe there is a difficulty in managing PoMs at the river basin scale (Table 1).

It should be acknowledged that there has been a long history of success across Europe in reducing nutrient loads from point sources from industry and urban wastewater treatment, due to the ability to control pollution at source and set emission limits for industry. However, many water bodies still fail good ecological status due to nutrient pollution, either because of diffuse sources of pollution from agriculture and rural dwellings, or insufficient treatment of waste water from smaller treatment works and/or discharges of untreated sewage during storm events. Two thirds of the 1st cycle European RBMPs have reported that basic measures are insufficient to reduce diffuse pollution from agriculture (European Commission, 2015a, 2015b), requiring supplementary measures. Even now, nutrient pollution is reported by member states to affect 28% of all surface water bodies and 18% of groundwater bodies by area (EEA, 2018). Insufficient management targets for nutrients that are not well linked to ecological targets, or the need to protect downstream water bodies, may be an additional reason for failure.

In many cases, environmental flow implementation is insufficient and water abstraction effects are underestimated. Invasive non-native species (INNS) are another relatively neglected area in the RBMPs. They are incorporated into some assessment schemes (as a response to pressures, such as eutrophication), but have generally not been considered as a pressure themselves, despite pronounced impacts on ecological status and ecosystem services (Vandekerkhove et al., 2013).

Results from a separate questionnaire sent to local water managers (Kuijper et al., 2017) indicated that often measures are prioritised, in part, based on limited finances from annual budgets and expert judgement on what may be the most cost-effective solution, or the less conflicting towards other sectors of activity. Water managers sometimes favour simple measures leading to quick improvements in order to demonstrate progress, but more complex situations where multiple stressors act on a larger scale, and where multiple stakeholders need to be involved, require careful and often long-term planning across the whole river basin (Kuijper et al., 2017; ICPDR, 2015). For example, ecological and chemical status and microbiological quality are often impacted by the same drivers (agriculture, urban wastewater and industry) and a closer integration of monitoring and management for ecological and chemical status would be beneficial, alongside management measures addressing microbiological quality for specific drinking water and bathing water protection zones within river basins (e.g. improved urban wastewater treatment, better manure handling). Given these findings, our analysis suggests three areas that might improve the use of PoMs to improve status: managing for multiple stressors; improved diagnosis of the issues and using an ecosystem services framework.

4.1. Managing multiple stressor combinations

Whilst our questionnaire responses highlight a clear need for increasing investment in restoration measures, they also raise the need to use WFD monitoring data to make more cost-effective decisions in river basin management that are supported by stakeholders. Most WFD assessment methods have been developed to be responsive to single stressors (Hering et al., 2010; Birk et al., 2012) but at least 40% of European waters are subject to multiple stressors (Nõges et al., 2016; EEA, 2018). The effects of combined stressors can be additive, i.e. the sum of their individual effects, one of the stressors may be dominant (i.e. the other stressors have no additional impact), or the effects of multiple stressors can be higher (synergism) or lower (antagonism) than the additive effects elicited by individual stressors (Piggott et al., 2016). There is currently limited evidence on the impact of multiple stressors on aquatic ecosystems, and most evidence is based around experimental studies (Brennan and Collins, 2015). Empirical studies using monitoring data are beginning to shed light on interactions between stressors in the real world (Richardson et al., 2018; Schinegger et al., 2016; Teichert et al., 2016). Currently these studies only examine interactions between two stressors and span limited waterbody types or stressor gradients (Nõges et al., 2016). Whilst this knowledge base on multiple–stressors is developing, it remains a challenge for river basin managers to use these insights to establish a practical "stressor-hierarchy" in management and decide which stressors to tackle first, or when it is necessary to tackle multiple stressors simultaneously. The river Ebro in Spain illustrates this complexity where very low precipitation, high temperatures and high water demand have resulted in low river flows and less dilution of nutrient pollution, greatly exacerbating eutrophication impacts (Herrero et al., 2018). On top of this, additional stressors, such as morphological alterations (dams) and introduction of invasive fish species add to the complexity and have delivered unpredicted ecological surprises, such as increases in biting blackflies with consequent impacts on the tourism economy (Sabater et al., 2008; Herrero et al., 2018).

Reviews from the literature can inform river basin managers about the likely success and failure of restoration activities and necessary recovery times (Borja et al., 2010b; Feld et al., 2011; Verdonschot et al., 2013; Feld et al., 2018). It is, however, important to point out that in many cases restoration projects have been unsuccessful because they did not consider all relevant pressures and lacked a logical, data-driven approach (Palmer et al., 2010). The limited success in moving all water bodies in Europe to good status opens up similar debates about whether PoMs are sufficiently effective or ambitious (Voulvoulis et al., 2017) particularly given the complexity of diagnosing the main cause of degradation when water bodies are impacted by multiple stressors.

4.2. Improved diagnosis of the cause(s) of deterioration

Two of the most widespread pressures simultaneously affecting Europe's waters are physical alterations affecting river hydromorphology, and diffuse pollution at the catchment-scale. Recent research (Lemm et al., 2019) highlights that many of the biological assessment metrics used in WFD classification, especially benthic invertebrates, respond to general degradation from multiple pressures and, therefore, do not generally provide causal inference in multiple stressor situations, making the choice of appropriate management measures difficult.

Similar to a doctor's diagnosis, tools are needed to infer the probability of potential causes of deterioration (stressors) from a range of symptoms (biological metrics and indices) of a water body allowing a more informed prescription to restore ecological health (Kelly, 2013; Elosegi et al., 2017). 27% of respondents to the MARS eConference questionnaire believe existing WFD biological metrics assessments can be used, in combination with relevant supporting elements, to diagnose the cause of deterioration, whilst 16% thought expert judgement was important (Table 3). In addition, 21% of responses felt that new diagnostic tools were needed. Tools can be built upon expert judgement or be driven by real monitoring data (Globevnik et al., 2017). 13% of

Table 3
Summary responses in the eConference questionnaire: what tools can best be used to diagnose the cause of degradation?

What tools can best be used to diagnose the cause of degradation?	No. respondents	% respondents
BQE assessments in combination with relevant supporting elements	45	27%
New diagnostic tools (c.f. talk by Christian Feld)	35	21%
Targeted operational monitoring	35	21%
Expert judgement	27	16%
New approaches to biomonitoring (c.f. talk by Annette Baattrup-Pedersen)	22	13%

respondents thought that new approaches to monitoring were needed to inform diagnosis (Baattrup-Pedersen et al., 2016). A further 21% felt that additional targeted operational monitoring would be needed to help managers make informed choices (Table 3).

An example of these tools is the use of trait-based diagnostics which utilise the same monitoring data used in ecological assessment, but operate independently from the generally taxonomy-based ecological status classification to help identify reasons for not meeting good status (Baattrup-Pedersen et al., 2016, 2018). Traits give insight into mechanisms behind status deterioration and, therefore, help diagnose these mechanisms behind degradation. Substituting taxonomic approaches with trait-based approaches may not provide a complete solution to identifying cause-effect, but they do represent ecosystem functioning better and allow managers to rank current stressors and select appropriate mitigation measures for recovery (Baattrup-Pedersen et al., 2018). Similarly, the use of process-based models can be beneficial to support management decisions, for example in setting environmental flows (E-flows) in rivers to sustain healthy ecosystem functioning (European Commission, 2015a, 2015b; von Schiller et al., 2017).

4.3. Incorporating an ecosystem service framework in water management

Ecosystem services are defined as the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010) and include the provision of water for different uses, the removal of pollution by microorganisms, the protection from floods provided by natural floodplains, and the opportunity for recreational activities, such as swimming, fishing, recreation and tourism (Stosch et al., 2017). As these services are important to society and the economy, showing the relationship between ecological status and the delivery of these services could strengthen the support for potentially costly management measures (Blackstock et al., 2015). The ecosystem's capacity to provide regulating and cultural services generally appears to increase with better ecological status (Pouso et al., 2018). Conversely, increased provisioning services, such as water supply or actively stocked fisheries, generally tend to degrade aquatic ecosystems, although this trade-off with provisioning services may be most apparent in less impacted waters (e.g. fish production could decrease if nutrient loads are reduced to very low levels in high status sites). This uncertainty was stressed in the questionnaire results, where the need for more practical demonstration studies to highlight whether ecosystem services are enhanced through achieving good status was ranked by 48% of respondents to the questionnaire as the highest priority (Table 4). Better tools to evaluate and monitor ecosystem services were also ranked as an important area for development to deliver this evidence (Table 4).

The concept of ecosystem services has already been adopted in the RBMPs in several EU countries, although often the term is not explicitly mentioned. The context of application is related to the integration of sectoral policies (see policy integration section below), the multiple service benefits of proposed management measures and cost-benefit analysis in the application of water policy (Vlachopoulou et al., 2014; Grizzetti et al., 2016a). Another important topic is the recovery of ecosystem services after restoring aquatic ecosystems (Gerner et al., 2018; Pouso et al., 2018). Indeed, an ecosystem service approach supports valuing all benefits, including hidden benefits, and the selection of multi-benefit measures, including nature-based solutions (Liquete et al., 2016). Practical examples of this are being taken forward, however, there are still many knowledge gaps for the translation of the approach into practice, especially concerning the availability of methods, tools and guidelines to measure services (Carmen et al., 2018).

Development and use of ecosystem service indicators can help enhance our understanding of the concepts and provide quantifiable messages (Smith et al., 2018). In Europe, the Working Group on Mapping and Assessment of Ecosystems and their Services (MAES) has developed a framework for assessing ecosystem services in support of the EU Biodiversity Strategy (Maes et al., 2016) and indicators for water ecosystem services have been proposed, distinguishing between indicators of service capacity, flow, sustainability and efficiency (Grizzetti et al., 2016b). An approach to evaluate the changes in ecosystem service provision and value resulting from mitigation activities at the water body scale has also recently been established (Gerner et al., 2018). In summary, our analysis highlights the value in RBMP to incorporate an ecosystem service framework when working with stakeholders in other policy sectors. This may help identify the optimal management measures needed to deliver multiple benefits associated with improving ecological status, e.g. to achieve good status and reduce flood risk.

5. Integration across policy sectors

To support integrated water management at river basin level, the implementation of the WFD has been accompanied by significant effort to involve other administrative sectors, stakeholders and the general public in river basin planning (Jager et al., 2016) as well as competent authorities from other countries sharing the basin in international river basin districts, e.g. Danube (ICPDR, 2015). However, developing a genuine culture of collaboration has proved challenging due to a number of factors, including the short implementation timeline required by the Directive, lack of expertise and experience of responsible authorities and the difficulty of participating parties to reach compromise (Voulvoulis et al., 2017). Successful participation requires sufficient time and resources and enabling governance arrangements (Reed, 2008). Based on experience of integrated catchment management worldwide, Rouillard and Spray (2017) show the importance of establishing a statutory framework that ensures the creation of strong partnerships between regional public and private actors to formalise co-management, including contractual agreements to leverage funding across organisations.

For the financing of the costs of the measures in the RBMPs the WFD relies to a large extent on the recovery of the costs of water services (WFD Article 9). It is noticeable that the WFD does not have its own specific EU funding for implementation, but it is integrated into the budget of the EU's LIFE financing instrument for environment and climate. LIFE funding amounts to €3.4 billion for the period 2014–2020, which can be compared to EU Regional Funds and the EU CAP of €350 billion and

Table 4
Summary responses in the eConference questionnaire: What activities are needed to incorporate an ecosystem service framework into river basin management? [Rank priorities in order, 1 being most important and 6 being least important].

Rank	Practical demonstrations of the link between status and services	Better tools to evaluate and monitor ecosystem services	Better linkages across policy areas	Greater scientific understanding of the benefits of ecosystem services	More research to bring together different disciplines	Additional legislation
1	48%	30%	28%	26%	14%	1%
2	23%	34%	18%	23%	26%	9%
3	14%	18%	27%	18%	20%	20%
4	8%	11%	6%	18%	21%	14%
5	6%	7%	18%	10%	12%	15%
6	1%	1%	3%	5%	7%	41%
Mean rank	2.0	2.3	2.8	2.8	3.1	4.6

€290 billion respectively. As a result of this vast difference, the implementation success of EU water policy is highly dependent on using financial instruments in other sectoral policies, or "water-mainstreaming", as well as on national funding. A common approach to water-mainstreaming has been to establish standards and certification schemes to promote best practice technologies or best management practices (e.g. Industrial Emissions Directive). Recent years have also seen the introduction of environmental safeguards and economic incentives in EU Structural and Investment Funds, including the Agricultural Fund for Rural Development, the Cohesion Fund and the Regional Development Fund, in a drive to reduce the environmental impact of economic development; and currently the EU are developing standards to further link financial investment with environmental protection (European Commission, 2018).

5.1. The need to integrate water policy in other sector policies

The latest assessment of the state of EU waters (EEA, 2018) highlights the large range of sectors contributing to the failure of achieving good ecological status, e.g. agriculture, forestry and aquaculture, energy (hydropower) and urban development. The need for better policy integration is not new but achieving this has clearly been problematic. Starting in the 1970s, European water law has developed a range of Directives focusing on the protection of the water environment from pressures arising from urban (Urban Waste Water Directive) and agricultural (Nitrates Directive) development and mainstreaming water protection into other EU environmental policy areas (e.g. Habitats and Birds Directives) and sectoral policies (e.g. CAP, Common Fisheries Policy, Floods Directive or the Marine Strategy Framework Directive) (Boyes et al., 2016). There is now a complex array of existing policy instruments influencing drivers and pressures on the water environment both in synergistic and conflicting ways (Rouillard et al., 2017). The implementation of the WFD has revealed the challenges with implementing effective integrated water resource management given this complex policy landscape (Voulvoulis et al., 2017). The UN Sustainable Development Goals (SDGs) for 2030 are the latest international policy driver for sustainable management of the Earth's resources. These more explicitly recognise the co-dependence of many policy areas (Nilsson et al., 2016). Governing the process for achieving the 18 SDGs in order to realise potential synergies and remove conflicts is now a growing area of policy-orientated research (Waage et al., 2015). For example, actions targeting food security in agriculture, aquaculture and fisheries can have positive or negative effects on the availability of water and its quality. Agriculture is probably the sector that has received the most attention as being problematic, in relation to achievement of WFD objectives (Jacobsen et al., 2017). The questionnaire results back this up, with a dominant belief that the need for integration is strongest with the agricultural sector (Table 5).

Four significant areas where agriculture impacts on ecological and chemical status are: (1) losses of soil and nutrients from agricultural land leading to eutrophication of waters; (2) losses of pesticides threatening chemical status; (3) morphological modifications of river networks, particularly riparian zones, to optimise conditions for agricultural production; and (4) abstraction of water for irrigation, exacerbating low flows and water levels in surface waters and groundwaters.

The European Court of Auditors (2014) examined whether the EU's water policy objectives had been successfully integrated into the CAP. They found that it had only partially been successful, in part due to the basic trade-off between the aims of the two policy objectives (food production vs good ecological health). Importantly, they highlighted weaknesses in the national implementation of the two instruments used for water mainstreaming in the CAP: cross-compliance and rural development programme funds. Each Member State has a choice in the balance of agricultural payments between direct income support to farmers and payments for agri-environment schemes to enhance the environment, with generally a much higher fraction of the budget assigned to the former. This relationship between those lobbying for greater access to CAP budgets to fund the ambitious PoMs required for delivering WFD objectives, and those focused on CAP's primary objective of food production, creates tension between the water and agricultural policy sectors (Koontz and Newig, 2014). Although this tension can be overcome through deliberation, it has at times created a barrier to collaborative developments (Matthews, 2013). The WFD's RBMP process includes dialogue with stakeholders and does allow for exemptions to account for economic activities, but RBMPs have tended to focus on voluntary measures based on financial incentives and on improving the environmental performance of agriculture, rather than on regulation. A more systemic approach across catchments clearly requires a stronger shared vision and wider participation in implementing effective measures (Voulvoulis et al., 2017).

Sustainable intensification has been proposed as a potential unifying framework aimed at catchment level integrated delivery of agricultural and water objectives (Petersen and Snapp, 2015). In this framework, improved "precision farming" and other best practices in land management are focused on achieving both higher yields and reduced resource use (water, fertilisers, pesticides), and consequently reduced environmental impact. However, the new water-saving irrigation techniques also promote an expansion of crops towards new crop areas which were marginal before. The Baltic Deal Project - putting best agricultural practices into work (EU Strategy for the Baltic Sea Region 2010–2013) is one large-scale example which sought to reduce losses of nutrients to groundwater, streams and lakes and eventually reduce nutrient loads to the enriched Baltic Sea, whilst maintaining agricultural production and farm income. The project has focused on knowledge-driven, improved agri-environmental advisory services, relevant measures and demonstration farm networks for peer knowledge transfer and environmental investments (Langaas, 2011). Increasingly, this framework has been recommended to frame the agriculture–water nexus (van der Veeren et al., 2017; European Commission, 2017).

In this context, it may be desirable to produce more formal guidance on the difficult boundaries between regulating polluting acts, requiring the polluter to pay and paying not to pollute. This is linked to questions over who pays for the environment and the resource costs of water services, but extends far beyond the WFD to other aspects of land use and land management. For example, whether upstream land managers, or downstream beneficiaries, should bear the cost of catchment protection or flood management. This introduces questions of distribution of costs

Table 5
Summary responses in the eConference questionnaire: To achieve greater improvements in the future, which policy areas need stronger integration with water policy? [rank the top six, 1 = High].

Rank	Agriculture	Urban Planning	Flooding	Climate	Energy	Industry	Forestry	Aquaculture	Health
1	76	18	10	17	22	11	4	8	5
2	13	28	30	21	18	18	13	10	20
3	1	18	17	19	15	29	21	21	11
4	2	6	9	11	9	11	11	5	10
5	0	8	4	9	10	8	7	10	10
6	3	5	6	4	7	6	9	12	14
Mean Rank	1.4	2.7	2.8	2.8	2.9	3.1	3.5	3.5	3.6

and benefits; and concepts of equity and fairness not explicitly discussed in the WFD, but implicit in the emphasis on public participation (see Heldt et al., 2017). Given the need to combine environmental objectives with social objectives in other policies (e.g. retaining rural communities, avoiding land abandonment), the issue of distribution is something that WFD implementation needs to address more explicitly. The increasing focus of ensuring the new CAP is 'socially acceptable' (European Commission, 2017), is one policy opportunity, external to the 2019 evaluation of the WFD, that provides for such debates.

There are clearly many other important policy arenas that need consideration if the WFD objectives of good status and sustainable water use are to be achieved. Climate change policy is one obvious arena that the WFD needs to take account of (Quevauviller, 2011). The risks it presents to both water security and agriculture should be a focus for strengthening the WFDs provisions to ensure that adaptation and mitigation measures are an explicit focus in the RBMPs. The Urban Water Agenda 2030 is a current European policy initiative that acknowledges the key role of cities in water resources management. It aims to support governments and water utilities to take further voluntary action to tackle ageing infrastructure, water scarcity and the increasing occurrence of extreme flood events (Koop and van Leeuwen, 2017).

6. Meeting the WFD targets by 2027 or beyond

Without revisiting lawyers' debates on the meaning of 'good status' (Hendry, 2017), there is still a lively debate on the nature of the core obligations required by member states to achieve it (van Kempen, 2012). Setting 2015 as the year when water bodies should have reached good status was identified as a major weakness of the Directive in our questionnaire survey (Table 1: "Too high expectations for the short term"). The questionnaire also provided views on the most important reason for waterbodies not achieving 'good ecological status' by 2027: identifying an over-arching concern that insufficient measures are being carried out, either due to a lack of resources or difficulties in working with other policy sectors at the river basin level (Table 1). These dates greatly underestimated the time required for countries to develop and intercalibrate all the assessment systems in all water categories needed for WFD status assessments, which was not even fully completed by 2015. Additionally, it grossly underestimated the time needed, following monitoring and status assessments, to plan and implement sufficient and relevant measures in dialogue with all sectors and stakeholders. Some member states had long histories of water management, others did not and what seemed feasible in the economic context of the late 1990s has been more challenging in times of austerity in many member states, particularly after the 2007 economic crisis (Völker et al., 2017).

According to the WFD, by 2027, the objective of good status should be achieved in all waters unless less stringent objectives have been defined. This is possible when water bodies are heavily affected by significant pressures or their natural condition is such that the achievement of these objectives would be infeasible or disproportionately expensive. It requires that member states still strive to achieve the highest status possible and that no deterioration occurs. After 2027, river basin management plans still need to be evaluated and updated every six years. An extension of the deadline for achieving good status is only limited to cases where the "natural conditions" are such that they cannot be achieved by this date, for example legacy pollution in soils, sediments and groundwater (Sharpley et al., 2013) or the time needed for recolonisation by plants and animals following intervention (Spears et al., 2016). The use of this provision still requires that measures needed to ultimately achieve good status have been included in the third RBMPs in 2021. The expected length of the time extension needed to achieve good status beyond 2027 should also be outlined in the 3rd RBMP in 2021. This means that, if EU countries are not convinced that they can justify natural conditions as the reason for failure, they will need to formally indicate the need for an exemption to allow "less stringent objectives". These can be revisited in the next update of the river basin management plan and, if feasible, raised back to good status. The up-coming 2021 deadline for the 3rd RBMPs is, therefore, creating a dilemma between what EU member states generally want to do (keep ambitions high) and the practical realities of predicting what they think they can achieve by 2027.

There is already discussion on phased achievement beyond 2027 to achieving the good status target based on 'technical feasibility' (e.g. managing invasive species) or 'disproportionate costs' (Dworak et al., 2016) by setting the objectives lower than good status for 2027 but demonstrating planned progression (e.g. from poor to moderate status, or moderate to good in some elements) and no deterioration. This may better reflect the reality of the time needed to negotiate and implement large-scale measures accepted by diverse stakeholders with differing agendas across water, food and energy sectors. It would, however, be beneficial for member states to receive clarification that such a phased approach is legally acceptable. In a review of the WFD, extending the deadline for achieving good status to an indefinite future date would risk taking the pressure off countries and a slowing down in improvements; a revised target end date, as in all environmental policy, would still be necessary. From the perspective of scientific evidence needs, greater understanding of the effectiveness of measures, demonstrated through large landscape-scale experiments, and further elaborating how "natural conditions", climate change and societal choices are likely to delay recovery, are two priority areas for further research to support achieving the WFD target. Understanding future trajectories is complex and new approaches, such as dynamic adaptive policy pathways (Haasnoot et al., 2013), may need to be adopted to take forward decision making and adaptive planning under deep uncertainty.

7. Conclusions

It is important to reiterate the need for more systemic, holistic and participatory science for this sustainability Directive (Blackstock and Carter, 2007). This paper has identified several areas where experts have identified challenges, gaps and opportunities for monitoring and assessment, management measures and policy and governance. The major recommendations to enhance future implementation of the Water Framework Directive in these areas are summarised in Fig. 1. In particular, there was widespread support for an enabling policy environment, requiring more attention to achieving policy coherence and the mechanisms allowing water policy to be mainstreamed via other major policies, such as the CAP and the Floods Directive. What is important, is that we do not lose the integrative water management framework and positive momentum the WFD has created. The focus on ecological status, that the WFD introduced in 2000, is better understood and accepted today and fits closely with the EU Biodiversity Strategy 2020 and the global goals of the UN Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES). Furthermore, the protection of water quality and water-related ecosystems are explicitly included (Goal 6 and Goal 14) in the UN Sustainable Development Goals. In short, the WFD's approach focusing on ecological status was essential and ground-breaking. Progress with management measures and improving ecological quality has been much slower than originally envisaged, but this progress needs to be built upon with stronger policy integration across sectors. Sufficient resources for both monitoring and management is essential to deliver evidence-based decisions that are cost-effective and of sufficient scale. The stakeholder process within the RBMP cycle also needs to provide a real arena for the provision of incentives and the regulation of poor practice.

Since its inception, the WFD has inspired other water policies around the world. After 18 years, its implementation now needs to improve to address and eliminate the internal implementation weaknesses in monitoring and management decisions, as well as improved integration with 'external' policies that affect aquatic ecosystems and water resources. We believe this is not a policy design problem, but largely an implementation problem. Improved understanding of the causes of deterioration under conditions of multiple stress, using evidence and

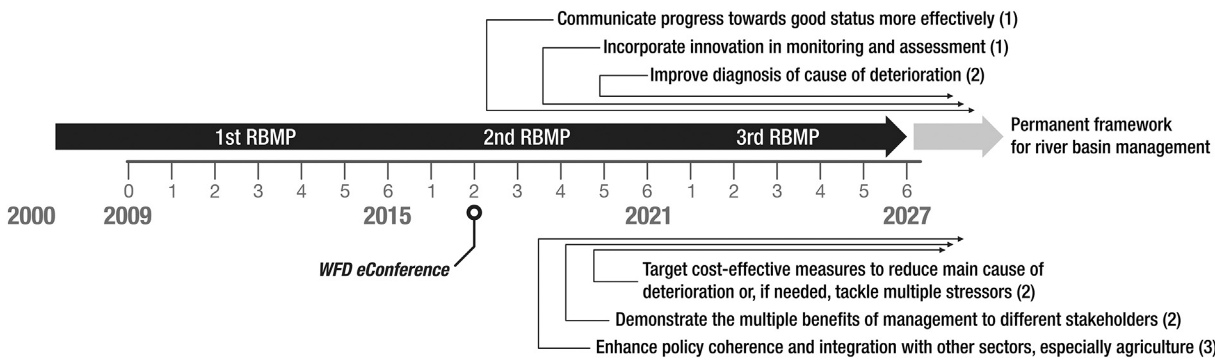

Fig. 1. Summary of recommendations to enhance future implementation of the Water Framework Directive up to, and beyond, the end of the 3rd River Basin Management Plan (RBMP) in 2027, in relation to three key topics (1) monitoring and assessment, (2) management measures, and (3) policy integration.

dialogue to select the best management solutions and greater policy integration in planning and implementing measures are three areas identified for further progressing WFD objectives. Integrated water resource management is never easy to achieve, but successful examples demonstrate that real progress can be made. Having a deadline for attaining the policy objective of good status, or higher, is essential, but even more important is to have a permanent framework for river basin management, to ensure that good status is maintained and emerging pressures are addressed. This requires a long-term perspective, certainly far beyond 2027.

Acknowledgements

Funding: This work was supported by the MARS project (Managing Aquatic ecosystems and water Resources under multiple Stress) funded under the EU 7th Framework Programme, Theme 6 (Environment including Climate Change), Contract No.: 603378 (http://www.mars-project.eu). Author contributions were also based on work from other EU-funded projects including: Sindre Langaas co-funded from the FAIRWAY Project (producing good water quality for drinking water supplies), funded by European Commission, Directorate General for Research under Framework Programme HORIZON 2020, Contract No.: 727984; Sergi Sabater GlobAqua (FP7-ENV-2013-603629); Josselin Rouillard AQUACROSS (H2020 Grant Agreement no. 642317). Angel Borja also provided inputs and results from a Summer School, organized by AZTI, with the support of the EEAcademy (European Environment Agency) and the Basque Water Agency (URA). Kirsty Blackstock and Laurence Carvalho were also supported from Scottish Government's Strategic Research Programme (2016–2021) WP1.2 on Waters. Bryan Spears was supported by the Our Phosphorus Future Project, supported by NERC grant no. NE/P008798/1, the United Nations – Environment, and the European Sustainable Phosphorus Platform. Thanks also to Jörg Strackbein, University Duisburg-Essen, for producing the graphical abstract.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2018.12.255.

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