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Safeguarding Freshwater Life Beyond 2020: Recommendations for the new Global Biodiversity Framework from the European Experience

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Abstract

The drafting of a new Global Biodiversity Framework for the Convention on Biological Diversity (CBD) and Biodiversity Strategy for the European Union (EU) render 2020 a critical crossroad for biodiversity conservation. Freshwater biodiversity is disproportionately threatened and poorly studied relative to marine and terrestrial biota, despite providing numerous essential ecosystem services. The urgency of the mounting freshwater biodiversity crisis necessitates approaches catered to the unique ecology and threats of freshwater life, which are not adequately addressed by current strategies. We present a set of 15 special recommendations for freshwater biodiversity to guide the CBD's post-2020 framework and the 2020 EU strategy based on European case studies, both challenges and successes. Our recommendations cover key outcomes and guiding concepts, enabling conditions and methods of implementation, planning and accountability modalities, and cross-cutting issues. They address topics including invasive species, integrated water resources management, strategic conservation planning, data management, and emerging technologies for freshwater monitoring, among others. These recommendations will enhance the ability of global and European post-2020 biodiversity agreements to halt and reverse the rapid global decline of freshwater biodiversity.

Introduction

Freshwater biodiversity—including aquatic organisms and those dependent upon wetlands and adjacent floodplains—is one of the most diverse and imperiled parts of the global biota (Strayer & Dudgeon, 2010; Vörösmarty et al., 2010; Reid et al., 2019). Freshwater ecosystems provide diverse and essential ecosystem services related to water security, carbon sequestration and food supply (MEA, 2005; Grizzetti, Lanzanova, Liquete, Reynaud & Cardoso, 2016; Vollmer et al., 2018). These ecosystems face numerous anthropogenic threats, including invasive aquatic species (IAS), habitat fragmentation, and pollution, and they are dependent on the quality, quantity and timing of fresh water, an increasingly scarce resource (Shumilova, Tockner, Thieme, Koska & Zarfl, 2019; van Rees, Cañizares, Garcia, & Reed , 2019). Awareness of severe declines in freshwater biodiversity has increased over the past four decades, with freshwater species facing population declines as high as 83%, exceeding those in terrestrial and marine systems (WWF, 2018). Despite this high level of threat and strong ties to human wellbeing, freshwater ecosystems are consistently underrepresented in biodiversity research and conservation (Tydecks, Jeschke, Wolf, Singer, & Tocker, 2018; Mazor et al., 2018). There is no global framework to guide policy responses to the freshwater biodiversity crisis, and actions to safeguard it have been inadequate (Harrison et al. 2018, IPBES, 2019). Concerted research and policy actions at a global scale are needed to halt declines and safeguard the future of freshwater life and associated ecosystem services (Darwall et al., 2018).

The Convention on Biological Diversity (CBD) is the primary international convention for biodiversity conservation, and an important means by which such action could be achieved. In decision X/10, the CBD (2010) adopted the Strategic Plan for Biodiversity 2011-2020, but its targets have not been achieved, and global biodiversity continues to decline (IPBES, 2019). More recently, in decision 14/34 (CBD, 2019), the members created a Global Biodiversity Framework (GBF) for post-2020 actions, as a ‘stepping stone’ to help achieve its 2050 vision of “Living in Harmony with Nature” (a zero draft is now available; CBD, 2020). The regulations of this post-2020 framework must be adequate for tackling rapid biodiversity loss, especially with respect to freshwater.

Within Europe, there is a parallel process to adopt a new Biodiversity Strategy (European Commission, 2019; hereafter "Strategy") also starting in 2020. A review of its predecessor reports useful progress, but a need for more ambition (European Commission, 2015). The Strategy reflects the commitments taken by the European Union (EU) to support the CBD, so similar considerations and priorities shape both initiatives. Although their revisions follow different processes, insights from the scientific community are essential to both.

In this contribution, we extend the ideas put forth by Tickner et al. (2020*;* Table 1) and provide freshwater-specific recommendations to guide the new GBF and Strategy. We have organized these recommendations to correspond with the organizational structure used by the CBD in their planning for the GBF (CBD, 2019), consisting of four clusters: 1) Outcome-oriented elements (vision, mission, goals, and targets), 2) enabling conditions and means of implementation (applied and logistical concerns), 3) planning and accountability modalities (monitoring, reporting, and review) and 4) cross-cutting approaches and issues. Given the parallels in timing and scope between the CBD and the Strategy, our goal is to simultaneously inform both agreements from a freshwater perspective, and to frame our recommendations at the international scale while drawing lessons and examples from the European experience. Before outlining our recommendations, we briefly review relevant policy mechanisms functioning at the global and European scale (Fig. 1) to provide a policy context to our recommendations.

Policy Background - The Global Freshwater Conservation Context

The Ramsar Convention on wetlands, founded in 1971, was the first global-scale political force in freshwater biodiversity conservation, focusing on sustainable management or 'wise use' of wetland habitats. Its list of wetlands of international importance now covers 13-18% of the global area of wetlands (Davidson & Finlayson, 2018), but outside of this, loss of wetlands, both inland and coastal, continues at the same pace as in the last century (Davidson, 2014; IPBES, 2019) with more than 35% of area lost since 1970 (Ramsar, 2018).

Table 1: Priority actions for bending the curve of freshwater biodiversity loss from Tickner et al. (2020).

1. Accelerate implementation of environmental flows
2. Improve water quality
3. Protect and restore critical habitats
4. Manage exploitation of freshwater species and riverine aggregates
5. Prevent and control non-native species invasions
6. Safeguard and restore river connectivity

The adoption of the CBD in 1993 provided additional international impetus for the conservation of freshwater biodiversity, although it treats freshwaters as part of the terrestrial realm. The CBD Strategic Plan for Biodiversity 2011-2020 included 20 Aichi Biodiversity Targets. Two of the most relevant are Target 11, the conservation of terrestrial and inland waters and coastal and marine areas and Target 9, the prevention, eradication and control of IAS.

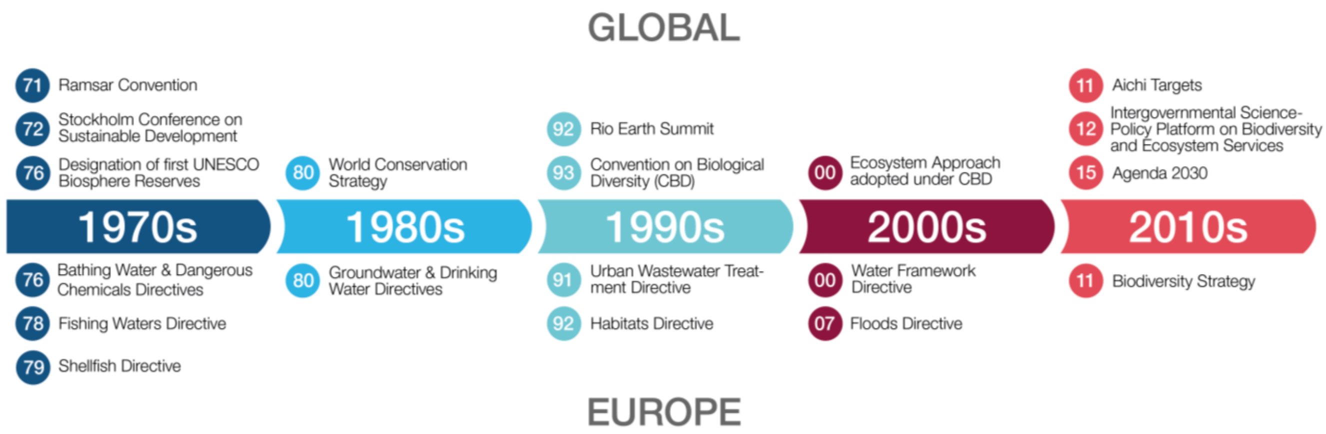

Figure 1: Selected international conventions (above) and European policies (below) directly relevant to freshwater biodiversity conservation and restoration.

Lastly, the Sustainable Development Agenda for 2030 integrates seventeen interlinked Sustainable Development Goals (SDGs), adopted in 2015 by the United Nations as a successor to the 2005 Millennium Development Goals. The SDGs guide national and international efforts in biodiversity conservation and sustainable development. SDG 6 "Clean Water and Sanitation" is inseparable from freshwater biodiversity given the ecosystem services provided by freshwater ecosystems (MEA, 2005). In addition, Target 6.6 explicitly mentions the protection and restoration of aquatic ecosystems including rivers, wetlands, aquifers and lakes, with their spatial extent over time as a specific indicator. SDG 15 "Life on Land" is mainly concerned with protection of forests and other terrestrial environments, only implicitly including inland waters. Furthermore, SDG 14 "Life below water", exclusively addresses marine life and coastal ecosystems, neglecting freshwater biodiversity and dampening political awareness of the urgent conservation needs of these systems (Darwall et al., 2018). Finally, SDG 13 calls for urgent action to increase resilience to climate-change related impacts on society but makes no formal link to the role of freshwater ecosystems in achieving it.

Policy Background - The European Freshwater Conservation Context

Four directives are of special relevance for freshwater ecosystems in the European Union and are legally binding for EU member states. The Birds and Habitats Directives (BHD) are key legislation for the protection of Europe's most valuable habitats and species. EU member states need to achieve good conservation status of listed habitats and a selection of endangered and/or umbrella species by designating Special Protection Areas and enforcing appropriate protection and restoration measures.

The Water Framework Directive (WFD; Hering et al., 2010) integrates previous water-related Directives (Fig. 1) to establish an EU-wide basis for integrated water resources management (IWRM) with the overall aim to "secure good ecological status" for all natural water bodies measured in relation to biological and chemical quality, water quantity and connectivity. It does not explicitly cover wetlands or ecosystem services. The WFD is regarded as a pioneering legislation for the radical changes it catalyzed in how freshwater systems are assessed and managed (Carvalho et al., 2019) in a balance between nature protection and sustainable use (Hödl, 2018). Although the WFD references the need for action to mitigate the effects of droughts and floods as one of its five purposes, it is primarily regarded as an environmental directive. The Floods Directive (FD) was thus adopted to reduce and manage risks to society caused by flooding. The WFD only implicitly considers the impacts of IAS through the ecological status assessment of water bodies (Vandekerkhove, Cardoso, & Boon, 2013). In January 2015 EU regulation 1143/2014 on the prevention of the introduction and spread of IAS entered into force, setting a common standard for combating IAS at the multinational scale (Tollington et al., 2017).

Special Recommendations for Freshwater Biodiversity post-2020

Having established the connection between the EU Strategy and the new Global Biodiversity Framework and the current policy context, we present our special recommendations (SRs; Fig. 2) for freshwater biodiversity. For each recommendation we provide a brief description of the rationale followed by ideas for its implementation in post-2020 frameworks.

Outcome-oriented elements (vision and scope)

SR1: Fresh water should be considered a true ecological "third realm" that deserves legal and scientific prominence in future frameworks and strategies

The severe population declines, critical ecosystem services and distinct ecological features and biodiversity associated with freshwater systems (e.g., connectivity at multiple scales, high level of endemism; Dudgeon et al., 2006) make them a separate ecological realm whose explicit recognition has important consequences for applied conservation. There is a need for separate policies on freshwater habitats and ecosystems, which are too often lumped in with terrestrial habitats (as non-marine) or with the marine environments (as aquatic). Future conservation agreements at global, continental and national scales should explicitly acknowledge freshwater ecosystems as a separate realm with distinct values, ecological dynamics, and conservation needs. For example, targets specifically directed to freshwater ecosystems could be added to SDG 13, 14, or 15. The delineation of freshwater protected areas should be improved where applicable, accounting for hydrological and biotic connections, to ensure that both terrestrial and aquatic species are protected, and pressures reduced (SR3 & SR5). Besides a representative protected fraction of terrestrial ecoregions, a comparable target should be created for freshwater ecoregions (Abell et al., 2008), and key areas for freshwater biodiversity, such as free-flowing rivers and wetlands, should be protected and restored to the extent possible (e.g. Dinerstein et al., 2019).

SR2: Freshwater ecosystems should be viewed and recognized as life supporting units that provide vital ecosystem functions and services in addition to their intrinsic value

To protect freshwater biodiversity, national and international agreements must recognize the unique economic and cultural value of freshwater biodiversity and the essential services it provides, especially when considering multiple uses by under-represented and economically disadvantaged people (MEA, 2005). Functioning freshwater ecosystems offer many opportunities for nature-based solutions to water-related problems (Boelee et al., 2017). In Europe, the MARS project specifically examined practical methodologies for assessing and valuing ecosystem services in the context of the WFD's river basin planning (Grizzetti et al., 2019), a good example of the type of explicit accounting that will be necessary to properly value these ecosystems. It is important to note that many freshwater ecological phenomena, including services pertaining to water supply, cross political borders (Munia, Guillaume, Mirumachi, Wada, & Kummu, 2018), so watershed-based management of ecosystems (see SR5) is a necessary measure. Communicating the potential for functioning ecosystems to alleviate freshwater scarcity in an increasingly climate-uncertain future will strengthen the rationale for protecting freshwater ecosystems.

SR3: Connectivity should be recognized as a vital and multi-dimensional part of conserving and managing freshwater ecosystems

Hydrological connectivity across various scales (e.g., landscape or drainage) and dimensions (e.g., upstream-downstream, channel-floodplain, hyporheic interactions) is essential for maintaining freshwater biodiversity (Grill, et al., 2019). With 2.8 million dams constructed worldwide and the ongoing unabated trends of river impoundment, addressing impacts of habitat fragmentation and connectivity loss is one of the critical conservation challenges for freshwater (Zarfl et al., 2019). In Europe, policy-supported management around flooding and renewable energy (Hermoso, 2017) has relied heavily on dams and channelization, likely driving population declines in a range of freshwater taxa including sturgeons and paddlefish (Jarić, Riepe, & Gessner, 2018).

On the other hand, increasing connectivity through various anthropogenic activities can facilitate the spread of IAS to new regions and promote biotic homogenization (Strecker and Brittain, 2017). In Europe, this is illustrated by ongoing range extensions of aquatic Ponto-Caspian species following the opening of inter-basin canals (Bij de Vaate, Jazdzewski, ketelaars, Gollasch & Van der Velde, 2002), potentially reducing endemism (Rahel, 2007). In some situations, barriers to dispersal may help isolate IAS from vulnerable native species and may slow down the spread of disease and parasites, reducing extinction risk (Manenti et al., 2019). Mitigating measures should be considered when opening new artificial waterways between previously unconnected water bodies and the evidence base on conservation trade-offs between native and invasive species should be strengthened (see SR9).

Future policies in freshwater biodiversity should clearly emphasize the nuanced and complex relationship between biological and hydrological connectivity for freshwater life. Strategic planning frameworks (see SR13) that take connectivity into account (e.g., Hill et al. 2018) should be applied to transparently balance competing interests.

SR4: Conservation policies for freshwater ecosystems should emphasize restoration, leveraging the carbon sequestration potential of peatlands and other palustrine wetlands

The pervasive degradation of wetland habitats, including those within protected areas (Acreman, Hughes, Arthington, Tickner, & Dueñas, 2019), makes habitat restoration as important as protecting additional space. Peatland drainage in Northern Europe has made the EU the second-highest global emitter of land-based greenhouse gases (Joosten, 2016), but rewetting and ecological restoration could massively reduce these emissions and lead to carbon sequestration (Moomaw et al., 2018). Accordingly, freshwater habitat restoration can simultaneously contribute to biodiversity and climate change goals. Future biodiversity policies should take advantage of this synergy by setting explicit, quantitative goals for the hydrological and ecological restoration of wetlands and other freshwater ecosystems. Dinerstein et al. (2019) outline actionable restoration goals which could guide goal setting for wetlands and other freshwater habitats.

Enabling Conditions and Means of Implementation

SR5: Freshwater ecosystems should be managed and delineated at the watershed scale, considering their drainage networks, catchment areas and bordering ecotones

Freshwater ecosystems do not function in isolation from their terrestrial and atmospheric context, but instead act as integrators or receivers of the effects of environmental change in the surrounding watershed (Dudgeon et al., 2006; Williamson, Saros, Vincent, & Smol, 2009). Their links to terrestrial and marine systems by both hydrological and biological mechanisms tie their fate to the ecological conditions of other realms of biodiversity that are often managed separately (Creech et al., 2017). Watershed-scale management is also necessary to accommodate transboundary freshwater ecosystems and prevent resource conflicts (Islam & Repella, 2015).

Abell, Allan, & Lehner (2007) proposed to integrate the protection of freshwater biodiversity focal areas (water features supporting targets of conservation concern) with catchment management, extending protection from riparian buffer zones to upstream areas. This could be augmented by combining the Freshwater Ecoregions of the World (Abell et al., 2008) with land-use management at large catchment scales (Paukert et al., 2017). In Europe, the WFD operates largely at the catchment or watershed scale and thus offers an exemplar for how the implementation of other biodiversity policies could be organized. The protection and restoration of freshwater ecosystems also requires a reduction in external pressures exerted by degradation of adjacent ecosystems to which they are connected (Schinegger, Trautwein, Melcher, & Schmutz, 2012); this calls for more effort in 'mainstreaming' freshwater biodiversity into other policy areas (SR6).

SR6: Global conservation strategies should make use of system thinking to properly navigate the strong societal and economic importance of freshwaters

The interactions of freshwater ecosystems with hydrology, other ecological realms, and society, (see SR2, SR3, SR5) lead to well-known characteristics of complexity, including nonlinearity, historical character, and feedback loops (van Rees, Garcia, & Cañizares, 2019). In order to adapt to and manage this uncertainty, future policies affecting freshwater should adopt a system-thinking approach (*sensu* Zhang et al., 2018) to avoid managing them in isolation and excluding potentially important allochthonous variables (van Rees & Reed, 2015; Sendzimir, Magnuszewski, & Gunderson, 2018). Such policies would view freshwater ecosystems as complex systems embedded in and connected with other socio-ecological systems, and would focus on monitoring essential variables to understand system functioning across multiple scales (Levin et al., 2013; Waylen et al. 2019).

Different environmental goals are not always perfectly aligned; for example, decreasing carbon emissions via hydropower development can conflict with river and floodplain restoration. In Europe, conflicts arose between the Common Agricultural Policy and freshwater conservation priorities (Jansson, Höglind, Andersen, Hasler, & Gustafsson, 2019; Rouillard et al., 2018). Explicit recognition of tradeoffs is necessary: win-win solutions are not always possible, so decision-makers must pay close attention to potential conflicts between legislation protecting dependent freshwater biodiversity and that which governs other environmental resources. Implementing policies for freshwater biodiversity should therefore accommodate and manage potential conflicts arising from the strong coupling of freshwater ecosystems with water resources. Potential conflicts and tensions can also occur during the implementation of other non-environmental policies. The challenge of integration and mainstreaming is thus a topic where European experience offers useful insights, for example highlighting the need for initiatives across stages of policy implementation, but as yet no complete solutions are available (Waylen, Blackstock, Tindale, & Juárez-Bourke, 2019).

SR7: Improved management and enforcement in existing freshwater protected areas should be prioritized

In densely populated and developed areas as in much of the EU, the creation of new protected areas can be socially, politically and economically challenging (Maiorano et al., 2015). This challenge is exacerbated in freshwater ecosystems, where protection also creates direct conflicts with stakeholders using the same freshwater resource (van Rees & Reed, 2015); indeed water abstraction and poor enforcement in existing protected areas limit their value to freshwater biodiversity (Acreman, Hughes, Arthington, Tickner, & Dueñas, 2019). In the case of the EU, the Natura 2000 network, the Ramsar list of Wetlands of International Importance and other networks provide a great opportunity to enhance conservation effectiveness, because the geographic ranges of many threatened species overlap with their coverage and thus could benefit from improved management within them (Hermoso, Morán-Ordóñez, Canessa, & Brotons, 2019b). By altering or improving habitat management in existing protected areas, substantial gains could be made for many listed species. Future policies should thus emphasize the political expediency and ecological effectiveness of intensifying management and enforcement in existing protected areas. This does not replace the need to protect additional natural areas, and this strategy should not viewed as an alternative to land acquisition for biodiversity conservation.

SR8: The identification and adoption of flagship umbrella species is a valuable tool for mainstreaming freshwater biodiversity conservation

Populations of the largest freshwater animals show dramatic declines (He et al., 2018). These and other charismatic species (e.g., Friedrich, 2018; van Rees, 2018) have been suggested as potential ambassadors of freshwater biodiversity that could help achieve both awareness and habitat protection for many other imperiled species and ecosystems (Kalinkat et al., 2017). The need for freshwater flagship umbrella species is especially large given the low accessibility and visibility of many freshwater ecosystems and species (Kalinkat et al., 2017; van Rees, 2018). This approach has been implemented in only a few, localized contexts, but has great promise for outreach around freshwater conservation issues. Biodiversity strategies focused on freshwaters should not neglect the political power (*sensu* van Rees, Cañizares, Garcia, & Reed, 2019) of flagship species, and should take advantage of its conservation efficacy.

SR9: Improve the global evidence base for IAS impacts and the selection of IAS indicators of freshwater habitat status

IAS listings have direct implications through regulatory frameworks for pre- and post-border biosecurity and management, yet their impact can also be indirect. Lists of impactful species are used to assess ecological status of freshwater habitats (Vandekerkhove, Cardoso, & Boon, 2013) in the EU. Provisions on presence or density of specific IAS also apply to conservation status assessments. We recommend using clear criteria and transparent processes to select those species to ensure a coherent approach. In recent years, a wealth of qualitative and semi-quantitative protocols emerged to assess the potential impact of IAS and work has been done to improve their application in risk management. The Environmental Impact Classification of Alien Taxa (EICAT) scheme (Blackburn et al. 2014) provides a unified classification to assess trends in IAS impacts and management (Hawkins et al., 2015). Although EICAT does not link into regulatory frameworks like the EU IAS Regulation, it could be further applied to provide standardized assessments of IAS impacts on freshwater biodiversity. Harmonizing IAS listings improves consistency across different policy regimes for freshwater ecosystems (e.g., Natura 2000, WFD), helps balance conservation trade-offs between native and invasive species (see

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SR3) and provides biosecurity to tackle selected IAS. Established frameworks should be used to control pathways for deliberate or accidental introduction (CBD, 2014).

Planning and Accountability Modalities

SR10: Freshwater monitoring programmes should be reviewed and better coordinated

Monitoring is essential to enabling adaptive (co)management, yet often given insufficient attention. Europe's WFD helpfully specifies a monitoring programme, and though improvements may be needed for it to fully inform management and policy needs (Waylen et al., 2019), its distinction between surveillance, operational, and investigative monitoring help ensure that monitoring allows consistent assessments of status, investigation of problems and appraisal of interventions. Opportunities for cost saving may arise from harmonization and data sharing with other policies. For example, within Europe WFD monitoring could be harmonized with monitoring under the BHD, FD, and international environmental agreements (e.g. CBD).

There is need to improve the long-term monitoring of important freshwater biodiversity variables (e.g., population size, species diversity, habitat quality indices) that are crucial to capturing ecological responses to anthropogenic and natural stressors, typically unfolding over decadal or longer time scales and potentially concealed by shifting baselines (Hillebrand et al., 2018). Europe's WFD mandates assessments of inland water bodies using multiple ecological indices (Birk et al., 2012), but this captures only a subset of the total biota at a given point in time. Further, there is no central data repository of raw data, impeding integrated data use in research (Hering et al., 2010). Additionally, monitoring in fresh waters has been geographically and taxonomically biased (Jackson et al., 2016; Alahuhta et al., 2018). We recommend financial and institutional support for monitoring and evaluation (including a dedicated freshwater biodiversity monitoring scheme), as well as trans-national coordination and integration of databases (see SR11). International efforts like GLEON (Weathers et al., 2013) and ILTER (Mirtl et al., 2018) offer excellent examples of how global networks can coordinate data collection and make data available for both research and public/management.

SR11: Freshwater biodiversity data should be managed according to the FAIR principles to support data mobilization and access

The availability and rapid mobilization of large freshwater datasets is essential to assessing the impacts of multiple stressors and management interventions for freshwater biodiversity (Linke et al., 2019). Although most freshwater monitoring initiatives are publicly funded, the data generated are often difficult to obtain, impeding efficient analysis of large-scale trends (Schmidt-Kloiber et al., 2019; De Wever, Schmidt-Kloiber, Bremerich, & Freyhof, 2019). Adherence to the FAIR data principles (*findable*, *accessible*, *interoperable*, and *reusable*; Wilkinson et al., 2016) as well as the development of institutional Open Data policies and mandating data availability upon the publication of scientific papers (De Wever, Schmidt-Kloiber, Gessner, & Tockner, 2012) are essential for improving access to freshwater data. Strategies advocating the collation of biodiversity data according to FAIR principles are already implemented within the Global Biodiversity Information Facility (GBIF). Additionally, the Freshwater Information Platform (FIP) in Europe is an excellent example of a knowledge base for freshwater biodiversity information (including a repository) that could guide similar endeavors.

SR12: Future biodiversity monitoring schemes should take advantage of novel research methods and data sources

Very few data are available on the occurrence and distribution of most freshwater species, particularly for taxa like parasites, meiofauna, protists, fungi, and bacteria (Grossart, 2019), although these play a critical role in ecosystem functions (Gessner et al., 2007). This lack of available information greatly hinders our knowledge of species composition and community dynamics for many groups. Improved methods for routine applications harbor great potential for reducing these gaps, for example making better use of earth observation and remotely-sensed spatial data products (Carvalho et al., 2019). Emerging methods include eDNA for species detection, metabarcoding, metagenomics and metatranscriptomics of bulk environmental samples for taxon diversity, proteomics approaches for functional processes, and *in situ* high-frequency monitoring (Pochardt et al., 2019; Pont et al, 2019). Monitoring can also benefit from non-traditional data sources outside of environmental agencies and academia (Waylen et al., 2019), including citizen science (e.g., Biggs et al., 2015) and internet data sources. The recently established field of conservation culturomics (Ladle et al., 2016) uses large bodies of digital text or other public data to analyze the interactions of humans with nature and biodiversity. Future strategies that support research and development of these and other emerging research methods would strongly benefit the conservation of freshwater biodiversity.

SR13: Future policies should encourage strategic planning in watershed management to balance human and wildlife water needs

Freshwater ecosystems are subject to heavy and often conflicting demands for ecosystem services due to the distinct goals of stakeholders, ectors, related policies and disciplines. Reconciling resource conservation with usage demands and balancing competing interests requires strategic planning (Seliger et al., 2016). Strategic planning integrates information on species distributions, ecosystem services (both supply and demand), management priorities, connectivity among ecosystems, and SMART targets (*sensu* Perrings et al., 2010) in a systematic, transparent, and repeatable process. Current approaches include frameworks such as multicriteria decision analysis (Langhans et al., 2019), or spatial optimization algorithms (Álvarez-Miranda, Salgado-Rojas, Hermoso, Garcia-Gonzalo, & Weintraub, 2019). Many freshwater-specific improvements on existing spatial planning and decision support tools have been developed (Hermoso et al., 2011) that consider the idiosyncrasies of planning in a freshwater context, including social equity and fairness (Domisch et al., 2019). Freshwater biodiversity management in the coming decade should take advantage of the decision support resources available for navigating the complexity of freshwater ecosystems and societal demands. Such support tools do not by themselves remove conflicts between goals (see also SR6) but can inform and enhance deliberation about how to handle recalcitrant trade-offs.

Cross-cutting issues and approaches

SR14: National biodiversity strategies and priorities, especially with regards to freshwater species listing and protection, should be better contextualized by global Red List assessments

The IUCN Red List is the most comprehensive global source of information on species extinction risk and represents a central information resource to set conservation priorities (Rodrigues, Pilgrim, Lamoreux, Hoffman, & Brooks, 2006). The Red List already contains information about >30,000 freshwater species, and could be used more directly to inform conservation priorities, for example in the EU. A large proportion of threatened biodiversity in the EU is not adequately covered by the BHD; this is especially the case for freshwater species. Only 14% of threatened freshwater fish, 3% of non-marine molluscs and 19% of dragonflies (on IUCN Red Lists) are included in the BHD (Hermoso, Morán-Ordóñez, Canessa, & Brotons, 2019a; Kalkman et al. 2010). These gaps limit the EU's capacity to respond effectively to current and future conservation challenges. Where bureaucratic and political obstacles make revisions of national priorities difficult, Red-Listed species could receive special funding through other internal programs (e.g., LIFE in the EU; Hermoso, 2017). Red-Listed species that are not nationally protected could be highlighted using alternative mechanisms at the national scale like Prioritized Action Frameworks and site management planning in the EU Natura 2000 system.

SR15: Future policies should clarify and enhance the interactions between IWRM and ecological research for freshwater biodiversity conservation

IWRM has quickly become the global standard for sustainably managing freshwater resources and addressing transboundary water conflicts (Allouche, 2016), and governs management in the WFD. However, its stakeholder-based, Habermasian approach is not readily compatible with the highly technical nature of freshwater ecological data required for including conservation goals in water management (Smith & Clausen, 2018; van Rees, Cañizares, Garcia, & Reed, 2019). The prevalence of multiple stressors on freshwater ecosystems (Ormerod, Dobson, Hildrew, & Townsend, 2010) further increases the technical complexity of this ecological information. Flow-response relationships (Tonkin et al., 2019) and other ecological knowledge are essential for reconciling and predicting ecological impacts with societal water needs, but interdisciplinary research is needed to bridge the gap between the 'top-down' nature of ecological research and the bottom-up process of IWRM. Future policies should make use of emerging frameworks (e.g., van Rees, Cañizares, Garcia, & Reed, 2019) to ensure that the

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implementation of IWRM considers the myriad interactions between human societies, freshwater resources, and wildlife.

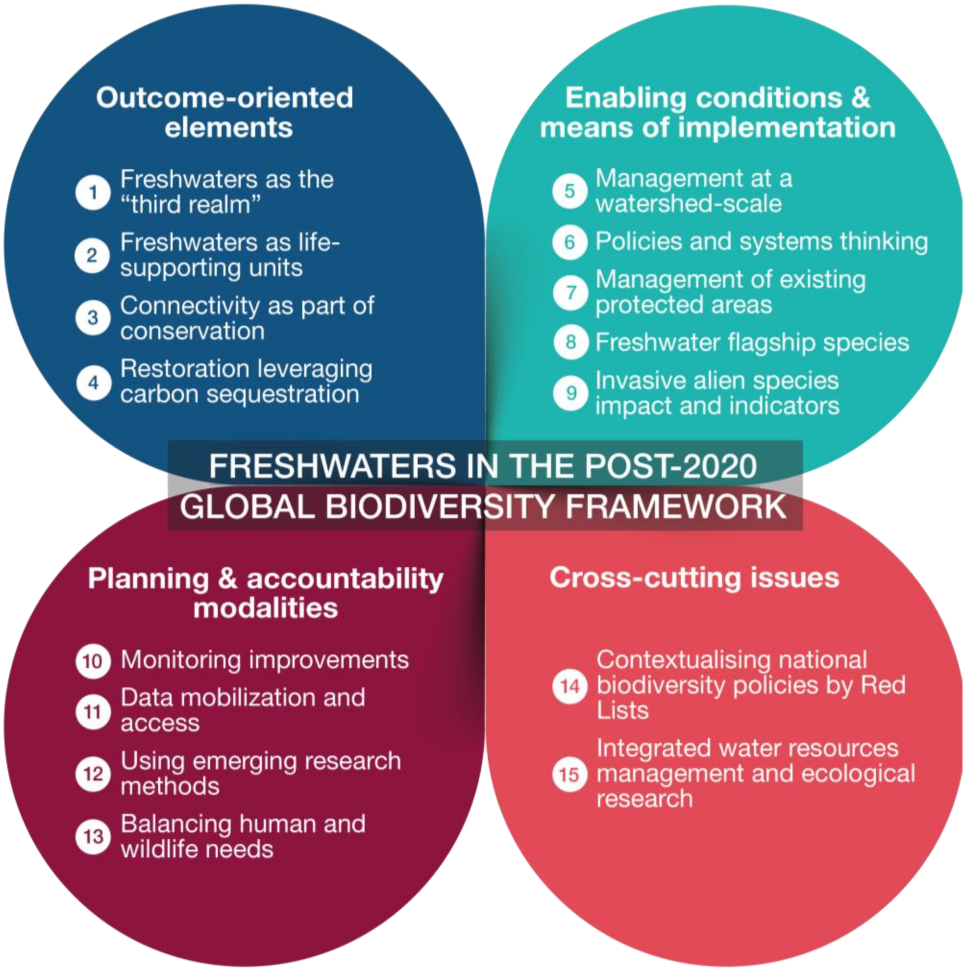

Fig. 2: Summary of the SRs organized around the four clusters of the GBF planning process

Concluding remarks

The protection of freshwater life is critical given the ecosystem services, diversity, and levels of threat associated with freshwater ecosystems. Strong policy responses at the global and national scale are needed to support the monitoring, planning, management, and conflict resolution necessary to slow and reverse losses of freshwater biodiversity, and now is the time for decisive action (Tickner et al., 2020). Our 15 recommendations (Fig. 2) for both the post-2020 Global Biodiversity Framework and European Biodiversity Strategy outline a suite of changes needed to protect freshwater life. These recommendations draw on an extensive review of current literature and decades of practical experience in freshwater research and conservation in Europe. Our list of recommendations is by no means exhaustive, but distils important points that are of shared relevance at the European and global scale. Some of these (e.g., SRs 10, 11 and 14) are also applicable to terrestrial and marine biodiversity. Additional recommendations from other regions, specifically low- and middle-income countries and the Global South, are also greatly needed to guide future management.

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