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Theory and practice to conserve freshwater biodiversity in the Anthropocene

Rebecca Flitcroft[1] | Michael S. Cooperman[2] | Ian J. Harrison[2,3] | Diego Juffe-Bignoli[4] | Philip J. Boon[5]

[1] USDA Forest Service, PNW Research Station, Corvallis, OR

[2] Gordon and Betty Moore Center for Science, Conservation International, Arlington, VA

[3] IUCN-SSC Freshwater Conservation Committee, 2011 Crystal Drive, Suite 500, Arlington, VA 22201

[4] UN Environment World Conservation Monitoring Centre (UNEP-WCMC), Cambridge, UK

[5] Freshwater Biological Association, Ambleside, Cumbria, UK

Correspondence
Rebecca Flitcroft, USDA Forest Service, PNW Research Station, 3200 SW Jefferson Way, Corvallis, OR 97330, USA.
Email: rflitcroft@fs.fed.us

Abstract

1. The unprecedented impact of human activities on nature has led scientists to propose we might now be in a new geological epoch: the Anthropocene. Significant human alterations of freshwater systems include massive changes to soil erosion–deposition dynamics, hydrological regimes via impoundment and diversion, land-use conversion, chemical and nutrient pollution, and human-assisted range expansion of invasive species. In this human-dominated epoch, biodiversity, which includes all life on Earth, is at risk, and freshwater biodiversity shows the strongest examples of the extent of this threat.
2. We live in a world where it is necessary to find optimal ways to balance the growing human need for fresh water with ensuring that freshwater ecosystems remain functional in support of the biodiversity that inhabits them and the services these systems provide.
3. Within the broader context of freshwater management in the Anthropocene, this special issue targets freshwater biodiversity and habitat conservation through a variety of lenses. Four main areas of emphasis include: conservation approaches; advances in model and tool development; enhancing water planning; and management and protection of species and habitats.
4. For manuscripts included in this special issue, all authors were instructed to demonstrate how the material presented, be it commentary, conservation prioritization, new methodology or other subject matter, is broadly applicable and transferable.

KEYWORDS

Anthropocene, ecosystem function, freshwater conservation, freshwater management

1 | FRESHWATER BIODIVERSITY IN THE ANTHROPOCENE

We are living in an era of unprecedented impact of human activities on global environments, natural processes and the organisms that rely on them. The extent of human reach is global and recognizable in the stratigraphy of the Earth (Waters et al., 2016), prompting scientists to propose the designation of a new geological epoch: the Anthropocene (Crutzen, 2002). Although not yet formalized by the International Commission on Stratigraphy (http://www.stratigraphy.org), the proposed epoch is defined by Oxford dictionaries as 'Relating to or denoting the current geological age, viewed as the period during which human activity has been the dominant influence on climate and the environment' (https://en.oxforddictionaries.com/definition/anthropocene). For freshwater ecosystems, these changes are manifested in massive alterations to hydrological regimes, soil erosion–deposition dynamics, land-type conversion, chemical and nutrient pollution and human-assisted range expansion of invasive species. These hallmarks of the Anthropocene describe stressors that contribute to the decline and extinction of freshwater biota worldwide.

In this human-dominated epoch, biodiversity, which includes all life on Earth, is at risk, and freshwater biodiversity shows the strongest examples of the extent of this threat. Freshwater ecosystems occupy less than 1% of the Earth's surface but contain as much as 12% of all known species, including a third of all vertebrate species (Garcia-Moreno et al., 2014). To illustrate the magnitude of recent change within freshwater ecosystems, the Freshwater Living Planet Index documents increasing rates of declines for populations of freshwater species, rising from an average of 76% decline of monitored populations between 1970 and 2010 (World Wide Fund for Nature, 2014) to an 83% decline between 1970 and 2014 (World Wide Fund for Nature, 2018). These declines are greater than those reported for terrestrial or marine species. Similarly, inland wetlands have declined in global extent by 64–71% during the twentieth century (Davidson, 2014), and 89% of wetlands are unprotected (Bastin et al., 2019; Reis et al., 2017). These declines in freshwater species and ecosystems are the consequence of myriad pressures, such as extensive water withdrawals from natural systems for direct human consumption or irrigated agriculture; the modification of physical traits such as the quantity, quality and timing of flows, and associated with this, water temperature and sediment loads; the severance of longitudinal and lateral connectivity; and the overharvesting of species of commercial or subsistence importance (Dudgeon et al., 2006; Garcia-Moreno et al., 2014; Reid et al., 2019). Furthermore, climate change that alters seasonal patterns of temperature and river discharge also increases stress on species with already compromised habitats; and the decline in wetlands, primarily through draining wetland areas for agriculture, is exacerbated by shifting precipitation regimes that are altering seasonal patterns of naturally available water (Kingsford, 2011; and references therein).

In the face of all these threats, freshwater ecosystems remain essential to human well-being, as they directly contribute to the livelihoods of billions of people and provide a range of goods and services estimated to be worth more than $4 trillion annually (Darwall et al., 2018 and references therein; Russi et al., 2013). Indeed, the importance of fresh water as a resource is a major driver of many of the threats noted above. Lovejoy (2019) commented that the status and trends of freshwater biodiversity has been particularly neglected because fresh water is widely understood and managed more as a physical resource vital to human survival rather than as the special and delicate habitat that it provides for an extraordinary array of organisms.

These are problems that will become more severe in the next few decades as we move into the Anthropocene. For example, average global water requirements for human needs are anticipated to exceed the current accessible and reliable supply by 40% by 2030 (Addams, Boccaletti, Kerlin, & Stuchtey, 2009), and the expected response to this challenge is significant investment in water control infrastructure to secure water supplies over the next several years (Vörösmarty et al., 2010). Yet water resource planning does not hold as a primary objective the maintenance of natural ecosystems and their constituent species in a relatively intact state; instead this is viewed only as a secondary beneficial outcome (Bhaduri et al., 2016; Green et al., 2015; Harrison et al., 2016; Vörösmarty et al., 2018). Moreover, despite the essential contributions of freshwater ecosystems and their resources to human well-being, these systems are often inadequately covered in international policy. For example, the Convention on Biological Diversity (CBD, 2019) recognizes that freshwater ecosystems, and the conservation and wise use of wetlands, were gaps in the CBD 2011–2020 Strategic Plan. The International Union for Conservation of Nature (IUCN) stated that far more emphasis needs to be placed on the importance of conserving freshwater biodiversity post-2020, given that a sustainable future depends upon targeted actions for the conservation of inland waters (IUCN, 2019a).

This special issue on freshwater biodiversity conservation in the Anthropocene is timely, as evidenced by the under-representation of this topic in the professional literature of humanity's global effects on ecosystems and species. To illustrate, in a literature search of the ISI Web of Science, 2724 articles related explicitly to the Anthropocene have been published since 2001, with a sharp rise between 2003 and 2008 (Figure 1). However, articles regarding biodiversity conservation, ecology, water resources and marine and freshwater biology and related topics only showed slight increases over this time period, and these topics constitute only 16% (443) of total Anthropocene articles.

2 | INVIGORATING FRESHWATER CONSERVATION APPROACHES

Within the broader context of freshwater management in the Anthropocene, this special issue targets freshwater biodiversity and habitat conservation through a variety of lenses. Our goal when soliciting and selecting articles for inclusion in this special issue was to avoid 'location-specific' manuscripts that would hold limited interest outside of that particular geography. Instead, all authors were instructed to demonstrate how the material present in their paper, be it commentary, conservation prioritization, the introduction of a new method or other subject matter, is broadly applicable and transferable. This special issue cannot address all of the challenges facing freshwater biodiversity in the Anthropocene (for example, the included papers do not directly discuss issues such as invasive species or overharvesting); for comprehensive summaries of threats, readers should consult some of the significant recent reviews of freshwater biodiversity and associated conservation initiatives (e.g. Darwall et al., 2018; Reid et al., 2019). However, this issue does highlight some key emerging areas of concern, and some possible solutions.

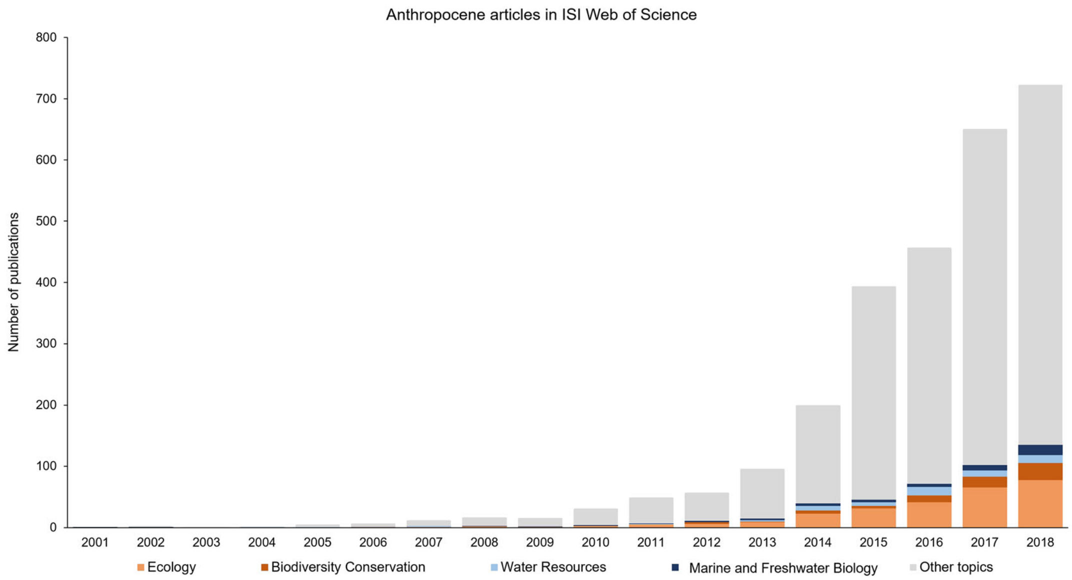

FIGURE 1 Number of articles in ISI Web of Science between 2001 and 2018 with the word 'Anthropocene' in the title or main text in the categories of ecology, biodiversity conservation, water resources, marine and freshwater biology and other topics

The 12 articles presented here cover a varied range of geographies and contexts from North America to South America crossing the ocean to Africa and Europe and further west to Asia and Australia. Biodiversity conservation that is linked to livelihoods of local communities is explored in large provinces such as the Andes (Tognelli et al., 2019), the Amazon (Reis et al., 2019) and Lake Victoria (van Soesbergen, Sassen, Kimsey & Hill, 2019). Water planning that includes life-history needs of specific species is described in the Columbia River Basin of the USA (coho salmon; Flitcroft et al., 2019) and in discrete systems such as the Hunter Valley in Australia (Linke, Turak, Gulbrandsen Asmyhr, & Hose, 2019), Greek lakes (Stefanidis, Sarika, & Papastergiadou, 2019) and Lake Ontario (North America) (Zolderdo et al., 2019). Taken together, these manuscripts are intended to convey the scope and complexity of freshwater conservation in this time of global transformation, as systems from the atmosphere to the Earth's crust adjust to vast human-derived change. In this respect, the topics discussed here align with the 'bright spots' approach for addressing the challenges of the Anthropocene, drawing on a mix of practices, views, values and regions that can be shared and scaled up to accelerate transformative change (Bennett et al., 2016).

Previous authors (e.g. Green et al., 2015; Harrison et al., 2016; Vörösmarty et al., 2010, 2018) have discussed the need to optimize the use of green infrastructure (i.e. natural ecosystems that are in a reasonably intact and functional condition) for the provision of water to downstream users. Here, Abell et al. (2019) take these concepts and highlight how 'source water protection' – the protection of water at its source to secure the quality and quantity for downstream human needs – can bring diverse co-benefits for protecting freshwater ecosystems. This approach of integrating human needs of freshwater systems with the requirement to conserve and protect the ecosystems that supply freshwater ecosystem services is essential for freshwater biodiversity conservation in the Anthropocene.

Linking the management of freshwater resources with aquatic conservation is also explored by Phang et al. (2019), by uniting the shared objectives of sustainable inland fisheries and freshwater biodiversity conservation. This innovative work demonstrates the misconception that fishing is an inherently adverse activity for freshwater biodiversity. Rather, the quest for the twin goals of sustainable fisheries and aquatic biodiversity conservation can be advanced by empowering fishing concerns, be they commercial or artisanal. The work presented by both Abell et al. (2019) and Phang et al. (2019) describes two approaches that unite resource provisioning and conservation goals, leading to greater socio-economic and political capacity to effect beneficial change. These align to similar approaches, such as that proposed by Noble, Fulton, and Pittock (2018), who demonstrated that focusing on the conservation of a keystone freshwater species (Murray crayfish, *Euastacus armatus*) can also support the achievement of a number of socio-economic goals in south-east Australia.

Planning for water and ecosystem protection also applies to vertical connections between surface water and groundwater in aquifers as well as the seasonal lateral connections along rivers. Linke, Turak, et al. (2019) show that, for a case study site in Australia, the *a priori* inclusion of aquifers in conservation planning did not significantly add to costs and the overall land that was needed to ensure adequate conservation. In contrast, retrospective inclusion of aquifers in conservation planning led to significant inefficiencies via novel costs (i.e. additional scientific effort, monetary costs and the need for additional land under protection). Similarly, Reis et al. (2019) explore seasonal inundation patterns of wetlands in the southern Amazon River and find that the integration of inundation dynamics captures regional differences in major wetland groups that would be relevant for conservation planning. Both applications demonstrate economies of scale when the broader scope of water source and season are considered.

Broadening the scope of water planning is a cornerstone of the description of ecosystem-based management (EBM) by Langhans et al. (2019). The article introduces innovations in eight core research areas for EBM, including modelling species distribution, ecosystem services supply and demand; planning with SMART targets, scenarios and across realms; evaluating and prioritizing management strategies; spatial planning for biodiversity conservation and ecosystem services; and quantifying uncertainties. This environmental planning and adaptive management approach jointly considers social and ecological needs and has been demonstrated to be effective particularly in marine applications. This data-intensive management scheme allows the exploration of different management innovations through complex modelling approaches that support decision-making.

3 | ADVANCES IN MODEL AND TOOL DEVELOPMENT

The call for evidence that certain practical actions are actually successful is not new. There is a growing movement for the assimilation of data on 'conservation evidence' to assist decision-makers in taking the best actions for conserving biodiversity (Sutherland, Dicks, Ockendon, Petrovan, & Smith, 2018). This includes an online database of case studies, https://www.conservationevidence.com/) and a journal, *Conservation Evidence*, that publishes new research on conservation management interventions. However, freshwater systems have typically received less attention than other systems in the assessment of conservation success, or even in the development of tools and indicators for measuring this success. For example, Morrison, Schulte, and Schenck (2010) noted that a lack of sufficient data was a significant constraint on the capacity of corporate water accounting to provide meaningful information on water related impacts and risks. Turak et al. (2017) noted that in the first decade of the twenty-first century, the data, tools and methods available were inadequate to quantify the decline in global biodiversity reliably, although they considered that advances in freshwater monitoring and the development of indicators were making it more feasible to monitor change.

Here, Abell et al. (2019) contribute to the call to evaluate the effectiveness of programmes aimed at accomplishing the shared objectives of water protection and freshwater biodiversity conservation. These authors note that, even with this information, it is necessary to ensure the effective design and implementation of projects, and to be ready to identify where projects have limitations (e.g. the discussion of fish passageways by Birnie-Gauvin, Franklin, Wilkes, & Aarestrup, 2019). Similarly, Langhans et al. (2019) draw attention to the importance of evaluating management strategies and quantifying their uncertainties.

One of the great challenges to freshwater ecosystem conservation is that fresh waters are embedded within the terrestrial matrix. Thus, actions on dry land will ultimately have impacts on aquatic systems, but cause and effect relationships of human actions and their consequences are often spatially segregated and difficult to infer. Hence, tools designed to protect freshwater ecosystems, or to promote sustainable use, must be able to assimilate terrestrial condition and trajectory if they are to fairly and realistically capture the present or future state of fresh waters. Fortunately, significant expansion of existing tools and databases such as the IUCN Red List of Threatened Species (IUCN, 2019b; and discussed by Tognelli et al., 2019) and HydroATLAS (http://wp.geog.mcgill.ca/hydrolab/hydroatlas/) is being complemented by a wave of new assessment methods for freshwater ecosystems and biodiversity. These include the Freshwater Health Index (Vollmer et al., 2018) and the Connectivity Status Index for the world's rivers (Grill et al., 2019). Systematic conservation planning, using tools like Marxan, will also become increasingly important for identifying networks of sites that can ensure species protection. For example, Hermoso, Filipe, Segurado, and Beja (2018) applied Marxan to identify priority areas for conserving freshwater biodiversity that are disrupted by dams in the Iberian Peninsula. Sayer, Carr, and Darwall (2018) used Marxan to identify networks of sites within the Lake Victoria basin, centred on the existing distribution of Key Biodiversity Areas and protected areas. Tognelli et al. (2019) also develop a spatially focused, systematic conservation planning approach for the freshwater ecosystems in the tropical Andes (see below). There are numerous other emerging tools and technologies that can further assist in assessing and responding to emerging threats to freshwater biodiversity (Jackson et al., 2016; Reid et al., 2019).

This special issue on freshwater conservation in the Anthropocene includes several examples of model development for improved management of freshwater ecosystems. Van Soesbergen, Sassen, Kimsey, and Hill (2019) have adopted the PREDICTS model (Projecting Responses of Ecological Diversity In Changing Terrestrial Systems; www.predicts.org.uk), which is well developed for projecting biodiversity responses to human activity in terrestrial communities, for its first application to freshwater biodiversity. Here, Van Soesbergen et al. (2019) compile a large database of land-use impacts on freshwater biodiversity in the Lake Victoria Basin, a biodiversity hotspot under increasing threat from unsustainable land conversion and intensification of agriculture (Sayer, Máiz-Tomé, & Darwall, 2018). Using the PREDICTS framework, Van Soesbergen et al. (2019) project anticipated impacts of future development on aquatic biodiversity under different scenarios of land-use change. This effort shows that the PREDICTS model can be successfully applied to freshwater ecosystems to identify areas and ecotypes at greatest risk under different socio-economic futures. In a similar vein and as noted above, Linke, Turak, et al. (2019) have successfully adapted spatial conservation planning models to include groundwater from aquifers. A better capacity to assess and sustainably manage groundwater resources will become increasingly important during the Anthropocene, because of severe levels of exploitation (Garcia-Moreno et al., 2014; Reid et al., 2019).

The application of new and existing models can help produce policy that balances development and conservation in the uncertainty of the Anthropocene. The value of any indicators or tools for assessing the status and conservation management of freshwater biodiversity depends on identifying and consulting end-users (Vollmer, Regan, & Andelman, 2016). Furthermore, data are ineffective if non-scientists cannot obtain, understand or use them. Joppa et al. (2016) illustrate this in a discussion of the increasing quantities of satellite data for land cover that are becoming available. They emphasize the need to create global maps that can be easily integrated and understood with conservation assessment processes.

4 | ENHANCING WATER PLANNING AND MANAGEMENT

In the Anthropocene, dams – whether for power production, irrigation supply or other purposes – are one of the greatest threats to river flows and the persistence of freshwater biodiversity and ecosystem processes and functions (Grill et al., 2019; Reid et al., 2019; Zarfl, Lumsdon, Berlekamp, Tydecks, & Tockner, 2015). Although there is an increasing trend towards dam removal, especially in the US, global rates of dam construction are greater than those of dam removal (Reid et al., 2019). Hence, as much as limiting dam construction, an equally important component of the future planning of dams will be to find ways of constructing and operating them in a less ecologically destructive way.

Environmental flows (eflows), which ensure adequate water is available in rivers for biological communities and ecological functions throughout the year, are recognized as a major component of water resource management (Davies et al., 2014). However, the increasing human demand for water (Addams et al., 2009; and discussion above) and changing flows resulting from climate change are making it more challenging for eflows to be effectively maintained. In addition, identification of optimum eflows often requires a large amount of hydrological and other ecological data, and careful application of the appropriate models (Reid et al., 2019; Richter, Mathews, Harrison, & Wigington, 2003). Over the last two decades this has stimulated a growing research effort into eflows, with an associated increase in the sophistication of methods (Davies et al., 2014).

A thorough understanding of natural flow regimes and ecological functions associated with these flows is at the core of defining eflows. At the global scale, however, the capacity to track hydrological data from stream gauges is declining, compromising the ability to manage hydrological risk and balance freshwater allocations for ecosystems and society (Ruhi, Messager, & Olden, 2018). Those authors proposed a set of actions at the political, institutional and technological scales to increase the coverage, reliability and accessibility of global water information systems. One of these actions is to build capacity in developing countries. As a component of this, the value of local knowledge of the flow regimes and ecology of rivers for planning eflow regimes should not be underestimated (Esselman & Opperman, 2009). Moreover, whereas detailed analyses and models of flows can be very useful for predicting optimal eflows, the basic observation of ecological conditions, at any point in time, can be extremely informative in identifying the seasonal water requirements of native biota. Of course, for eflows to be effective, there needs to be both the political will and the regulatory framework to translate science into policy. For example, detailed technical guidance has been published by the European Commission (2015) to help the Member States of the European Union (EU) to implement the EU Water Framework Directive (Council of the European Communities, 2000).

The natural flow regimes of rivers are currently threatened by physical modifications to watercourses and through the fragmentation of flows (Poff et al., 2003). Moreover, as noted above, climate change induces changes to flows and water temperature (Reid et al., 2019), making flows less predictable and more 'flashy.' In this issue, Flitcroft et al. (2019) use coho salmon (*Oncorhynchus kisutch*) as a model organism to demonstrate how species-specific life history and ecological knowledge can be integrated with data on current and projected future river discharge and water temperatures derived from climate models. These integrated datasets can then be used to assist in developing an adaptive management framework for sustainable fish populations in the face of climate change.

Improvements in the development and implementation of flow protections are complemented by work under way around the world to improve fish passage at dams, including bi-annual fish passage conferences (http://fishpassage.umass.edu/). However, as noted by Birnie-Gauvin et al. (2019), far more research is needed to make fish passage structures more effective, as fish passageways are typically designed using knowledge gleaned from rivers in the northern hemisphere and for strong-swimming salmonids. These engineered solutions are not transferable to tropical rivers and the life-histories of the fish inhabiting them (Reid et al., 2019; Roberts, 2001). Birnie-Gauvin et al. (2019) show that the design and management of dams and fish passages has to consider more than the physical fragmentation of rivers created by dams to include the broader issue of ecosystem modification created by dam construction. Ultimately, a holistic approach to population-scale assessments of the effects of dams within the broader framework of habitats above and below the dam must be adopted to achieve long-term ecosystem management.

5 | PROTECTING SPECIES AND HABITATS

Numerous multinational agreements specifically identify the protection and sustainable management of freshwater ecosystems as urgent needs. Perhaps foremost among these is the Ramsar Convention (www.ramsar.org), focused on the conservation and wise use of all wetlands. The protection of freshwater ecosystems is also the focus of the Aichi Biodiversity Target 11 (Juffe-Bignoli et al., 2016) and Sustainable Development Goals (SDGs) 6 and 15. Aichi Biodiversity Target 11, one of the 20 targets to be achieved by 2020 by signatories of the Convention on Biological Diversity, calls for a global protected area system that covers 17% of terrestrial and inland waters. However, it is well recognized that even when freshwater ecosystems are included within protected areas, management is not usually focused on freshwater ecosystems, and these ecosystems may be compromised by upstream threats from outside protected areas (Abell, Lehner, Thieme, & Linke, 2017; Bastin et al., 2019; Thieme et al., 2016; Thieme, Rudulph, Higgins, & Takats, 2012). Terrestrially focused protected areas do not address the protection of entire catchments nor the connectivity of fresh waters through this landscape space. The adequate protection of freshwater ecosystems, however, can bring many benefits for conservation and sustainability in the

Anthropocene. These are discussed, for example, in a collection of papers drawn together by Finlayson, Arthington, and Pittock (2018) on the conservation and management of freshwater ecosystems, and their role in protected areas. Besides the protection of biodiversity, protected areas can assist in providing improved water quality for downstream populations (Dudley, Harrison, Kettunen, Madgwick, & Mauerhofer, 2016; Harrison et al., 2016) and are a critical tool for water provision and regulation in the landscape.

Protected places designed for freshwater conservation have been shown to be effective at conserving fish biodiversity in lakes of eastern Ontario by Zolderdo et al. (2019). In their work, the authors found that long-term conservation in specific portions of lake environments resulted in the effective maintenance of species richness, not simply in protected areas but also in the transitional areas around them.

Freshwater protection often targets species known to be vulnerable to extinction, or that have high economic value. In an effort to expand the effectiveness of protected areas in aquatic conservation, Tognelli et al. (2019) have assessed multiple conservation scenarios in the tropical Andes by including threatened species as well as those that are vulnerable to climate change. Their study indicates that there are often many more freshwater areas that need to be protected than are manageable; nevertheless, it is important to identify priority areas for conservation action that provide networks of freshwater conservation with connection between them. Tognelli et al. (2019) and Zolderdo et al. (2019) highlight how these protected areas can act as refugia for species, which may then move out to populate areas nearby and so provide regional benefits. Both Tognelli et al. (2019) and Linke, Hermoso, and Januchowski-Hartley (2019) found that expanding the species of interest increased the area that needed to be considered for conservation, but there was significant overlap in prioritized locations. By planning for all scenarios, Tognelli et al. (2019) were able to develop a more robust protection plan that incorporated current conservation concerns and future climate considerations.

Prioritization of sites for restoration is a persistent challenge for the development of freshwater protected areas. Stefanidis et al. (2019) explore lake biochemistry to identify co-variates of macrophyte cover and diversity in mainland Greek lakes. They identify specific environmental gradients that support macrophyte assemblages that are indicative of changes in abiotic environmental changes. These results contribute to the scientific foundation that supports freshwater biodiversity management and environmental policies in eastern Mediterranean lakes.

6 | BEYOND 2020: POLICY

The papers in this special issue illustrate the challenges faced by freshwater species in the Anthropocene, but also some of the progress being made in research and data collection that are helping to improve understanding of the trends and threats facing fresh waters. However, the full value of the topics presented in this issue will only be realized when applied to the practical management of ecosystems and freshwater biodiversity. This includes the translation of conservation recommendations that can be adopted easily by policy-makers (Harrison et al., 2018) and acknowledging the particular challenges and opportunities associated with freshwater conservation (Irvine, 2018).

The United Nation's SDG targets require broad and detailed knowledge of global to local dynamics of water availability and use. Scientific research and evidence have an important role to play in facilitating the implementation of SDGs (Bhaduri et al., 2016). This may not be a straightforward challenge. For example, the Outcome document, 'Making Every Drop Count' from the High Level Panel on Water (HLPW, 2018) does not mention the importance of freshwater biodiversity or its role in providing natural resources in its recommendations on 'Water and Environment', even though freshwater biodiversity was mentioned in the Framing Note recommendations that were supplied to the Panel (Vörösmarty et al., 2018).

It is ironic that intact and functioning freshwater ecosystems are implicit requirements for achieving several SDG targets (Vörösmarty et al., 2018). For example, Goal 6: 'Ensure availability and sustainable management of water and sanitation for all' (information on progress at http://dialogue.unwater.org/resources/) includes the specific freshwater conservation target to protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes by 2020 (https://sustainabledevelopment.un.org/sdg6). This overlaps with SDG 15 'Life on lands' that includes Target 15.1 that by 2020 ensures the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services. An indicator of this target is the proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas (https://sustainabledevelopment.un.org/sdg15).

Achieving international goals and targets for freshwater conservation will require the adoption at a national level of some of the approaches or analyses presented in this special issue. Ultimately, the process of applying these in practice is more directly dependent on developing integrated solutions that meet multiple objectives at local scales (Abell et al., 2019).

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ORCID

Rebecca Flitcroft https://orcid.org/0000-0003-3341-996X

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