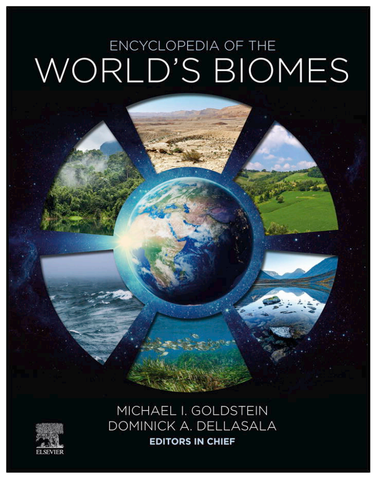

From Reid, A.J., Carlson, A.K., Hanna, D.E.L., Olden, J.D., Ormerod, S.J., Cooke, S.J., 2020. Conservation Challenges to Freshwater Ecosystems. In: Goldstein, M.I., DellaSala, D.A. (Eds.), Encyclopedia of the World's Biomes, vol. 4. Elsevier, pp. 270–278.
ISBN: 9780128160961

Elsevier

Conservation Challenges to Freshwater Ecosystems

Andrea J Reid, Carleton University, Ottawa, ON, Canada; and University of British Columbia, Vancouver, BC, Canada
Andrew K Carlson, Michigan State University, East Lansing, MI, United States
Dalal EL Hanna, McGill University, Ste. Anne de Bellevue, QC, Canada
Julian D Olden, University of Washington, Seattle, WA, United States
Steve J Ormerod, Cardiff University, Cardiff, United Kingdom
Steven J Cooke, Carleton University, Ottawa, ON, Canada

Abstract

Natural freshwater ecosystems represent the terrestrial phases of the global hydrological cycle and include rivers, streams, lakes, ponds, wetlands as well as groundwaters. While fresh waters comprise only 0.01% of the water on Earth and constitute less than one-tenth of the global land surface area, they support >10% of all recorded species including ~30% of all vertebrates. Freshwater ecosystems support the provision of numerous ecosystem services which range from natural flood management, water supply, health, mental well-being to fish nurseries. However, freshwater ecosystems, their biodiversity and the services they provide are being jeopardized by a multitude of anthropogenic (human-mediated) stressors. Some of these threats are generated internally (habitat alteration, fragmentation, overexploitation) while others are external (invasive nonnative species, climate change, atmospheric pollution). Fortunately, many options for freshwater ecosystem conservation exist but require urgent action.

What Are Freshwater Ecosystems?

Natural freshwater ecosystems represent the terrestrial phases of the global hydrological cycle and include permanent rivers, streams, lakes, ponds, wetlands as well as groundwaters. Variations in precipitation, meltwater between seasons and hydrological events also lead to periodic or episodic inundation of floodplains, seasonal wetlands or temporary channels that form transient freshwater ecosystems to which many organisms are adapted. Artificial environments, such as canals, reservoirs, and drainage ditches, also support freshwater species. In contrast with marine and transitional ecosystems (e.g., mangroves, salt marshes, lagoons, estuaries, and open oceans), fresh waters are characterized by lower salt content (fresh water: <5 ppt vs. marine: >30 ppt) and are often subdivided into being "lotic" (flowing) or "lentic" (still) systems (Wetzel, 2001). Fresh waters occur around the world from the poles (e.g., glaciers, ice sheets) through temperate zones to the tropics. Yet, fresh waters comprise only 0.01% of the water on Earth and constitute less than one-tenth of the global land surface area (Lehner and Döll, 2004) while marine systems cover more than 70% of the globe and account for >97% of the Earth's water (NOAA, 2018). Freshwater drainage basins (i.e., watersheds (North America; used hereafter) or catchments (United Kingdom)) are clearly defined units in terrestrial landscapes, formed where precipitation collects and drains downslope to a common outlet at lower elevation such as an estuary, bay or landlocked wetland (Fig. 1). Being both hydrologically connected and topographically low in the landscape means that fresh waters are open systems that transfer matter, energy and solutes, including pollutants, to and from neighboring ecosystems (Hynes 1975; Brooks et al., 2003). Their connected nature means they are conduits for the longitudinal or lateral movement of organisms, including invasive species, that are now among a wide range of stressors that endanger the disproportionately large biodiversity that inhabit these ecosystems (Reid et al., 2018).

Rivers and Streams

Rivers and streams are lotic systems that connect aquatic and terrestrial environments, circulating precipitation and sediments from the land to lakes, estuaries and oceans. They cover less than 1% of Earth's nonglaciated land surface (694,000–852,000 km^2; Allen and Pavelsky, 2018). The world contains a diversity of rivers and streams—distinguished by permanency (e.g., permanent and

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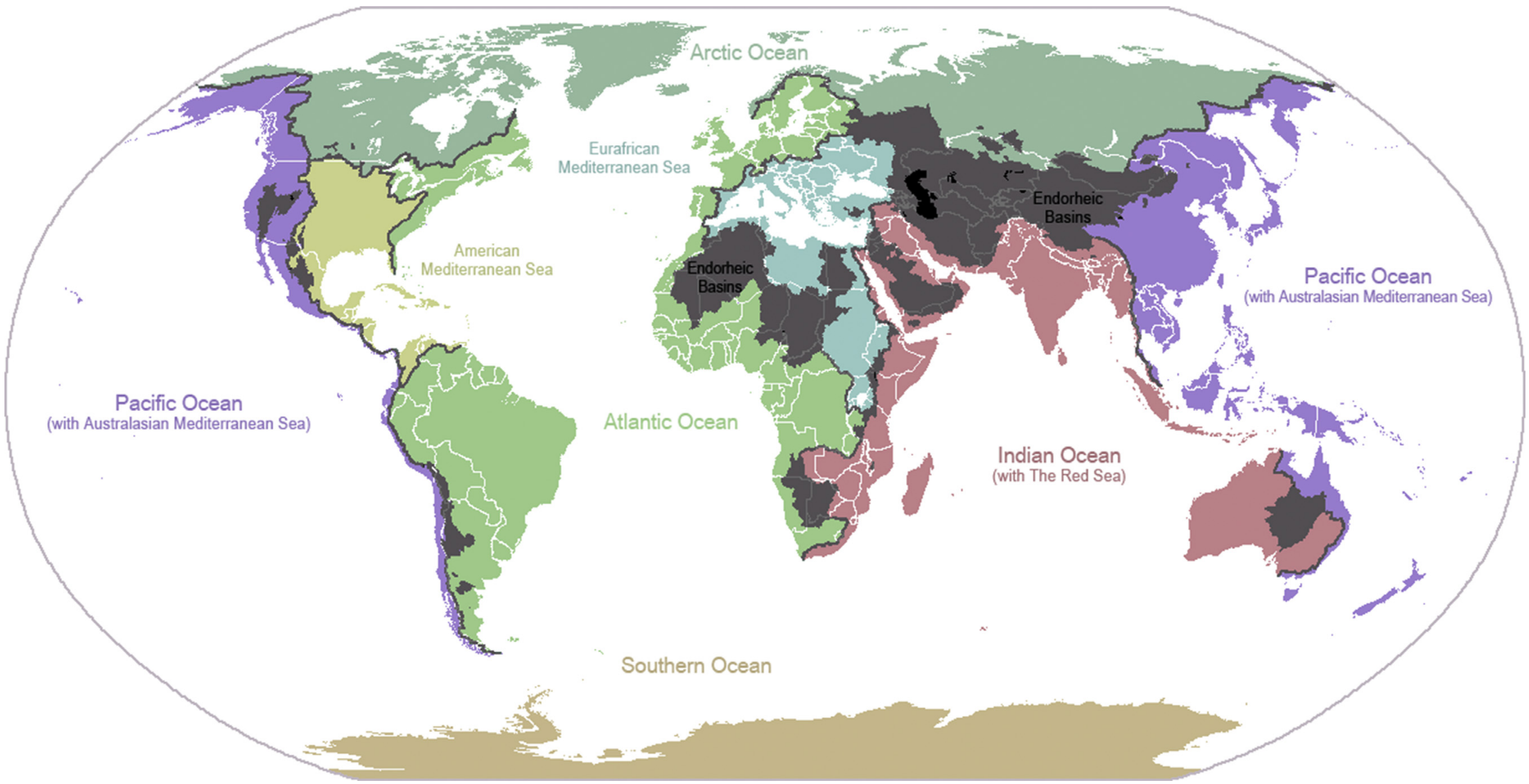

Fig. 1 Major continental divides of the world, showing drainage of fresh waters into the major oceans and seas—*gray* areas are endorheic (terminal) basins that do not drain into marine ecosystems. Courtesy Public Domain.

intermittent), channel shape (e.g., braided and meandering), biodiversity (e.g., algae, invertebrates, fishes), ionic composition (e.g., major ions and macro-nutrients) and other factors—but the vast majority of riverine ecosystems have been altered by humans (Grill et al., 2019).

Lakes and Ponds

Lakes and ponds are lentic systems, many of which are fed and drained by rivers and streams. The world contains at least 304 million natural lakes spanning 4.2 million km^2 (Downing et al., 2006). However, the majority are small (>91% are 0.001–0.01 km^2 [0.1–1 ha]) and few are large (0.005% >100 km^2 [10,000 ha]; Cael and Seekell, 2016). Natural lakes and ponds are found predominantly in mountainous regions, rift zones and areas with ongoing glaciation. Many artificial lakes and reservoirs are constructed for agricultural or industrial purposes (e.g., hydroelectricity; Grill et al., 2019)

Freshwater Wetlands

Wetlands (e.g., swamps, marshes, bogs, and fens), which are either permanently or seasonally inundated by water, are among the most productive habitat types in the world. They cover an estimated 5.4–6.8% of the Earth's land surface area (Lehner and Döll, 2004). Wetlands are found on every continent and can be characterized as being saltwater, brackish (intermediate salinity) or freshwater. Artificial wetlands are also built for wastewater treatment and stormwater runoff.

The Immense Biodiversity of Fresh Waters

To many, freshwater biodiversity means "fish." Yet, freshwater fish are but one of many organisms that live in fresh waters or depend upon freshwater ecosystems for nourishment or reproduction. While fresh waters comprise just a fraction of the water on Earth, they support >10% of all recorded species (Dijkstra et al., 2014; Mittermeier et al., 2010), estimated at ~126,000 freshwater-dependent species (IUCN, 2019). In fact, ~30% of all vertebrates live in freshwater ecosystems or are entirely dependent upon them—from the amphibians (which exceed 4300 species) and freshwater snakes and turtles to many aquatic birds and even some freshwater-dependent mammals (such as platypus and freshwater dolphins). If one considers just fish, the numbers are also impressive. Of the nearly 30,000 fish species identified to date, well over 10,000 of them are considered to be freshwater—with estimates of around 45% of all fish residing in freshwater at some point during their lives. Beyond the vertebrates, freshwater is also home to many plants and invertebrates. For example, according to the International Union for Conservation of Nature (IUCN, 2019), 5600 Odonata (dragonflies and damselflies), and 5000 mollusk species depend on freshwater habitats (Strong et al., 2007). Even freshwater crabs are incredibly abundant with nearly 1500 species (Yeo et al., 2007). Fresh water clearly has disproportionately high biodiversity. Freshwater wetlands as well as rivers and littoral zones of lentic systems are also home to many plant and algae species albeit they have not been well inventoried from a biodiversity perspective (Denny, 1994; Spence, 1982).

Freshwater Ecosystem Services

Freshwater ecosystems support the provision of numerous ecosystem services—the diverse benefits, both material and nonmaterial, that people obtain from ecosystems (MEA, 2005). Another way to think of ecosystem services is as the contributions nature makes to people (Díaz et al., 2018). Examples of the benefits people derive from freshwater ecosystems vary from having clean water to drink, to feeling a spiritual connection to rivers, lakes and wetlands, to avoiding flooding events and the associated consequences. Freshwater systems also support numerous important ecosystem processes, such as nutrient cycling, which are sometimes referred to as "supporting services" (Carpenter et al., 2009).

The concept of ecosystem services is useful to help freshwater researchers and practitioners consider the diverse ways these systems interact with, and contribute to, human well-being. It encourages a holistic approach to thinking about ecosystems in terms of both social and ecological dimensions (MEA, 2005), with numerous interacting components that vary across space and time (Rodríguez et al., 2006). An associated challenge with employing the ecosystem services concept, however, is how to accurately assess and quantify services. Although there is no single standard method that can be broadly applied to assess freshwater ecosystem services, and ultimately, the appropriate method depends on the purpose of assessment, there are fortunately a growing number of ways this is being achieved in freshwater ecosystems (**Table 1**) and robust recommendations for how to conduct holistic assessments considering freshwater specific features such as connectivity (Hanna et al., 2018).

Freshwater Biodiversity in Crisis

Despite the importance of fresh waters and their flora and fauna to human needs and wellbeing, freshwater biodiversity is in crisis (Harrison et al., 2018). Global estimates show that freshwater species populations have declined on average by 83% over the last

Table 1 Examples of freshwater ecosystem services and methods that can be used to assess them.

Selected freshwater ecosystem services	*Example methods that can used to quantify freshwater ecosystem services*
Drinking water	Water samples collected from a water source used for drinking and analyzed for nutrient concentrations, bacteria, and trace-metals to assess the quality of water for drinking
	A web-based survey sent to residents of a watershed asking them where they source their drinking water and how satisfied they are the quality and quantity of water they have access to
Sense of place	Interviews with people living within X kilometers of a stream asking them to describe if and how that stream contributes to their sense of place
	Interviews with people living within X kilometers of a stream asking them what monetary value they would be willing to pay to maintain their access to that stream
Recreation (e.g., paddling)	Distribution of a survey to park visitors determining if recreational paddling was one of the activities they conducted during their visit
	Classification of rapids along a river in terms of their recreational value for recreational white-water paddling
Food provision (e.g., fish)	Participatory mapping assessing locations visited by relevant community members to catch fish and the amount and species of fish caught
	Assessment of locally relevant fish contaminant concentrations (e.g., mercury, chromium) to assess the quality of fish for consumption
Flood mitigation	The percent of wetland coverage in a watershed, used as a proxy for the relative capacity for flood mitigation
	The amount of people found in a floodplain and the financial values of their assets as a means to assess the importance of flood mitigation

Before assessing freshwater ecosystem services researcher or practitioners have to make decisions concerning which ecosystem services are relevant for quantification, the appropriate spatial and temporal scales of assessments, the aspect of ecosystem services that is of interest—that is, do they want to quantify the capacity of a system to provide a service, the actual provision of a service, or the demand for a service, the best indicators that can be used to represent the services they are trying to quantify and establish who are the appropriate stakeholders or individuals that should be involved with quantification.

four decades (**Fig. 2**; WWF, 2018). Knowledge of the conservation status and distribution of freshwater taxa is limited relative to terrestrial species (Darwall et al., 2011), yet there is growing evidence that extinction risk in fresh waters is exceptionally high. Currently, almost one in three freshwater species is threatened with extinction worldwide, exceeding the risk of extinction compared to their terrestrial counterparts (Collen et al., 2014). Reptiles are potentially the most threatened freshwater taxa, with nearly half of species threatened or near threatened (Collen et al., 2014). Moreover, 40% of assessed freshwater bivalves (Lopes-Lima et al., 2018), 32% of all crayfish (Richman et al., 2015), 32% of all amphibian species (Stuart et al., 2004), 32% of assessed crab species (Cumberlidge et al., 2009), 25% of all mammals and fish (Collen et al., 2014), and 10% of assessed dragonflies and damselflies (Clausnitzer et al., 2009) are near threatened, threatened or extinct, according to the IUCN Red List criteria. This lends urgency to the study of diversity and of the relative risk of extinction of species in freshwater ecosystems, yet freshwater species remain a low priority on national and international conservation agendas, such as the United Nations Sustainable Development Goals (SDGs; Lynch et al., 2017; Reid et al., 2017). Conservation of freshwater biodiversity is partly impeded by an inadequate understanding of the economic value of freshwater species (and the services they provide) as well as a robust understanding of how freshwater species are at risk from multiple interacting stresses.

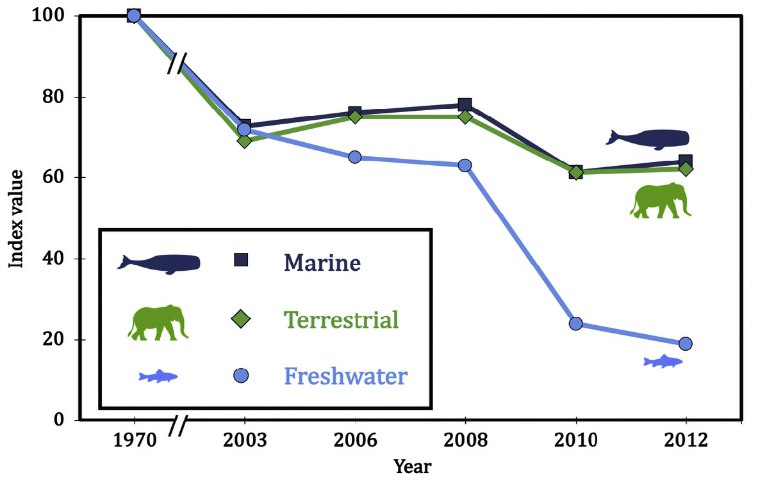

Fig. 2 The World Wide Fund for Nature (WWF) Living Planet Index (LPI) reveals remarkable decreases for freshwater species relative to marine or terrestrial species. These index declines are relative to a benchmark value of 100 in 1970. Dates given here refer to years in which estimates of abundance were made, as LPI reports typically refer to data from 4 years earlier (e.g., the 2016 LPI is based on 2012 data). Data from World Wildlife Foundation (WWF). (2018). Living Planet Report—2018: Aiming higher. In: *Gland*, Grooten, M. and Almond, R. E. A. (eds.). WWF.

Anthropogenic Stressors

Despite this downward trajectory for freshwater taxa, less than 20% of recent papers deal with aquatic species demonstrating a persistent bias in the conservation literature towards terrestrial organisms (Di Marco et al., 2017). This is problematic for many reasons. Firstly, terrestrial biodiversity indicators are a poor surrogate for freshwater biodiversity (Darwall et al., 2011). Furthermore, while some leading freshwater conservation solutions depend on management at the terrestrial/freshwater interface (e.g., reduced agricultural runoff), many land-based conservation efforts for freshwater biodiversity require implementation over large spatial extents at channel, riparian (relating to river banks) or watershed scales (Darwall et al., 2011). Finally, and as demonstrated above, freshwater ecosystems represent hotspots of endangerment due to the convergence of biological richness and the many forms of human freshwater exploitation. Due to an incurred 'debt' arising from low-viability populations that are in the process of dwindling to extinction, it is likely that freshwater extinction risks will remain high over the forthcoming decades (Strayer and Dudgeon, 2010). Nor will anthropogenic pressures on freshwater ecosystems ease soon, in view of the threats reviewed below.

Why are freshwater species facing such high rates of extirpation and extinction? The answer, in part, was outlined in a seminal review paper by Dudgeon et al. (2006), "Freshwater biodiversity: importance, threats, status and conservation challenges." Here, they identified (i) overexploitation, (ii) water pollution, (iii) flow modification, (iv) destruction or degradation of habitat, and (v) invasion by exotic species as the five leading causes of population declines and range reductions of freshwater organisms worldwide. This authoritative paper has been cited over 1800 times, placing it among the top-cited 1% of papers in the field of Biology and Biochemistry (Web of Science®). However, over the last decade, and as we advance into the epoch now being referred to as "The Anthropocene" (Crutzen, 2006), these threats have escalated and/or evolved, and new or previously unrecognized threats have become more apparent. To address this knowledge gap, Reid et al. (2018) provided a critical update on the status and threats to global freshwater biodiversity. Therein, they identified (i) changing climates, (ii) e-commerce and invasions, (iii) infectious diseases, (iv) harmful algal blooms, (v) expanding hydropower, (vi) emerging contaminants, (vii) engineered nanomaterials, (viii) microplastic pollution, (ix) light and noise, (x) freshwater salinization, (xi) declining calcium, and (xii) cumulative stressors as the most significant contemporary challenges to freshwater conservation (**Fig. 3**; **Table 2**; see Reid et al., 2018 for references).

Options for Freshwater Ecosystem Conservation

> Protect the best, restore the rest, adapt where pressed.

As revealed throughout this review, pressures and threats to the world's freshwater ecosystems arise at all scales from the local to the global. They are propagated through the aquatic, groundwater, riparian and watershed systems from which lake, rivers and wetlands are formed. Some of these threats are generated internally (habitat alteration, decreased longitudinal or lateral connectivity, pollution, over-exploitation) while others are external (invasive nonnative species, climate change, atmospheric pollution; WWF, 2018). Additional complexity also arises as threats to freshwater ecosystems evolve (Reid et al., 2018). Some of the resulting changes affect freshwater species directly, while alteration in fluxes or exchanges of nutrients, matter and energy affect many ecosystem processes with indirect consequences for populations, species or communities of organisms (**Table 2**).

Approaches to freshwater ecosystem conservation should ideally be effective in the face of all of these threats and pressures, while also protecting as completely as possible the Earth's diversity of freshwater organisms, freshwater ecosystems and the services they provide. Set against this ideal, however, is the fact that freshwater ecosystems are embedded in terrestrial landscapes whose use and management is seldom focused on conservation, but more on activities such as agriculture, silviculture, extractive industries, urban land or transport that can each cause downstream change or lead to the direct exploitation of water and associated resources. In many freshwater ecosystems, the consequences have developed over decades to centuries—meaning that conservation often has to involve repair or restoration of areas degraded by past impacts as well as the protection of more natural ecosystems.

Boon (1992a,b) developed a hierarchy of options for conserving freshwater ecosystems which ranged from "protection" where systems were relatively pristine; "limitation" or "mitigation" of damage where economic activities were sanctioned in or around freshwater ecosystems; through to "restoration" where past impacts would be reversed. A further option has since been recognized where impacts are considered inevitable—for example from climate change—and involves "adapting" freshwater ecosystems to accommodate or offset the worst effects (Thomas et al., 2016). Hierarchical concepts like these have been the source of the conservation mantra: "protect the best, restore the rest, adapt where pressed."

No matter where in this hierarchy conservation options are applied to freshwater ecosystems, there are two major and related constraints. The first stems from the connections between freshwater ecosystems and their surroundings through which fluxes and flow-paths bring both positive (e.g., resource subsidies) and negative effects (e.g., pollutants; Hynes, 1975; Likens, 2013). The ideal conservation strategy would be to designate, protect, manage or restore entire watersheds as reserves to control such fluxes, but competition with other land-uses often forces compromises so that action can only be localized (**Fig. 4**). The second major issue is one of scale: where freshwater ecosystems are large—such as in the case of the World's great lakes or river systems—the sheer spatial extent over which conservation problems arise is a challenge in its own right, for example because drainage basins are

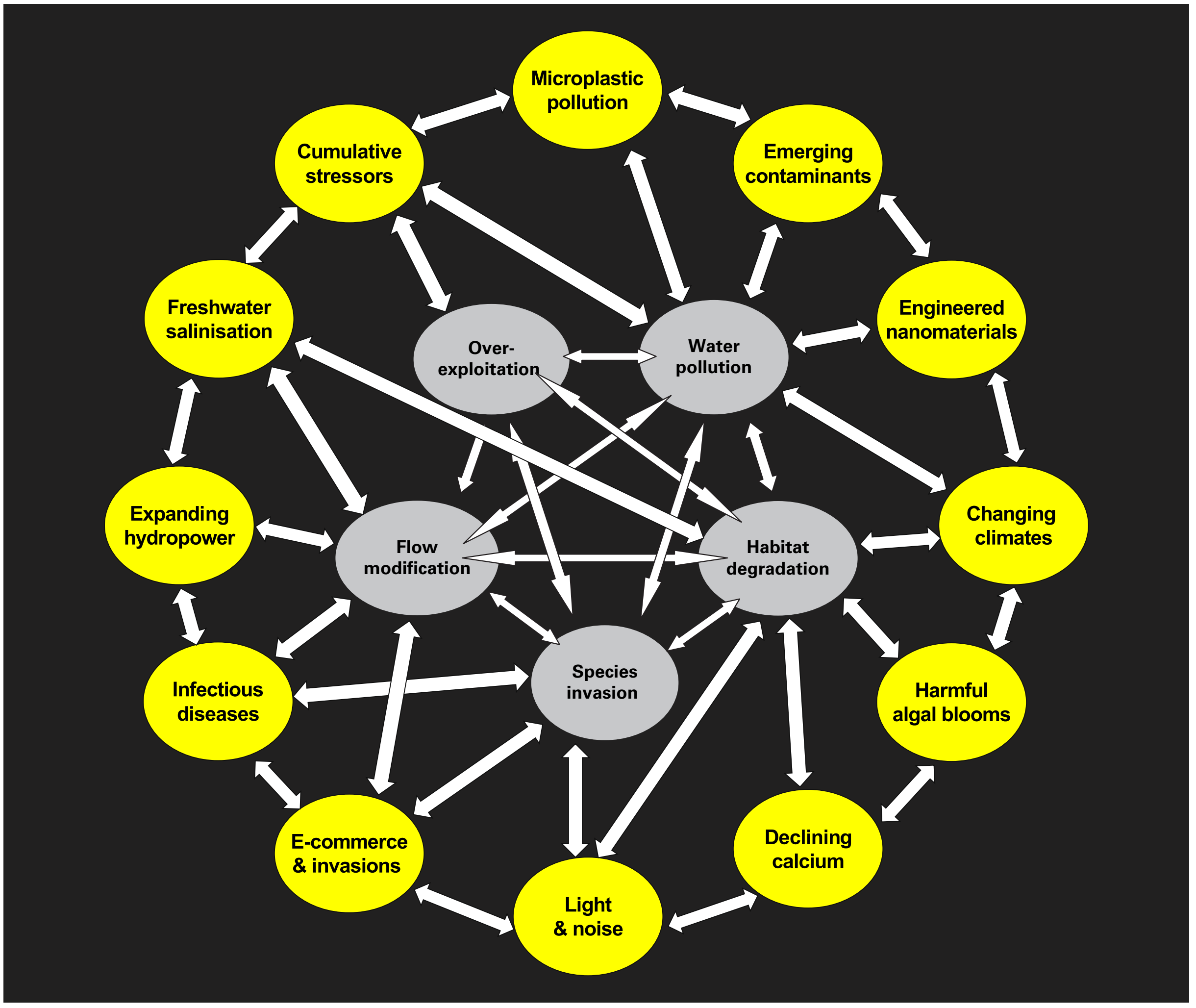

Fig. 3 The five major threat categories and their established or potential interactive impacts on freshwater biodiversity from Dudgeon et al. (2006), shown in the inner *gray circles*. The 12 major threat categories and their established or potential interactive impacts on freshwater biodiversity from Reid et al. (2018), shown in the outer *yellow* circles.

extensive (often international), while organisms adapted to these systems have endemic character or migratory life cycles that require protection ideally over entire systems such as from source to sea.

In non-aquatic ecosystems, the designation of nature reserves is a mainstay of conservation action, and this same approach has been applied to freshwater ecosystems for decades—for example through the specifically aquatic Ramsar Convention (Gardner et al., 2015), through European Natura 2000 Sites under the European Union Habitats Directive (92/43/EEC), or in the United Kingdom as Sites of Special Scientific Interest. In most of these cases, however, designated areas achieve only limited reach, for example from bank-to-bank in rivers, occasionally extending into riparian zones or floodplain wetlands, or to the protection of headwaters often as part of larger terrestrial reserves. In the absence of the protection of freshwater ecosystems at scale, alternative approaches attempt to control or regulate some adverse pressures—a prime example being Europe's Water Framework Directive (WFD 2000/60/EEC). The WFD simultaneously identifies adverse pressures while encouraging beneficial "programs of measures" to protect or restore freshwaters to "good ecological status"—for example through reduced nutrient inputs or improved wastewater treatment.

Beyond designation or restoration, other potential instruments to encourage freshwater conservation include government financial incentives to replace "income foregone"—for example as part of agri-environment schemes where land-owners are funded to provide sensitive land-management in place of intensification. Voluntary "codes of practice," for example in the production forestry, extractive or building industries, also set standards by reducing damaging practice. Large-scale demonstration activities sometimes illustrate how freshwaters can be protected in freshwater ecosystems where Indigenous peoples, governments or nongovernmental organizations can influence land management at scale. Increasingly, also, market mechanisms are being explored to protect or restore freshwater through "natural capital" or "markets for ecosystem services" that account more fully for the benefits provided by high quality freshwater ecosystems—for example reduced treatment costs in water supply, natural flood management, health and mental being, or nurseries for important fish stocks (Ormerod, 2014). Key needs in applying such market mechanisms are in identifying providers and users of ecosystem services, ensuring that payments and benefits flow accordingly, and in sourcing investments to fund schemes equitably and sustainably.

Table 2 Characteristics of long-standing (indicated by 'a' superscript) and emerging ('b' superscript) threats to freshwater biodiversity: their geographical extent (and focal regions); the severity of their effects; examples of attendant ecological changes; our degree of understanding; and potential options for mitigating threat effects.

Emerging threat (regions)	*Severity of effects*	*Ecological changes*	*Degree of understanding*	*Mitigation options*
Over-exploitation (global)[a]	Already causing extinctions; likely to cause more	Alters species size, range, and survival (target + bycatch)	Well understood, but interactive stressor effects unclear	Global commitments; expand freshwater protected areas
Water pollution (global)[a]	Already causing extinctions; likely to cause more	Alters species survival, with clear ecosystem effects	Increasingly well understood but high unpredictability	Improve surveillance; management to favor ecosystem controls
Habitat degradation (global)[a]	Already causing extinctions; likely to cause more	Alters species survival, with clear ecosystem effects	Well understood, but interactive stressor effects unclear	Global commitments; expand freshwater protected areas
Species invasion (global)[a]	Already causing extinctions; likely to cause more	Alters species survival, with clear ecosystem effects	Increasingly well understood but high unpredictability	Improve surveillance; management to favor ecosystem controls
Flow modification (global)[a]	Already causing extinctions; likely to cause more	Fragments river systems, inhibiting species movement	Well understood, but interactive stressor effects unclear	Ameliorate passage infrastructure; assess all project impacts
Changing climates (global)[b]	Already causing extinctions; likely to cause more	Alters species size, range, phenology, and survival	Moderately well understood but high unpredictability	Global commitments; expand protected areas; restore refugia
E-commerce and invasions (global)[b]	Significant role in trade of nonnative plants and animals	Creates novel modes of long-distance dispersal	Largely unregulated activities that are poorly understood	Online consumer accountability tools; awareness campaigns
Infectious diseases (tropics)[b]	Already causing extinctions; likely to cause more	Alters species survival, with clear ecosystem effects	Increasingly well understood but high unpredictability	Improve surveillance; management to favor ecosystem controls
Harmful algal blooms (nutrient-rich, warm)[b]	Linked to species losses; likely to cause more	Reduces species growth, survival, and reproduction	Increasingly well understood, some unpredictability	Improve surveillance; management to favor ecosystem controls
Hydropower (emerging markets)[b]	Already causing extinctions; likely to cause more	Fragments river systems, inhibiting species movement	Well understood, but interactive stressor effects unclear	Ameliorate passage infrastructure; assess all project impacts
Contaminants (developed markets)[b]	Unclear how biodiversity will be changed	Alters some species health, abundance and reproduction	Largely understudied and thus poorly understood	Improve medication disposal; advance wastewater treatment
Nanomaterials (developed markets)[b]	Unclear how biodiversity will be changed	Causes minimal acute toxicity in some species	Considerable uncertainty around long-term effects	Improve detection and characterization; create targeted formulations
Microplastics (developed markets)[b]	Unclear how biodiversity will be changed	Potentially detrimental effects on species health	Considerable uncertainty around long-term effects	Reduce plastic usage; legislation to curb use of specific products
Light and noise (developed markets)[b]	Linked to species disturbance; likely to continue	Alters behavior and physiology of some species	Well understood, but ecosystem-level effects unclear	Identify less harmful types; reduce usage; educate users
Salinization (coastal lowlands)[b]	Linked to species losses; likely to cause more	Reduces species growth, survival, and reproduction	Increasingly well studied and understood	Control point sources; strategic release of freshening flow
Declining calcium (softwater lakes)[b]	Linked to species declines; likely affecting foodwebs	Causes shifts in lake invertebrate assemblages	Increasingly well understood; solutions unevaluated	Further reduce acidic precipitation; replenish calcium in watersheds
Cumulative stressors (global)[b]	Contributing to extinctions; likely to cause more	Magnifies impacts; create ecological surprises	Poorly understood with high levels of unpredictability	Identify multipurpose solutions that protect biodiversity hotspots

[a]Information derived from Dudgeon et al. (2006).

Modified from Reid, A. J., Carlson, A. K., Creed, I. F. et al. (2018). Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews* **94**, 849–873.

Socio-Political Dimensions of Freshwater Conservation

Fresh water is distributed across the terrestrial landscape as river, lake, and wetland systems, typically arranged as watersheds whereby water flows from upland areas to lowland areas (**Figs. 1 and 3**). Watersheds have long been recognized as logical planning and management units given that they inherently link land and water (Hynes, 1975) and transcend geopolitical boundaries. This has been amplified in recent years given that watersheds are an example of a coupled social-ecological system and should be

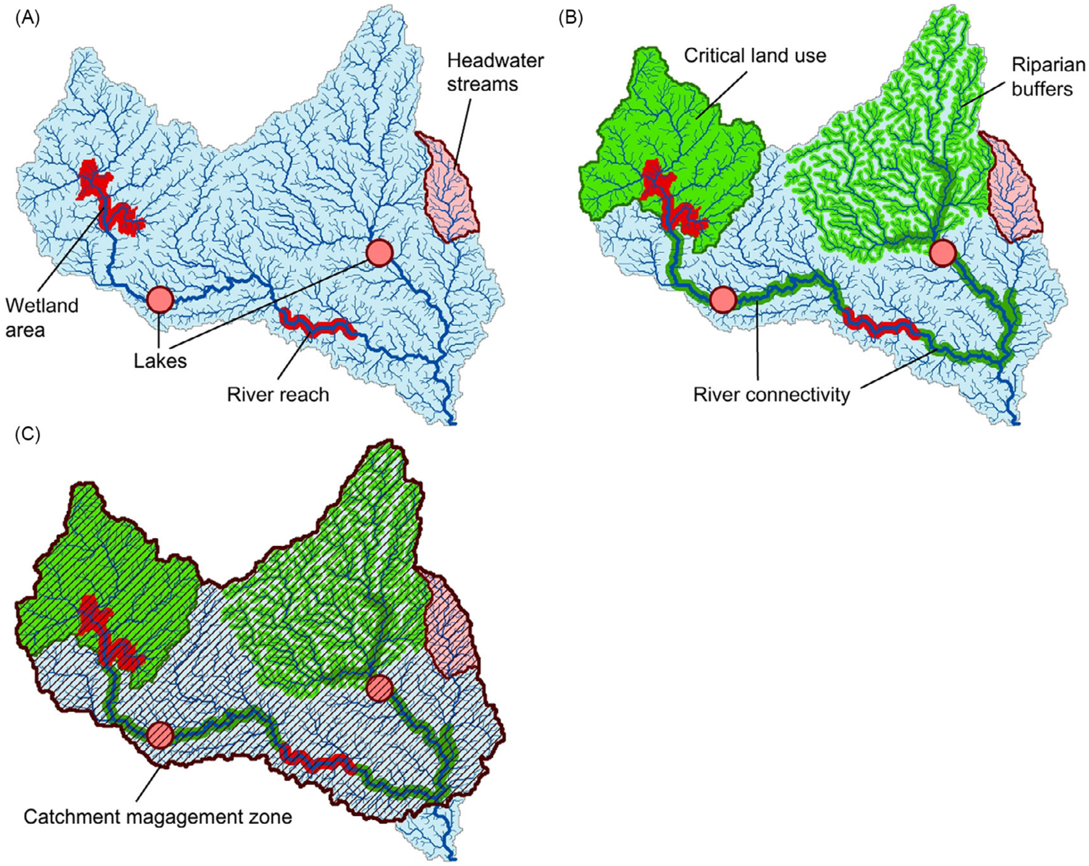

Fig. 4 Options for the conservation of key features affecting freshwater ecosystems. Schematics of freshwater protected area zones include: (A) freshwater focal areas (e.g., particular river reaches, lakes, headwater streams, or wetlands supporting focal species, populations, or communities); (B) critical management zones, such as river reaches connecting key habitats or upstream riparian areas; and (C) a catchment management zone, covering the entire catchment upstream of the most downstream freshwater focal area or critical management zone. Modified from Abell, R., Allan, J. D. and Lehner, B. (2007). Unlocking the potential of protected areas for freshwaters. *Biological Conservation* **134**, 48–63.

managed accordingly (Nguyen et al., 2016). For centuries humans have settled on or near freshwaters for transportation, irrigation, power (initially for mills and now for electricity), drinking water, and food (fish) yet humans have also altered the lands that drain and contribute flow to freshwater systems. Given human dependence on contemporary land-use change (e.g., roads, dams, agriculture, forestry, and urbanization), conservation of freshwater biodiversity is remarkably challenging (Crist et al., 2017). Indeed, it is generally understood that the most profitable path toward the conservation of freshwater biodiversity requires engaging with sectors that use water or otherwise alter upland areas that indirectly contribute to biodiversity loss via habitat alteration (e.g., water quality impairments, loss of spawning habitats) as demonstrated above. In the marine realm, one of the biggest drivers of biodiversity loss is overfishing which can most easily be solved by working directly with resource users rather than in freshwater where the industries and actors that negatively influence freshwater biodiversity (e.g., farmers) may be very disconnected and lack the incentives to do so (Beard et al., 2011).

Freshwater biodiversity loss is often considered to be a hidden crisis in that much freshwater biodiversity is unobserved beneath the water surface (Reid et al., 2018). As such, it has been difficult to generate the public and political will to enable meaningful investments or behavioral change needed to protect and restore freshwater biodiversity (Cooke et al., 2013). Grassroots, community-driven actions and stewardship are often heralded as the path forward for freshwater conservation (Silk and Ciruna, 2013) yet that alone fails to account for the broad-scale threats facing such systems. The so-called "food-energy-water nexus" (Smajgl et al., 2016) emphasizes the inherent interconnections of these major issues. Should we prioritize biodiversity preservation over stable energy sources or food for people in some of the most impoverished regions of the globe? Clearly there are difficult ethical, socio-economic and political discussions needed to chart a responsible path forward that represents a win-win-win scenario where freshwater biodiversity is both valued and protected. Global policy instruments often fail to consider freshwater biodiversity (summarized in Darwall et al., 2018) as it is considered a "domestic issue" yet there is a need for elevating freshwater biodiversity to one that is of common global concern (Harrison et al., 2018). Working from both bottom-up and top-down is essential for valuing freshwater biodiversity and committing to a future where we not only respect and conserve freshwater biodiversity but work to actively restore it.

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