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Facing our freshwater crisis *via* fluid and agile communication: A grand challenge

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Introduction

Earth has been labeled the blue planet because of its abundance of water that covers most of its surface, but the majority is salt water in our oceans. Oceans account for ∼352 million km^2 or 69% of the planet's surface, land for 150 million km^2 or 29%, and fresh water for 9 million km^2 or 2% (Shiklomanov, 2000). Most of the fresh water is locked away in glaciers and ice sheets on Greenland and Antarctica, with less than a third accessible to biota (Shiklomanov, 2000). This miniscule fraction of fresh water is our most precious natural resource, the foundation for life in terrestrial environments, and humanity depends on it, but the resource faces enormous threats. My aim in this brief editorial is to define the freshwater resource, succinctly summarize the major threats it faces, and underscore recent calls for conservation. My review is cursory, but I call attention to various recent exhaustive reviews. I end with my views on how journals can help advance global freshwater conservation efforts.

The relevance of freshwater

Fresh water is fundamental to sustaining life, ecosystems, and society. We use fresh water daily for necessities such as drinking, food production, and sanitation but also for industrial purposes such as power generation and manufacturing. Freshwater ecosystems including lakes, rivers, wetlands, groundwater, and estuaries are indispensable for life on Earth. They are fundamental for a range of benefits and services such as buffering floods, bridging over drought periods, providing natural water purification systems, supporting habitat for aquatic life, and diluting pollution and salty water. Fresh water is also important to humans for cultural and leisure reasons. Nevertheless, its scarcity, uneven spatial and temporal distribution, and growing demand continues to threaten water quality, ecosystems, and human societies.

Water shortages can threaten societies. Deficiencies in water availability or access can impose high human health costs, lead to conflict, unrest, and devastate ecosystems. Communities such as artisanal and subsistence fishers, rural populations, and farmers that rely on sound freshwater ecosystems for their income and survival are especially affected by water degradation and scarcity. As growing human populations raise demand for water and land, draining of wetlands continues, rivers are impounded to store water and protect land from flooding, groundwater is depleted, and insufficient water and nutrients reach estuaries to maintain their pulsed flow needs. Landscape modifications and their ecological impacts are unavoidable if human populations continue to expand. Yet, at the same time, societies cannot continue to expand without the life-support system provided by freshwater ecosystems. Therefore, the basic challenge is balancing landscape modifications linked to societal expansions against their unavoidable ecosystem impacts. The impacts to freshwater ecosystems originate from intrinsic traits and extrinsic threats.

Intrinsic traits

The threats facing fresh waters arise from several traits of freshwater environments. First is the small representation of inland water bodies. Fresh waters are rare compared to other landscape surfaces. Lakes, rivers, and wetlands account for about 9 million km^2, mostly as minute, isolated water bodies, surrounded by 150 million km^2 of land (Shiklomanov, 2000). There are an estimated 100 million lakes and reservoirs > 0.2 ha covering the non-glaciated areas of the planet (Verpoorter et al., 2014). Small water bodies dominate the counts, but intermediate and large-sized water bodies dominate the total surface area. Correspondingly, the surface area of running water is nearly 0.8 million km^2 (Allen and Pavelsky, 2018), with roughly half of this area represented by rivers smaller than 90 m wide. Overall, the network of streams and rivers covering our planet is estimated at an astonishing 64×10^6 to 75×10^6 km of perennial and non-perennial reaches (Lin et al., 2021; Messager et al., 2021), or nearly 80–100 round trips to our moon.

Second, fresh waters are effectively isolated islands embedded in continental land masses (Magnuson et al., 1998). Each freshwater island is mostly separate from others, although the extent of isolation varies greatly. The biota can mix among these islands, but the extent of mixing is limited by connectivity that can temporally be nil. Therefore, freshwater occupants may have limited prospects for dispersal across lakes, and among rivers and drainage basins. This isolation promotes diversity of biota, but also diversity of impacts.

Third, water always flows downwards. As water runs over catchments, it collects and carries sediment, nutrients, and pollutants that drain into fresh waters and concentrate in lakes, wetlands, reservoirs, groundwater, and estuaries. Thus, freshwater composition and characteristics are heavily influenced by activities within the catchment, whether natural or anthropogenic. Consequently, conservation of freshwater systems also requires protection of huge catchments, not just confined isolated water bodies.

Extrinsic threats

We already are in a difficult situation facing regionally increasing risks of water shortages. Yet, human pressure on fresh waters continues to grow as populations spread and level of affluence rises. While there is evidence that water consumption is diminishing in some regions (Cooley and Gleick, 2009), socioeconomic expansion is likely to raise overall usage. As economies grow, industry expands, energy requirements soar, and water consumption increases. Societies need fresh water to expand, which inevitably results in competition with conservation needs.

Pollution and salinization are major threats, particularly in developing regions with rapid growth, booming industry, but weak environmental controls (Chaudhry and Malik, 2017; Cunillera-Montcusí et al., 2022). Runoff from agriculture, mining, industry, urban areas, municipal sewage, and various other sources all contribute significantly to freshwater pollution and salinization. Uncontrolled expansion of these human developments can cause various harmful water quality problems as well as emerging freshwater diseases exacerbated by environmental degradation (Okamura and Feist, 2011). Pollutants, including nutrients, pesticides, pharmaceutics, plastics, fecal waste, viruses, and others not only endanger drinking water and stress freshwater organisms, but also lead to losses of diversity and functionality of aquatic ecosystems, and disappearance of the benefits and services that aquatic ecosystems deliver to human societies.

Ecosystem modifications such as dam construction, water diversions and withdrawals, wetland draining, and floodplain detachment generally have major effects on fresh water (Carpenter et al., 2011). The tendency of human communities to concentrate around fresh water exacerbates anthropogenic impacts, often more severely than on any other feature on the landscape. Societies have constructed about 50,000 large dams >15 m tall (Berga et al., 2006) to impound some of the largest rivers in the world. Consequently, 23% of rivers 100-500 km long, 49% of rivers 500-1,000 km long, and 64% of rivers >1,000 km long are no longer free flowing (Grill et al., 2019). Nearly 70% of wetlands have been drained since 1900 (Davidson, 2014), and these losses and degradation continue into this century (Darrah et al., 2019). Limiting freshwater flow is threatening estuaries and dependent coastal environments (Gillanders and Kingsford, 2002). The extensive groundwater reductions experienced in agricultural regions cause loss of aquatic habitats (Danielopol et al., 2003). Humans have become a predominant force on fresh waters.

Amid all these impacts, climate change is increasing temperature. Most of the effects of temperature come down to water as higher temperature increases water demand and intensifies hydrological cycles. Climate change has the capacity to destabilize freshwater ecosystems and the freshwater conditions to which ecosystems and civilizations are attuned, endangering species, the security of water, and food and energy systems. Some regions will get too much fresh water and others not enough, with consequences on flooding, drought, aquifers, fires, infrastructure, disease proliferation, water quality, aquatic habitats, and aquatic flora and fauna (Gallana et al., 2013; Hoegh-Guldberg et al., 2019). Changes in temperature and water availability can be particularly challenging to freshwater taxa as most are confined to a specific water body and have few opportunities to move into more suitable environments. Genetic change is possible as it is the only option for organisms unable to migrate or acclimate. Changes in freshwater distribution will have consequences for various economic sectors, principally agriculture, energy, and transportation (Tol, 2018). These changes could lead to various government policy modifications. Such policies can have societal consequences triggered by changes in quantity and quality of fresh water and increase the likelihood of conflicts in transboundary watersheds. Freshwater solidarity and policy transparency will be tested as nations struggle to develop solutions that address their needs for fresh water. Changes to freshwater resources can have a big impact on societies and our lives.

Threats to biodiversity

The interaction of intrinsic traits of freshwater environments and extrinsic threats has produced a biodiversity crisis (Dudgeon et al., 2006; Harrison et al., 2018; Reid et al., 2019). For example, as of 2022 nearly 15% of over 24,000 freshwater fishes assessed, and nearly 35% of over 7,000 amphibians were considered threatened (i.e., critically endangered, endangered, or vulnerable; IUCN, 2022). These taxa keep ecosystems functioning and balanced by contributing biomass, production, nutrient cycling, and various regulatory processes. Freshwater fishes also support the dietary needs of humans, as well as various cultural necessities and leisure activities. It has been estimated that about 35% of freshwater taxa might either become threatened or pushed to extinction by the year 2100 (Isbell et al., 2022). Many predictive biodiversity models suggest alarming consequences for biodiversity this century (Bellard et al., 2012), with the least optimistic predictions putting us at the threshold of another mass extinction (Barnosky et al., 2011). The stakes are high.

Facing the freshwater crisis

Various far-reaching evaluations have recently been published to address the alarming downward trend and urgency of the problems facing fresh waters, with the goal of changing the present biodiversity trajectory, i.e., to bend the curve of global freshwater biodiversity loss. Specifically, Tickner et al. (2020) presented an Emergency Recovery Plan that listed six priority actions focused on environmental flows, water quality, habitats, resource exploitation, invasive species, and connectivity. Twardek et al. (2021) expounded on implementing concerted efforts to make sure that the Emergency Recovery Plan pressures policy makers, professional organizations, industry, researchers, and managers at local scales. These and other inspirational and visionary analyses have outlined needed global initiatives and suggested practical local-scale actions and policies to protect and recover the planet's freshwater ecosystems (e.g., Bunn, 2016; Reid et al., 2019; van Rees et al., 2020; Arthington, 2021; Buxton et al., 2021; Harper et al., 2021; Cooke et al., 2022; Maasri et al., 2022). These reviews have provided both galvanizing and practical guidance for implementing critical biodiversity recovery programs.

But reduced biodiversity is not the only challenge faced in freshwater conservation (Bunn, 2016; Dudgeon, 2019). The high and growing demand for fresh water is creating scarcity and degrading the quality of this renewable resource. Regional over-withdrawal of surface water and groundwater has led to redistribution and depletion. Excessive pollution and crumbling infrastructure to provide safe, disease-free drinking water are among the major problems faced by communities (Stauffer, 2013). The intensities of these problems are regionally uneven resulting from spatial and temporal distribution of water. Lack of water can cause food shortages, disease, starvation, migrations, and political conflict (but see an alternative view by Biswas and Tortajada, 2019). These problems could be solved through improved management of water resources infrastructure, and advances in technology (Green et al., 2015). New technologies and adaptation through policy, planning, management, economic tools, and adjustment of human behaviors are required to preserve our endangered and precarious freshwater resources. Overall, assessments suggest we still have time to stabilize and undo the degradation of fresh waters, or at least to avoid drastic changes. But to have any chance of doing so, rapid scientific progress is needed.

Rapid scientific progress *via* fluid and agile communication

An essential but often underrated ingredient for scientific progress, and the fabric that connects isolated scientific achievements, is a fluid and agile communication ecosystem. In the natural sciences, specialized scholarly journals are a vital instrument for communicating research findings and a hub for advancing scientific progress (Cole, 2000). Specialized scientific journals not only facilitate development of networks of scientists that focus on solving very specific problems (Kuhn, 1970), but also speed up science progress in ways that other forms of scientific communication (e.g., seminars, workshops, conferences, books) cannot. Journals are commonly divided into well-defined bite-size articles. A scholarly article generally gives a brief representation of the current state of a narrow topic and contributes results that advance the cutting edge of the topic. Articles on a topic often succeed each other in short intervals. New articles are expected to rely on preceding ones, by incorporating methods and arguments developed in prior articles. Each new article raises new questions and invites new ideas, and thus more articles. This quick succession of articles, within a well-oiled publication environment, facilitates rapid progress.

To a large extent journals shape, regulate, and assist the scientific communication process. Journals do so in various ways, some of which may have influential consequences to identifying relevant topics and legitimate issues, how research is conducted and under what standards, what is presented and how, and how results are interpreted. The journal pre-structures what and how authors can contribute. The journal's peer review system can present a sizable obstacle, but when cleared it gives the research a certain status of validity. Scientific journals not only convey scientific results but, in many ways, can also influence the effectiveness and promptness of communication, and may even slow scientific progress if the system is inefficient.

Stimulating fluid and agile communication

The challenge for freshwater science journals is to stimulate scientific communication and achieve the rapid progress required to bend the curve in freshwater recovery. While there are many aspects of journal communication that need attention to address this challenge, I highlight three that I believe are particularly relevant to facing the crisis: promptness, access, and breadth.

Promptness

The publication process is often not fast enough. The expectation was that with advances in digital publishing and the proliferation of journals, publication would be faster, but not so according to recent reports (Powell, 2016; Christie et al., 2021). For conservation-oriented journals, and with exceptions, time to publication from initial submission of a year or longer is not unusual. This is too long if we want scientists to build upon recent findings. Innovation is necessary to accelerate progress but requires buy-in from the scientific community that frequently prefers what is familiar. Some examples of innovation are the use of artificial intelligence to evaluate manuscripts rigorously, consistently, and efficiently. These systems are often designed to deliver decision support via robotic checks but leave the responsibility of a final decision to a person with the proper expertise. Innovation such as this has trimmed down the average time from submission to final decision in various online journals. For example, through suchlike innovations, Frontiers journals reportedly have reduced time to an average of 61 days (https://www.frontiersin.org/about/peer-review; accessed 13 November 2022). The promptness challenge can only be surmounted through persistent innovation and a commitment to leave behind the security of outdated ways.

Access

There are three aspects of access I want to briefly touch on, including access to the published literature, access to the publication language, and access to editorial boards, all critical to fast progress in freshwater science. First, Gold Open Access journals (i.e., licensed under Creative Commons Licenses to be freely distributed) have been made viable by the internet. Gold Open Access (other open access models exist including Green, Bronze, and Hybrid open access; Piwowar et al., 2019) is a relatively new set of principles and practices through which research results are made accessible online to the whole world, without readers getting locked out by paywalls. The research gets more visibility and higher impact (Breugelmans et al., 2018). According to Piwowar et al. (2019), 31% of all journal articles were available as open access in 2019 and received 52% of article views; these authors projected that by 2025, 44% of all journal articles will be available as open access and will receive 70% of article views. But there is a catch—someone must pay for the publisher's operating costs. In Gold Open Access, the costs are transferred from the reader to the author. This swap creates a brand-new set of budget problems, inequities, and ethical controversies (Joseph, 2013; Tennant et al., 2016) and it will take a few years for the publishing universe to readjust. While authors, funders, research institutions, libraries, publishers, and governments adjust to open access, many publishers provide partial or full article processing charge waivers to authors with insufficient funding if the article passes independent peer review.

Second, English currently dominates scientific communication (Tardy, 2004), placing at a disadvantage a huge body of freshwater scientists with capacity to contribute to the global research effort. Biases created by language have allowed the research of some western countries to prevail, possibly producing only a partial image of freshwater science research (Hamel, 2007; Konno et al., 2020). To succeed we must be sensitive to this language challenge and help non-native English speakers get their work published through assistive resources such as readability screening, and access to language editing services both before review and after acceptance.

Third, it is necessary to provide access to a diverse editorial board with a global perspective. Diversity applies to gender, race/ethnicity, and national origin. Inclusivity is not just fair but makes sense because ostensibly inclusivity enhances creativity and problem-solving (Friedman et al., 2016), both essential to our goal of bending the curve.

Breadth

Confronting the vast challenges we face requires a breadth of research directed at all aspects of freshwater science. To address this urgency, adequate attention must be given to publishing material relevant to all types of freshwater specialties and ecosystems, including contiguous and linked terrestrial environments. Bringing multiple disciplines together can provide a dynamic forum for conservation of our precarious freshwater resources. To this end, the journal will organize into 15–20 specialty sections, each with a Section Chief Editor(s) and its own editorial board to facilitate and expedite communication. The journal is expected to launch with four specialty sections including Aquatic Population Health and Diseases, Freshwater Species Evolution and Ecology, Freshwater–Human Impacts, and Rivers and Floodplains. Future sections may include Aquifers, Catchments, Climatic Impacts, Conservation and Resource Management, Ecotoxicology, Fisheries, Invasions, Lentic Systems, Limnology, Microbiology, Molecular Biology and Genomics, Nutrients, Policy and Politics, Social Sciences, Sustainability, and Water Quality.

In addition, creating article collections that focus on timely and cutting-edge research topics could help assemble the world's leading experts on a hot subject to push the boundaries of thought on the issue. Research topics are article collections that focus on a timely and trending research theme. Approaches such as these will help stimulate and accelerate progress in freshwater science.

Author contributions

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Conflict of interest

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