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INLAND WATERS

Science Brief for the Post-2020 Global Biodiversity Framework

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INLAND WATERS IN THE POST-2020 GLOBAL BIODIVERSITY FRAMEWORK

Recommendations for amending the GBF text

1. Explicit inclusion of inland water ecosystems in Post-2020 Global Biodiversity Framework (GBF) goals, targets, and indicators is required to restore and safeguard these most threatened and least protected ecosystems and biodiversity on the planet.

Inland waters have received little attention from the global conservation community. They are not explicitly included in Targets 1 and 3 of the current version of the Post-2020 Global Biodiversity Framework (GBF); rectifying this omission is essential if the world is to bend the curve of biodiversity loss. Inland waters are disproportionately rich in biodiversity, hosting one third of known vertebrate species and as many fish species as are found in the world's oceans. They also provide critical ecosystem services, including fisheries that feed hundreds of millions of the world's poorest people. Abundances of freshwater vertebrate populations are declining at more than twice the rate observed on land or in the oceans. Freshwater invertebrates and fishes are going extinct faster than those on land and in coastal marine areas.

2. Target 1 should be updated to "all terrestrial, inland water, coastal and marine areas" to ensure consideration of inland waters within biodiversity-inclusive participatory spatial planning or other effective management processes.

The post-2020 GBF should ensure that expected investments in infrastructure and resource use should include biodiversity inclusive spatial planning for the conservation of inland waters ecosystems and address the multiple, and often distinct, drivers of loss and degradation, including dams and other infrastructure, mining and other extractive activities, increased demand for water, urban expansion, climate change, and invasive species. These threats must be considered both locally and in the context of the connected nature of rivers and other inland waters ecosystems.

3. In line with Goal A of increasing connectivity, integrity and area of natural ecosystems, Target 2 on ecosystem restoration needs to include inland water-specific objectives and use several rather than one single, potentially inappropriate, metric. At least 300,000 km of river length and at least 350 million hectares of inland waters, including coastal ecosystems should be under restoration by 2030.

The rates of loss and degradation of inland water ecosystems are greater than in other realms. Restoration of inland waters is crucial to reverse biodiversity loss, and can often enhance strategically important ecosystem services, reduce risks and support recovery from natural disasters, aid resilience to climate change impacts and contribute to food security. Restoration objectives should be expressed as measurable units, to avoid inland water ecosystems being neglected within an overall percentage for terrestrial ecosystems. Whereas most inland water ecosystems can adequately be covered by an area target (ha), the longitudinal nature of rivers requires that restoration objectives should be in linear units (km).

4. Target 3 should be adjusted to read "... at least 30 per cent globally of terrestrial, inland water, coastal and marine areas ... are conserved through ... systems of protected areas and other effective area-based conservation measures ..."

The proposed ambition in the post-2020 GBF provides an opportunity to strategically expand the global protected and conserved area estate with enhanced representativeness of areas of particular importance for inland waters ecosystems biodiversity, including through the identification of Key Biodiversity Areas (KBAs). Explicit recognition of inland waters is needed in Target 3 to ensure their representation. In addition to meeting percentage targets, protected areas need to be effectively managed, ecologically representative, well-connected, and equitably governed. Habitat quality needs to be maintained by ensuring connectivity at appropriate spatial scales, including the protection of hydrologically connected catchments and habitats.

Key messages on monitoring and reporting for inland waters

1. Greater capacity is needed for monitoring biodiversity and measuring ecological connectivity of inland waters. Priority should be given to hotspots, regions with unique biodiversity, and places experiencing rapid or extensive change. Monitoring of inland waters should be integrated into a cross-realm global biodiversity observation system.
2. Data infrastructures facilitating the mobilization of and access to freshwater biodiversity data from inland water ecosystems need urgent support and funding comparable to those available for terrestrial and marine biodiversity. Data exchange must be implemented in national/regional policies with required open access data publishing following international standards.
3. Citizen science, Indigenous science, and Indigenous Knowledge (IK) needs to be actively included within monitoring, conservation and ecological restoration of inland waters biodiversity. Greater effort must be put into supporting citizen science initiatives, particularly in remote/understudied locations where such initiatives may fill important data gaps. Emphasis should be placed on supporting Indigenous-led monitoring and conservation activities for inland waters.
4. Specific attention needs to be given to needs for different levels of biological organization represented by the three milestones under Goal A.
    - *Ecosystems (milestone 1).* More diverse inland water ecosystem types should be reported under Target 1, Goal A1 of the Post-2020 GBF. There is a need for technological advances and development effort to extend Earth observation capabilities to cover other inland waters ecosystems.
    - *Species (milestone 2).* Better representation of inland water species is needed in current indices used to assess population trends and species status. As a priority, critical data gaps need to be addressed.
    - *Genes (milestone 3).* Monitoring of genetic diversity using advance molecular tools is essential for directing conservation efforts in inland water ecosystems, many of which are isolated units with unique physical and chemical characteristics that drive adaptation and intraspecific genetic diversity.

Introduction

Inland waters[1] host a significant proportion of global biodiversity, with the freshwater component accounting for perhaps 12% of all non-microbial species within less than 1% of the Earth's surface (Garcia-Moreno et al. 2014). They include over one third of the vertebrates, almost all of the amphibians, and half of the fishes (Dudgeon et al. 2006, Carrete Vega & Wiens 2012). And although knowledge of invertebrates is insufficient, many crayfishes, snails and pearl mussels are imperilled or already extinct (Richman et al. 2015, Lopes-Lima et al. 2018, Neubauer et al. 2021). Yet neither this freshwater biodiversity, nor inland water areas in general, receive adequate conservation attention (Juffe-Bignoli et al. 2016, Gonçalves & Hermoso 2022) and they are not explicitly included in Targets 1 and 3 of the current version of the Post-2020 Global Biodiversity Framework (GBF). This omission should be rectified (Tickner et al. 2020) — not only because inland waters are hotspots of biodiversity; they are also hotspots of endangerment. Between 1970 and 2018, there was an 83% (range −74% to −89%) decrease in the average abundance of more than 6,000 populations of freshwater animals — more than twice the rate of decline observed in their marine or terrestrial counterparts (WWF 2022). Populations of migratory fishes, living partly or exclusively in fresh waters, fell by 76% over a similar period (Deinet et al. 2020); declines of the largest freshwater species (> 30 kg body mass) were even higher (−99% and −97% in the Indomalaya and Palearctic realms, respectively (He et al. 2019). IUCN Red List assessments (www.redlist.org) indicate that over a third of species in some groups of freshwater animals are threatened, with the sturgeons (27 species) now considered to be the most endangered group of animals on the planet.

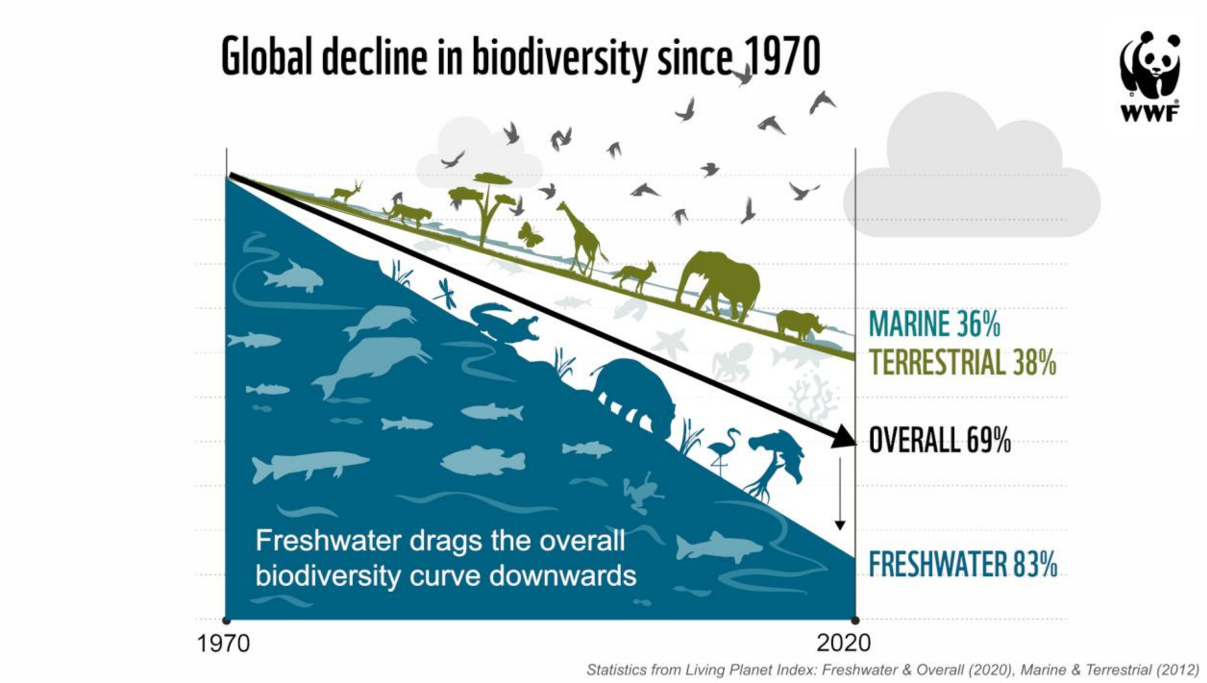

Figure 1. This WWF graphic summarizing the Living Planet Index shows that the freshwater biodiversity associated with inland water ecosystems has declined more steeply than that on land or in the sea, although significant reductions are apparent in all realms.

[1] Inland waters comprise all kinds of non-oceanic water bodies, or components thereof, on or adjacent to the land, including groundwater. They can be fresh, saline or brackish but, in practice, consideration of inland waters focuses on fresh water – because freshwater environments dominate inland waters, and because of their importance globally (see https://www.cbd.int/waters/inland-waters/). Accordingly, we use the term 'inland water' ecosystems and, hereafter, refer to the associated 'freshwater biodiversity' that they support.

Inland waters and the biodiversity they support face a vast array of threats (summarized by Dudgeon 2020), and their variety and intensity appear to be increasing (Reid et al. 2019). Land-use change (including flow alteration caused by rising water abstraction for agricultural, industrial and domestic uses), loss of connectivity due to dams and other infrastructure and pollution are the dominant direct drivers of biodiversity loss from inland waters (Jaureguiberry et al. 2022); invasive species have also had significant impacts (Ricciardi & MacIssac 2011, Marshall 2018). Climate change is playing a relatively small role thus far, although there is growing evidence that shifts in the frequency of extreme flow events will have major impacts upon freshwater biodiversity (Sabater et al. 2022). Importantly, in many places, the multiple drivers of biodiversity decline (e.g., habitat loss and fragmentation) are associated with reductions in human water security and wellbeing (Vörösmarty et al. 2010), so measures to improve the former — such as improved pollution control and restoration— should benefit the latter (Herrera et al. 2017, Fisher et al. 2019). Furthermore, protection of biodiversity in inland waters will maintain the supply of ecosystem services, most notably capture fisheries that — although widely overexploited — provide animal protein for over 150 million people globally (McIntyre et al. 2016), and it is notable that there is a correlation between the yields and species richness of fisheries (Brooks et al. 2016). In other words, measures to conserve freshwater biodiversity could also help bring about sustainable use of inland waters by humans, and would be consistent with GBF draft Target 5 on the harvest, trade and use of wild species.

This document calls for more attention to inland waters in the refinement and implementation of the GBF. It makes recommendations for changes to the text of the GBF and identifies ways in which monitoring and reporting for the GBF can better address specific needs of inland waters.

Spatial planning that is inclusive of biodiversity in inland waters

Target 1. Ensure that all land and sea areas globally are under integrated biodiversity-inclusive spatial planning addressing land- and sea-use change, retaining existing intact and wilderness areas (CBD 2021)

The role of spatial planning is to help to reconcile environmental concerns with development pressures. Protected areas are one of the keystones of biodiversity-inclusive spatial planning, but their designation is generally focused on terrestrial biodiversity, or, more recently, on marine biodiversity and only rarely on freshwater biodiversity (Abell et al. 2007). Moreover, Target 1 of the Post-2020 GBF speaks only to biodiversity-inclusive spatial planning of terrestrial and sea systems, excluding inland waters and the impacts of changes in water use. Biodiversity-inclusive spatial planning addresses loss and degradation of biodiversity both within and outside protected areas. This is particularly important for inland waters, as to protect freshwater biodiversity the whole catchment needs to be considered and watershed boundaries should be used to define the planning domain. A recent analysis from the Amazon Basin demonstrates the potential for integration of terrestrial and inland water planning - integrated cross-realm conservation planning in the Amazon resulted in an increase in freshwater benefits up to 600% for a negligible reduction in terrestrial benefits (Leal et al. 2020).

Inland water ecosystems are impacted by multiple stressors due to their location at the lowest point in the surrounding landscape and their interconnected nature. To be effective and feasible, integrated terrestrial-freshwater conservation planning needs to be aligned with or incorporated into current environmental policies and laws (Cecilia et al. 2020). In particular, conservation planning for inland waters should not take place at the expense of compromising existing protected areas on land, as these often hold the last populations of endangered species and are under increasing pressures globally (Mascia et al. 2014). Linkages between freshwater-terrestrial realms are often neglected in cross realm studies relative to marine-terrestrial realms. An efficient way to achieve integration in conservation planning is to preferentially select areas where freshwater and terrestrial biodiversity priorities overlap to incorporate freshwater biodiversity in determining priority areas for conservation.

Biodiversity considerations have often been precluded from spatial planning, with inland waters biodiversity particularly neglected. Integrated spatial planning needs to deal with multiple threats and their drivers, which include increasing demand for food, energy and water, urban expansion and climate change (Dudgeon 2019). Where they still occur, areas of high freshwater biodiversity importance, such as free-flowing rivers, should be retained or the mitigation hierarchy should be followed (Thieme et al. 2021). Addressing the effects of development will require using well-designed mitigation activities to complement reserve design and spatial planning that maintains critical habitats for species and ecosystem services (Linke & Hermoso 2022). Example applications include planning for sediment mitigation (Hermoso et al. 2012), identifying high conservation value areas for protection or special management (e.g., Grill et al. 2020, Holland et al. 2012, Worthington et al. 2022) and integrated management of introduced plants and animals (Cattarino et al. 2018). Management is best planned and executed in multiple scales of basin or other planning units with a local focus of actions combined with initiatives that take account of connectivity and disturbances in the surrounding catchment (Abell et al. 2007). In order to ensure that inland waters are included within biodiversity-inclusive participatory spatial planning or other effective management processes, Target 1 language should be updated to "all terrestrial, inland water, coastal and marine areas".

Restoration objectives for inland waters

Target 2. Ensure that at least 20 per cent of degraded freshwater, marine and terrestrial ecosystems are under restoration, ensuring connectivity among them and focusing on priority ecosystems (CBD 2021)

The rates of loss and degradation of inland water ecosystems are greater than in other realms (IPBES 2019). Major drivers of loss and degradation of inland water ecosystems include direct conversion for agriculture and urban development, pollution due to run-off, invasive species and alteration of flows and hydrological connectivity due to water abstraction and infrastructure such as dams. For river ecosystems, in particular, loss of fluvial or river connectivity is considered one of the main threats (Dudgeon et al. 2006) and has been linked with the extinction and population declines of freshwater species (Dias et al. 2017).

Ecological restoration of inland waters is crucial to reverse biodiversity loss, and can often enhance strategically important ecosystem services, reduce risk and support recovery from natural disasters, aid resilience to climate change impacts and contribute to food security (Speed et al. 2016). Habitats in inland water ecosystems differ dramatically in species composition and diversity from the terrestrial and marine ones, but unfortunately these specific biodiversity values have been overlooked in the implementation of the Aichi Target 15 (CBD 2016). For this reason, ecosystem-specific objectives should be established and inland waters should have their own objective, alongside those for the land and sea. Ecological restoration objectives for inland water ecosystems should be expressed as units. Whereas most inland water ecosystems can adequately be covered by an areal target (ha), the longitudinal nature of rivers requires that restoration objectives should be in linear units (km).

There are several options for including explicit restoration objectives for inland waters into Target 2, as discussed in the Ecosystem Restoration Science Brief (Future Earth and GEO BON, 2022). The main distinction to be made concerns ecological restoration and rehabilitation (Gann et al. 2019), the possibility of having separate quantitative objectives and their position in the framework (both under Target 2, or ecological restoration objectives under Target 2 and rehabilitation objectives under Target 10 or 11).

Recommended Area (ha) Inland Water Restoration Target

The Wetland Extent Trends (WET), derived from 1970 to 2015 data, is a robust index for measuring wetland loss (Dixon et al. 2016, Darrah et al. 2019). To develop an inland waters objective for areal

extent of inland waters restoration, the WET Index has been extrapolated until 2022, assuming that the rate of decline over the last ten years of the index (2006-15) continued. On that basis it was calculated that 976 million hectares of inland waters remained in 2022 with a total loss of 949 million hectares since 1970. An area-based ecological restoration objective that restores 30% of lost inland waters equates to restoring 285 million hectares.

The objective for ecological restoration of degraded inland waters is based on two global wetland surveys undertaken in 2017 and 2020 which showed (respectively) that 24.2% and 22.8% of inland waters were recorded as being in a poor state (McInnes et al. 2020, Simpson et al. 2021). The average of the two surveys (23.5%) was used to indicate the percentage of inland waters that should be classed as degraded. Using the 2022 extrapolation from the WET index, this equates to a degraded area of 229 million hectares. Thus a 30% target for restoring degraded inland waters equals 69 million hectares. Hence the total inland waters area that should be under ecological restoration by 2030 is at least 350 million hectares.

Recommended Linear (km) River Restoration Target

Inland waters connectivity can extend in four dimensions: longitudinally (up- and downstream in the case of a river channel), laterally (between main channel, floodplain and riparian areas), vertically (between the groundwater, river and atmosphere) and temporally (seasonal variations in natural flow regimes and the transport of sediment, nutrients and organic materials) (Tickner et al. 2020; Ward et al. 1989). The Connectivity Status Index (CSI, Grill et al. 2019) incorporates separate indicators for each of the four connectivity dimensions; river fragmentation, flow regulation, sediment trapping, water consumption and infrastructure development in riparian and floodplain areas. 30% of the total river kilometers of impacted river reaches (CSI < 95%) equates to a global target for ecological restoration of transformed to natural river reaches of at least 300,000 kms. Target 2, should make explicit mention of the absolute areas and linear extent of inland waters involved: specifically, it should include '.... at least 350 million hectares of inland water ecosystems and at least 300,000 km of rivers ....'

Protected areas and other effective area-based conservation measures

Target 3. Ensure that at least 30 per cent globally of land areas and of sea areas, especially areas of particular importance for biodiversity and its contributions to people, are conserved… (CBD 2021)

The current extent of protected area coverage of inland water ecosystems falls far short of the 30% recommended under Target 3 in the draft GBF. Globally, only 16% of river reaches are protected, but if adequate protection upstream is considered, this figure falls to only 13% (Abell et al. 2017). The proportion is even lower in some river basins such as the Murray-Darling basin (3.5%) or Mississippi (1.9%). Similarly, only 16% of the world's wetlands are protected under IUCN categories I-VI (Reis et al. 2017). These values are far less than the proposed 30% target, and would call for an expansion of protected areas and OECMs (Other Effective Area-based Conservation Measures) with specific attention to the following: effective and equitable management; areas of particular importance to biodiversity, their ecological representativeness, the maintenance of connectedness within and between water bodies, and the requirement to manage these areas effectively and equitably.

The proposed ambition to protect and conserve 30% of terrestrial, marine and inland water freshwater areas by 2030 provides an opportunity to strategically expand the global protected and conserved area estate with enhanced representativeness of areas of particular importance for freshwater biodiversity. One way to ensure ecological representativeness of protected inland water ecosystems would be to stratify biomes and ecotypes and ensure that examples of each type are afforded protection. Furthermore, the particular requirements of freshwater biodiversity need to be considered in the management of protected areas. A particular requirement is the need to account for hydrological connectivity - both to

minimise propagation of disturbance and to provide migration corridors for threatened species. The Global Swimways programme proposed by Worthington et al. (2022) provides one starting point, as it sets a basis for identifying rivers of global importance for migratory fishes. Certainly, there is an urgent need to take account of the special requirements of freshwater biodiversity in view of the degree of threat facing species in inland waters: for instance, a recent analysis revealed that 27% of molluscs were endangered (Linke & Hermoso 2022), as are 23% of fish species assessed by the IUCN.

In particular, Key Biodiversity Areas (KBAs) provide a mechanism for ensuring that areas of importance for freshwater biodiversity are recognized, based on a global standard (IUCN 2016). According to the World Database of KBAs (BirdLife International 2022), nearly one third of existing KBAs assessed against the Global KBA Standard (IUCN 2016) are in freshwater systems, most of them designated as Important for wetland birds. The KBA Standard provides a mechanism to 'level up' other taxa such as freshwater fishes, aquatic plants, dragonflies, molluscs and decapod crustaceans such as crayfishes. Currently there are just 313 KBAs identified for these groups, representing 8% of inland water KBAs in freshwater systems and 2% of KBAs overall. As well as being in SDG and CBD indicators, KBAs can also help to attract funding and safeguard sites from harmful development or degradation (The KBA Partnership 2018). However, in order to take advantage of the KBA Standard to guide expansion of protected areas of particular importance for freshwater biodiversity, a great effort will be needed to identify additional KBAs. Because the KBA standard is science-led and data-driven, identification of new areas for protection will require the mobilisation of existing freshwater biodiversity datasets as well as targeted generation of new global and site-level biodiversity data.

The new designation of "other effective area-based conservation measures", only formally defined by the CBD in 2018, provides another major opportunity to expand the conservation estate. OECMs are based around successful outcomes for biodiversity, whether or not management is aimed at conservation. To be effective, protected areas need to be managed equitably. Experience shows that protected and conserved areas are only effective in the long-term if they are supported by the human communities living in them or nearby. This means that management objectives should be agreed on by all relevant stakeholders to reflect the diversity of interests and needs that converge in a particular freshwater ecosystem (Cañedo-Argüelles 2019). Success is predicated on people being involved in key decisions - a participatory approach - and in the case of state or privately-run areas, managers and staff being aware of and sympathetic to local concerns. It also means that assessment of effectiveness - a key concern in the GBF - needs to include assessment of issues such as governance quality and social outcomes. Methods of achieving this are increasingly becoming available. Target 3 should be adjusted to "*... at least 30 per cent globally of terrestrial**, inland water,** coastal and marine areas ... are conserved through ... systems of protected areas and other effective area-based conservation measures ..."*

Monitoring and reporting the status of inland water biodiversity

To support the GBF monitoring framework (CBD 2022b) a Global Biodiversity Observing System (GBiOS) was proposed (CBD 2022a). GBiOS would be underpinned by a theory-driven framework e.g. Essential Biodiversity Variables (EBV, Pereira et al. 2013) in the same way that the Global Climate Observing System (GCOS, Spence & Townsend 1996) is supported by Essential Climate Variables (ECV, Bojinski et al. 2014). The EBV framework can be implemented for inland waters globally (Turak et al. 2017) and locally (Haase et al. 2018) to monitor inland water biodiversity and connectivity but coordination with other realms is needed for understanding cross-realm interactions. The inland water component of GBiOS would build on existing programs such as river health programs (Dickens et al. 2022). These are implemented nation-wide and regularly in some countries (e.g., EU, Japan, Korea, South Africa, and the USA), at varying scales and frequency in others (Feio et al. 2022). Other programs that would contribute to building the inland water component of GBiOS include The Global Mangrove Watch (Bunting et al. 2022) and the Global Lake Observation Network (GLEON, Hamilton et al. 2015) and International Long Term Ecological Research (ILTER) nodes (Peñas et al. 2022).

Mapping inland water ecosystems

Milestone A.1 Net gain in the area, connectivity and integrity of natural systems of at least 5 percent (CBD 2021)

Improvement in the mapping of multiple ecosystem functional groups of inland water ecosystems is necessary for reporting to Target 1, Goal A1 of the Post-2020 GBF (CBD, 2021). The draft GBF monitoring framework (CBD 2021) includes the headline indicator A.0.1 extent of selected natural and modified ecosystems. Currently, changes in open water bodies and mangroves are mapped and monitored over time (Darrah et al. 2019, Bunting et al. 2022), however many other global ecosystem types recognized under the Ramsar Convention (Ramsar Convention Secretariat 2016) and IUCN typologies (Keith et al. 2022) are not represented in any global reporting. For example, changes in estuarine ecosystem types such as salt marshes (McOwen et al. 2017) and sea grasses (Short et al. 2007) are currently not reported, owing to commission and omission errors and lack of time-series analysis. Similarly, representation of ecosystem types in the IUCN freshwater-terrestrial transitional zone (from forested wetlands to marshland vegetation), their substrates (peat vs. non-peat) and subterranean-freshwater realms (groundwater ecosystems or underground streams and pools) should be significantly improved. Global datasets may under-represent wetlands by up to 87%, as was shown in a recent comparison to wetlands mapped at a country-wide scale for South Africa (Van Deventer 2021). Rivers present an even bigger challenge, given that their narrow linear extent can limit the detectability of their channels, which may also vary seasonally. Currently, only changes in the extent of open water bodies including reservoirs are reported to the Sustainable Development Goal (SDG) sub-indicator 6.6.1a, while information on changes to palustrine wetlands are deficient, regardless of whether they are included under SDG 6.6.1a or 15. Global reporting of changes to these SDGs, as surrogates of biodiversity, should be aligned and expanded to include more types for the GBF.

Many of the wetland ecosystem functional groups proposed under the IUCN's global ecosystem types are discernible with freely-available, and vegetation-sensitive spaceborne satellite images, that shows promise in mapping additional categories of inland water ecosystem types, such as forested wetland and vegetated marshlands (for example: Niculescu et al. 2020, Van Deventer et al. 2022). Time-series data can be used to characterise hydrological periodicity of inland water ecosystems, facilitating typing of systems to IUCN biodiversity classes such as permanent, seasonal, episodic or freeze-thaw rivers or wetlands, or further refinements of the hydrological regime (Rolls et al. 2017). A concerted global effort is needed to improve monitoring of inland water ecosystems in which field validation of changes in plant species composition, degradation and transformation must complement and support remote sensing products generated from various platforms at various scales. Improving the mapping of more inland water types, will furthermore refine the reporting of the integrity of inland water ecosystems, better inform spatial planning, and improve monitoring.

In addition to global monitoring of inland water biodiversity, there is an urgent need to identify and sample biodiversity hot spots and regions that are experiencing rapid or pervasive change, such as polar habitats, where the gain in diversity resulting from geographic range expansion of temperate species is predicted to result in a loss of the unique diversity adapted to these extreme environments (Heino et al. 2020). Ongoing efforts to promote coordinated monitoring and assessment as part of the Arctic Council's Conservation of Flora and Fauna working group represents steps towards filling data and monitoring gaps in that region. The Circumpolar Biodiversity Monitoring Program's Freshwater group completed the first circumpolar-scale assessment of status and trends in freshwater biodiversity through the compilation, harmonisation, and analysis of existing data from all Arctic countries (Lento et al. 2019, Goedkoop et al. 2022). The framework and approach developed for that program can be used for similar large-scale assessments in other biomes and contribute to a fully global biodiversity observation system for Inland waters under GBiOS.

Measuring population trends of inland water species

Milestone A.2 The increase in the extinction rate is halted or reversed, and the extinction risk is reduced by at least 10 per cent, with a decrease in the proportion of species that are threatened, and the abundance and distribution of populations of species is enhanced or at least maintained (CBD 2021).

The Living Planet Index (LPI) is a measure of the state of the world's biological diversity based on population trends of species globally, including those from inland water ecosystems. Only vertebrate species are used in calculating the LPI (WWF 2022) - among them migratory fishes as well as wetland-dependent species (Westveer et al. 2022). This, in addition to a large proportion of the datasets being from the global north, leads to a biased perspective of decline. Invertebrates are abundant, functionally diverse, and are representative of a large variety of ecosystem types and habitats, including those where no fishes or amphibians occur (Collier et al. 2016). Invertebrates, phytoplankton, amphibians, and aquatic plants are used globally in biodiversity monitoring and ecosystem health assessments, and data on their changing abundances could be easily integrated into the LPI calculations

The Red List Index (RLI; Butchart et al. 2007) – used to show trends in extinction risk for species, and to track governments' progress towards targets for reducing biodiversity loss – is more comprehensive than the LPI, in that it includes vertebrates, invertebrates and plants. However, there are major differences in the geographic and taxonomic coverage. Like the LPI, the RLI is biased towards well monitored species. Global Red List assessments cover freshwater decapod crustaceans (crabs, crayfishes, shrimps) and odonates (dragonflies and damselflies), and the assessment for fish is due to be completed in 2023. Only 50% of all known freshwater molluscs have been assessed so far, as have few of the aquatic insects; aquatic plants are not well covered (3,600 assessments), with aquatic fungi (4 species) even less so. The recently established Ephemeroptera, Plecoptera and Trichoptera (EPT) Specialist Group aims to close the gap on assessments for aquatic insects such as mayflies, stoneflies and caddisflies. Plans are underway for the establishment of a Freshwater Fungi Specialist Group. Although there are a significant number of IUCN Specialist Groups, they often lack adequate funding to undertake assessments, particularly assessments of under-represented groups (Bachmann et al. 2019). There is a need for dedicated resources and attention to expand species assessments to strengthen the representation of freshwater biodiversity in the IUCN Red List and to support assessments in trends, threats, and conservation potential of these species, as well as the identification of Key Biodiversity Areas for inland waters. Re-assessments are also urgently required as at least two comprehensive assessments for a taxonomic group are needed to calculate a Red List Index over time.

Mobilization of biodiversity data from inland waters

Indicators in the monitoring framework for the post-2020 GBF should meet the criterion "The data and metadata related to the indicator are publicly available." (CBD 2022b). Although a variety of biodiversity data portals exist (Schmidt-Kloiber & De Wever 2018), freshwater biodiversity information can be challenging to locate. To get an overview on data sources, the establishment of a comprehensive compilation of freshwater biodiversity data outlets that also include data types other than occurrence data (e.g., remote sensing, environmental DNA (eDNA) data) is essential (Maasri et al. 2021). In terms of extracting species data from existing biodiversity data portals, a reliable taxonomy with clear tagging of freshwater and freshwater-dependent species – like, e.g., that provided by the Freshwater Animal Diversity Assessment (FADA, Balian et al. 2007) – is necessary.

Although most estuarine and freshwater monitoring initiatives are publicly funded, the data generated are often difficult to obtain, mainly because they are hosted on a variety of different (emerging) data portals or on institutional or personal systems (Schmidt-Kloiber et al. 2019). Generally, the adherence to the FAIR data principles (*findable, accessible, inter- operable*, and *reusable*) as well as institutional

Open Data policies are often missing (De Wever et al. 2012). Inconsistent reporting practices among institutions further impede the use of data from multiple sources, necessitating the application of international data standards (e.g., Darwin Core; Wieczorek et al. 2012) to harmonise data. Moreover, data may not be accompanied by sufficient metadata (e.g., methodological information, habitat conditions, used taxonomy) thereby constraining broad-scale comparability (Wetzel et al. 2018, Nicholson et al. 2020). Guidelines such as the recently published one on how to produce DarwinCore MOTU occurrence datasets from eDNA sampling (Nilsson et al. 2022) could show the way forward and allow for greater taxonomic coverage of biodiversity data. A concerted and funded effort to mobilise, digitise, and harmonise existing data is essential. This approach needs to include actors spanning from policy makers to members of local community groups or citizen scientists (Twardek et al. 2021). Data collection must be implemented in national/regional policies with required open access data publishing following international standards.

There are some inland water focussed initiatives, such as the Freshwater Information Platform (FIP), the South African Freshwater Biodiversity Information System (FBIS) and the Freshwater Network on GBIF that provide data on freshwater biodiversity that goes beyond occurrence data. FBIS is a powerful platform for hosting, searching, visualising, downloading and publishing freshwater biodiversity data (Dallas et al. 2022) that, in combination with the various FIP tools (Schmidt-Kloiber et al. 2019), could overcome current gaps and challenges, if globally endorsed and supported.

Measuring within species genetic variation of inland water species

Milestone A.3 Genetic diversity of wild and domesticated species is safeguarded, with an increase in the proportion of species that have at least 90 per cent of their genetic diversity maintained (CDB 2021).

Inland water ecosystems encompass diverse topographies, with numerous unique physical, chemical, and environmental characteristics. Isolated populations in ponds or lakes can drive genetic diversity, adaptation and cryptic species (Hoban et al. 2022). Genetically unique populations can be of conservation concern because they may be vulnerable to human impacts or rapid environmental changes, with Milestone A.3 of the GBF targeting maintenance of at least 90% of intraspecific genetic diversity.

When assessing intraspecific (within species) genetic diversity and the genetic composition of populations for conservation actions, the application of standardized metrics (e.g., EBVs) can help to allow for comparisons across time and space (Hoban et al. 2022). To monitor ecosystem health and undertake timely conservation action, it is important to prioritize species at risk of decline or extinction (e.g., IUCN Red Listed species) and flagship, priority or indicator taxa (e.g., sport fishing targets or those supporting major fisheries). However, deciding which populations warrant priority for genetic evaluation can be challenging as many freshwater species are threatened and basic genetic information on most of them is lacking, although some guidance on this process has been proposed recently (Hvilsom et al. 2022).

For assessment within and between populations, genome-wide markers such as RADseq (Garrison et al. 2021) or genome skimming (Dalapicolla et al. 2021) are highly sensitive and accurate. In cases where molecular data are not available or too costly to collect, indicators such as estimates of effective population size (Ne) or numbers of assessed populations can be applied without the need for DNA data (Hoban et al. 2022). For producing baseline data and monitoring environmental DNA (eDNA) metabarcoding is a rapid and cost effective approach (Wu et al. 2022) for community composition, range distribution and intraspecific genetic diversity (Skelton et al. 2022). However, poor reference datasets (Jackman et al. 2021) or low species discriminatory power of some molecular markers for recently diverged taxa (Shu et al. 2021) may limit usefulness in specific circumstances, requiring adherence to adequate metadata standards.

Citizen science and Indigenous Knowledge

Effective monitoring conservation, and ecological restoration of the biodiversity of inland waters must include the variety of observation and knowledge systems that exist, and find a way to build stronger collaborations by bridging knowledge systems to enhance our understanding of biological diversity (Tengö et al. 2017). For example, citizen science initiatives have the potential to fill spatial and temporal monitoring gaps and contribute to more robust estimates of inland water biodiversity (Metcalfe et al. 2022). Globally, citizen scientists have contributed to monitoring of water quality, freshwater biodiversity, endangered and invasive species, and ecosystem change (Van Rees et al. 2021, Metcalfe et al. 2022, Premke et al. 2022). Their contributions may range from recorded observations or collection of samples to co-development of monitoring programs (Metcalfe et al. 2022), as well as support for the IUCN Red List assessments (Böhm et al. 2022). However, it is necessary to recognize the ways in which citizen science data differ from institution-led monitoring initiatives and ensure that data are used in a way that is effective and that recognizes their value as different from and complementary to other monitoring data (Metcalfe et al. 2022).

Recently, there has been increased emphasis on the need to consider Indigenous science and Indigenous Knowledge (IK) in assessments of freshwater biodiversity and ecological change, but progress on understanding the role of Indigenous science and IK in such assessments is still being made. Researchers and policy makers must understand that the knowledge systems and worldviews under IK should not be integrated or assimilated into Western science (Tengö et al. 2017, Henri et al. 2021). Rather, effort must be placed on developing approaches to bridge these knowledge systems by recognizing that they each hold equal value, and identifying commonalities between them while preserving the differences that define them (Tengö et al. 2017, Reid et al. 2021, Langhans & Schallenberg 2021). Such approaches do not seek to change or adapt one knowledge system to align with the other, but instead highlight the complementary nature of both ways of knowing while recognizing the unique contributions from each (Tengö et al. 2017, Reid et al. 2021).

Monitoring to support national and international policy on biodiversity cannot be conducted without the involvement and leadership of Indigenous Peoples, including through Indigenous-led efforts and the use of Indigenous methodologies (Tengö et al. 2017) as has been advocated for Arctic fresh waters (Heino et al. 2020). There is a long history of so-called "helicopter research", whereby researchers conduct their studies with little to no collaboration, outreach, interaction, or relationship building with Indigenous and Local Communities (Haelewaters et al. 2021). In contrast, monitoring programs developed through co-production with Indigenous and Local Communities are based on a foundation of respect, engagement, and co-development of questions and approaches that are locally relevant (Cooke et al. 2021). Furthermore, Indigenous-led programs and programs that integrate Indigenous methodologies have been shown to offer holistic and transdisciplinary approaches to addressing research questions (Moewaka Barnes et al. 2021), and to act as a tool to support Indigenous governance and facilitate engagement in decision making (Wilson et al. 2018). Support for the co-production of freshwater biodiversity monitoring and conservation efforts will result in greater engagement of Indigenous communities, more relevant monitoring questions, and a more holistic understanding of biodiversity issues.

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