

CHAPTER 1

Declining Freshwater Biodiversity: Causes, Concerns & Protective Actions

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Abstract

Biodiversity is at risk globally. Anthropogenic and different factors owing to changing climatic conditions are continuously threatening and triggering this pathway of extinction. As per Red List (IUCN), almost 1/3rd of various freshwater species is threatened and near about 80 or more species have been linked to extinction. The year of 2020 is entitled as “Black year for freshwater fish” (IUCN version 2020). The UNESCO have validated different scientific claims of more sensitivity of aquatic organisms to changing environmental conditions; hence greater severity of freshwater ecosystem compared to terrestrial and marine ecosystems is an alarming concern. The year 2020 held the Convention on Biological Diversity conference and it significantly recommended an Emergency Recovery Plan to bend the freshwater biodiversity curve. The severity has reached every corner of the globe and meltdown of arctic water bodies has raised serious concerns in recent pasts. The biodiversity of freshwater species decreases with latitudinal rise and longitudinally biodiversity is reported to be greater at the unglaciated region. Greater challenges are imposed in analysing the temporal trend in these regions because of restrictions in time line and fewer monitoring sites. Howsoever it is evident that freshwater fishes are colonizing northward along river corridors & biodiversity “hotspots” have become notable. Several global initiatives are at work and work map of restoration is chalked out. It is important that much integrated approach involving people of all sectors joins the RACE (Reshape, Appreciate, Connect and Elevate) strategies of restoring the biodiversity.

Keywords: Freshwater, Fish, Biodiversity, Extinct, Arctic, IUCN

Introduction

Biological Diversity is the basis of nature’s balance. Biodiversity represents the rich variety of life in every ecosystem on earth. Biological diversity (or biodiversity for short) has been long back very well defined by

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Convention on Biological Diversity, Rio, 1992 as “the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.” Biodiversity is continuously degrading and an international team of experts under the Millennium Ecosystem Assessment – MEA (2005) investigated several parameters and areas that led them to conclude that “Human actions are fundamentally, and to a significant extent irreversibly changing the diversity of life on Earth eventually triggering the loss of biodiversity. Changes in important components of biological diversity were more rapid in the past 50 years than at any time in human history”. The report very well summarised the important aspects like reduced conversion ratio of different ecosystems owing to habitat loss; declining population size (or range) of a varied taxonomic group; homogeneous distribution of species subjective of regional losses of taxa and alien introductions; and increased extinction threat for higher taxonomic groups (cycads, conifers, lower and higher invertebrates). The Genetic diversity has also been noted to be declining particularly among domesticated species.

Biodiversity and Mankind: A long association

The biodiversity has always influenced mankind through different ways; few major services being crops & livestock’s supply, biochemical & natural medicines, different regulatory services, being a repertoire of cultural/aesthetics/spiritual/educational services and as important supporting system pertaining to their involvement in soil formation, cycling of nutrients, water and by influencing primary production. Hence any alterations in biodiversity have substantial impact on social and economic consequences owing to degrading ecological services (Charles & Dukes, 2007).

Though natural causes have been implicated to degrading biodiversity and ecosystem changes, the anthropogenic activities largely contributes to current degradation like increasing consumption of ecosystem services *viz.*, growing usage of fossil fuels because of rising population and per capita consumption, changing river conditions as a consequence of water withdrawal and building of dams, loss of coral reefs & damage to sea floors, overexploitation, pollution and many more (Gora *et al.*, 2023). With different driving forces in action, the loss of biodiversity and critical impact on ecosystems’ services would be accelerated and worsened in next few decades (Walter Reid, Director of the Millennium Ecosystem Assessment, May 18, 2005, and United Nations, New York, USA).

Regulatory actions to restore biodiversity and ecosystem

Global biodiversity crisis have been a major topic of consideration for the scientific community and several conservation initiatives have taken place like Ramsar Convention in 1971, the World Heritage Convention of 1972, the Convention on Migratory species (Bonn Convention) held in the year 1979, the famous Convention on Biological Diversity (CBD) of 1992 followed by various national and international legislations (Laladhas *et al.*, 2022). The year 2002 is landmarked for the World Summit on Sustainable Development. The leaders across the globe met in Johannesburg to accelerate the worldwide efforts on conservation and restoration & decided to work for “significant reduction in the current rate of loss of biodiversity”. They targeted to achieve this by the year 2010. This meet was an endorsement of the earlier Ministerial Declaration of 6th Conference of CBD held on 14th April, 2002 (Stroud *et al.*, 2023).

As per the MEA 2005, different goals & targets of biodiversity restoration & conservation can be accomplished only if sustainable use of biodiversity gets integrated with the sectorial economic development *viz.*, forestry, agriculture, coral zone management. The conservation and restoration of ecosystem and biodiversity needs a wider and inclusive approach involving personal, professional and group efforts from government/non-government organisations, business communities, local bodies, tribes and communities.

The Decade on Biodiversity, 2011-2020 (as declared by United Nations) ended with various reviews compiling the views of important conservation associations – CBD, SDGs (Sustainable Development Goals), UNFCCC (UN Framework Convention on Climate Change). The mission was further extended to “Halt the loss of species, ecosystems and genetic diversity by 2030”. The grand mission was further targeted to recover

biodiversity and ensure a world of people “living in harmony with nature” by 2050. This is the declared decade of Ecosystem Restoration (2021-30, (UN DER, 2021-2030) and the scientific community have already assigned a new epoch period “Anthropocene” owing to the much needed repair of the damaged planet we are living in. The different ecosystems are damaged to various extent, the severity are utmost in freshwater ecosystems (Harrison 2021).

Freshwater Ecosystem

The planet Earth needs water for sustained life and survival of its inhabitants. However, this water is in rare supply and is restricted to certain places. Almost 3 % of the planet is freshwater and lesser than half of it flows as liquid which is available for consumption. A major fraction of that is solidified as ice in the glaciers and polar caps, implying the preciousness of this resource. The freshwater biodiversity loss and thereby ecosystems’ restoration is hence a global crisis (Sathya *et al.*, 2023). Howsoever the initiatives have to begin from local & regional level. Hence the ground practitioners of a localised area followed by community formation of similar thinking individuals and organisations, knowledge disseminators, restoration practitioners, policy makers etc. are integral to work in a unified way for achievement of the target. Much needed is network building for sharing different conservational and restoration stories (success as well as failures) of the vivid practitioners for a better designing of the approach to accomplish the goals (Bennett, 2004). The UN-DER website displays many such stories and the peer-reviewed journals have always been a big repertoire of information and instances.

A. Importance of freshwater ecosystem: This is an immensely versatile ecosystem that includes lakes, rivers, streams, wetlands, underground aquifers. These aquatic systems are essential for the planet and its inhabitants. The freshwater biomes cover only 0.01% of total earth’s surfaces but are the supplier system of essential requisites for mankind and livelihood. The freshwater ecosystem is reported to be the habitat for a third of vertebrates including 40 % of fishes. As per IUCN Red List (2022), 1/3rd of freshwater species are threatened with extinctions and they comprise of turtles (58.5 %), fishes (21.7 %), crayfish (30 %), mammals (37.3 %) and 29.9 % of amphibians. They influence forests, mountains, marine realms and various coastal zones. Hence they are the primary support for terrestrial and marine ecosystems and are indispensable for sustainable development and well-being of all. The freshwater biodiversity is highly valued and they support an array of ecosystem services including material, non-material and regulatory services (Bon *et al.*, 2022).

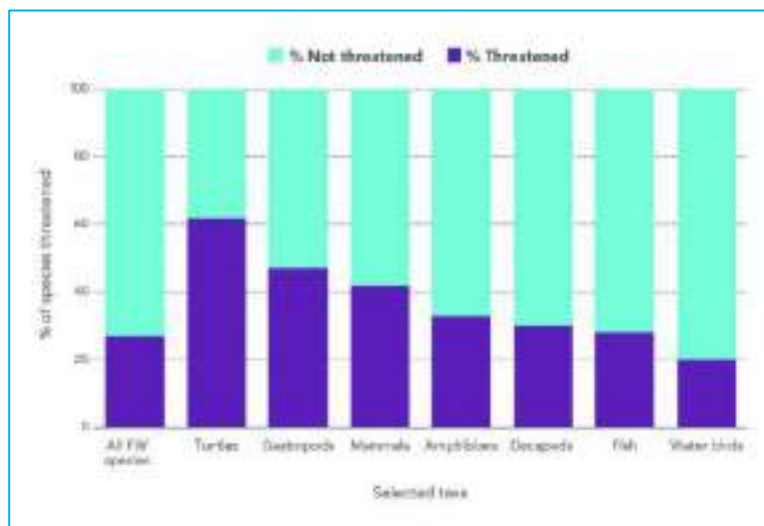


Figure 1: Percentage of freshwater species threatened with extinction at the global level. (Image Source: WWF, 2020)

Different freshwater realms naturally exchanges resources between the habitats. The rivers and streams carries salts & nutrients from the mountains and distribute it to the ponds, lakes and wetlands situated at lower

elevations and finally to oceans. Through waterways different species set their route of migration and eventually channelizes the nutrients from oceans to upstream freshwater ecosystem. Lentic ecosystems like ponds, lakes exchange nutrients seasonally. In a cyclic fashion, cold water sinks to the bottom for being denser than warm water. With the declining temperature as winter arrives, the temperature of surface water reduces than that of the bottom causing it to undergo the cycle again. The same process repeats when the floating surface ice melts in the spring. The nutrients gets churned from the floor and brought back to the surface. This normal nutrition cycling is integral to the healthy condition of the aquatic ecosystems (Rose *et al.*, 2023).

B. Severity of freshwater ecosystem: The aquatic ecosystems are the final receiver from any trophic level. Hence any alterations anywhere ultimately reaches the water bodies. A third of inland wetlands worldwide have declined as recorded from 1970 till the year 2015 which is approximately three times faster than forest loss (Convention on Wetlands, 2021). The free flowing rivers have decreased. Overall, the WWF 2020 data suggests around sharp decline (~84%) in the Living Planet Index for freshwater vertebrates; twice the biodiversity reduction rate in terrestrial and marine ecosystems (Bernhardt *et al.*, 2022).



Figure 2: The ecosystem services dependent on freshwater’s biodiversity (Lynch *et al.*, 2023)

Freshwater ecosystems are important biodiversity hotspots. In the earlier part of the text, the IUCN Red List of freshwater species was discussed. To further add to this, it is important to mention that freshwater species make up almost 9.5 % of fauna on Earth. Living Planet Report, 2016 described the population trend and showed that freshwater species declined 3.9 % annually since 1970 which as described earlier is greater than the declining rate of species on land. A major fraction of the analysis is 'data deficient' (DD) implying insufficient data for analysing abundance, distribution & assessing conservation.

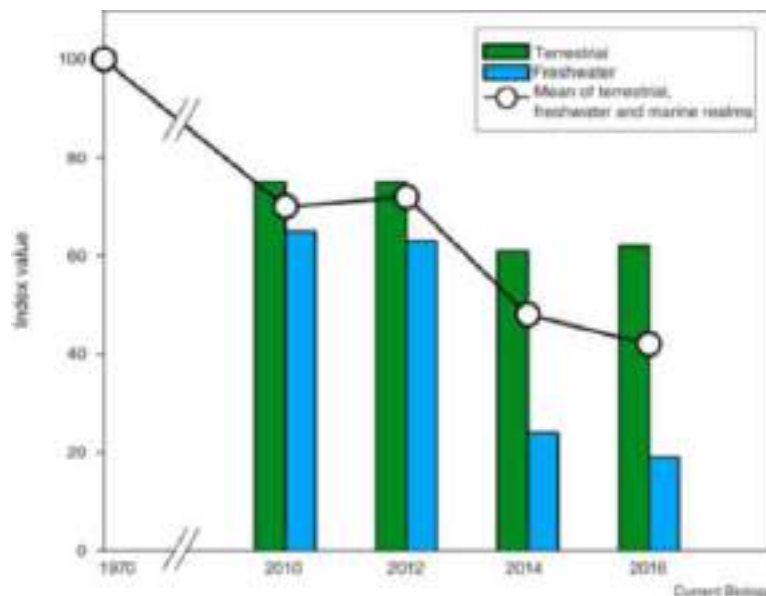


Figure 3: The WWF Living Planet Index data depicting population trend in different realms (Dudgeon, 2019)

C. Threats to freshwater biodiversity: Encountering changes and alterations for ecosystems are not unusual. Fluctuating temperature, changing population statistics, altered water levels of the aquatic bodies are common observations in nature. The water residents have adaptations allowing them to adjust till the normal conditions are restored. The balance system fails to work during acute disturbance.

The anthropogenic factors are several that are leading to the loss and deterioration of biodiversity including those of habitats, river fragmentation, modification of flowing path, pollution, overexploitation, introduction of invasive species, salinization of water etc. (Dudgeon, 2019).

Brief descriptions of important factors are as follows:

- i. **Altered flow conditions:** Construction of hydrothermal projects severely disrupts the normal flowing direction of the water hence interfering with the biota of the area. This also creates obstruction to the normal movement of animals' especially migratory species and interferes with the dissolved nutrients levels *viz.*, organic carbon, sediments etc. The riverine section gets transformed into a reservoir above the dam. This results into reduced sediment flux back to the oceans. A major volume of the river's volume is severely impacted because of the altered flowing path and/or fragmentation. Increasing usage of water for irrigation and various other needs owing to higher population trend are the constraints leading to reduced down flows and at times dewatering and dry river banks.
- ii. **Pollution:** The origin and form of this is various. So are its consequences. A wide range of contaminants & pollutants originating from power stations, mines, agricultural land, factories, oily products from roads & impermeable surfaces, pharmaceutical and livestock wastage, micro & macro plastic, landfill seepage and others are deleterious with effects being lethal or sub-lethal. The steep increment in pollution because of urbanization and rigorous livestock farming are serious threats with solutions unknown.

- iii. **Land-use change in drainage basins:** Soil erosion and sedimentation of lakes and rivers are notable changes in last few decades and are increasing at an alarming rate because of removal of vegetable leading to increased run-off. Replacing vegetation with plants are leading to run-offs (both surface & sub-surface), introduction of organic matter, variation in shading and water temperature as the replaceable plants often have been found to have different water requirements. Often the run-offs from agricultural land have greater impacts as they end up fortifying the water bodies with agrochemicals and excessive nutrients leading to eutrophication.
- iv. **Overexploitation:** The earth and its reservoirs were bestowed with biological resources. But overexploitation like exhaustive fishing practices using electricity, poison, fine meshed net are threatening. Overfishing, foul play with crocodile hideouts, turtle shells & their body parts, declining amphibian numbers for increased usage as food material, disturbing the eggs and nestlings of colonial birds are hampering the water quality, quantity and altering the food web critically.
- v. **Invasive species:** The introduction of invasive species has been reported from several habitats. In the freshwater ecosystem, the scenario is not very different. The invasive species increases competition and makes the existing conditions tough for the native species. Besides, the invasive species introduces new diseases and in certain situations often acts as pathogen themselves. Hybridization is another severity reported in many situations that arises when the alien and native species are evolutionary closer to each other.
- vi. **Global Climate Change:** The impact of changing climatic conditions is notable and the adversities are evident at the genetic level. The rainfall patterns have changed, glaciers meltdown is prominent and extreme events like cyclones are more frequent. Most of the ecological processes related to freshwater ecosystem are altered. With the increased riverine temperature, the different water-dwelling species are facing difficulties. Several species have been reported to be extinct and many are dispersing towards cooler habitats of higher altitudes.

The increasing biodiversity of fish species in Northeast Atlantic and the Arctic Ocean have increased in last three decades. It is a matter of great worry as the modelling studies have reported increased species arrivals from lower altitudes and local disturbances prevailing due to global warming (Cesc Gordo-Vilaseca, 2023).

The figure below is a representation of important threats to freshwater ecosystem.

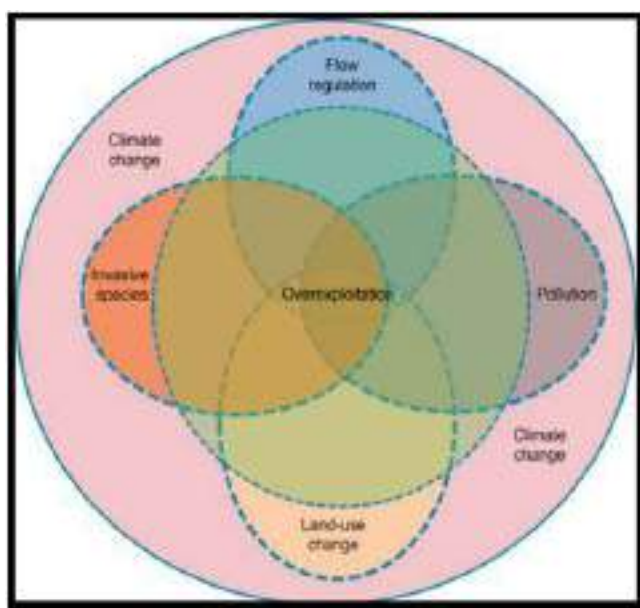


Figure 4: The potential threats to freshwater ecosystem (Dudgeon, 2019)

Recovery Plan: Agenda, Accomplishment & Challenges

The year 2020 was a pivotal year related to the future of Earth's biodiversity. In November, the world's government met at the Convention on Biological Diversity (CBD) conference to conserve and restore freshwater biodiversity. Considering the severity and urgency of the situation, global framework with guided policy was a necessity. The Emergency Recovery Plan was an attempt to reverse the rapid worldwide decline in freshwater biodiversity. It was quite similar to the concept of species recovery plans of US Endangered Species Act 1973 and the Australian Environment Protection and Biodiversity Conservation Act 1999 held earlier. The plan was proposed with 6 priority actions:

- I. Accelerated implementation of environmental flows: Some of the actions taken were as follows:
 - River basin planning – Different legislative measures are being incorporated involving legally mandated management agencies targeting environmental flows. Ex- Crocodile River in South Africa.
 - Water allocation – Initiatives for water reserves aiming to water allocation across the country is an important measure for sustainability in environmental flows. Mexico has set an example in this regard with the initiative of allocating 189 rivers across the country.
 - Infrastructure design and operation – Every operation has integrated the framework of benefitting downstream fisheries as evidenced from Three Gorges Dam of China.

- II. Improved water quality: The work areas were many and some highlighted here are as follows:
 - Waste water treatment - The Urban Waste Water Treatment Directive of European Union has established ways to reduce sewage pollution.
 - Regulation of polluting industries – There are instances that have shown restoration of aquatic life and cleaning up of the water bodies through removal and relocation of pollution sources, boosting business and residential development at the same time. An instance of Singapore waterfront typically sets this example where industries and different farms were removed and relocated establishing clean waterfront.
 - Market instruments – Strategies have been employed relating to nitrogen reducing practices. Example being that of Lake Taupo in New Zealand where catchment scale nitrogen caps were combined with farm based permits and trading; thus dealing with persistent diffusion problems in pastoral agriculture.

- III. Improved agricultural practices - Better management practices are integral to reduction in fertilizers and pesticides usage thus preventing them to reach different water sources.
 - The sugarcane and cotton farms of India & Pakistan have largely employed these strategies to bring out the desired outcome as evidenced from global platforms like Better Cotton and Bonsucro.
 - Practices of Nature-based solutions as exemplified by China is worth appreciating. Restoration of floodplain lakes along the central Yangtze significantly improved water quality with enhanced fisheries and floodplain biodiversity.

- IV. Protect and restore critical habitats – Conservation of the natural habitats are integral to conservation of species. Some of these effective actions are as follows:
 - Protected areas – The Government in many countries are taking strict measures for protecting the designated area. Gazettement is integral for effective implementations. Colombian government has set an example in this regard by protecting an important Ramsar Site. They have restored the free flowing of Bitá River (a sub river basin of Orinoco). It's a rare example showing restoration of mega area (~825,000 hectares) through an international designation.
 - Land-use planning or markets for ecosystem service – Judicious planning, management and execution can effectively restore ecosystem processes. The Catskills-Delaware Watersheds have safeguarded urban

water supplies. This cost effective system was an initiative of New York City Watershed Agreement and it has set an example globally to establish the changes.

- Habitat restoration – Wetlands are important habitats and their restoration are effective strategies for conservation of biodiversity. International agreement by representatives from Romania, Ukraine, Moldova and Bulgaria could restore around 60,000 hectares of floodplain wetlands along River Danube. This has set an extraordinary example of international agreement to bring effective restoration.

V. Manage exploitation of species and riverine aggregates: Priority actions were many and few are listed as follows:

- Science-based fisheries management – The legislative measures have already enshrined ecosystem's approach to the management of fisheries. An East African country, Malawi has already been into this since 1990. These efforts have integrated co-management with fishery management as exemplified by sustainable harvest of high valuing Chambo fish, an *Oreochromis* sp. with the breeding or nursery sanctuaries for commercial species.
- Community fisheries management – The Oxbow lake on the River Jurua, have undergone community protection and management of its resources that have resulted several fold increase in population size of *Arapaima gigas* fish. Hence, these community based management can induce rapid recovery of different endangered population.
- Bycatch reduction – Some of the conservation strategies modulates the by-catchment of species. The closures were used in a different combination as well as variations in traps were practiced to prevent the catching of platypus within commercial carp and eel fishery zone in the New South Wales of Australia.
- Reducing aggregates demand – The wastes can be recycled or used as an aggregate substitute, hence suggesting effective management of resources. Around ninety percent of wastes are recycled by Germany. India stood as an example by employing non-toxic municipal waste as an aggregate substitute for road construction.

VI. Prevent & control non-native species invasion: Some of the effective measures are as follows:

- Identification and control of introduction pathways – Using varied combination strategies like prohibition of live fish transport, using electrical barrier and scientific risk assessment, invasion of non-native carp species were significantly prevented in the Great Lakes of United States and Canada.
- Control and eradication of established invasive non-native species – Effective management measures can be implemented by interfering with spread of non-native species. The weed, *Mimosa pigra* (a native of tropical America) was introduced with the objective of ornamental curiosity. However its invasiveness and spreading potentiality suggested important environmental impacts in Australia and measures were taken to work for zero tolerance towards the weed in Kakadu National Park of Australia. .

VII. Safeguard and restore freshwater connectivity: Some of the important actions are as follows:

- System-scale infrastructure planning – Myanmar has established that environmental assessment strategies can bring out important outcomes. The assessment recommended no hydropower dams on the mainstream of major river basins, hence proposing a “Sustainable Development Framework” for hydropower projects. These initiatives have kept the main streams of Salween and Irrawady River free flowing. It has set an example for conservation of riverine network with high biodiversity values and safeguarding of local communities dependent on them.
- Dam reoperation and removal – The River Penobscot of United States have undergone strategic removal of dams and several reoperations of around 1500 kms that has boosted the population of migratory fish species keeping the electricity generation capacity unaltered.

- Levee repositioning – The Dutch Government introduced “Room for the River Program” in 2007 aiming to manage higher water level of the rivers by modulating different factors leading to this. The project improved environmental quality of the entire riverine framework by allocating extra rooms for the River for coping up with large sudden discharges during climate changes. The measures involved creating water buffers, increasing the depth of side channels, relocation of levees, construction of flood bypasses, lowering the levels of flood plains etc. The Rhine river of Netherlands along with Ijssel, Meuse and Waal have shown significant improvement in conditions as a result of these conservation strategies.

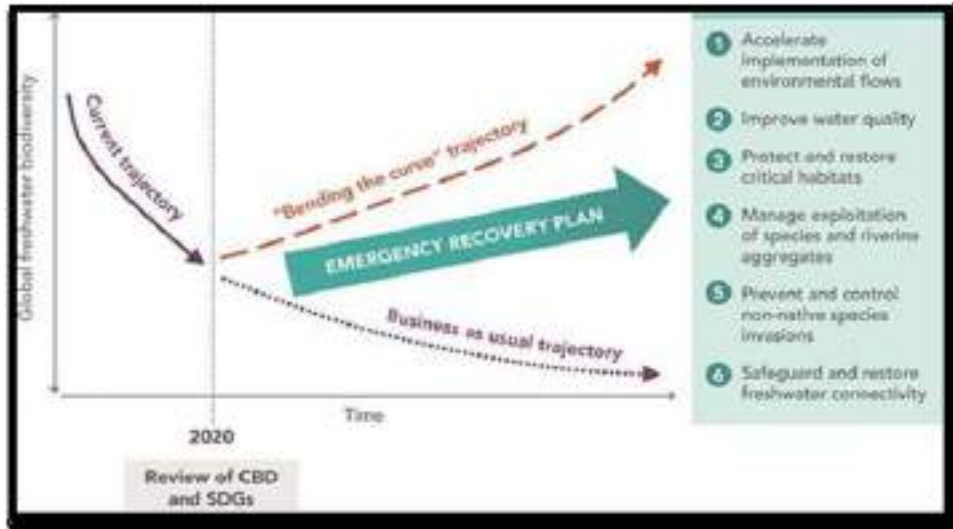


Figure 5: The Emergency Recovery Plan for freshwater biodiversity: Six priority plans for global action to bend the curve of freshwater biodiversity loss (Tickner *et al.*, 2020).

In spite of the different global moves to integrate different objectives in the SDGs, freshwater ecosystem health is affected and still under-represented. Freshwater biodiversity has received lesser attention and consideration. The funding’s for freshwater biodiversity conservation and the publication of findings are relatively less. The figure 6 summarises the number of publications for freshwater, marine and terrestrial ecosystem under the category of “Biodiversity & Conservation” of Web of Science. It clearly reveals from the search performed dated January 23, 2022 that data, details & studies focused on freshwater ecosystem are fewer. The recognition for freshwater ecosystem is compromised and so are the global initiatives.

Number of peer-reviewed publications within the Biodiversity & Conservation category of the Web of Science Core Collection for freshwater, marine and terrestrial ecosystems. Search performed on January 23, 2022.

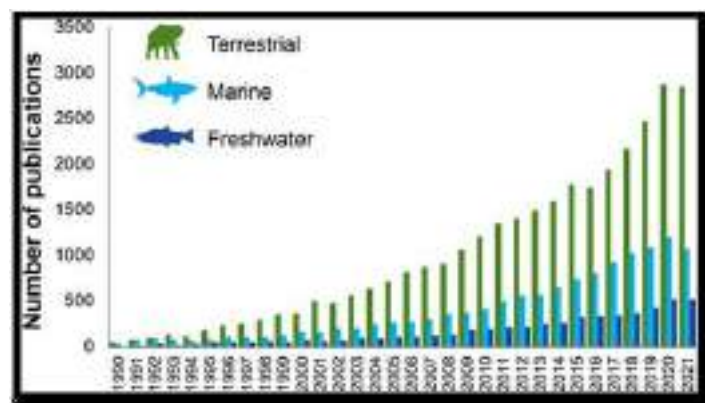


Figure 6: Statistics of peer-reviewed publications of freshwater, terrestrial and marine ecosystem (Gauvin *et al.*, 2023)

Freshwater ecosystems and its biodiversity are versatile and they are beneficial to mankind. However, their status is certainly in danger. Time is changing and so our perception for this particular ecosystem. The RACE framework is in progress with the potential to execute the change. It is important that we realise the urgency and in every move we inculcate the practice of valuing, protecting and conserving the freshwater biodiversity.



Figure 7: The attempt to restore freshwater biodiversity (RACE, Gauvin *et al.*, 2023)

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