Chapter 2
Declining Freshwater Species Biodiversity

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ABSTRACT

Freshwater is a precious resource that is essential for human survival and liquid surface freshwater accounts for just 0.2% of total volume of water on Earth. Wetlands, which are home to one of the most biodiverse species of plants and animals, account for just 6.4% of the earth's surface. On a global scale, the wetlands and freshwater ecosystems are under pressure and are seeing declining species diversity. Freshwater biodiversity has not been part of the ongoing mainstream conservation efforts and has been largely ignored. This is in part due to invasive human activities, pollution, climate change, deforestation, habitat destruction and degradation, the introduction of alien competing species, and excessive consumption. This chapter gives a broad overview of the current scenario of declining freshwater species biodiversity and threats to vulnerable aquatic ecosystems. Delineation of biodiversity hotspots, adoption of a proactive approach, and focused conservation efforts towards freshwater ecosystems are some of the suggested remedial measures to address this global problem.

DOI: 10.4018/978-1-6684-9034-1.ch002

NEED FOR CONSERVATION OF FRESHWATER ECOSYSTEMS

Fresh water ecosystems are one of the most productive ecosystems in the world and home to an estimated 1,26,000 species of plants and animals. Freshwater is a precious resource that is essential for human survival that accounts for just 2.3% percentage of total planetary water, remaining quantity is saline or locked up as ice and glaciers unusable from a human perspective. Wetlands which are the home to one of the most biodiverse species of plants and animals account for just 6.4% of area of the earth (Rawat et al., 2015).

Freshwater is a rare and precious natural resource, forming constituting a small fraction, about 1 / 1,00,000th of total water of this planet. As the population continues to grow the global demand for freshwater is expected to increase exponentially. This demand for fresh water is expected to overtake supply by 2030 leading to severe water Scarcity (Harrington & Fisher, 2014).

This chapter gives a broad overview of current scenario of declining freshwater species biodiversity and threats to the vulnerable aquatic ecosystems. Delineation and conservation of Biodiversity hotspots, adoption of a proactive approach, focussed and concerted conservation efforts towards freshwater ecosystems, are some of the suggested remedial measures to address this global problem. Many freshwater bodies like rivers span many countries which means that disease or extinction can rapidly spread across many countries via waterbodies. Many species of freshwater amphibians, reptiles and crustaceans are also under threat of extinction. Riverine species of plants and animal seem to be most susceptible to human activities, followed by marsh and lake species (Harvey, 2013).

DECLINING FRESHWATER BIODIVERSITY

According to the available study findings, freshwater biodiversity is in serious trouble and is declining far more rapidly than the most severely impacted terrestrial ecosystems. On a global scale the wetlands and freshwater ecosystems are under pressure and are seeing declining species diversity with one-third of species threatened with extinction globally, according to some estimates. Fresh water biodiversity has not been part of the ongoing mainstream conservation efforts and has been largely ignored by conservationists (Belgrano et al., 2015).

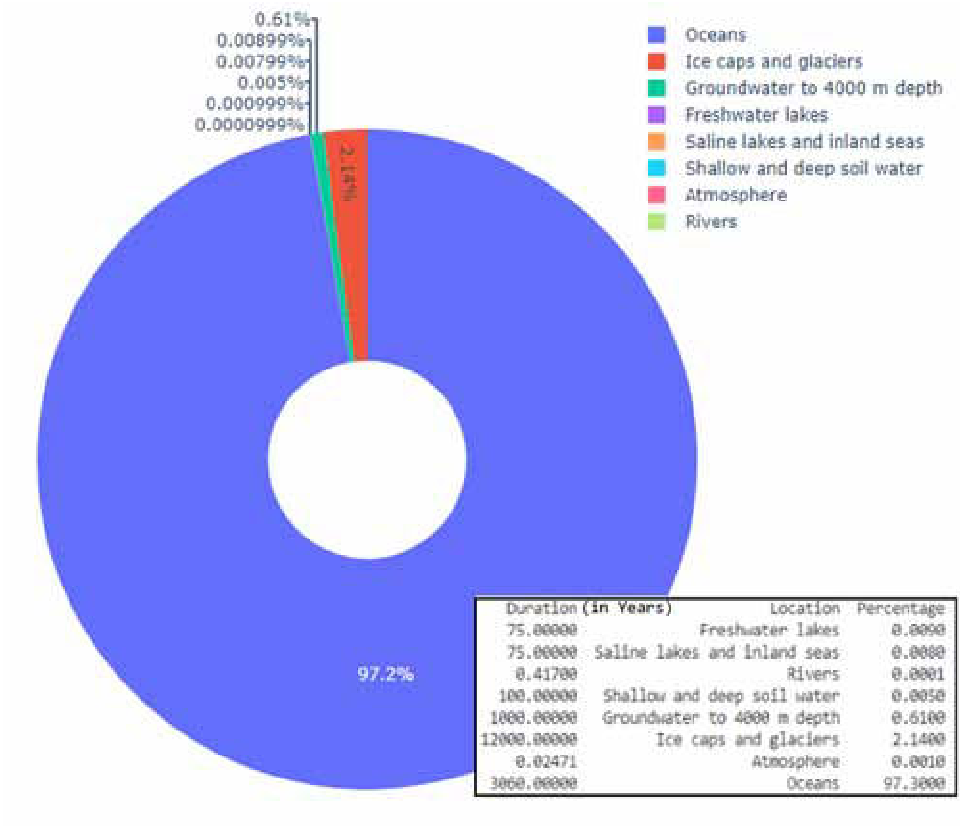
Freshwater ecosystems are among the most endangered on the planet and are experiencing biodiversity losses on a par with or even larger than those of terrestrial systems. With around one-third of the 28,000 freshwater species examined for the International Union for Conservation of Nature (IUCN) Red List threatened with extinction, the global loss of freshwater species continues unabated. There are now

25% more extinct fish species in North America than there were in 1989, and up to 86 more species could become extinct by 2050. The loss of habitat, overfishing, invasive species, pollution, and hydrological changes are all blamed for the decline in freshwater biodiversity (Eldredge, 2002).

The given research findings show a worrying decline in freshwater biodiversity. Compared to terrestrial and marine environments, freshwater ecosystems have larger proportions of extinct and threatened species, with populations of vertebrates declining by 83% between 1970 and 2018. With just 2.3% of the Earth's surface is covered by freshwater habitats, where almost one-third of all vertebrate species reside. In North America, the rate of extinction in freshwater habitats is thought to be 4% per decade, and 32% of all amphibian species are thought to be endangered (Berlatsky, 2014).

Freshwater biodiversity is declining because of several reasons, including hydrological changes, habitat loss and degradation, overfishing, invasive species, pollution, and the several effects of climate change. This is in part due to invasive human activities, pollution, climate change deforestation, habitat ruin and degradation, introduction of alien competing species, and undue human consumption (José Galizia Tundisi & Takako Matsumura Tundisi, 2016).

Figure 1. Percentage of various compartments of water in our biosphere along with their turnover periods in the box. Surface freshwater in form of lakes and rivers that can be directly accessed by humans and animals totals about 0.0091% of the total water. Freshwater sources and ecosystems are a precious and rare resources that cannot be squandered away to pollution and human greed.
(Graph redrawn in plotly.com by authors based on data from the book Freshwater Ecology: Concepts and Environmental Applications of Limnology by Dodds, W. K., & Whiles, M. R. 2000.) produced with plotly.com.



Duration (in Years)	Location	Percentage
75.00000	Freshwater lakes	0.0090
75.00000	Saline lakes and inland seas	0.0080
0.41700	Rivers	0.0001
100.00000	Shallow and deep soil water	0.0050
1000.00000	Groundwater to 4000 m depth	0.6100
12000.00000	Ice caps and glaciers	2.1400
0.02471	Atmosphere	0.0010
3060.00000	Oceans	97.3000

The loss of variety and richness in the many kinds of living things and their interactions within an ecosystem is referred to as decreased ecosystem diversity. Many factors, including human activity, climate change, natural catastrophes, and pollution, can contribute to this loss. Reduced diversity in an ecosystem can cause imbalances in the natural processes necessary to maintain the ecosystem's health. For instance, the extinction of one species of plant can have an impact on other organisms' ability to feed, which might cause a drop in population. This may have repercussions across the ecosystem and eventually cause the whole system to become unstable (Berlatsky, 2014).

FRESHWATER ECOSYSTEMS ARE AN UNTAPPED GENETIC LIBRARY

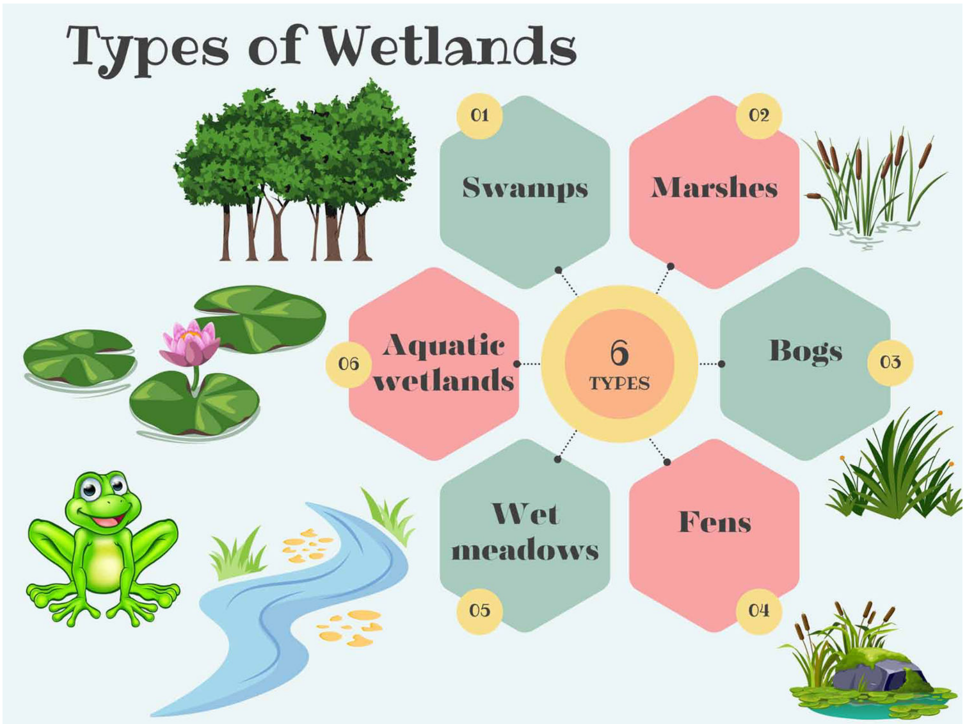
The gene pool of aquatic fauna and flora is a precious natural resource that is untapped to its full potential and is base material for genetic manipulation. Freshwater home to a global 12% of plant species and 40% of fish species (Harvey, 2013). For example, thermally stable *Taq* DNA polymerase (DNA polymerase I) used in DNA amplification or Polymerase Chain Reaction technology was discovered in an aquatic bacterium living in hot springs called *Thermus aquaticus*. It was found in hot freshwater springs of Yellowstone National Park (Levin, 2001).

WETLAND ECOSYSTEMS

Wetland ecosystems offer both humans and the environment a variety of beneficial services and advantages, such as bettering water quality, storing carbon, providing habitat for wildlife, and supporting fisheries and leisure activities. The amount of biomass produced by the plants and other animals that dwell in wetland environments is a measure of their productivity (Dodds & Whiles, 2020).

Since they contain large concentrations of nutrients that encourage the growth of plant life, such as nitrogen and phosphorus, wetlands are extremely productive environments. The plants in wetlands produce vast amounts of biomass through photosynthesis, which provides food and habitat for a range of other creatures, including birds, fish, amphibians, and invertebrates (Keddy, 2016).

Figure 2. The six types of wetlands are namely, 1. swamp, 2. marsh, 3. fen, 4. bog, 4. wet meadows, and 6. shallow water or aquatic
(Drawn by authors from page 444, Life on Earth An Encyclopaedia of Biodiversity, Ecology, and Evolution, Vol-1, Eldredge N. 2002)



ECOSYSTEM SERVICES

Freshwater ecosystems provide numerous important services to humans and animals in form of food for example crabs, shrimps and fishes, recreation like swimming and boating, temperature regulation, carbon sequestration, flood protection and portable drinking water. The following services to rendered humans by freshwater ecosystems (Levin, 2001).

Biodiversity: A wide variety of plant and animal species, many of which are unique to freshwater habitats, can be found there. Most fauna and flora of wetland have developed many unique adaptations like for survival in a low oxygen and changing aquatic habitat.

Cycling of nutrients: Freshwater environments are crucial to this process, which is necessary for ecosystems to function.

Nutrition: Freshwater ecosystems are source of nutrition for both humans and animals. Fish harvested in freshwater forms a bulk of inland human diet. Fish is a rich source of essential fatty acids like Omega 3 Fatty acid, and vitamin D essential for human survival in temperate and arctic climates.

Storage of Carbon dioxide: Freshwater ecosystems absorb and store carbon dioxide, which helps to regulate the climate of the planet.

Filtration: Freshwater ecosystems can function as inherently effective systems for purifying water by eliminating impurities and pollutants.

Scientific study: Freshwater ecosystems offer significant opportunities for study that help us comprehend how ecosystems function and the effects of human activity on the environment.

Drinking water: For many people worldwide, freshwater habitats provide as their main supply of drinking water.

Irrigation: Crop irrigation, which is crucial to produce food, uses freshwater.

Flood prevention: During periods of high rainfall, wetlands and other freshwater ecosystems can absorb extra water, lowering the likelihood of flooding.

Habitat: Freshwater environments serve as vital homes for a variety of fish and wildlife species.

Recreation: Activities like swimming, boating, fishing, and hiking are possible in freshwater habitats.

Thus, freshwater ecosystems offer a wide range of services that are vital to both the survival of humans, and other animals. (G. Timothy, 2020).

BIODIVERSITY OR BIOLOGICAL DIVERSITY

Biodiversity or Biological diversity refers to species richness. Biodiversity refers to the variety of species that are found a particular locale. Species biodiversity is the abundance of various species found a particular locale. Genetic biodiversity is the variations in the single gene of a species. The accelerated rate of loss of Biodiversity loss observed in all ecosystems of our biosphere is deemed as **Biodiversity crisis**. There three main types of biodiversity, namely genetic diversity, species richness, and ecosystem diversity (P Legendre & L Legendre, 1988).

Species-area Curves are logarithmic plot of number of species to area of an ecosystem. A trivial reduction in area will cause drastically(logarithmic) decline in the species diversity for example Reduction by a factor 2 will lead to loss of 10^2 =100 species loss. This explains the dramatic loss of diversity due to habitat loss (P Legendre & L Legendre, 1988).

Whittaker's biodiversity markers are designed as alpha, beta, and Gamma. Alpha is number of species in an ecosystem. The comparison of species diversity as we transition from one ecosystem to another is done using Beta. Gamma diversity is a measure of diversity in a large area (P Legendre & L Legendre, 1988).

THREATS TO AQUATIC BIODIVERSITY

Biotic Pollution

Biotic pollution is introduction of foreign species that competes with the native species and alters the ecological balance of a place. Invasive Species is when the alien species is environmentally or economically damaging. Introduction of Water hyacinth or Water lettuce into water bodies of India is example of Biotic pollution (Dodson, 2005). These invasive species are a great threat to endemic, slow-growing and sensitive species like Cryptocoryne sp. or River Crinum Lilly.

Habitat Fragmentation

Habitat fragmentation is the process of breaking up a habitat into numerous smaller islands by human intervention. Typical examples include building dams, canals and bridges and embankments on rivers. These fragments of habitat support far fewer species than original habitat. Native species become stressed due to loss of their homes and this favors establishment of alien species (Keddy, 2016).

Aquaculture as Threat to Aquatic Biodiversity

Aquaculture is the practice of farming aquatic flora and fauna for commercial purposes, this excludes natural harvest like fishing and trapping. Aquaculture has impact on the local biodiversity of a locality. The uneaten fodder, urinary and other waste of aquaculture may contribute to Eutrophication. Hormones and chemicals like Antifungals used in aquaculture may reach natural waterbodies through runoffs and affect the amphibian, crustacean, and fishes. Species may escape cultivation and become potentially invasive in new habitats. Expanding aquaculture may lead to habitat fragmentation, resource depletion, altered food web and fall in indigenous biodiversity (Richman et al., 2015).

Loss of Biodiversity Due to Deforestation

Deforestation is loss of Biodiversity due excessive logging of trees of Forrest for human use of the land for example, agricultural purposes or building houses. Loss of such Forrest can lead to increased soil erosion, global warming, lowland floods, landslides, mud slides, and silt loading of downstream waterbodies (G. Timothy, 2020).

Damage to Aquatic Ecosystems and Loss of Biodiversity by Eutrophication

Plant macronutrients namely nitrogen, phosphorus, and potassium (NPK) are essential for growth of macrophytes and increases productivity of aquatic ecosystem. Paradoxically, excessive nutrients from agricultural runoff and sullage from homes containing soap and detergent use often, often reduce the aquatic diversity (G. Timothy, 2020). Higher levels of Phosphate (lesser extent ammonium), primarily trigger excessive growth and proliferation of algae and few pollution tolerant species like cattail or lesser bulrush (*Typha angustifolia*), water lettuce (*Pistia stratiotes*), water hyacinth (*Eichhornia crassipes*). This process is called eutrophication. Contamination of a waterbody may be from point sources (sewage from town) or from diffuse sources (soil erosion from deforestation or excessive cattle grazing) (Levin, 2001).

Change in Seasonal Patterns of Waterflow

The construction of dams and canals on rivers leads to alteration of water flow pattern. Excessive diversion of water by canals may reduce quantity of water causing disturbances in ecosystems. Dams may lead to redistribution of water by flooding certain areas and drying out some tributaries. All these activities disturb the fragile aquatic ecosystems built and balanced in a time frame of millions of years (Rawat et al., 2015).

Excessive Commercial Harvesting

Excessive commercial harvesting is also affecting the biodiversity of freshwater ecosystems. Travancore dwarf pufferfish (*Carinotetraodon travancoricus*) of South-west India, is a voracious fish which keeps populations of freshwater snails and molluscs in check. They are popular in aquarium trade due to bright coloration. This fish is now threatened due to excess harvesting for aquarium trade and habitat loss. Loss of this voracious species is likely to lead to increased populations of freshwater snails, which in turn might have implications on human health. Freshwater snails are known to be intermediate hosts of numerous animal parasites like *Schistosomiasis*, or bilharzia. (Sigee, 2005).

EXCESSIVE FISHING AND DISRUPTIVE METHODS OF FISHING

Exploitation of marine resource like excessive fishing, disruptive methods of fishing like using dynamite and cyanide, bottom trawling for fishing have threatened the costal ecosystems and endangered a precious resource that is source of nutrition for humans. Coral reefs that are home to many varieties of marine organisms are being destroyed at an alarming rate by disruptive fishing practices, increasing ocean temperatures and acidification of ocean waters (O'Sullivan & Reynolds, 2008).

CONCEPT OF PROTECTED AREA- ECOREGION

To accomplish certain conservation goals, a protected area is a geographically delimited area that is recognized and administered. It could be a conservation area, national park, wildlife sanctuary, or some other kind of reserve. Conserving biodiversity and preserving natural and cultural treasures for future generations are the main goals of a protected area. Governments, non-governmental organizations, and community-based organizations all create and maintain protected areas.

Ecoregion is defined by WWF as "a relatively large unit of land or water containing a geographically distinct assemblage of species, natural communities, and environmental conditions" (EPA, *Ecoregions | US EPA* 2020).

BIODIVERSITY HOTSPOTS

Biodiversity hotspots are regions of high biodiversity that must be protected. 36 such regions are declared throughout the world and includes Western Ghats and Sri Lanka. A total of 2.3% of world area is taken up by these 36 Biodiversity hotspots but is home to around 43% of world population of fauna. Most of the world's biodiversity can be found in these hotspots, which are frequently found in tropical and underdeveloped nations. The Western Ghats in India, the Cape Floristic Area in South Africa, and the Atlantic Forest in Brazil are a few examples of hotspots for biodiversity (National Geography Society, *Biodiversity hotspots* 2021).

BIODIVERSITY HOTSPOTS IN INDIA

There are numerous biodiversity hotspots, or areas with a high concentration of rare and endangered species, in India. The main biodiversity hotspots in India are as follows:

Western Ghats: One of the world's 34 biodiversity hotspots is the Western Ghats Mountain range, which runs parallel to India's west coast. Many endemic plant and animal species, including as the lion-tailed macaque (*Macaca silenus*), Nigiri tahr (*Nilgiritragus hylocrius*), the clouded leopard (*Neofelis nebulosa*) and the Asiatic black bear (*Ursus thibetanus*) and Malabar large-spotted civet (*Viverra civettina*), can be found there (Chitale et al., 2014).

Eastern Himalayas: The states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura are all part of this hotspot, which is situated in northeastern India. The red panda is one of the many plant and animal species that call it home (Joseph et al., 2010).

Indo-Burma: This region includes sections of Myanmar, China, Thailand, Laos, and Vietnam in addition to northeastern India. Several endemic plant and animal species, such as the Siamese crocodile, the Burmese python, and the Irrawaddy dolphin, can be found there (Chitale et al., 2014).

Sundaland: This region includes parts of the Philippines, Malaysia, Indonesia, Brunei, and India. Many rare plant and animal species, like as the Bornean orangutan, Sumatran rhinoceros, and Javan rhinoceros, can be found there (Joseph et al., 2010).

Nicobar Islands: The Sundaland hotspot includes the Nicobar Islands, which are situated in the Bay of Bengal. Several endemic plant and animal species can be found there. a few of which include the Nicobar megapode, the Nicobar tree shrew, and the Nicobar pigeon (Chitale et al., 2014).

For the long-term survival of many species and the preservation of India's natural heritage, it is imperative that these hotspots and their biodiversity be protected.

FRESHWATER BIODIVERSITY HOTSPOTS OF THE WORLD

Regions with a high concentration of endemic freshwater species that are threatened by human activities including habitat destruction, pollution, and climate change are known as freshwater biodiversity hotspots. Following are some instances of hotspots for freshwater biodiversity:

Mekong river basin: More than 1,000 species of freshwater fish, including the Mekong giant catfish, one of the biggest freshwater fish in the world, may be found in the Mekong River watershed. Other rare and threatened species found in the area are the Siamese crocodile and the Irrawaddy dolphin.

Lake Victoria: East African Lake Victoria, the second-largest freshwater lake in the world, is home to more than 500 species of cichlid fish, many of which are endemic. Several additional aquatic and terrestrial species, many of which are threatened by pollution and overfishing, are supported by the lake and the marshes that surround it.

Amazon river system: The largest river system in the world, the Amazon River basin is home to more than 3,000 species of freshwater fish, many of which are unique to this planet. The Amazon River dolphin and the gigantic otter are just two of the numerous other aquatic and terrestrial animals that call this area home.

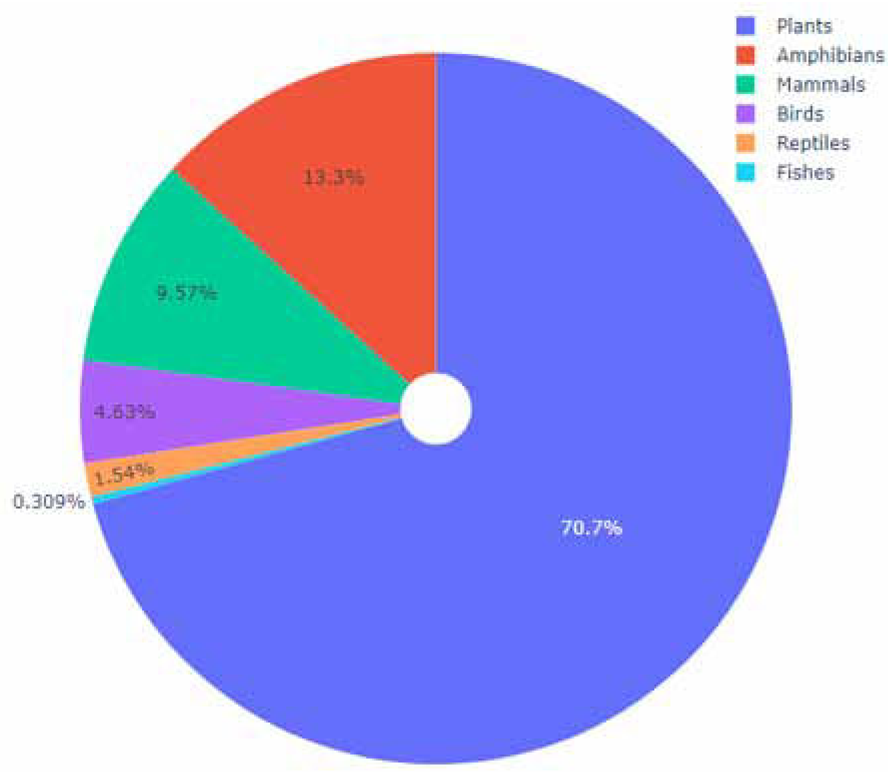
Great lakes of North America: Around 200 fish species, as well as a broad variety of other aquatic and terrestrial species, call the Great Lakes of North America, which include Lake Superior, Lake Michigan, Lake Huron, Lake Erie, and Lake Ontario, home. A sizable commercial fishing business is supported by the lakes, which are also a substantial supply of drinking water (Dudgeon et al., 2006).

WESTERN GHATS: FRESHWATER BIODIVERSITY

The Western Ghats are home to globally most biodiverse fauna and flora many of which are threatened with extinction. About 325 species of plants and animals found in IUCN Red Data List species, are found in Western Ghats (Reddy et al., 2016).

Seasonal mass flowering of wetland endemic, composite, *Senecio bombayensis*, or sonki (hindi sona = golden) covers entire section of hills in an orange-golden sheen. There are streams and medows filled with *Cryptocoryne spiralis* and rocky-marshes of *Hygrophila pinnatifida* or Dwarf hygrophila. Wet meadows full of short lived Habenaria grandiflora Ground white orchids flowers poking above the grass canopy. It is estimated that 50 to 60% of species found in Western Ghats are endemic.

Figure 3. IUCN red data list of threatened species occur in the Western Ghats in percentage
Redrawn by authors based on data available on from IUCN website, produced with plotly.com



Almost 300 species of freshwater fish, many of which are endemic, can be found in the Western Ghats, a mountain range in southwestern India. Many other aquatic and terrestrial species, including some endangered turtle and amphibian species, call this area home. An extensive variety of amphibian species can be found in the Western Ghats. Many of these species are in danger of extinction because of things like habitat loss, pollution, climate change, and other issues (*IUCN SSC Western Ghats*).

ENDANGERED AMPHIBIANS OF WESTERN GHATS

Western Ghats endangered amphibians are being protected, but more must be done to save their habitats and stop further population reduction (“Home: ENVIS center on biological diversity," 2023).This is the list few of the Western Ghats' critically endangered amphibians:

Purple Nose Frog: The IUCN has designated the rare and elusive purple nose frog (*Nasikabatrachus sahyadrensis*), which is exclusively found in the Western Ghats, as an endangered species. It spends much of its existence underground and only comes out to reproduce during the monsoon season.

Malabar tree frog: The Western Ghats' forests are home to the Malabar tree frog (*Rhacophorus malabaricus*), an arboreal frog that is considered endangered owing to habitat loss and degradation.

Gundia Tree frog: Only located in the Western Ghats of Karnataka, the Gundia Indian tree frog (*Polypedates gundia*) is classified as highly endangered due to habitat loss.

Beddome's leaping frog: The Western Ghats' streams are home to the Beddome's leaping frog (*Indirana beddomii*), which is considered endangered owing to habitat loss and pollution.

Dancing frogs of the Western Ghats: *Micrixalidae* are family of dancing frogs that are endemic to western Ghats. They are named so because of their habit of dancing or waving their feet at female frogs as mating ritual.

Dancing cave frog *Micrixalus spelunca*: Dancing cave frog *Micrixalus spelunca* discovered in 2014 inhabits dark caves of Tamil Nadu. DNA Fingerprinting technology has discovered several new species dancing frogs, all of which are vulnerable due to habitat destruction and pollution.

Kerala's Silent Valley Frog: Due to habitat degradation and fragmentation, the tropical frog known as the silent valley frog (*Micrixalus thampi*) that can only be found in Kerala's Silent Valley National Park is classified as severely endangered.

Kottigehar dancing frog: Due to habitat loss and pollution, the Kottigehar dancing frog (*Micrixalus kottigeharensis*), a rare frog that inhabits streams in the Western Ghats, is classified as severely endangered (Daniels, 1992;Vijayakumar et al., 2016).

ENDANGERED FRESHWATER FISH SPECIES OF WESTERN GHATS

A variety of freshwater fish species can be found in the Western Ghats, a mountain range in India, many of which are threatened by habitat loss, pollution, overfishing, and other reasons. Here are some instances of Western Ghats freshwater fish that are in danger of extinction:

Humpback mahseer: Only the Chalakudy River in Kerala is home to the large freshwater fish known as the humpback mahseer (*Tor remadevii*). Due to habitat destruction, overfishing, and the building of dams and weirs, it is critically endangered.

Kerala Hill stream Loach: Kerala Hill stream Loach (*Pseudogastromyzon myersi*): The streams of the Western Ghats are home to this little, vibrant fish. Due to habitat loss and degradation brought on by deforestation and pollution, it is critically endangered.

Travancore Anchovy: This little, silvery fish, known as the Travancore Anchovy (*Stolephorus travancoricus*), is found in the rivers and estuaries of the Western Ghats. Overfishing, habitat loss, and pollution have made it endangered.

Malabar Pufferfish: Malabar Pufferfish (*Carinotetraodon travancoricus*) Western Ghats' streams and rivers are home to this diminutive freshwater pufferfish. Because to habitat degradation and overfishing for the aquarium trade, it is critically endangered. This is a popular aquarium fish in the west known for its puffing habit and its voracious appetite of predating on the pest snails.

Vellayani Peacock Eel: The Vellayani Peacock Eel (*Macrognathus aral*) is a fish that resembles an eel that is found in Kerala's Vellayani Lake. Because to habitat loss, pollution, and overfishing, it is critically endangered.

These are only a few of the numerous rare freshwater fish species that can be found in the Western Ghats. To prevent the continued reduction of these distinctive and significant species, conservation actions are required (Jumani et al., 2018; Patil et al., 2018; Raghavan et al., 2007).

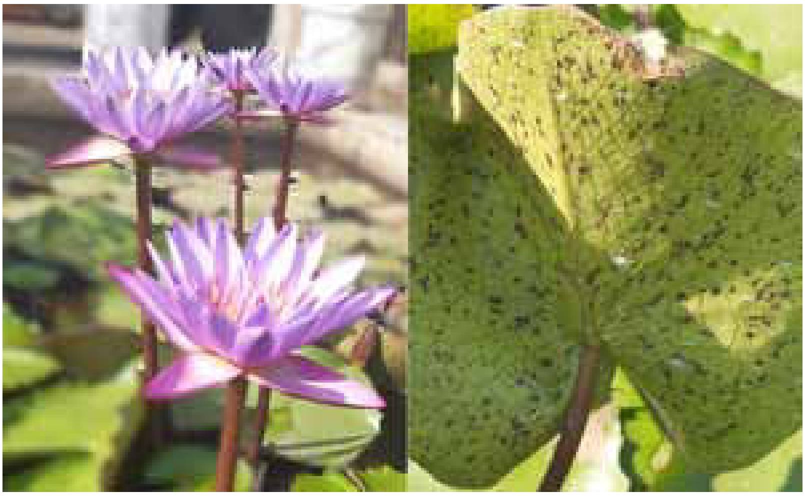
MY CASE STUDIES ON ENDANGERED MACROPHYTES OF WESTERN GHATS

The following section is my own survey and analysis of the situation of threat to aquatic plants that are found in the western ghats ("checklist of plants of Maharashtra," 2022).

BLUE WATER LILY OR *NYMPHAEA NOUCHALI*

The blue water lily, or *Nymphaea nouchali* (N.L. Burman) is an aquatic plant that grows in ponds, lakes, and still streams. It has stunning blue blossoms and is employed in conventional medicine. Nonetheless, this species faces serious risks from pollution and habitat destruction ("Wetlands," 2020).

Figure 4. Nymphaea nouchali (Burm. f.) Red-blue water lily, known as Neelkamal in Hindi. This species is native to India. Habitat fragmentation and filling up marshes for agricultural activities has pressurized this species. This is Nymphaea nouchali var. nouchali identified by its blue coloured flowers and under surface of floating leaves are coloured an texture of blue-purple



ROTULA AQUATICA (LOUR.)

Rotula aquatica (Lour.) famous for medicinal properties in Ayurvedic stream of medicine, this wetland plant is now endangered due to excessive harvesting and loss of habitat. This species in sensitive to pollution and has a relatively slow growth rate. Specimens thrive in rainy seasons, flower in winters, and become quiescent in hot summers. Specimens cannot survive on lateritic soils and need very high humidity for cultivation ("Wetlands," 2020).

CRINUM VIVIPARUM (LAMK., R. ANSARI & V.J. NAIR)

This live bearing aquatic crinum lily is a close cousin of garden variety of white lily, having adapted to a life in water (Rajamani & Iyer, 2023a). This is a very slow growing species with special adaptation to survive among the rocky, shallow, waterlogged banks of western ghat streams. Due to habitat destruction and slow growth, this species is now threatened. Specimens can survive on garden soils hitherto flower once in two or three years (Dudgeon et al., 2006; Bastmeijer, 2016a).

CRYPTOCORYNE RETROSPIRALIS (ROXBURGH KUNTH)

Cryptocoryne retrospiralis is another endemic species found in Maharashtra, Karnataka, and Kerala. This species closely resemble another common ubiquitous species found everywhere in India *Cryptocoryne spiralis var spiralis*. The leaves are stiff, and Lance shaped. *C. crispatula var. crispatula* is another species closely resembling this species but not distributed in South-west India but found in Indo-Burma-China belt (Bastmeijer, 2016a).

CRYPTOCORYNE SIVADASANII (BOGNER)

Cryptocoryne sivadasanii is a rare endemic species localized to Karnataka and Kerala. The leaves of this species grow to long lengths and are devoid of a leaf blade. The species is available on some aquarist websites and collection from natural habitat has threatened this species. The spathe of this species does resemble Cryptocoryne retrospiralis as does its annual cyclical growth pattern. Because of Pollution and garbage disposal in Kerala and Karnataka stream this species is under threat (Bastmeijer, 2016a).

CRYPTOCORYNE COGNATA (SCHOTT)

Cryptocoryne cognata is a very rare and endemic species of Cryptocoryne, found only in Ratnagiri district of Maharashtra. It was considered a lost species for 150 years but rediscovered in 1990s. Due to endemic nature of this species, I believe this species is highly threatened (Rajamani & Iyer, 2023b). Most rivers and streams of Ratnagiri district are witnessing phenomenal pollution, garbage littering and habitat destruction due to population growth and growth of tourism in this region. This problem is compounded with low tolerance of Cryptocoryne to pollution and climate change.

LAGENANDRA SPECIES

Lagenandra species are rare aquatic species confined to the streams and rivers of Western Ghats. The species is known to occur naturally in the province of Karnataka, Kerala and Sri Lanka. *Lagenandra* species that are found in India/Sri Lanka include *Lagenandra meeboldii* (Engl.C.E.C. Fisch.), *L. nairii* (Ramamurthy & R.Rajan), *L. ovata* (L. Thwaites), *L. toxicaria* (Dalzell), and *L. undulata* (A.R.K. Sastry).

This genus is threatened and on decline in the wild. Their tolerance to pollution is low and plants seem to be unable to grow outside high humidity zones found near waterbodies. There may be yet undiscovered species in these native habitats as the genus has not been well studied. Some species like *Lagenandra meeboldii* bleeding heart are prized by aquarists for their unique leaf coloration. This species is also found frequently aquarium trade of the West. Excessive collection from wild is putting pressure on this exotic genus (Bastmeije, 2016b).

ERIOCAULACEAE OR PIPE WORT FAMILY

Most members of the *Eriocaulaceae* family are small aquatic or semiaquatic plants that thrive in moist soil or shallow water. They are typically little plants; several species only reach a height of a few millimetres (Rajamani & Iyer, 2022). They stand out for their characteristic rosettes of leaves and their tiny, insignificant flowers, which are frequently encircled by bracts. *Eriocaulaceae* is a family of flowering plants that includes around 1200 species

India is home to many species of Eriocaulon, which are commonly known as pipeworts. With over 130 species, India possesses one of the world's richest biodiversity of *Eriocaulaceae* floras. Some of the Eriocaulon species found in India include:

1. *Eriocaulon cinereum* - Assam, Meghalaya, West Bengal, and Sikkim.
2. *Eriocaulon quinquangulare* - Kerala, Karnataka, Tamil Nadu, and Maharashtra.
3. *Eriocaulon madayiparense* - Kerala.
4. *Eriocaulon karaikkalense* - Tamil Nadu.
5. *Eriocaulon koipilliense* - Kerala.
6. *Eriocaulon nilgiriense* - Tamil Nadu.
7. *Eriocaulon quinquenerve* - Kerala, Karnataka, Tamil Nadu, and Maharashtra.
8. *Eriocaulon robustum* - Assam, Meghalaya, and Arunachal Pradesh.
9. *Eriocaulon sedgewickii* - Assam, Meghalaya, and Arunachal Pradesh.
10. *Eriocaulon subulatum* - Assam, Meghalaya, and Arunachal Pradesh.

Eriocaulon quinquangulare, Eriocaulon sexangulare, Eriocaulon sedgewickii, Eriocaulon robustum, and Eriocaulon euryspermum are among the most prevalent *Eriocaulaceae* species in India. Some of these plants are often used in aquariums as beautiful plants. These plants are frequently utilized in Indian traditional medicine. Although the conservation status of many *Eriocaulaceae* species in India is unknown, many species are thought to be vulnerable or endangered because of habitat loss (*Eriocaulaceae - Efloraofindia*, n.d.).

AMPHIBIAN BIODIVERSITY OF NORTH-EAST: NEW SPECIES OF SIJU CAVE CASCADE FROG OR AMOLOPS SIJU DISCOVERED IN 2023

In 2023, team of scientists working for Zoological Survey of India (ZSI) made discovery of a new species of cave dwelling frog called *Amolops siju*. This frog was found deep inside Siju cave in Meghalaya state's, Southern Garo Hills district. Siju cave is a system of limestone caverns 4 kilometers long. Previously they had discovered 3 new species of cascade frogs of genus *Amolops* namely: *A. chanakya, A. tawang, and A. terraorchis*. This is another example of undiscovered freshwater amphibian biodiversity of Northeastern part of India.

India is home to a diverse array of aquatic plants, many of which are endangered due to habitat loss, pollution, and other human activities. These are just a few examples of the many endangered aquatic plants of India. Conservation efforts such as habitat restoration, pollution control, and the regulation of invasive species are necessary to protect these important species and the ecosystems they inhabit (Abellán et al., 2007).

PORTULACA LALJII (P. SIVARAMAKRISHNA & P. YUGANDHAR SP. NOV.)

In 2020 a new and rare species of wild sun rose plant called *Portulaca laljii (Portulacaceae* family) has been discovered in the Eastern Ghats, Prakasam district Andhra Pradesh province. This species is unique in possessing thick tuberous roots, that are succulent. This is an adaptation for its arid, rocky, and hilly habitat. This new species is named in honour of Indian Botanist, Dr. Lal Ji Singh. The species seems to be endemic, confined to a narrow range and hence vulnerable.

MAJOR LOSS OF AMPHIBIAN BIODIVERSITY

Amphibian's populations are in decline in not just areas around human habitats like villages and towns. Amphibians counts in even remote areas without any direct interference from human are showing a declining trend. The IUCN Global Amphibian Assessment estimates that as many as 168 amphibian species have vanished and are now thought to be extinct. A third of all amphibian species are in decline, and if they are not brought into captivity, more than 40% could go extinct by the year 2060 (Briggs et al., 2010).

Agricultural runoff containing Pesticides and herbicides, leading to contamination of ponds and lakes has been linked with fall in frog populations. Scientists at university of Southern Florida discovered that Atrazine herbicide interacted with Phosphate in NPK fertilizers to produce weakness of frog immune system. Such immunosuppressed frogs could not fend off trematode and other infestation.

Global increase in temperature has been linked to growth and Expansion of Chytrid fungus that causes major mortality among frog populations. Lastly, incidence of deformities like extra limbs or malformed limbs or missing eyes, is on rise. This has been linked with pollution and pesticide contamination of water (Lips et al., 2006).

CHYTRID FUNGUS PANDEMIC OF BATRACHOCHYTRIUM DENDROBATIDIS- GLOBAL LOSS OF AMPHIBIAN BIODIVERSITY

An important problem that has been linked to a chytrid fungus pandemic is the global loss in the biodiversity of amphibian populations. The infection causes swelling, sloughing, and ulceration in the skin of frogs, which can be fatal. It has been determined that chytridiomycosis, a fungus that is spread by the chytrid fungus ***Batrachochytrium dendrobatidis*** (Bd), is the main reason amphibian populations are declining in many parts of the world (Fisher et al., 2009).

Environmental persistence: Even in the absence of amphibians, the chytrid fungus can persist for long periods of time in the environment. As a result, it is challenging to stop the fungus's growth and it continues to pose a threat to amphibian populations.

Global distribution: Every continent where amphibians are found has been confirmed to have chytrid fungus, which has led to population decreases and extinctions in many regions of the world. It poses a danger to amphibian biodiversity because of its widespread global distribution and capacity to influence several amphibian species.

Treatment ineffectiveness: Wild amphibians infected with the chytrid fungus are now untreatable. In captive breeding operations, antifungal treatments have been employed, but these techniques are not workable for wild populations.

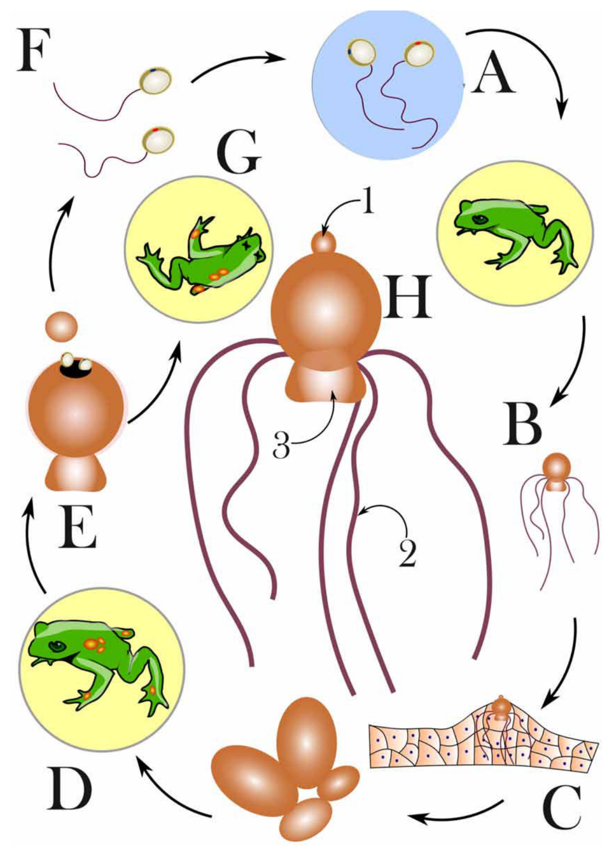
The illness affects amphibians' epidermis (outer skin layer), which is crucial to their life because it is involved in amphibian respiration, maintaining hydration, and defense against external pathogens (Fisher et al., 2009).

LIFE CYCLE OF CHYTRID FUNGUS IN AMPHIBIANS

Chytridiomycosis is a disease that affects frogs and is brought on by the chytrid fungus (*Batrachochytrium dendrobatidis*). The free-swimming zoospore stage and the encysted stage are the two primary phases of the chytrid fungus' life cycle in amphibians.

Zoospore stage: The chytrid fungus begins its life cycle as a flagellated, motile zoospore. From fully developed sporangia, which are reproductive structures, zoospores are released into the environment. They employ enzymes to pierce the top layer of skin because they are drawn to the skin secretions of amphibians.

Figure 5. Lifecycle of Chytrid fungus Batrachochytrium dendrobatidis (BD) that is causing global decline in Amphibian biodiversity. The fungus exists in two stages namely Zoospores that are motile and find fresh hosts or reinfect the original host (labelled A). They are actively motile by flagella. Zoosporangia, (shown under labels B. and H.) that form once they attach and encyst in the outer soft tissue of an amphibian host, most commonly a frog (Labelled E). The zoosporangia produce numerous roots like rhizoids (labelled 2 in H) and acquire a cap (labelled 1 in H) and possess a unique cellular body under the sporangium called apophysis that seems to act as a bridge between sporangia and feeding rhizoids. C. Intracellular development of zoosporangia, with eventual death of the frog in about 2 weeks from cardiac failure (labelled G). The gestating zoosporangia lose their cap (labelled E) and release numerous motile Zoospores on contact with water. This disease has emerged as a panzootic disease in the 21st century maybe due to global warming or effect of pesticides in weakening the immune systems of frogs. This has caused major decline in the worldwide freshwater biodiversity.
An original illustration of the authors



Encysted stage: The zoospore changes into an encysted form, which is capable of asexual reproduction once it has entered the amphibian. More zoospores are released into the environment as the encysted form develops and creates new sporangia.

The chytrid fungus may complete its life cycle in a matter of days, which enables it to spread quickly throughout amphibian populations. Even in the absence of amphibians, the encysted stage can survive in the environment for a very long time (Longcore et al., 1999).

PATHOPHYSIOLOGY OF THE CHYTRID FUNGUS IN AMPHIBIANS

Amphibian chytrid fungal pathology is complicated and multifaceted. The following characteristics define the pathophysiology of the chytrid fungus in amphibians:

Hyperkeratosis: When the fungus infects the keratinized skin of amphibians, it results in an expansion of the skin's thickness. As a result, the exchange of gases, liquids, and electrolytes across the skin may be reduced, which may cause mortality.

Osmoregulation disruption: Amphibians' skin plays a key role in controlling the equilibrium of their electrolytes and water. By harming the skin and reducing its ability to function, the chytrid fungus upsets this equilibrium and causes electrolyte imbalances and dehydration.

Ulceration: As the illness worsens, the skin suffers increasing skin damage, which results in ulceration. Amphibians suffer both systemic illnesses and eventual death from this infection.

Immune system disruption: The chytrid fungus can also impair amphibians' immune systems, rendering them more vulnerable to other diseases.

Heart failure: If the infection is serious enough, it may travel to the heart, causing heart failure and eventual death.

Chytrid fungus poses a serious threat to frog populations due to its pathogenic characteristics, thus efforts to stop its spread and create efficient therapies are essential for conservation efforts. Chytrid fungus has been linked to the decline and extinction of numerous species, and it poses a serious threat to amphibian populations all over the world. It is essential to comprehend the chytrid fungus' life cycle to create efficient management and control plans (Scheele et al., 2019).

RESTORATION OF WATER CHEMICAL QUALITY

The act of returning water's chemical composition to its original or desired state is referred to as "water chemical restoration." Usually, this is done to raise the standard of water used for drinking, irrigation, and industrial uses.

Pesticides, herbicides, fertilizers, and industrial pollutants are just a few of the substances that can contaminate water and endanger both human health and the environment. Chemical restoration may entail several procedures that can eliminate or lower the concentration of dangerous compounds in water, including filtration, disinfection, oxidation, and ion exchange.

Water chemical restoration may entail adding chemicals to water to change its pH, alkalinity, or hardness, improving its appropriateness for uses, in addition to eliminating impurities. For instance, adding lime or chlorine to water can raise the pH and lessen acidity while also disinfecting the liquid. Ultimately, water chemical restoration is a significant component of water management and is essential to ensure that everyone has access to clean water in a sustainable manner (Dodds & Whiles, 2020).

By removing any impurities or toxins using various chemical techniques like filtration, distillation, or reverse osmosis, water can be chemically restored. With these procedures, the water is returned to its cleanest state by being separated into its constituent molecules and other impurities. Water is filtered by running it through a porous substance, like activated carbon, which collects and eliminates contaminants. Water is boiled in the distillation process, and any contaminants that do not evaporate are left behind after collecting the condensed vapor in a different container. When water is forced through a semipermeable membrane, it selectively allows water molecules to pass through, leaving behind any impurities that are too large to pass through the membrane. This process is known as reverse osmosis (Shahidi & Fereidoon Naczk, 1992).

Water impurities can also be eliminated via chemical processes including ozonation, UV radiation, and chlorination. By adding chlorine to the water, which reacts with pollutants and destroys bacteria and other germs, chlorination is accomplished. Strong oxidants are used through ozonation and UV light to degrade and eliminate water pollutants (Welch & T Lindell, 1992).

In general, the procedure used to restore water chemically relies on the kind and quantity of contaminants present as well as the required level of purity (Welch & T Lindell, 1992).

MATRIX ASSEMBLY CLUSTER SOURCE (MACS), AN ECO-FRIENDLY PROCESS TO REMOVE CHEMICALS FROM WATER

The Matrix Assembly Cluster Source (MACS), a recently developed machine, was used to develop a ground-breaking solvent-free water treatment process. Toxic chemical removal from water now has a new, eco-friendly method according to Swansea University researchers. The study was conducted by Professor Richard Palmer at Swansea University's Centre for Innovative Materials, Processing, and Numerical Technologies (IMPACT), with funding provided by the EPSRC (Cai et al., 2020).

This represents a revolution in the way that water treatment and other catalytic processes are approached. (Cai et al. 2020) Professor Palmer stated that the MACS method of designing functional materials at the nanoscale "opens up whole new horizons across a wide range of fields, from physics and chemistry to biology and engineering."

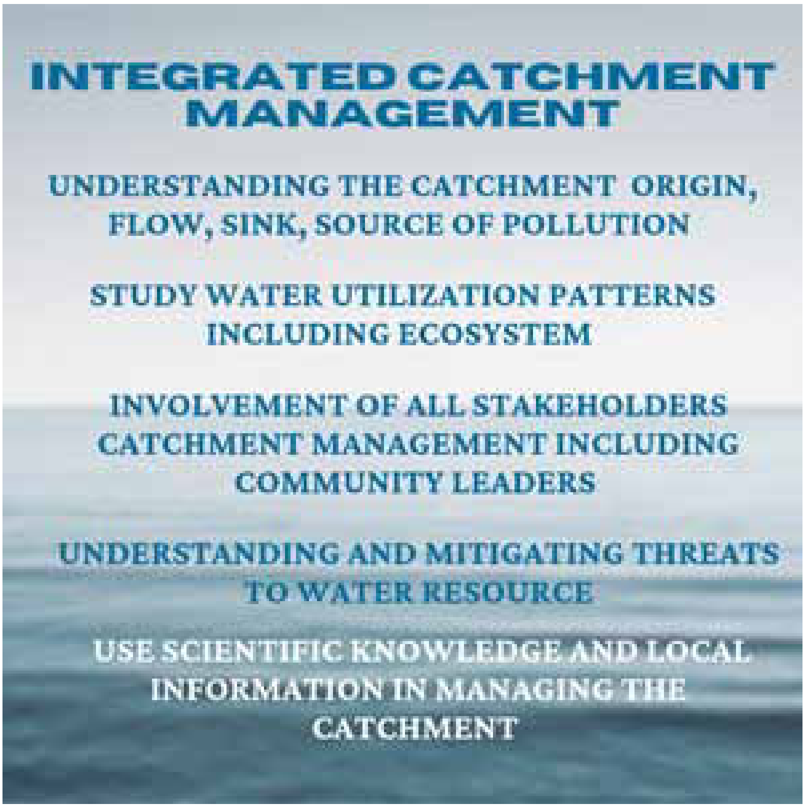
WATER POLICY REFORM-LEGISLATION

Water managers face an urgent need for water policy reform that can support a sustainable future for people and nature, as climate change estimates indicate even bigger imbalances between water supply and demand in the coming decades. The water flows of western rivers have been increasingly harnessed over the past 150 years to supply water for farming, public water supplies, electricity generation, and other purposes. This has allowed for rapid growth in cities and the regional economy as well as the production of agricultural goods that are exported around the world. Nevertheless, this growth has come at a high cost to the environment (Samiha Ouda et al., 2020).

INTEGRATED CATCHMENT MANAGEMENT (ICM)

A basin of water is a defined geographic area where natural resources are managed using a comprehensive strategy called integrated catchment management (ICM). This is a technique to managing land, water, and other natural resources within a catchment area in a coordinated and sustainable way. The area of land from which water flows to a certain body of water, such as a lake or river, is referred to as the catchment area. A catchment is a piece of land where water from precipitation such as rain and other types collects before flowing into a river, lake, or other body of water (Riddiford, 2021).

Figure 6. The steps involved in implementation integrated catchment management (ICM) for effective and sustainable utilisation of water resources like streams, lakes, and rivers



ICM aims to strike a balance between the need to use natural resources like water, land, and forests responsibly and the desire to conserve them for future generations. It entails teamwork among numerous stakeholders, including government agencies, regional communities, non-profit groups, and businesses (Samiha Ouda et al., 2020).

ICM's guiding principles include:

1. **Involve all stakeholders:** All parties involved in the planning and decision-making process work together to make sure that all points of view are considered.
2. **Responsive:** ICM acknowledges that natural systems are complex and undergoing ongoing change. As a result, management plans should be responsive to changing conditions.

3. **Ecosystem-based approach:** ICM adopts an ecosystem-based approach, acknowledging the interconnectedness of natural systems and the need for all management decisions to take the ecosystem into account.
4. **Balance approach:** ICM strives to strike a balance between the need to utilise natural resources sustainably and the need to safeguard and conserve them for future generations.

ICM understands that a catchment's natural resources are interrelated and that decisions made in one area of the catchment may have an impact on nearby areas. To ensure that these resources are utilised sustainably and in concert, ICM aims to integrate their management across various sectors and stakeholders (*A Beginners Guide to Integrated Catchment Management and the EPA's Role*, 2016).

The following crucial steps are often included in ICM:

Mapping watershed areas: Knowing the watershed entails mapping the area, identifying the important natural resources, and analyzing how they interact. ICM aims to incorporate a wide range of stakeholders in the management of the catchment, including regional communities, farmers, business, and governmental organizations.

Creating a management plan: A management plan is created that outlines the steps required to manage the natural resources in a sustainable and coordinated manner based on the stakeholders' input and an understanding of the catchment.

Modelling water flow: We can identify and target the best solutions to solve an issue by simulating the flow, terrain, and species of a watershed. We can select and target the best solutions to solve a problem by simulating the flow, terrain, and species of a watershed. For native fish, large timber significantly increases habitat complexity (G. Timothy, 2020).

Implementation and monitoring: The management plan is put into practice, and development is tracked to make sure the actions are having the desired effects. Stakeholders may improve results for the environment and the populations that depend on it by cooperating (Abellán et al., 2007).

ICM is becoming more widely acknowledged as a successful strategy for managing natural resources in a sustainable and integrated way. ICM has been used successfully to enhance the management of natural resources in various regions of the world, including Europe, Asia, and Africa (*A Beginners Guide to Integrated Catchment Management and the EPA's Role*, 2016).

STEPS TO PEVENT DECLINE OF FRESHWATER BIODIVERSITY

Our planet's health and sustainability may be significantly impacted by the loss of freshwater biodiversity. The following suggestions can stop this decline:

Habitat protection: Protecting the habitats where freshwater species dwell is one of the best methods to stop the loss of biodiversity in the freshwater ecosystem. This can be done by taking steps to conserve some places, control how land is used, and avoid polluting freshwater habitats.

Pollution reduction: Pollution reduction is essential for safeguarding freshwater ecosystems. Increased usage of ecologically friendly products, stronger laws on industrial and agricultural operations that contribute to water pollution, and a decrease in the amount of plastic garbage that enters rivers are some approaches to accomplish this.

Improve Research: Funding scientific investigation can aid in our understanding of freshwater ecosystems and the dangers they confront. This may result in the creation of better freshwater resource management techniques and more successful conservation initiatives.

Public awareness and interest: Raising public understanding of the value of freshwater biodiversity can aid in increasing public support for conservation initiatives. This can be accomplished through media efforts, educational initiatives, and public relations campaigns that highlight the importance of freshwater ecosystems and the dangers they confront.

Encourage environmentally friendly water usage: Promoting environmentally friendly water use can assist to protect freshwater resources and lessen the strain on ecosystems. This can be accomplished by taking steps like raising public awareness of water conservation, promoting water-saving technologies, and encouraging the adoption of irrigation techniques that require little water.

Encourage sustainable methods: Encourage sustainable fishing methods, as they can significantly reduce freshwater biodiversity. Sustainable fishing approaches, such as the use of selective fishing techniques and catch quotas that prevent overfishing, should be promoted to stop this (José Galizia Tundisi & Takako Matsumura Tundisi, 2016;Dmitriĭ Mikhaĭlovich Bezmaternykh, 2013).

IN SITU CONSERVATION ACTIVITIES

In situ conservation, as opposed to captive environments like zoos or botanical gardens, refers to the preservation of species within their native habitats or ecosystems. There are numerous initiatives being made to conserve species in situ since this strategy is frequently more successful at conserving a species' genetic diversity and ecological interactions. In situ conservation activities include, for example:

Protected areas: To preserve natural habitats and ecosystems, national parks, animal reserves, and other protected areas have been created. These areas are managed to reduce human disturbance and safeguard species from dangers like habitat loss and poaching.

Restoration: Restoration of degraded ecosystems can help native species thrive by creating better conditions for their survival. This can entail getting rid of unwanted species, growing native vegetation, or repairing natural streams. Community-based conservation involves collaborating with regional groups to advance ethical land-use decisions, curtail unlawful hunting and poaching, and create conservation zones that are under local control.

Wildlife corridors or Habitat corridors: By connecting fragmented ecosystems with wildlife corridors, inbreeding is reduced, and genetic diversity is increased. This allows for the mobility of animals and encourages genetic exchange. Habitat corridors are bridges that connect various island created by habitat fragmentation.

Relocation of species: Species may occasionally need to be temporarily removed from their natural habitats and reproduced in captivity to secure their survival. They can be returned into their natural habitats once their population has grown.

These are only a few instances of the worldwide in situ conservation initiatives that are being made. To ensure that endangered animals and their habitats are protected for future generations, numerous organizations, governments, and individuals are cooperating (Eldredge, 2002).

EX SITU CONSERVATION ACTIVITIES

Ex situ conservation is the practice of protecting animals away from their natural habitats, frequently in well-regulated environments like zoos, botanical gardens, or seed banks. Examples of ex situ conservation initiatives include as follows:

Captivity breeding: Programs that breed endangered species in captivity with the intention of returning them to the wild are known as captive breeding programs. Programs for captive breeding are carried out in venues like zoos, aquariums, and wildlife refuges.

Botanical gardens and seed banks: For the goal of conservation, these organizations gather and store seeds and other plant materials. By doing this, you can protect genetic diversity and guarantee the survival of plant species that could be under danger of extinction in their native habitats. These institutions gather and preserve genetic material from threatened species in their DNA and tissue banks. This can be used to support conservation efforts and is beneficial for study.

Cryopreservation: Cryopreservation is the process of storing genetic material, including as sperm, eggs, and embryos, in liquid nitrogen for use in conservation initiatives in the future. This method is frequently applied to endangered species conservation.

Reintroduction programs: These entail returning animals raised in captivity or who have undergone rehabilitation to their original habitats. The goal is to rebuild declining wild populations of endangered species.

Ex situ conservation activities are crucial for safeguarding and preserving threatened species and their genetic diversity overall (Eldredge, 2002).

CONCLUSION

These studies suggest that stopping the decline of freshwater species biodiversity can be achieved through restoring natural hydrological regimes and water chemical status, creating clean-water ponds for biodiversity, and implementing whole-catchment management and conservation actions. These studies suggest that stopping the decline of freshwater species biodiversity can be achieved through restoring natural hydrological regimes and water chemical status, creating clean-water ponds for biodiversity, and implementing whole-catchment management and conservation actions.

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