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Freshwater biodiversity threats and conservation constrains

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Abstract

The freshwater ecosystem is the most varied and vibrant ecosystem on this planet. It occupies less than 1% of the Earth's surface making only 0.01% of the world's available water sustaining more than 126,000 species. Due to its maximum share of planets biodiversity, they are global hotspots of biological richness with a high rate of decline too. Freshwater biodiversity is a priceless natural resource in terms of scientific, economic, educational and cultural aesthetics. Currently, it is in a very critical crisis and its conservation is vital. Overexploitation of resources, pollution through various anthropogenic ventures, water flow modification through dams and canals, habitat loss, exotic species invasion and their combined and interacting influences are the prime causes of vanishing freshwater biodiversity in Anthropocene. Apart from these direct threats climate change poses the greatest risk. Multiple stressors that lead to loss of sensitive species and an overall reduction in diversity increasingly influence freshwater ecosystems. Anticipating ecological responses to climate change rational and deliberate planning of engineering responses to climate change must be the pressing priority. Supplies of the freshwater ecosystem in terms of food capture to meet the demands of protein requirements will sustain only when freshwater ecosystems remain healthy. This review highlights the key forces declining freshwater biodiversity.

Water is essential for life in general and humans in particular. Food production in the form of rain-fed and irrigated agriculture, livestock production, fisheries and aquaculture depend upon the availability of freshwater. Freshwater ecosystems are a fundamental resource for human life providing clean water, food, livelihoods and other ecosystem services. The freshwater ecosystem is the most dynamic ecosystem on this planet Earth. Although freshwater makes up only 0.01% of the World's available water and approximately 0.8 % of the Earth's surface, yet this tiny fraction of global water supports and sustains more than 126,000 species in its ecosystems. Due to its maximum share of planets biodiversity, they are global hotspots of biological richness with a high rate of decline too.

Almost one-third of freshwater

biodiversity face extinction due to habitat loss, the introduction of alien species, pollution and over-harvesting (Tweet by IUCN @IUCN Oct 21, 2019). IUCN also states that over 140,000 described species rely on freshwater habitats for their survival (https://twitter.com/iucn/status/1186303678141128705). Freshwater is the basic need of an ever-growing population and its scarcity has created rivalry among its users especially in the densely populated parts of the world[10]. Rivers, lakes, and inland wetlands such as deltas, peat lands, swamps, fens, and springs are home to an extraordinary diversity of life. Covering less than 1% of Earth's surface, these habitats host approximately one-third of vertebrate species and 10% of all species[36]. Freshwater ecosystems also provide services to billions of people, including impoverished and vulnerable communities[25]. Freshwater ecosystems are the most endangered ecosystems in the world. Declines in biodiversity are far greater in freshwaters than in the most affected terrestrial ecosystems[33]. The rate of decline of vertebrate populations is much higher in freshwaters than in terrestrial or marine realms.

Biodiversity loss has always existed as a natural process but threats to biodiversity arise when the rate of extinction exceeds the rate of speciation. The levels of endemism among freshwater species are remarkably high. Biodiversity loss primarily related to human interactions with natural resources. In the early phases of life, humans remained as one component of the ecosystem but, very recently, humans have become a factor in the ecosystem and started reshaping the biodiversity. Humans have drastically disturbed the natural rate of extinction of species. Factors that cause loss of biodiversity have exceeded the factors that cause gains in biodiversity. The rate of speciation affected adversely due to which many species have disappeared from the earth and many are facing varying degrees of the threat of extinction. Humans have caused a widespread planetary change, ushering in a new geological era, the Anthropocene (a term first coined in the 1980s by Eugene F. Stoermer, a freshwater biologist). Among many consequences, biodiversity has declined to the extent that we are witnessing a sixth mass extinction[4].

This paper reports a comprehensive review of published studies that qualitatively and quantitatively examine the current threats to freshwater biodiversity. Multiple stressors lead to a loss of sensitive species and an overall reduction in diversity increasingly influence freshwater ecosystems.

Major threats to Freshwater Biodiversity :

Threats to freshwater biodiversity grouped as following interacting categories: overexploitation; water pollution; flow modification; destruction or degradation of habitat; invasion by exotic species; and hydropower. Climate change occurring at the global scale together with nitrogen deposition and runoff patterns are superimposed threats upon all of the previous categories. These threats to global freshwater biodiversity reviewed and grouped under five major interacting categories by Dudgeon *et al.*,[10]. They are overexploitation; water pollution; flow modification; destruction or degradation of habitat; and invasion by exotic species. Overexploitation primarily affects vertebrates, mainly fishes, reptiles and some amphibians; whereas the other four threat categories have consequences for all freshwater biodiversity from microbes to megafauna[10]. Freshwater pollution problems are still pandemic in most developing countries[27]. Agriculture, domestic and industries are the point sources of freshwater pollution in most of the countries. Some industrialized countries have made considerable progress in reducing water pollution from domestic and industrial point sources; however, threats from excessive nutrient enrichment and other chemicals such as endocrine disrupters and antibiotic pollution are still growing. Worldwide, antibiotic usage exceeds 100,000 tons per year and there is increasing concern over the fate of these substances. Antibiotics are ubiquitous in the environment and a significant concentration detected in freshwaters[7].

Habitat degradation brought about by excavation of river sand and forest clearance leads to habitat alterations such as shoreline erosion, smothering of littoral habitats, clogging of river bottoms. Flow modifications are pervasive in running waters adding up to the threats. Invasion and deliberate introduction of exotic species add to the physical and chemical impacts of humans on freshwaters. Exotic species invasions often result in native biodiversity loss. One of the most evident effects of biological invasions is the loss of native taxonomic diversity; however, current knowledge on invasions effects underlined a potential increase in functional diversity[28, 29]. The particular vulnerability of freshwater biodiversity also reflects the fact that freshwater is a resource for humans that may be extracted, diverted, contained or contaminated in ways that compromise its value as a habitat for organisms.

Emerging threats to Freshwater Biodiversity:

Emerging threats to freshwater biodiversitynecessitiesattention in the Anthropocene shown in figure 1. These emerging threats arechanging climates; e-commerce and invasions; infectious diseases; harmful algal blooms; expanding hydropower; emerging contaminants; engineered nanomaterials; microplastic pollution; light and noise; freshwater salinisation; declining calcium; and cumulative stressors[32].

Climate change potentially threatens approximately 50% of global freshwater fish species[8]. Ecological responses to an average warming of only approximately 1°C are already apparent. Out of 31 ecological processes that underpin freshwater ecosystem functioning from genes to populations, 23 affected by climate change alone, including reductions in body size, shifts in distribution, changes in phenology, algal blooms and desynchro-nisationof interspecific interactions[34]. Invasive species are a primary threat to freshwater biodiversity, *e-commence* in the trade of non-native plants and animals in a broad overview identify e-commerce as a significant contributor to national-level biosecurity risk[9].Transactions carried outthrough a range of methods in e-commerce making the management of e-commerce risks challenging. *Infections* can dramatically affect freshwater biodiversity; the aquatic medium facilitates the survival of many infectious parasites. Many micro parasites like viruses, fungi, protozoans, bacteria and macro parasites like flukes, roundworms, tapeworms,

Figure 1. The Emerging threats of freshwater biodiversity.

arthropods depend on freshwater hosts for transmission[22]. Freshwater algae provide energy and nutrients to connected aquatic food webs. The accumulation of algal speciesis termed harmful *algal blooms* (HABs) threatensthe freshwater biodiversity[20]. The bloom species create adverse physiological conditions for their competitors, altering energy or nutrient fluxes through food webs as they produce toxic compounds that reduce growth, survival and reproduction in other organisms or contaminate food webs.Many eutrophic habitats that host recurring HABs already experience thermal extremes, low dissolved oxygen and low pH, making these locations potential sentinel sites for conditions that will become more common in larger-scale systems as climate change accelerates[15,1]. *Hydropower dam* construction endangers freshwater biodiversity as dams modify natural flow and thermal regimes and decrease river–floodplain connectivity, aquatic productivity and fish access to spawning and nursery habitats[23]. Freshwater receives*pollution* from point-source discharges such as urban runoff, agriculture, industries and aquaculture that can impair freshwater biodiversity directly through toxicity.Contamination of the freshwater ecosystem by pesticides pollution has been established long ago[5].

Engineered nanomaterial's (size range 1–100 nm) used in a multitude of industrial, clinical and consumer applications are finding their way into freshwaters[6]. Many formulations are prone to aggregation and precipitation in natural waters. Freshwater fish and crustaceans are at realistic exposure concentrations, but sensitivity can vary by order of magnitude across species and life stages.

Plastics are broken down by mechanical forces and ultraviolet radiation into smaller fragments called '*microplastics*' (plastic particles <5 mm). Microplastics include micro beads (particles added to cosmetics), nurdles (small pellets used to produce other plastics), fragments (portions of larger pieces) and microfibers (from synthetic clothing)[2]. Microplastic pollutants vary among freshwater systems but microfibers often comprise >75% of the plastic debris. Freshwater organisms including birds[19], fishes[3] and invertebrates[38] ingest microplastics and extrapolation frommarine findings would suggest emerging risks to freshwater organisms. *Light pollution* increasingly regarded as an insidious stressor for freshwater biodiversity[18]. Early studies revealed that artificial light alters the migration of the zooplankter Daphnia[31] potentially altering their interactions with fish. Light also alters the behaviour of organisms often closely attuned to circadian cycles. The effects of *noise* on freshwater organisms studied for water birds, endangered black-faced spoonbills (*Platalea minor*) freshwater turtle's and anurans shows negative impact. Research has revealed that boat noise elevates the stress hormone cortisol in aquatic organisms. However, how these disturbances scale up to ecosystem-level effects is unknown, although noise can alter how sediment-dwelling invertebrates affect ecosystem properties[35].

Studies suggest that freshwater *salinisation* isoccurring at an unprecedented rate and scale[16], but there remains no global synthesis of thisproblem. The threat posed by salinisation is far from new, but predicted to intensify with climate change. Vegetation clearance is one of the obvious reasons for freshwater salination. Anthropogenic drivers of freshwater salinisation include disposal or accidental spillage of saline wastewater, strip mining of oil sands, whichexposesmarine sediments and shallow saline aquifers[14] and the expanding use of salt to de-ice impervious surfaces[12,24]. Increased salinity kills freshwater species owing to toxic levels of sodium and chloride ions in their cells and reduced capacity to take in essential ions and water. These effects can reduce species diversity and significantly alter trophic systems by reducing food sources for consumers[13].

A recently identified threat to the freshwater biodiversity is the slow but widespread decline in *calcium* (Ca) concentrations in low-carbonate systems across eastern North America[30], Europe[17] and likely elsewhere. Ca is an essential nutrient for all forms of life, but the ecological ramifications of this new threat still not fully researched. The natural variation of environmental factors in freshwater basins determines their biodiversity. Among them, calcium is a key physiological compound for freshwater invertebrates. It is required for shell formation, muscle contraction; it mediates gene expression and allows counteracting acidosis during stress periods, among other functions. Although the distribution of different freshwater species suggested to link with the environmental calcium concentration yet no research studies have confirmed this[11]. There is long-standing recognition that environmental stressors can interact to affect freshwater ecosystems. The accelerating rate of global change has focused attention on the cumulative impacts of novel and extreme environmental changes that are stressors[21]. As integrators of local catchment and regional processes, freshwater ecosystem ranked highly sensitive to the net effects of multiple stressors, yet there has not been a large-scale quantitative synthesis.

Preservation and Management Gears :

Freshwater ecosystems provide vital resources for humans and support high levels of biodiversity yet are severely threatened throughout the world. The expansion of human land uses, such as urban and crop cover, typically degrades water quality and reduces freshwater biodiversity, thereby jeopardizing both biodiversity and ecosystem services[26]. Despite their limited spatial extent, freshwater ecosystem hosts remarkable biodiversity, including one-third of all vertebrate species. This biodiversity is declining dramatically: Globally, wetlands are vanishing three times faster than forests, and freshwater vertebrate populations have fallen more than twice as steeply as terrestrial or marine populations. Threats to freshwater biodiversitywell documented but coordinated action to reverse the decline is lacking. Tickner *et al.*,[37] recently presentedan Emergency Recovery Plan to bend the curve of freshwater biodiversity loss. Priority actions include accelerating the implementation of environmental flows; improving water quality; protecting and restoring critical habitats; managing the exploitation of freshwater ecosystem resources, especially species and riverine aggregates; preventing and controlling non-native species invasions; and safeguarding and restoring river connectivity. They also recommend adjustments to targets and indicators for the Convention on Biological Diversity and the Sustainable Development Goals and roles for national and international state and non-state actors.

Freshwater ecosystems comprise not more than 0.01% of total global water volume and occupy less than 1% of the Earth's surface that is equivalent to approximately 3% of the land area. A small amount of freshwater that is actually available is a habitat for a number of species making it hotspots of global biodiversity. This scarce resource is sustaining a significant amount of animal biodiversity much of which is now threatened.

The most leading and persistent cause of declines in freshwater systems population is the degradation of habitat, water pollution, increasing global human population, water flow modification through the construction of dams, overexploitation of fishes and other aquatic invertebrates are also adding up to the loss of freshwater biodiversity. The Anthropocene has brought multiple new and varied threats that disproportionately affect freshwater systems. These emerging threats include changing climates, e-commerce and invasions, infectious diseases, harmful algal blooms, expanding hydropower, emerging Contaminants, engineered nanomaterial's, microplastics, light and noisepollution, freshwater salinization, declining calcium and cumulative stressors.

A mixture of strategies will be essential to preserve freshwater biodiversity in the long term. It must include reserves that protect key, biodiversity-rich water-bodies especially those with important species radiations and their catchments, as well as species- or habitat-centred plans that reconcile the protection of biodiversity and societal use of water resources in the context of human-modified ecosystems. Importantly, effective conservation action will require a major change in attitude toward freshwater biodiversity and ecosystem management, including general recognition of the catchment as the focal management unit and greater acceptance of the trade-offs between species conservation, overall ecosystem integrity and the provision of goods and services to humans.

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