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RIVERINE BIODIVERSITY AND IMPORTANCE, POTENTIAL THREAT AND CONSERVATIONAL CHALLENGES: A REVIEW

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ABSTRACT

Seven percent of the world's biodiversity is found in freshwater ecosystems, which are the richest and most promising resource for human life and functioning (Dudgeon et al., 2006; Reid et al., 2019). It comprises extremely endangered wetlands, rivers, lakes, riparian zones, ponds, and streams. because of a number of stressors, including species invasion, land-use changes, point sources, diffused pollution, water extraction, eutrophication, growing hydropower, increased resource use, and climate change (Cantonati et al., 2020; Flitcroft et al., 2019). The WWF's 2016 Living Planet Index report states that the freshwater organism has experienced a sharp drop in population and eventual extinction. According to the Living Planet Index (2016), the number of freshwater vertebrate species decreased by 81% in 2014 before increasing to 83% in 2018 (Grooten and Almond, 2018). Furthermore, data from the IUCN Red List confirm that freshwater vertebrate and invertebrate species are at serious risk of extinction (Ricciardi and Rasmussen, 1999; Collen et al., 2014). Approximately 84% of the threatened megafauna that is located outside of the current protected area is found in the freshwater ecosystem (Carrizo et al., 2017). Despite being a serious concern, the decline in freshwater organisms is not given enough attention. This could be because freshwater biodiversity, especially microorganisms and protists, has received less attention than its terrestrial equivalent (Darwall et al., 2011; Cantonati et al., 2020).

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INTRODUCTION

Freshwater conservation is dependent on management strategies at the terrestrial-freshwater interface, including watershed sizes, agricultural runoff, and land-based conservation initiatives (Darwall et al., 2011). In actuality, however, compared to a terrestrial ecosystem, the freshwater environment, which is delicate and complex, is under a great deal of stress in the form of species extinction, habitat modification, and fragmentation (Veríssimo et al., 2018; Reid et al., 2019; Barrett et al., 2018).

River hydrology, water quality, biodiversity, ecology, and other features are maintained by a river continuum gradient controlled by drivers that can be both large-scale (climatic, geological factors) and small-scale (valley form, rain, snow, groundwater, and vegetation). Therefore, a thorough understanding of the biodiversity, productivity, biogeochemical cycle, influence scale and controls, and rivers is essential for a healthy riverine ecosystem (Naiman et al., 1993). The biodiversity of rivers is a reflection of their local niche and their upstream and downstream terrain, as they engage in intriguing interactions with a wide range of environments from their source to their mouth. The connectedness over time of rivers results in a number of relationships, including close hydrological links, such as lateral hydrological links to coastal regions and floodplains, and biological relationships (McCabe, 2010). Floodplain connections in this river aid in maintaining the natural processes such as the reciprocal exchange of materials and nutrients with the environment the basis

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for the existence of the entire riverine ecosystem (Ward et al., 1999; Feld et al., 2014). The river and its naturally occurring riparian corridors are distinct, intricate, and intertwined.

River movement in its corridors affected by various processes such as sediments, nutrients and organic matter exchange, river bank erosion, diverse habitat development, hyporheic zone etc. Therefore these connections within river environment if broken then it can collapse the entire river ecosystem (Boulton et al., 1998; Malcolm et al., 2005).

The rivers have huge importance for mankind and are of high economic importance as they provide wide range of essential goods and services. However, there has been adverse impact on rivers because of overexploitation to fulfill several requirements of humans. As a consequence that has led to the deterioration in their natural attributes, resulting in biodiversity loss, degradation in characteristic habitat and ecosystem services mechanism that both aquatic and terrestrial animals use for dispersal. It includes Fish migration, drifting macroinvertebrates, flotation-based hydrochory, and other organisms mobility within the riparian zone (Keruzore et al., 2013).

As mentioned above, this article focuses on the significance of river ecosystems, new threats to which they are vulnerable, and the difficulties in restoring river ecosystems and biodiversity. The introduction of river biodiversity and river habitat, as well as new direct and indirect threats and difficulties resulting from many factors in the restoration and management of the river ecosystem, are all covered in detail in the four sections of the current study.

Fresh water Fauna of River: Approximately 7% of all biodiversity worldwide is found in river ecosystems that are rich in a variety of plant and animal groups (Dudgeon et al., 2006; Reid et al., 2019). Due to variations in temperature, light, water chemistry, hydrologic regime, substrate type, food resources, geology, and species pools, river systems and riparian zones provide a wide variety of habitats for flora, fauna, and microorganisms (Meyer et al., 2007).

As a valuable resource, freshwater ecosystems and their biodiversity support about 40% of the world's fish diversity, a quarter of all vertebrate species, and other species like amphibians, aquatic reptiles (crocodiles, turtles, snakes, etc.), and mammals (dolphins, otters, muskrats, etc.) (Cazzolla Gatti, 2016). The biodiversity of freshwater ecosystems is rich in species with local ecological significance, including several major groups like decapod molluscs, crustaceans, and aquatic insects (caddis and mayflies), prokaryote diversity (micro algae and fungi richness), and several invertebrate groups. However, the data on freshwater biodiversity is insufficient and has not been thoroughly studied (Dudgeon, 2000; Benstead et al., 2003).

Habitat in Freshwater River: Rivers run through a variety of environments that change over short time intervals because they comprise both aquatic and terrestrial areas. This contributes to the rivers' dynamic nature and abundant biodiversity. Because it offers a wide range of shelters, nesting, and feeding options, river habitat shows high conservation values (Holmes and Raven, 2014). The local climate and underlying geology support the inherent qualities of the river and its environment. "Habitat mosaics," which are patchworks of interconnected habitats produced by the combined efforts of numerous physical, chemical, and biological processes, are developed within intrinsic patterns (Addy et al., 2016). Medium-sized units, such as several to tens of square meters, are used to depict habitats, and these units work together to create the building blocks of a habitat mosaic.

Furthermore, on a broader scale, a river reach can be defined as a section of the river that harbors a distinctive cluster of these habitat types. Because they are nestled inside longer river segments, reaches form river networks (Frissell et al., 1986). From grains of sand to floodplain meadows, rivers and streams are linked to a variety of habitats. These include regions characterized by flow types (such as waterfalls, rapids, and pools), morphological features (such as river banks, gravel bars, and oxbow lakes, etc.), and dominant plant species (such as bankside vegetation, beds of aquatic plants, etc.). (Mainstone et al., 2016; McCabe, 2010). The flowing water force and channel morphology frequently rearrange to create a distinct, dynamic, and complex heterogeneous environment.

The unidirectional flow of rivers helps many organisms drift, particularly downstream, and aids in hydrochory for plants (Nilsson et al., 2010). Furthermore, spiral movement produced by open water phase motion recycles organic matter and nutrients released by organisms (Webster et al., 2016). Additionally, it aids in the delivery of food for a variety of species, including drift feeders, who rely on water flow to supply food, like forage fishes, and filter feeders, which include Caddis flies, Black flies, Midges, Mussels, and others (Wallace et al., 1980; Richardson and Mackay, 1991). The structure of an ecosystem and its function are closely related.

In a river ecosystem, structural features include things like biological communities, water properties, channel shape, water movement force, etc., while function refers to things like metabolism, decomposition, nutrient cycling, dissolved organic matter uptake and degradation, exoenzymatic activities, biomass accumulation, etc. (Schiller et al., 2017). Therefore, the river ecosystem's food web heterogeneity is influenced by its structure and function. Furthermore, organic matter—such as leaf litter, seeds, woody material, aquatic microphyte beds, etc.—even in tiny river particles plays an important role in primary production and the efficient operation of the food web. These particulate organic components, which vary in size from nano to micro, are processed throughout the process and sent to the downstream habitat (Cantonati et al., 2020).

Headwater streams, sometimes known as "source streams" for rivers, typically originate from a variety of sources in high mountains, including glaciers, surface runoff, lakes, springs, a combination of groundwater inputs, etc. (Ward, 1994, Rattan et al., 2021). A unique combination of physical, chemical, and biological conditions can be found in the river network's glacial and pro-glacial river streams, which flow through the extreme habitat of alpine forests. These streams also provide resources that are available in large channels downstream, providing small habitat and refugia for small organisms from large-bodied predatory species, among other things (Brittain et al., 2001).

A diverse consortium of microorganisms, including bacteria, fungus, tardigrades, sporadic rotifers, and others, characterize the glacial ecosystem at source streams, supra-glacial streams, and melt pools (Hodson et al., 2008). However, proglacial river systems' α-, β-, and γ-alpine biodiversity is declining due to the alarming rate at which glaciers are retreating due to global warming, which also reduces river water supply sources (Whittaker, 1960; Jacobsen et al., 2012). Typically small, occasionally steep, erosive, and connected by forest canopies are river sources. This produced an environment that was cool, well-oxygenated, and rich in organic materials and food (Addy et al., 2016).

The river gained sufficient water and width on its way to the sea, resembling an open canopy state as it coincided with lower gradient landscapes. Because to the creation of riffles, rivers stay welloxygenated even when they get warmer and contain less food than upstream. At relatively shallow water in an open canopy state with strong flow velocity, riffles form. Because it offers fishes a feeding place, predator protection, and nesting locations for species like salmon, lamprey, and trout, it thus becomes a stream productive habitat for a variety of organisms (Meyer et al., 2007; Brooks et al., 2005). Potamal rivers typically have a low gradient, are very wide, and are not greatly impacted by riverine vegetation.

Fine solid suspensions of organic matter which reduce light penetration are maintained by water currents is largest food supply for such rivers (). Glides and pools are deep water areas with low to intermediate current velocity, on gravel or sand river beds often occupied by various aquatic plants and provide protection and food to various species. Biological communities are extremely controlled by changes in physical habitat and food base of the river system from source to mouth (). Classification of benthic micro invertebrate on the basis of functional feeding habitat, aquatic ecologist form five groups these are grazers (by scraping), periphyton (by substrate), collectors (by consume fine particulate), shredders (leaf eaters) and predators (animal prey) (Cantonati et al., 2020Ward et al., 1999McCabe, 2010).

Water mass retention time in rivers generally influences the growth of the biota; as retention periods increase, phytoplankton biodiversity increases. However, if retention times are too short, there is less succession and a greater abundance of small forms of zooplanktons in the river ecosystem. Zooplankton populations are more prevalent in side channels than in the lower portions of rivers because they can proliferate efficiently in locations with low flow velocities (Feld et al., 2014; Rabeni et al., 2005). River depth, velocity, and substrate size and texture all affect the species richness and population of invertebrates. As a result, species spread out across tiny microhabitats, which has an impact on the ecosystem's biological relationships.

For adult fish, dragonflies, and other aquatic insects, backwaters—an area connected to the main channel but devoid of flow serve as crucial refuges and breeding grounds (Addy et al., 2016).

Important habitat, aquatic microphytic beds serve as breeding grounds for fish, amphibians, and invertebrates. These regions are abundant in oxygen, nutrients, and trap sediments (Keruzore et al., 2013). Specialized habitat for plants, aquatic birds, animals (such as otters and bats), and invertebrates (such as flies, spiders, and ground beetles) is created by riverbanks and exposed sediments. By allowing them to establish nesting sites (in burrows or sand martin colonies), it helps species (Palmer et al., 2010). One kind of physical habitat in a stream that forms pools and eddies is tree roots and in-stream woody material. In addition to preventing direct sunlight, it helps stabilize sediments, improve water quality, and serve as a home for bacteria, fungi, algae, and insects (Gregory et al., 2003; Gippel et al., 1996).

THREATS TO FRESHWATER FAUNA:

Uncontrolled, careless, and overly exploitative resource usage is the main threat to biodiversity on Earth and to humanity. The hazard level was significantly increased by the effects of climate change and the human population boom (Woodward et al., 2010; Dudgeon et al., 2006). The resilience and proper operation of the ecosystem are essential to freshwater security. Due to the effects of direct and indirect risks now being felt and growing more quickly, two-thirds of the world's population may experience severe water stress by 2025 (Thornton and Herrero, 2010; Gardener et al., 2015). Because to the worsening state of rivers, almost 50% of freshwater species have decreased since 1970 (Gleick and Palaniappan, 2010). Despite this, 2.7 billion people who experience severe water stress each year are directly supplied with water by around 200 river basins (Gardener et al., 2015).

DIRECT THREATS TO FRESHWATER FAUNA:

Subsections address threats that have arisen as direct effects of geogenic and anthropogenic activities on the freshwater environment and biodiversity.

Pollution

Aquatic pollution is a serious problem that needs to be addressed right away on a worldwide scale. In actuality, freshwater availability on Earth makes up a very small portion of the global water distribution less than 0.01%. About 0.0002% of all water is found in this river (Dudgeon et al., 2006). There are several sources and routes of pollution in the freshwater ecosystem, which can lead to widespread effects such eutrophication, declining water quality, and water scarcity. Point source discharges, such as those from mining, oil production, agriculture, urban runoff, illicit drugs, personal care product additives, the paper and pulp industry, and active pharmaceutical ingredients (like diclofenac, carbamazepine, etc.), have an indirect impact on surface water quality through habitat destruction and a direct impact through ecotoxicity (Holetom et al., 2011; Hughes et al., 2013).

Due to their surprising biological activity, persistent nature, and bioaccumulating qualities, such as DDT, all of these emergent pollutants have attracted a lot of interest worldwide (Holetom et al., 2011). The effects of these newly discovered contaminants and their mixes on freshwater ecosystem function and biodiversity are still being investigated.

Around the world, urban runoff plays a major role in the accumulation of newly developing contaminants in rivers. Natural and synthetic hormones, endocrine disrupting substances (such as estrogen mimic and acetaminophan), antimicrobial substances (such as antibiotics, antivirals, and antidepressants), personal care items, pesticides, and other contaminants were found in municipal effluents (Sumpter and Jobling, 2013). Fish species that are sensitive to both natural and synthetic hormones, the natural microbial community, algal diversity and periphyton, and the loss of genetic diversity are just a few of the ways that all of these pollutants impact biodiversity.

For instance, intersex in male fishes and their progeny was caused by vitellogenin production (Jobling et al., 2002; Schwindt et al., 2014; Harris et al., 2011; Kidd et al., 2007; Hamilton et al., 2016).

Accordingly, the main producers and consumers of the freshwater food web are having a negative impact on the healthy food web and causing it to decrease (Kidd et al., 2014). Engineered nanomaterials (1–100 nm) with special chemical and physical properties and a high surface area to volume ratio are employed in a variety of consumer goods, therapeutic, and industrial applications (Stone et al., 2010).

According to Gottschalk et al. (2013), engineered nanomaterials in rivers are prone to aggregation and precipitation, with concentrations ranging from ng/l to µg/l. This has led to the exposure of both infaunal and epifaunal organisms (Selck et al., 2016). With the growth of the nanotechnology sector in recent years, the concentration of nanomaterials in surface water has been found to range between µg/kg. It is challenging to forecast environmental risk because of the lack of information on nanoparticles' toxicity threshold, realistic exposure concentration, and sensitivity magnitude across species and life stages (Callaghan and MacCormack, 2017).

Due to their high bioavailability and broad spectrum of toxicity, some research has indicated that freshwater, crustaceans, and pelagic species are susceptible to these nanoparticles. The industrial expansion in the pharmaceutical and agricultural sectors, primarily in the areas of surface coating, herbicides, pesticides, and fertilizers, has a significant impact on the freshwater ecosystem (Von der Kammer et al., 2012; Coll et al., 2016). Due to their long-term risk and significant influence on particle fate and bioactivity, engineered nanomaterial-related products (titanium oxide, zinc oxide, and silver) have created new issues because of their characteristics, which include water chemistry, weathering, dissolution, structure variation, and aggregation kinetics (Wang et al., 2016).

Because of human activity, alien species invasions of freshwater ecosystems are particularly significant, challenging to control, and irreversible in nature (Strayer, 2010). The freshwater ecosystem's biogeochemistry, biodiversity, and economic usage were all negatively impacted by these invaders (Cox, 1999; Davis et al., 2007). The invasion-induced changes in ecological and evolutionary economic elements have led scientists to propose a new epoch, which Gordon Orians has named the "Homogocene" (Strayer, 2010). More than hundreds of freshwater species have been shown to be invasive, having spread outside of their natural habitats through various means such as aquaria, canals, ballast water, and anthropogenic induction. Consequently, there are several invasive species in a number of freshwater bodies (Duggan et al., 2005; Gertzen et al., 2008; Padilla and Williams, 2004; Mills et al., 1993 and 1996).

Therefore, invasion is a very non-random mechanism; however, the biological and taxonomic traits of the invasive species are taken into account, in addition to the environmental features of the invaded habitat and the location of the native alien species (Strayer, 2010). The invaded ecology is profoundly and widely impacted by some invasive species. Mollusks are ecologically significant invasion classes in freshwater ecosystems that disrupt the lower trophic level food chain because of their primary consumer feeding behavior. Furthermore, fishes from the center or higher trophic level disturb the food web (Strayer, 2010). Furthermore, alien plant species with large biomass and unique physical traits pose a serious threat to the freshwater ecosystem and have a variety of engineering consequences related to invasion (Jones et al., 1994).

The possibility of alien species to build "no-analogue" ecosystems that are unmanageable in the future poses a serious threat to the current pure ecology. The invaded ecosystem's hydrology, biotic composition, and biogeochemical cycle can all be significantly disrupted and altered by the invading species. Preventive actions should be taken to manage, limit, and regulate invasions and the effects they have on the ecosystem (Strayer, 2010).

Deforestation

Deforestation is one of the major threats to river biodiversity and is visible everywhere in the world. caused uncontrolled water logging, flash floods, increased runoff, and sedimentation (Dudgeon, 1999). Together with seasonally fluctuating river flow, deforestation increases the frequency and severity of floods, which has a significant and negative impact on the freshwater ecosystem and human population (Dudgeon, 2000).

By supporting the river ecosystem in the form of geomorphological, physical, chemical, and biological circumstances, the riparian vegetation maintains a multifaceted functional role as well as a zone of interaction between several species (Srivastava, 2007).

Furthermore, by providing food, shelter, and nesting places for organisms, the riverbank forest community—which ranges from mature woodland to species-rich grassland—displays a unique kind of habitat (Srivastava, 2007). To create an efficient sustainable management and conservation plan, more thorough research on the function of flood plains, riparian vegetation, and soil and water use must be done (Addy et al., 2016).

Hydropower Projects:

The 19th century saw an increase in the building of dams on rivers for multiple uses. Dams have significantly changed the distribution, abundance, and extinction of species by changing the hydrology, morphology, structure, and function of rivers and freshwater ecosystems (Bunn and Arthington, 2002, Poff and Schmidt, 2016). (Adams and Hughes, 1986; Holmquist et al., 1998; Pringle et al., 2000; Richter et al., 1997; Nilsson et al., 2005; Dudgeon et al., 2006; Anderson et al., 2018; Oliveira et al., 2018) The dams lead to fragmentation, disturb the natural flow of water, sedimentation, and disturb biotic communities. Large upstream areas being submerged and the river's unnatural flow are linked to the effects of dams.

For ecological activity to occur, such as fish migrating upstream while rivers are flowing freely, natural flow variability is necessary. There will be serious harm to the health of the river if no compensatory flow is provided (Hart et al., 2002). However, depending on each river's unique characteristics, the influence on physical habitat may differ (Gordon, 1984). One typical issue that might lead to the formation of armored river beds is the decreased supply of sediments caused by obstructions in the river's natural flow (Kondolf, 1997). River flow management, fragmentation, morphology, and structure have all changed as a result of hydropower expansion. This has changed fish migration, sediment transport, primary production, groundwater levels, and biodiversity. Water management systems have a significant impact on the diversity of freshwater fish and people's livelihoods that depend on rivers because they split aquatic habitat, preventing focus species (salmonids) from moving in a certain direction, which affects fish harvest and food security as well as some migratory species (shrimps).Therefore, there are a number of possible effects of hydropower increase on the ecology and human population that are still unknown and need more thorough research.

Loss, relocation, and modification of habitat

Rivers' natural character has deteriorated since the industrial revolution, leading to a loss of ecosystem services, biodiversity, and distinctive habitat. River habitat is one of the most endangered habitat types in the world due to a variety of stresses (Addy et al., 2016). Channelization, the construction of in-stream structures (bank reinforcement and flood embankment), flow modification, dredging, impoundment weirs and locks, dams, gravel extraction, and the removal of in-stream trees all contribute to habitat loss through physical harm (Palmer et al., 2010). Because of their adaptability, the organisms can employ a variety of habitats when the conditions of the river change. For instance, riffles sustain plant life by containing diatoms and microscopic algae, serve as a home for aquatic insects, and cause fish to seek cover during strong flow. Young (2001). According to Addy et al. (2016), interlinking among the habitat is crucial to preserving the diversity and integrity of the river habitat. River channelization has a number of negative effects, including decreased water and matter exchange in floodplain areas, loss of water storage, increased downstream flooding, and downstream siltation, all of which lead to a clog of salmon and trout reeds and hypoxia conditions for macroinvertebrate communities (Rabeni et al., 2005; Soulsby et al., 2001).

INDIRECT THREATS TO FRESHWATER BIODIVERSITY

Many indirect concerns that significantly affect the freshwater ecosystem have an impact on the river system. The functioning, structure, and dynamics of the river ecosystem are now more vulnerable to significant disruptions as a result of these indirectly generated concerns. A few serious indirect hazards are covered in the subsection.

Severe weather and climate change

Due to the quick and unpredictable changes in the climate, freshwater species are migrating to more climatically conducive places. Climate change affects freshwater biodiversity in a number of ways, including limiting nutrient inputs, favoring cyanobacteria over eukaryotic algae, endangering water birds, mollusks, and other species, desynchronizing interspecific interactions, and causing a variety of other ecological responses of the freshwater system. Climate change also includes changes in water temperature and annual precipitation that result in frequent drought and floods, discharge alteration, and disease outbreaks.

Numerous regional studies came to the conclusion that climate change is making freshwater salination a greater danger (Herbert et al., 2015). About 1.5 × 107 ha of freshwater peat land are under risk due to sea level rise (Henman and Poulter, 2008; Wicke et al., 2011). The extinction of salt-intolerant taxa, the unbalancing of sodium and chloride ion levels, the reduction of critical ion capacity in water, the reduction of rhizome viability, surface sediment anoxia, and ecosystem fecundity are just a few of the ways that salination impacts biodiversity. Parental bedrock weathering, lumber, and forests are the sources of calcium in freshwater systems. Large-bodied Daphnia, crayfish, and other aquatic species are impacted by calcium, a vital nutrient in the environment.

Challenges:

Because biodiversity is endemic and dependent on the location of rivers and wetlands that act as sinks for land-use pollutants, conservation of biodiversity is a challenging undertaking. Additionally, freshwater faces intense competition from a variety of human stakeholders in many regions of the world (Jungwirth et al., 2002; Reed, 2008). Because it is impacted by a number of variables, including the upstream drainage network, the surrounding terrain, the riparian zone, and downstream reaches, protecting freshwater biodiversity is the most important conservation task. Seldom are such requirements fulfilled (Dudgeon et al., 2006).

The majority of river modifications have been carried out with the greatest of intentions, but without adequate awareness of the potential repercussions (Tockner and Stanford, 2002). The riverine ecology and aquatic, wetland, and terrestrial ecosystems have seen significant changes as a result of rapid population growth and technological advancement.

There are no longer any pristine natural settings that have eluded direct or indirect human interference (Smith et al., 2014). The types and effects of numerous physical changes to river systems must be identified in order to establish sustainable restoration practices. Understanding other pressures is also necessary for a sustainable plan to be successful (Piégay et al., 2005). Areas designated as floodplains are created for a variety of purposes, including urbanization, agriculture, and industry. These uses are frequently linked to channelization, flood embankments, and bank reinforcement, which lower evapotranspiration rates and soil water storage, resulting in increased peak flows and decreased baseflows (Skidmore et al., 2012). The biodiversity of river corridors depends on riverine forest and vegetation groups, which also support river banks by giving them strength and erosion resistance while influencing the form of the river. Consequently, species-rich meadows and forests in floodplain areas are now uncommon as a result of changes in land use patterns. Enhancing agricultural land drainage, improving navigation, and lowering the incidence of localized flooding problems are the goals of channelization.

CONCLUSION

The freshwater ecosystem and the services it provides are vital to the survival of all living things. When it comes to freshwater management, the impact of human systems and climate change on riverine resources is essential. In order to protect these essential and priceless natural resources, we must first create a sustainable society where we set new standards for water conservation and wise resource usage. In order to provide potential mitigation solutions in a comprehensive manner, this study attempted to identify and critically examine the dangers and challenges faced by the biodiversity of rivers.

Our well-being depends on the ecosystem's ability to function properly because it offers all of our needs as well as a variety of advantages that are sometimes disregarded because human demand patterns are expected to increase and species extinctions are expected to continue at their current rate.

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