

Fish Biodiversity Conservation

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SUMMARY

Freshwater fish biodiversity plays an important role in keeping aquatic ecosystems healthy while also supporting human livelihoods through food security, cultural significance, and economic benefits. However, despite their value, freshwater fish populations are declining rapidly across the world due to human activities such as habitat destruction, pollution, overfishing, invasive species, changes in water flow, and climate change. Although freshwater ecosystems cover only a small portion of the Earth, they support a remarkably high level of biodiversity, making them especially sensitive to environmental disturbances. The combined impact of these pressures has accelerated species loss, increased extinction risks, and disrupted essential ecological processes. To address these challenges, conservation efforts need to be integrated and adaptive, focusing on habitat protection, sustainable water management, pollution control, climate-resilient strategies, and effective biodiversity monitoring. Strong policy support, interdisciplinary scientific research, and active involvement of local communities are equally important for successful conservation. A balanced approach that considers ecological, social, and economic aspects is essential to protect freshwater fish diversity and maintain the ecosystem services they provide. Greater collaboration among researchers, policymakers, and communities will be key to ensuring the long-term health and resilience of freshwater ecosystems for future generations.

INTRODUCTION

Global ecological equilibrium and a variety of ecosystem services are supported by the complex web of aquatic life, especially the biodiversity of fish (Meinam *et al.*, 2023). According to Rumschlag *et al.* (2025), freshwater systems alone are home to more than 18,000 fish species, which make up a sizable percentage of vertebrate diversity and are essential cultural and economic resources for human societies. Freshwater fish populations are facing enormous pressures from human activities, resulting in a global loss in their numbers and variety, despite their immense ecological and socioeconomic significance (Pawde *et al.*, 2023). The main causes of this loss include overexploitation, pollution, invasive species, habitat degradation, and climate change; therefore, immediate and all-encompassing conservation measures are required (Pawde *et al.*, 2023; Showers, 2024). A comprehensive understanding of the intricate relationships between fish species, their habitats, and the numerous stresses they encounter must be incorporated into such initiatives, which must go beyond simple preservation (Bhakta & Saxena, 2024).

Since about one-third of all freshwater fish species are currently endangered, families including the Cyprinidae, Leuciscidae, and Salmonidae are disproportionately affected (Vardakas *et al.*, 2025). Therefore, it is critical to comprehend the complex patterns and causes of freshwater fish extinctions. Furthermore, although the ecological and social importance of freshwater and marine fishes is well known, the number of species in each environment is very similar, despite differences in size and volume (Arthington *et al.*, 2016). This emphasizes the remarkable biodiversity per unit area observed in freshwater habitats, which makes them especially susceptible to regional disruptions and worldwide environmental shifts (Abass *et al.*, 2024). According to Haase *et al.* (2025), there has been a concerning 81% decrease in freshwater migratory fish populations worldwide between 1970 and 2020, highlighting the detrimental effects of human activity on riverine ecosystems.

Importance of Fish Biodiversity

Given their critical role in food security, nutrient cycling, and the general health of aquatic ecosystems, fish biodiversity preservation is therefore not just an ecological imperative but also a socio-economic need (HM, 2024;

Marnis *et al.*, 2024). Despite comprising up only 1% of the planet's surface, freshwater habitats are home to an astounding 51% of all fish species, making their conservation disproportionately important (HM, 2024). From flood management and water purification to sustaining a variety of food webs that eventually benefit human populations, these aquatic ecosystems offer a wide range of ecosystem services (Lynch *et al.*, 2023). However, a biodiversity crisis with concerning rates of population reduction and extinction risk in freshwater creatures has resulted from the ongoing human pressures on freshwater ecosystems (Reid *et al.*, 2018).

Globally, fish populations are decreasing as a result of swift changes in land use and climate, and suitable freshwater habitats are changing significantly (Dutta *et al.*, 2024). The vulnerability of freshwater fish to extinction is increased by these environmental changes in conjunction with other stressors such as pollution, habitat fragmentation, and the introduction of non-native species (Makki *et al.*, 2023; Martelo *et al.*, 2024; Su *et al.*, 2021).

Data from primarily terrestrial tetrapods, rather than the more endangered aquatic fauna, have thus far influenced environmental policies and conservation priorities, as thorough worldwide assessments of extinction risk have traditionally ignored speciose freshwater groups (Overed-Sayer *et al.*, 2025). Despite making up only 0.01% of the world's water and 2.3% of its land surface, freshwater ecosystems are home to at least 9.5% of all known animal species and are declining three to six times more quickly than both the marine and terrestrial realms (Reid *et al.*, 2018; Tockner, 2021). This oversight has serious ramifications.

Threats to Fish Diversity

This concerning discrepancy highlights the pressing necessity of reassessing conservation strategies in order to effectively handle the various challenges affecting freshwater ichthyofauna (Dudgeon, 2010). These dangers result from a number of human-caused activities that significantly change freshwater ecosystems, such as pollution, habitat loss, changed flow patterns, and the introduction of exotic species (Tockner, 2021). Approximately one-third of vertebrates and half of fishes are among the over 10% of all known species that are critically endangered due to these stressors, which together cause a sharp reduction in freshwater biodiversity (Overed-Sayer *et al.*, 2025). These crucial freshwater ecosystems are degrading more quickly than in terrestrial settings, despite the fact that they offer invaluable services to both nature and society (Albert *et al.*, 2020). The disproportionate effects of climate change on freshwater systems, where changing precipitation patterns and rising air temperatures directly alter vital habitat characteristics like water temperature and flow regimes, further exacerbate this increased susceptibility (Barbarossa *et al.*, 2021).

These environmental alterations can result in quick evolutionary changes or the extirpation of sensitive fish species when paired with other human-induced stressors to establish novel selection pressures (Comte *et al.*, 2021). According to climate models, for example, only a small number of river basins will actually go extinct by 2090 as a result of habitat loss brought on by climate change, but freshwater species are rapidly declining at rates higher than those of terrestrial and marine taxa as a result of several interrelated stresses (Aloo *et al.*, 2017; Collen *et al.*, 2013; Rees *et al.*, 2023). Oceania's naturally depauperate freshwater fish fauna, on the other hand, may have fewer endemic species that are intrinsically susceptible to extinction, which may account for the region's lower documented extinction rates (Vardakas *et al.*, 2015). Although dams, habitat loss, and pollution may have more immediate effects, the combination of these three factors poses a serious existential danger to freshwater biodiversity (Dudgeon, 2019). For species that have limited ranges or specific habitat needs, the combined effects of these stresses frequently show up as localized extirpations and population decreases (Su, 2020).

Conservation Strategies and Management Measures

Implementing comprehensive conservation plans and proactive management methods that incorporate ecological, social, and economic factors is necessary to address these complex threats (Showers, 2024). In order to preserve fish species for future generations, these policies must place a high priority on the preservation and restoration of vital freshwater habitats, reduce pollution sources, and guarantee sustainable water resource management (Bogárdi *et al.*, 2020). According to Miranda (2023), in order for conservation paradigms to be effective, they must take into account a comprehensive understanding of freshwater ecosystems and recognize the intricate interactions between the biological characteristics of fish species and external human pressures. The synergistic effects of multiple stressors, such as climate change, which drastically changes the physical, chemical,

and biological characteristics of freshwater habitats, must also be taken into account in such paradigms. This will increase the likelihood of extinction and require the integration of scientific research, ecosystem monitoring, and community engagement (Ali & Siva, 2022; Showers, 2024).

Furthermore, in addition to traditional conservation strategies, adaptive management techniques are crucial for addressing the ever-changing difficulties presented by climate change (Showers, 2024). This calls for a transformation in conservation strategies that are adaptable and sensitive to environmental shifts, going beyond static protected areas to dynamic interventions at the landscape scale (Showers, 2024). According to Máiz-Tomé *et al.* (2018), these interventions must take into account both ex-situ conservation initiatives to maintain genetic diversity and in-situ conservation, which is frequently combined with sustainable use strategies. Effective ecological policies and impact evaluations in freshwater conservation also depend on a solid taxonomic understanding supported by a high level of biodiversity input (Ottoni *et al.*, 2023). Protecting the distinctive ecosystem services that freshwater fish offer, such as nutrient cycling and water purification, which are sometimes underestimated yet essential for ecological stability and human well-being, requires such all-encompassing strategies (Showers, 2024).

Therefore, it is essential to take a comprehensive, integrated, and more successful approach to sustainable water management and freshwater biodiversity conservation. This approach should cover the entire spectrum of activities, from preserving genetic diversity to restoring and safeguarding functional habitats and ecological processes (Rees *et al.*, 2025). Scientists, policymakers, and local communities must work together to implement policies and regulations for the development of energy and water infrastructure as well as fisheries management in order to ensure the long-term resilience and health of the ecosystem (Bhakta & Saxena, 2024; Showers, 2024). Conservation efforts must take into account both past and present pressures, given the complexity of biodiversity changes and the quick reorganization of biological groups brought on by human effects (Danet *et al.*, 2024).

Role of Communities and Policy in Conservation

Effective freshwater fish conservation programs are built on the foundation of strong legislative and legal frameworks as well as the active participation of local people (Showers, 2024). This involves involving inland fishermen and indigenous peoples in planning and data gathering to encourage ownership and stewardship of conservation efforts, which will ultimately result in more sustainable fish population management (Showers, 2024). Navigating the intricate problems of freshwater fish conservation and guaranteeing the long-term sustainability of these ecosystems depend heavily on cooperative strategies that combine scientific study with Indigenous ecological knowledge (Showers, 2024). According to Torres-Romero *et al.* (2024), the adoption of stronger national and international policy frameworks that support sustainable livelihoods can also be very important in reducing anthropogenic pressures and reducing the risk of extinction that these important ecosystems and the species that make them up face.

The preservation of freshwater ecosystems should be given top priority in these frameworks, both for their inherent biodiversity worth and for the vital ecosystem services they offer, like food security and water purification (Showers, 2024). Furthermore, a bold new strategy is needed to restore and protect freshwater biodiversity, which calls for integrated approaches to both the conservation of freshwater biodiversity and sustainable water management (Rees *et al.*, 2025). Fostering inter- and transdisciplinary collaboration not only within scientific fields but also actively participating in policymaking calls for a fundamental, revolutionary shift in policymaking that incorporates combined riparian-freshwater research (Hoppenreijns *et al.*, 2023).

Recognizing the significant effects of human activity on freshwater biodiversity and the necessity of methods that address both species gains and losses, especially in highly dynamic riverine systems, are part of this (Danet *et al.*, 2024). The fact that widespread development, environmental degradation, and the rapid rate of climate change pose a serious danger to the ecosystem services that freshwater biodiversity provides must be clearly acknowledged in these efforts (Phang *et al.*, 2019).

CONCLUSION

The biodiversity of freshwater fish is essential to maintaining the health of aquatic ecosystems and sustaining human life through food, livelihoods, and financial gains. Freshwater fish populations are decreasing quickly worldwide, though, due to increasing human pressures such habitat destruction, pollution, climate change,

invasive species, and unsustainable resource usage. These issues impact food security, ecosystem balance, and the welfare of communities that rely on these resources in addition to endangering fish survival. To address this situation, robust and adaptable conservation measures are required. Restoring ecosystems, managing water resources responsibly, reducing pollution, implementing climate-resilient techniques, and enhancing biodiversity monitoring are all examples of this. Involving local populations, promoting scientific research, and fortifying policies are all equally crucial for effective conservation. Working together, researchers, legislators, and local stakeholders can guarantee more durable and successful results. In the end, protecting freshwater fish biodiversity necessitates an integrated, balanced strategy that takes human demands and environmental health into account. It will take sustained dedication to conservation and prudent resource management to protect freshwater ecosystems and keep them resilient for coming generations.

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