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Review paper

Understanding the Threats on Aquatic and Semi-Aquatic Habitat

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ABSTRACT

Recent focus on aquatic ecosystems has underscored the increasing dangers posed by human activities and climate change, resulting in intensified efforts to comprehend the dynamics of these systems and the risks linked to their alteration. The pressures on freshwater ecosystems are unprecedented and increasing. Contemporary human activities have resulted in catastrophic reductions in freshwater biodiversity, environmental degradation, and a diminishing gene pool. Aquatic biodiversity is declining as a consequence of increased harvest pressures, pollution, habitat alteration, introduction of non-native species, and climate change. Safeguarding and rehabilitating these ecosystems are not merely an environmental obligation but also crucial for the preservation of life on Earth.

1. Introduction

Aquatic and semi-aquatic environments, including rivers, lakes, wetlands, estuaries, mangroves, and marshes, are among the most productive ecosystems on Earth. They offer habitat for several species of flora and fauna, sustain fisheries, manage hydrological cycles, and assist in flood control. Numerous human settlements rely directly on these ecosystems for sustenance, water, and economic resources. Nonetheless, these ecosystems are confronting significant risks from escalating human activity and environmental alterations. Comprehending these dangers is essential for safeguarding biodiversity and preserving ecological equilibrium. Aquatic and semi-aquatic environments have been identified as highly impacted spaces or system types globally. The biodiversity of aquatic and semi-aquatic habitats is increasingly imperilled by both natural factors and human activities. The modifications commence with habitat destruction and direct changes, compromising essential environmental characteristics that promote functional connectedness for aquatic organisms. Currently, biodiversity is experiencing a significant decline worldwide, underscoring the necessity of conservation planning (Sarkar, 2016). Biodiversity is an abbreviation for biological diversity, referring to the total number, variety, and variability of living creatures, as well as the diversity of their ecosystems (Sarkar and Mazumder, 2016). Biodiversity encompasses the totality of richness and variation among all living organisms. Aside from protected areas and reserve forests, scientific research on the biodiversity of unique ecosystems in India is scant, similar to other regions globally (Sarkar, 2016). Biological diversity refers to the variety of living organisms, encompassing diversity within species, across species, and across ecosystems, together with the ecological processes in which they are involved (McNeely,1991).

The ongoing escalation of anthropogenic activity exacerbates their impact on aquatic ecosystems, from continental to marine, which are the most modified ecosystems on Earth (Logez et al., 2025). The global risks to marine ecosystems are significantly perilous due to the fragility of marine environments (Casper, 2010). Marine ecosystems exhibit significant responsiveness to variations and alterations in physical settings, while concurrently demonstrating resilience and adaptability to these changes (Steele 1998; Pan et al. 2013). The fragility of freshwater habitats arises from the disproportionate proliferation of plant and animal populations within the aquatic ecosystem (Irfan and Alatawi, 2019).

2. Landscape of Aquatic and Semi-Aquatic Habitats

Aquatic ecosystems, including lakes, rivers, ponds, marshes, and wetlands, abound with biodiversity. Aquatic and semi-aquatic habitats constitute roughly 2.3% of the Earth's terrestrial surface. They are prominently included in the majority of national, provincial, state, and regional plans, constructing a complex and contentious landscape. Aquatic biodiversity escalates with latitude, peaking in tropical regions (Irfan and Alatawi, 2019). Freshwater habitats contain over 10% of identified species, although occupying little about 1% of the Earth's surface (Santos, 2024). Water-related surface areas fulfil three-quarters of human requirements; nonetheless, a considerable percentage of rivers, lakes, aquifers, wetlands, and floodplains are strained to meet various demands. Stressors that severely impact the aquatic ecosystem include floods and the introduction of deleterious substances into water, whether resulting from natural disasters or human activities. Approximately 75% of the Earth's wetlands have been eradicated, endangering 28,000 freshwater species with extinction (Darwall et al., 2018). Aquatic resources and their biodiversity are interconnected, serve a variety of purposes, and are vital to the sustainability of biotic communities (Irfan and Alatawi, 2019). Aquatic plants are significant constituents of aquatic ecosystems, crucial for the preservation of biodiversity in every region (Mazumder and Sarkar, 2020; Mazumder et al., 2021). Researchers classified several plant species located in and near water environments: blooming plants, mosses, liverworts, encrusting lichens, stoneworts, and other significantly proliferating algae species. Aquatic flora may exhibit isolated or discontinuous growth and availability due to variations in distribution, frequency, intensity, establishment success, and growth rates (Irfan and Alatawi, 2019). Ensuring access to safe and nutritious food is a significant global goal; nevertheless, the effects of biological invasions stemming from aquaculture and fishing pathways on human well-being remain well comprehended (South et al., 2025). Studies on freshwater fish and amphibians indicate that approximately one-third to one-half of all species face threats of endangerment or extinction (Brook et al., 2008).

3. Primary Threats of Aquatic habitat

Aquatic and semi-aquatic habitats have frequently been overlooked in monitoring and assessments compared to other ecosystems. Key indicators and status evaluations pertain to ecological integrity, aquatic species, and socio-economic utilization potential. Indicators specify habitat type, condition, and water quality, whereas effective approaches measure pertinent parameters. Augmented technical capacity would help enhance data accessibility and prioritizing for monitoring networks. Aquatic and semi-aquatic habitats confront a complex crisis caused by several and frequently interrelated challenges that cumulatively undermine ecosystem structure, function, and biodiversity. Due to overexploitation of species, the introduction of exotic plants and animals, pollution from cities, industry, and agricultural areas, as well as the loss and alteration of biological niches, aquatic biodiversity is continuously declining in both freshwater and marine ecosystems (Irfan and Alatawi, 2019). Overall, the crisis in aquatic and semi-aquatic habitats arises from the intersection of climate change, invasive species, chemical pollutants, physical habitat alteration, pollution events, and changes in biological communities. Addressing this crisis requires urgent greenhouse gas mitigation, pollution control, habitat conservation, management of invasive species, and enhanced ecological research and monitoring to support adaptation and resilience of these critical ecosystems (Gangloff et al., 2016; Kernan, 2015; Pratchett et al., 2011). Globally, freshwater and estuarine systems are the most adversely affected by human activities, primarily due to agriculture and urbanization.

4. Habitat Destruction and Alteration

Aquatic habitats are some of the most fragile and biodiverse places on the planet as they offer vital services, encompassing water filtering, carbon sequestration, fishing resources, and recreational benefits (Chaturvedi et al., 2025). Alteration of physical habitats constitutes a significant risk for aquatic and semi aquatic system. The transformation of wetlands and other semi-aquatic ecosystems for agricultural, urban, and infrastructural purposes has led to significant habitat destruction. Wetlands are often drained or filled to accommodate human habitation, transportation infrastructure, and industrial areas. Natural aquatic body in forested area are frequently deforested for aquaculture and coastal development. Infrastructure and development initiatives, including utility-scale solar energy installations, may result in habitat destruction, fragmentation, desiccation of temporary water bodies, and depletion of groundwater, particularly in arid areas. Rapid urbanization and changes in land use in the subtropical and tropical regions to accommodate an increasing population are detrimental to freshwater ecosystems (Jaman et al., 2022). Linear infrastructures, such as roads and railways, interrupt the hydrological and ecological connectivity of rivers and wetlands by permanently altering their natural flows, which is aggravated by construction of impermeable structures (Liu, 2016). Human alteration of natural hydrological systems, especially via the construction of dams, reservoirs, and irrigation channels, profoundly modifies the physical and ecological dynamics of rivers and wetlands. Dams interfere with natural flow patterns, sediment conveyance, and seasonal inundation cycles vital for sustaining biological equilibrium. These alterations ultimately disturb hydrology and aquatic ecosystems reliant on ephemeral and perennial water sources. Hydrological and geomorphological alterations significantly impact riverine and lacustrine ecosystems (Ban et al., 2025).

5. Overexploitation

Aquatic organisms are vital to the diets of many individuals globally; however, people lack accurate knowledge regarding the population levels that sustain these fisheries. The overexploitation of certain species to satisfy human greed can lead to a decline in genetic diversity, hence reducing the relative abundance of individual species or groups of interacting species. This process can diminish population size due to disruptions in age structure and sex composition (Irfan and Alatawi, 2019). Technically the resource being exploited may be destroyed as a result of overexploitation or, conversely, overharvesting. Fishing exploitation undermines the genetic integrity of fish populations by depleting certain alleles from the genome, hence diminishing genetic diversity. Several aquatic plants were used as edible leafy vegetables and medicinal purposes and thus utilized massively (Mazumder and Sarkar, 2019). The excessive harvesting of aquatic plants for consumption, livestock feed, and commercial purposes may result in the localized extinction of vulnerable species (Sahu and Kurrey, 2025). Overfishing and unsustainable extraction methods have resulted in substantial reductions in global fish populations. Intensive fishing pressure often targets commercially valuable species, which can disrupt trophic structures and ecological interactions. Destructive fishing methods, including bottom trawling and chemical fishing, further damage benthic habitats and non-target species.

6. Climate Change

Climate change is a significant catalyst of habitat degradation, as it modifies temperature patterns, water chemistry, sea levels, precipitation distribution, and ocean currents, resulting in region-specific effects such as reduced river flow and surface water availability in freshwater ecosystems, and coral degradation in marine settings (Pratchett et al., 2011). In numerous areas, climate change is presently modifying hydrological processes, undermining freshwater connection and ecosystem integrity (Döll and Zhang, 2010). Hydromorphic alterations and climate change, particularly droughts that concentrate pollutants and floods events that redistribute them, significantly impact all principal aquatic systems. Climate change is also expediting the proliferation of invasive species by modifying temperature patterns, intensifying extreme weather occurrences, and altering species distributions (Kernan, 2015). Increased water temperatures, variations in salinity, and modified precipitation patterns are all factors that can promote the development of invasive species in new regions (Noah, 2024). The changing climate generates ambiguity about the locations of habitats and ecosystems, as ongoing alterations in the freshwater regime cause rapid variations in habitat features. Such quick changes can impede access to refuge regions that would support aquatic species during extreme weather, so increasing reductions. Climate-induced changes to the hydrological regime increase the likelihood of irreversible alteration or loss of these systems, exacerbating the vulnerability of aquatic species already suffering from habitat loss or degradation due to human activities (Dahal et al., 2025).

Climate change is anticipated to elevate the frequency of extreme events, including droughts and floods, which can significantly modify aquatic habitats by altering flow rates, inundation extent, and sediment transport. Increased frequency of extended droughts can impact habitat availability, productivity, and species composition in aquatic ecosystems. Severe flooding incidents have enabled the proliferation of *Salvinia molesta*, a floating fern that swiftly blankets water surfaces, obstructing sunlight and diminishing oxygen levels (Flood et al., 2020). Climate change may exacerbate the proliferation of lionfish, as elevated water temperatures extend their habitat and augment their reproductive efficacy (Noah, 2024). These invasive species flourish in warmer waters are particularly alarming in marine ecosystems (Noah, 2024).

7. Pollution and Contamination

Pollution and contamination compromise the health and hazard levels of aquatic and semi-aquatic habitats through three mechanisms: the accumulation of pollutants in food chains, pollution from sediments that cover habitats, and toxicants that directly disrupt ecosystem structure and function (Thrupthi and Devi Prasad, 2023). Domestic sewage is a significant source of water pollution, particularly in regions where wastewater treatment infrastructure is lacking or inadequate (Ibrahim and Aboshio, 2024). When fertilizers are applied at elevated amounts, they readily runoff and leach into surface water bodies. Excessive usage of organic manure can also lead to eutrophication and algal blooms, potentially resulting in diseases (Sedyaaw et al., 2024). The augmentation of water bodies with phosphates from agriculture, sewage, and industry is considered a primary factor in the decline of aquatic plants, as it facilitates a shift from clear water conducive to macrophyte growth to detrimental conditions dominated by phytoplankton and filamentous algae (Lambert and Davy, 2010). The phenomenon is known as Eutrophication. This results in eutrophication, algal blooms, and hypoxia, which inhibit the growth of indigenous aquatic macrophytes and modify community composition (Nafea and Zyada, 2015). Numerous sources indicate that, relative to other aquatic plant species, microalgae frequently exhibit heightened sensitivity to specific toxins present in municipal and industrial wastewaters (Blinova 2004; Paixao et al. 2008).

Pollution from diverse sources- such as petroleum hydrocarbons, pesticides, microplastics, and nutrient enrichment- degrades water quality and ecosystem health. The extensive application of pesticides in agriculture has resulted in their contamination of aquatic systems, where even minimal amounts can produce harmful consequences (Gilliom et al. 2006). Some studies revealed that the most prevalent impacts of pesticides on aquatic vegetation included reduced phyto-mass and alterations in the leaf structure of vascular plants (Ceschin et al., 2021). Industries release a range of contaminants, such as heavy metals, organic compounds, and thermal effluents, directly into aquatic environments (Ibrahim and Aboshio, 2024). Heavy metals such as mercury, arsenic, and chromium are environmentally persistent and can bioaccumulate in aquatic creatures, resulting in harmful effects across the food chain. Oil spills cause immediate and long-term contamination of aquatic habitats, affecting ecosystem integrity and potable water supplies. They threaten aquatic organisms through toxic exposure and habitat degradation. Some of these substances can induce endocrine disruption in fish, resulting in reproductive failure and population decreases (Gilliom et al. 2006). Chemical pollutants, particularly endocrine-disrupting chemicals (EDCs) and heavy metals, exert additional ecological stress. EDCs influence biological activities, with sub-lethal effects impacting behaviour, reproduction, trophic interactions, and potentially inducing transgenerational effects in aquatic populations (Windsor et al., 2017). Heavy metals bioaccumulate and bio magnify, presenting toxicity threats to aquatic creatures and human consumers, while degrading water quality and aquatic ecosystems. Recent research in Southern Tigris-Euphrates basin has recorded the accumulation of heavy metals in various submerged aquatic plant species, including *Vallisneria spiralis*, *Ceratophyllum demersum*, *Potamogeton crispus*, and *Potamogeton perfoliatus* (Naser et al., 2025). This pollution alters physiology of aquatic plants and animals, threatens biodiversity, and compromises food safety through bioaccumulation routes. Mebane et al. (2012) observed that heavy metal contamination in rivers can result in the reduction of sensitive macroinvertebrate species, which are essential for nutrient cycling and energy flow. Plastic contamination has also emerged as an escalating issue in both freshwater and marine ecosystems. Significant plastic litter can lead to entanglement or ingestion by aquatic species, whereas microplastics are increasingly identified inside aquatic food webs.

8. Invasive Species

Biological invasions are primarily caused by commercial activities that interfere with a species' natural biogeography. Invasive aquatic organisms are introduced via several means, both intentional and unintentional (Chaturvedi et al., 2025). Invasive species are creatures that have been brought to regions outside their indigenous range, either deliberately or inadvertently, and successfully form self-sustaining colonies. By altering species composition, ecological structure, and function, invasive species exacerbate this catastrophe. The most immediate and detrimental impact of invasive species is their capacity to outcompete native creatures for resources, including food, habitat, and breeding sites (Gallardo et al., 2016). The population dynamics of aquatic invasive species are challenging to forecast, with effects manifesting over extensive spatial scales across biotic ecosystems and influencing broad hydrological and biogeochemical processes. The ecological impacts of aquatic invasive species are extensive and frequently permanent (Noah, 2024). Pressures on native aquatic biodiversity are exacerbated by the combined effects of climate change and invasive non-native species, which frequently makes managing these changes difficult. Invasive species often modify physical habitats, occasionally resulting in enduring effects. Invasive species often modify physical habitats, occasionally resulting in enduring effects. Invasive plants also exert effects at the community level. In most cases, invasive macrophytes, including *Pistia stratiotes* and *Eichhornia crassipes*, frequently outcompete indigenous species, resulting in diminished biodiversity and modified ecological functionality (Mazumder and Sarkar, 2020). Plants like *Phragmites australis* invades wetland regions, displacing indigenous marsh flora and diminishing habitat availability for avian species, amphibians, and fish (Stiers et al., 2011). Experiments in ponds demonstrated that dense monotypic stands of *Hydrilla verticillata* altered the taxonomic character of invertebrate assemblages compared to multi-species macrophyte treatments, yet both treatments exhibited no difference in invertebrate taxonomy richness (Theel et al., 2008). The introduction of common carp into the Kashmir Valley has resulted in the near extinction of native schizothoracids, whereas *Osteobrama belangiri* in Loktak Lake, Manipur, is swiftly vanishing due to the presence of common carp (Bamaniya, 2024). In spite of theses international development strategies in Asia, Africa, and South America advocate for non-native species aquaculture to foster economic growth and enhance human well-being, despite significant environmental risks, based on the assumption that such aquaculture will improve availability to essential nutrients (South et al., 2025).

9. Conservation Strategies and Management Approaches

The conservation of biodiversity involves the strategic planning and management of biological resources to ensure their extensive utilization and sustained availability, while preserving their quality, value, and diversity. The majority of current conservation initiatives focus on terrestrial ecosystems rather than aquatic ones, even though many aquatic species are in risk of extinction. The destruction of aquatic ecosystems has profound ecological, social, economic, and cultural repercussions. Documented effects encompass species extinction, interruption of harvesting cycles, and the loss of essential direct and indirect ecosystem services crucial for human subsistence. If left unchecked, these processes would inevitably result in the degradation of delicate freshwater ecosystems and the concomitant loss of their environmental and cultural legacy. Restoration programs offer opportunity to analyse design principles, practices, and community engagement tactics that improve sustainability and stakeholder ownership.

Climate change is influencing the timing, amount, and duration of inundation in wetland complexes, as well as modifying the amplitude and frequency of low-flow and high-flow events in river systems. Accelerated climate change adversely affects the biodiversity of rivers and streams (Nimma et al., 2025). Climate change may lead to extinction across various taxonomic levels. Species with severely restricted geographic ranges are susceptible to global extinction. This applies to fish, where regional variations in the proportionate prevalence of specialized species render them susceptible to worldwide extinction. The sustainable management of freshwater ecosystems must anticipate future changes in the types of small wetland complexes linked to adjacent waterways, the nature of open-water habitats, and the characteristics of high- and low-flow events interacting with evolving landscapes.

Once established, aquatic invasions are challenging to manage. Conventional removal methods frequently fail to eradicate target species, and invasive species may demonstrate superior growth rates relative to native species following perturbation (Gettys, 2019). Furthermore, the monitoring of current invasions and the introduction of novel species underscores the necessity to monitor arriving aquatic invasives and their effects on targeted communities. Enhancing the capacity to identify and document novel aquatic species would augment system comprehension and aid in the conservation of biodiversity in areas where monitoring is practicable. An urgent necessity exists to enhance efforts to reduce biodiversity losses and to establish long-term strategies for the preservation of this valuable resource.

10. Conclusion

Pollution, habitat destruction, hydrological alteration, climate change, overexploitation, and biological incursions cumulatively lead to the deterioration of these ecosystems. Confronting these difficulties necessitates cohesive environmental management, enhanced regulatory frameworks, sustainable resource utilization, and international collaboration. Safeguarding aquatic ecosystems is essential for preserving biodiversity, as well as for maintaining long-term environmental stability and human welfare.

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