



Review

Impact of Anthropogenic Interventions on Fisheries Biodiversity

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Abstract: Fisheries biodiversity plays a vital role in maintaining aquatic ecosystem health, ensuring food and nutritional security, supporting economic development, and sustaining the livelihoods of millions of people worldwide. However, increasing anthropogenic activities have significantly altered freshwater and marine ecosystems, resulting in habitat degradation, declining fish populations, and loss of biodiversity. The introduction of exotic fish species has led to Competition with native species for food and habitat, hybridization, genetic erosion, and the Spread of diseases, thereby threatening indigenous fish diversity. River dams disrupt natural flow regimes, fragment aquatic habitats, obstruct fish migration routes, alter spawning and breeding grounds, and reduce recruitment of economically important migratory species such as hilsa and mahseer. Shore protection structures, including seawalls, groynes, and breakwaters, modify coastal habitats, interfere with sediment transport, and reduce the productivity of nearshore ecosystems, negatively affecting fish assemblages and artisanal fisheries. Although micro hydropower projects are often

considered environmentally sustainable alternatives for renewable energy generation, they can alter stream hydrology, reduce environmental flows, and fragment river connectivity, leading to declines in native fish abundance. Offshore oil exploration and production further contribute to fisheries biodiversity loss through hydrocarbon pollution, underwater noise, habitat disturbance, and degradation of sensitive marine ecosystems. Collectively, these impacts threaten the sustainability of capture fisheries, reduce the livelihoods of fishing communities, and contribute to the long-term loss of aquatic biodiversity.

Keywords: Anthropogenic interventions, fisheries biodiversity, exotic fish species, river dams, coastal structures, micro-hydropower, offshore oil exploration

Introduction:

Biodiversity refers to the variety of life on Earth, including the diversity of genes, species, and ecosystems, and it is essential for maintaining ecological balance and ecosystem stability (CBD, 2020). Aquatic biodiversity,

comprising freshwater and marine organisms such as fish, shellfish, aquatic plants, microorganisms, and marine mammals, provides a wide range of ecosystem services that support human survival and economic development. Fisheries play a vital role in global food security by supplying high-quality protein and essential nutrients to billions of people while also contributing significantly to employment, trade, and the livelihoods of coastal and inland communities (FAO, 2022). The sustainability of fisheries and aquatic ecosystems depends on the maintenance of healthy biodiversity and ecological processes that support the growth, reproduction, and survival of aquatic organisms (IPBES, 2019). Over the past century, rapid population growth, industrialization, urbanization, and technological advancement have intensified human activities, resulting in unprecedented pressure on natural ecosystems (IPBES, 2019). Anthropogenic activities such as land-use change, agricultural expansion, pollution, deforestation, mining, dam construction, hydropower development, coastal engineering, offshore oil exploration, and overexploitation of aquatic resources have significantly altered freshwater and marine environments (UNEP, 2021). These activities have caused habitat degradation, water pollution, changes in hydrological regimes, eutrophication, sedimentation, and fragmentation of aquatic ecosystems, ultimately reducing biodiversity and ecosystem resilience (Zarfl *et al.*, 2019). Climate change, driven largely by human activities, has further intensified these impacts by increasing water temperatures, ocean acidification, sea-level rise, and the frequency of extreme weather events that affect aquatic species and their habitats (IPCC, 2023). Among the various anthropogenic pressures, overfishing remains one of the greatest threats

to aquatic biodiversity because it reduces fish populations, alters food-web dynamics, and affects the structure and functioning of aquatic ecosystems. Fishing practices such as bottom trawling, destructive harvesting methods, by-catch, and ghost fishing also damage benthic habitats and unintentionally remove non-target species, contributing to biodiversity loss (NOAA, 1992). In addition, the introduction of non-native or invasive species through aquaculture, ballast water discharge, and accidental release has altered native communities by increasing competition, predation, and disease transmission. River regulation through dams and hydropower projects disrupts natural flow patterns and blocks migratory pathways of fish, leading to declines in many freshwater species. Similarly, coastal development involving seawalls, ports, and breakwaters modifies shoreline habitats, affecting breeding, nursery, and feeding grounds for many aquatic organisms (Airoldi *et al.*, 2021)

The concept of responsible fisheries emphasizes the sustainable utilization of aquatic resources while minimizing adverse environmental impacts and conserving biodiversity for future generations (FAO, 1995). Effective fisheries management requires an ecosystem-based approach that integrates biodiversity conservation with sustainable resource use and considers both ecological and socio-economic factors. Protecting aquatic biodiversity is essential not only for maintaining ecosystem services but also for ensuring food security, economic stability, and climate resilience in the future (IPBES, 2019). Therefore, understanding the impacts of anthropogenic activities on biodiversity is fundamental for developing appropriate conservation strategies, restoring degraded ecosystems, and promoting the

sustainable management of fisheries and other aquatic resources.

Exotic Species and Their Impact on Fisheries Biodiversity

Exotic fish species are non-native fishes that have been intentionally introduced into India from different parts of the world for purposes such as aquaculture, food production, ornamental fish keeping, sport fishing, mosquito control, and aquatic weed management. The introduction of these species began during the British colonial period and continued after independence to improve fish production, meet the growing demand for animal protein, and increase the economic returns from fisheries. Several exotic species, including common carp (*Cyprinus carpio*), tilapia (*Oreochromis mossambicus*), grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), Pangasius, and trout, have become well established in Indian freshwater ecosystems because of their rapid growth, high reproductive capacity, adaptability to a wide range of environmental conditions, and resistance to diseases. These characteristics have made them valuable for aquaculture and have significantly increased fish production in many parts of the country. However, the introduction of exotic fishes has also resulted in several ecological challenges. Common carp disturbs bottom sediments during feeding, increasing water turbidity and reducing water quality, while also competing with native fish species for food, space, and breeding habitats. Tilapia reproduces rapidly and often forms dense populations that suppress the growth and survival of indigenous fishes. Grass carp, although

introduced to control aquatic weeds, can alter aquatic vegetation, destroy habitats used by native species, and affect the ecological balance of freshwater ecosystems. As a result, the abundance of several native fish species has declined, leading to a reduction in biodiversity and changes in ecosystem structure and function (Swain *et al.*, 2017). In addition to ecological impacts, exotic fishes also have important economic and environmental consequences. Many exotic species escape from aquaculture ponds during floods or through accidental releases and establish breeding populations in rivers, lakes, reservoirs, and wetlands. Once established, they are extremely difficult and expensive to eradicate. These invasive species compete with native fishes for food and shelter, prey on eggs and juveniles of indigenous species, alter aquatic food webs, increase water turbidity, reduce dissolved oxygen levels, introduce parasites and diseases, and may hybridize with native fishes, leading to genetic erosion. Such changes reduce the productivity of natural fisheries and negatively affect the livelihoods of local communities that depend on native fish resources. The spread of invasive species also threatens endangered fish populations and disrupts the ecological stability of freshwater ecosystems. Therefore, effective policies, strict quarantine measures, regular ecological monitoring, responsible aquaculture practices, public awareness, and scientific management are essential to regulate the introduction and spread of exotic fishes while conserving India's rich aquatic biodiversity and ensuring the sustainable use of freshwater resources for future generations (Gaupale & Sontakke, 2024).

Table.1 : Major Case Studies of Exotic Fish Impacts in India

Exotic Species	Region(s) Affected	Major Impacts	Key Findings from Case Studies	References
Tilapia (<i>Oreochromis mossambicus</i> , <i>O. niloticus</i>)	South India, Northeast India, reservoirs	Competition with native fishes, biodiversity decline	Established self-sustaining populations, displaced native carps and altered fish community composition in several reservoirs	Singh & Lakra (2011)
African Catfish (<i>Clarias gariepinus</i>)	Ganga Basin, Assam, West Bengal	Predation on native fishes, biodiversity loss	Highly invasive predator that threatens indigenous catfish and other freshwater fishes; breeding populations reported from Indian rivers	Singh (2014)
Common Carp (<i>Cyprinus carpio</i>)	Kashmir (Dal Lake, Wular Lake)	Habitat degradation, increased turbidity, decline of native fishes	Bottom feeding disturbs sediments and aquatic vegetation, negatively affecting native snow trout populations	Bhat <i>et al.</i> , 2024

Damming of Rivers and Its Impact on Fisheries Biodiversity

River damming plays a crucial role in supporting human development by providing flood control, hydropower generation, irrigation, domestic water supply, and increased agricultural production (Chen *et al.*, 2023). However, the construction of dams also causes major ecological changes by disrupting the natural flow of rivers, fragmenting aquatic habitats, and reducing habitat connectivity (The Hindu, 2017). These alterations block fish migration routes, interfere with spawning and feeding activities, and contribute to declines in fish diversity and populations, particularly among migratory species

(American Geophysical Union, 2023). In India, the widespread construction of dams and barrages has led to the degradation of riverine fisheries, threatening biodiversity while also affecting the livelihoods, nutrition, and economic security of millions of people who depend on inland fisheries (Dandekar, 2012). Therefore, adopting sustainable river management practices, including environmental flow releases, habitat restoration, fish passage facilities, adaptive dam operations, and long-term ecological monitoring, is essential to restore river connectivity and conserve freshwater ecosystems for future generations.

Table 2. Key Case Studies of River Damming and Its Impacts on Fisheries in India

S. No.	Dam / River	State	Impacted Fish Species	Key Ecological Impacts	Socio-Economic Impacts	Reference
1.	Indira Sagar Dam- Madhya Narmada River	Madhya Pradesh	<i>Tor tor</i> , <i>Labeo rohita</i> , <i>Mystus seenghala</i>	Fragmented habitats, blocked migration, loss of spawning grounds	40-60% reduction in fish catch; displacement of fishing villages	Dandekar, 2019
2.	Farakka Barrage Ganga River	West Bengal / Bihar	<i>Tenualosa ilisha</i> (hilsa)	Migration blocked	70% decline in upstream hilsa catches	Bhaumik <i>et al.</i> , 2020
3.	Tehri Dam Bhagirathi River	Uttarakhand	<i>Schizothorax richardsonii</i>	Altered flow, temperature, sediment; reduced spawning	Decline in cold-water fish populations	Bharti <i>et al.</i> , (2023)

Construction of Shore Protection Walls and Their Impact on Fisheries Biodiversity

Coastal wall structures such as seawalls, groynes, breakwaters, and revetments are widely used along vulnerable shorelines to protect coastal settlements, infrastructure, and economic activities from erosion, wave impact, storm surges, and rising sea levels (Angnuureng *et al.*, 2023). These hard-engineering systems work by reducing wave energy and stabilizing specific sections of the coastline, making them an important form of coastal defense in highly exposed or densely populated areas. However, their installation significantly alters natural coastal processes by disrupting sediment transport, changing wave patterns, and modifying shoreline morphology. Although they may reduce erosion at the site of construction, they often contribute to increased erosion in nearby unprotected areas due to sediment imbalance and interruption of longshore drift.

In addition to physical changes, coastal wall structures also influence marine ecosystems by replacing natural habitats with artificial surfaces. This transformation affects benthic communities and alters the distribution of

marine flora and fauna, including seagrasses, macroalgae, mollusks, crustaceans, and other organisms dependent on natural sediment environments (Anton *et al.*, 2019). These habitat changes can reduce biodiversity, disrupt ecological interactions, and negatively affect breeding, feeding, and nursery grounds for fish and other aquatic species. Although some artificial structures may provide limited new habitats for opportunistic species, they cannot fully replace the ecological functions of natural coastal systems.

Coastal wall structures also have socio-economic consequences, particularly for coastal communities that depend on fisheries and shoreline resources. Reduced access to beaches, changes in fish abundance, and alterations in nearshore ecosystems can negatively affect artisanal fishing activities and local livelihoods. While these structures are designed to protect human life and infrastructure, their long-term impacts may increase vulnerability for communities that rely heavily on marine resources. In many cases, the high cost of construction and maintenance, combined with their tendency to

shift erosion rather than eliminate it, raises concerns about their long-term sustainability. Overall, coastal wall structures provide important protection benefits but also generate significant environmental and social

challenges. These impacts highlight the need for balanced coastal management approaches that consider both engineering solutions and ecological conservation to ensure sustainable shoreline protection.

Table 3: Case Studies in India on Shore Protection Structures and Fisheries Impacts

State / Region	Type of Shore Protection Structure	Key Ecological Impacts	Impacts on Fisheries	References
Kerala (Kollam, Alappuzha, Thrissur)	Granite seawalls (450 km along coast)	Increased erosion south of structures; beach narrowing; habitat loss in shallow waters	Decline in sardine and anchovy catch; obstruction of traditional landing sites	KSDMA (2020); CMFRI (2021)
Tamil Nadu (Ennore–Chennai Coast)	Seawalls, groynes, artificial headlands	Sand trapping on one side and erosion on the other; loss of mudflats	Decline in seabass and croaker spawning areas; displacement of fishers	NCCR (2020); TN Coastal Zone Atlas (2021)
West Bengal (Sunderbans – Sagar Island, Gosaba)	Reinforced concrete embankments	Reduced tidal flushing; salinity imbalance; mangrove fragmentation	Decline in hilsa, mud crab, threadfin bream	Sarkar et al. (2016)

Micro Hydral Power Stations and Their Impact on Fisheries Biodiversity

Hydropower dams are widely recognized as important infrastructure for supporting economic development by providing electricity generation, flood control, irrigation, water supply, and navigation services (Yoshida *et al.*, 2020). As global demand for low-carbon energy increases, hydropower has become a key renewable energy source that contributes significantly to reducing greenhouse gas emissions and supporting national energy security goals. However, large-scale dam construction significantly alters natural river systems by changing hydrological regimes, reducing sediment flow, and blocking fish migration routes, which are essential for maintaining productive freshwater ecosystems. These changes weaken

river connectivity and disrupt ecological processes that sustain fisheries and agriculture. Freshwater ecosystems are among the most biologically diverse environments on Earth, yet they are highly vulnerable to human disturbances such as dam construction. The presence of dams has been linked to increased extinction risk for many freshwater species, including fish, amphibians, mammals, mollusks, and aquatic insects, with species living near dam-affected areas showing higher vulnerability due to habitat loss and fragmentation (Ding *et al.*, 2026). These impacts result from altered flow regimes, changes in water temperature, reduced sediment transport, and loss of floodplain connectivity, all of which are essential for breeding, feeding, and migration cycles of aquatic organisms. In large river basins, such disruptions contribute to declining fish

populations and reduced ecosystem resilience, which in turn affects food security and livelihoods dependent on inland fisheries. Overall, global evidence indicates that while hydropower development supports renewable energy production and economic growth, it also poses significant risks to freshwater biodiversity, fisheries productivity, and socio-economic stability. The continued expansion of dams, particularly in developing regions, is expected to intensify pressure on already vulnerable river ecosystems. This highlights the importance of integrated river basin management, improved environmental assessment, and sustainable planning approaches that balance energy needs with the conservation of freshwater ecosystems and the protection of dependent human communities.

Case Studies of Micro-Hydral Power Projects in India and Their Ecological Impacts :

Bageshwar, Uttarakhand (Upper Saryu River Basin): A five-year field study reported that micro-hydel projects in the upper Saryu catchment caused about 40–45% of natural water sources to dry up, reducing river flow and degrading fish habitats. The decline in fish availability affected traditional fishing livelihoods, with more than 10% of fishing-dependent households shifting to other occupations, while agriculture also suffered due to reduced water availability (The Times of India, 2021).

Western Ghats, Karnataka: A study in streams affected by small hydropower projects found a significant decline in freshwater fish diversity and abundance, particularly among endemic Western Ghats species. Water diversion for power generation reduced stream flow, fragmented habitats, and altered natural river conditions, demonstrating that even small hydropower projects can have substantial negative impacts on riverine fisheries and aquatic biodiversity (The Times of India, 2018).

Oil Rigs and Their Impact on Fisheries Biodiversity

Oil rigs (offshore oil and gas platforms) are large engineered structures installed in marine environments for the exploration, extraction, and partial processing of hydrocarbons such as crude oil and natural gas. These installations are typically located on continental shelves, where water depths and seabed conditions allow for either fixed-bottom structures or floating systems anchored to the seafloor in deeper waters. Fixed platforms are commonly used in shallow to moderately deep waters and are secured using steel jackets or gravity-based foundations, while floating rigs and drillships are deployed in deeper offshore zones where seabed anchoring is not feasible. Although their primary function is energy production, oil rigs inevitably introduce long-term physical alterations to marine environments by adding large artificial structures to ecosystems that are otherwise dominated by soft sediments, thereby modifying local habitat complexity, hydrodynamic conditions, and biological interactions.

From an ecological perspective, oil rigs generate complex and often contradictory impacts, functioning simultaneously as potential habitat providers and sources of environmental disturbance. Their submerged components act as artificial reef structures, creating hard substrates that are quickly colonized by marine organisms such as algae, barnacles, sponges, mollusks, and corals, depending on regional environmental conditions. This colonization process can increase local structural complexity and attract a wide range of fish species, including commercially valuable populations, thereby enhancing localized biomass and altering trophic interactions around the platform (FISHBIO, 2015). In some cases, these structures may serve as refuges, feeding grounds, or aggregation points, particularly in otherwise sediment-dominated seabeds where hard substrates are limited. However, this apparent ecological enhancement does not necessarily reflect overall ecosystem improvement, as oil rigs may also act as ecological traps by concentrating fish around

human activity zones, increasing their vulnerability to fishing pressure and predation. At the same time, oil rigs are associated with significant environmental risks and stressors that can negatively affect marine ecosystems at both local and regional scales. Routine operational discharges, including produced water, drilling muds, and chemical additives, can alter water quality and introduce contaminants into surrounding habitats. More severe impacts arise from accidental events such as blowouts, explosions, structural failures, or pipeline leaks, which can release large volumes of oil and toxic substances into the marine environment over short time periods. These incidents can cause acute mortality in fish, plankton, and benthic organisms, while also degrading spawning and nursery habitats essential for fisheries productivity. The resulting ecological disruption can persist for extended periods due to contamination of sediments and bioaccumulation of hydrocarbons within food webs, ultimately affecting commercial fisheries and coastal livelihoods (Gomez and Green, 2013). Indirectly, such disturbances can also lead to fishery closures, economic losses, and long-term reductions in stock resilience.

Case Study: Mumbai High Oil Fields, Maharashtra (2018–2023)

Offshore oil production and drilling activities in the Mumbai High region have been associated with hydrocarbon contamination, operational discharges, and restricted fishing zones. These activities have reduced access to traditional fishing grounds, and fishermen have reported declines in catches of Bombay Duck (*Harpadon nehereus*), Indian Mackerel (*Rastrelliger kanagurta*), and Ribbonfish (*Trichiurus lepturus*) around offshore installations (NCSCM, 2023).

Conclusions:

The various anthropogenic pressures, overfishing remains one of the greatest threats to aquatic biodiversity because it reduces fish populations, alters food-web dynamics, and affects the structure and functioning of aquatic

ecosystems. Fishing practices such as bottom trawling, destructive harvesting methods, by-catch, and ghost fishing also damage benthic habitats and unintentionally remove non-target species, contributing to biodiversity loss. In addition, the introduction of non-native or invasive species through aquaculture, ballast water discharge, and accidental release has altered native communities by increasing competition, predation, and disease transmission. River regulation through dams and hydropower projects disrupts natural flow patterns and blocks migratory pathways of fish, leading to declines in many freshwater species. Similarly, coastal development involving seawalls, ports, and breakwaters modifies shoreline habitats, affecting breeding, nursery, and feeding grounds for many aquatic organisms. Collectively, these impacts threaten the sustainability of capture fisheries, reduce the livelihoods of fishing communities, and contribute to the long-term loss of aquatic biodiversity.

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