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Impacts of Invasive Fish Species on Native Fish Species: Mechanisms, Evidence, and Management

H.S. Banyal, **Neha Bains** ✉

Department of Bio Sciences, Himachal Pradesh University, Shimla

✉ nehabains12345@gmail.com DOI : 10.5281/zenodo.17332225

Abstract

Invasive fish species (IFS) are major drivers of biodiversity loss and ecosystem change in inland and coastal waters worldwide. Through predation, competition, habitat modification, hybridization, disease transmission, and indirect food-web effects, invasives reduce native species abundance and richness, erode genetic integrity, and alter ecosystem functioning. This review synthesizes recent evidence on impact pathways, highlights representative case studies (e.g., Nile perch in Lake Victoria; tilapias, *Clarias* spp., and *Pterygoplichthys* spp. in Asia), evaluates monitoring tools (notably environmental DNA), and outlines management and research priorities. Emphasis is given to quantitative attribution of impacts, the role of propagule pressure and environmental change, and integrated prevention–detection–response strategies.

Introduction

Biological invasions are increasingly recognized as one of the foremost anthropogenic stressors on freshwater biodiversity, rivaling habitat degradation, overexploitation, and pollution in their ecological consequences (Gozlan et al., 2024). Freshwater ecosystems are inherently vulnerable to invasions due to their spatially fragmented structure, which restricts natural dispersal of native species and limits opportunities for recolonization following disturbance (Raghavan et al., 2024). In addition, these systems are subject to disproportionate human pressures, including water abstraction, flow regulation, aquaculture practices, and recreational activities, all of which amplify the susceptibility of native communities to invasion.

Invasive fish species (IFS) are introduced through a variety of pathways. Intentional introductions often stem from aquaculture initiatives aimed at enhancing food security, recreational stocking programs designed to improve fisheries, or the use of exotic fishes in biological control of pests. Unintentional introductions, on the other hand, occur through mechanisms such as aquaculture escapes, deliberate aquarium releases by hobbyists, and hydrological connectivity created by artificial canal networks linking previously isolated river basins. These diverse pathways contribute to the establishment of non-native populations across different habitats, from small headwater streams to large reservoirs.

Once established, IFS often exhibit rapid population growth, broad environmental tolerance, and competitive superiority over native taxa. Their ecological effects manifest through multiple mechanisms, including direct predation on endemic species, competition for food and habitat, habitat modification, and the introduction of novel parasites and pathogens. Beyond ecological consequences, the socio-economic implications are significant ranging from declines in capture fisheries and aquaculture production to impacts on livelihoods, cultural practices, and conservation investments. Because many invasions proceed unnoticed until populations become well established, early detection, ecological risk assessment, and the implementation of rapid response strategies are crucial for safeguarding native ichthyofaunal diversity (Gozlan et al., 2024; Raghavan et al., 2024).

Methodology

This review synthesizes primary research, regional assessments, and recent methodological papers (2015–2025). Literature searches were performed across Web of Science, Scopus, PubMed and publisher platforms using keywords: “invasive fish”, “impact”, “competition”, “predation”, “hybridization”, “eDNA”, plus region filters (India, Africa, Asia). Priority was given to empirical studies with comparative designs, synthesis papers, and methods papers addressing detection and attribution. Regional case studies (Lake Victoria, Indian reservoirs and wetlands) were chosen for illustrative value because they exemplify distinct impact pathways and management challenges (Gozlan et al., 2024; Raghavan et al., 2024; Pringle, 2005).

Results and Discussion

Impact pathways

Multiple, often interacting mechanisms explain how IFS affect native fishes:

1. Direct predation and trophic cascades. Large introduced predators can rapidly reduce native prey. The Nile perch (*Lates niloticus*) invasion of Lake Victoria led to collapses in native haplochromine cichlid diversity and major food-web reorganization effects documented with time-series catches, dietary studies and population genetics (Pringle, 2005; Kitchell et al., 1993). These cascades altered benthic–pelagic coupling and ecosystem services, showing that a single high-impact predator can restructure whole communities (Pringle, 2005).

2. Exploitative and interference competition. Planktivorous/omnivorous invasives (e.g., tilapias, silver carp, common carp) compete with native planktivores or benthivores for food and nesting sites. Tilapias (*Oreochromis* spp.)

often defend nests and monopolize littoral habitats, reducing recruitment of native species; carp bioturbation increases turbidity and reduces macrophyte habitat used by many natives (Raghavan et al., 2024; Gozlan et al., 2024).

3. Habitat modification / ecosystem engineering. Certain invaders reshape habitat grass carp remove macrophytes; common carp resuspend sediments; armoured catfishes (*Pterygoplichthys* spp.) burrow and erode banks. These physical changes reduce nursery and spawning habitats for native fishes, resulting in population declines even where direct predation is minimal (Suresh et al., 2019; Parvez et al., 2023).

4. Hybridization and genetic swamping. Introduced congeners can hybridize with native taxa (e.g., trout in upland streams), causing introgression, reducing adaptive variation and, in some cases, producing demographic swamping (Gozlan et al., 2024).

5. Disease and parasite transmission. Invasive fishes may introduce novel pathogens or change disease dynamics by acting as reservoirs or amplifiers. Such shifts can increase morbidity or mortality in native species and complicate aquaculture biosecurity (Gozlan et al., 2024).

6. Socio-ecological and economic impacts. Invasives change fisheries composition and livelihoods. Lake Victoria's Nile perch fishery produced short-term economic gains (larger, exportable fillets) but also long-term ecological costs and social disruption for communities reliant on native species (Pringle, 2005). Together, these pathways often act synergistically: habitat degradation, for instance, can magnify competition and predation effects, while climate warming can open new thermal niches to tropical invaders, increasing propagule success (Gozlan et al., 2024; Raghavan et al., 2024).

Table 1. Ecological, biological, and socio-economic impacts of invasive fish species on native fish fauna.

Invasive Fish Species	Native Species Affected	Type of Impact	Ecological Consequences	Reference
Clarias gariepinus (African catfish)	Indigenous catfishes *(Clarias batrachus, Heteropneustes fossilis)*	Predation, competition for food, fast growth rate	Decline of native catfish populations, altered trophic interactions	Singh & Lakra, 2011
Oreochromis mossambicus, O. niloticus (Tilapias)	Indian major carps *(Labeo rohita, Catla catla)*	Competition for spawning/nesting sites, feeding interference	Reduced recruitment of carps, habitat modification, displacement of natives	De Silva et al., 2004
Cyprinus carpio	Benthic indigenous fish and	Habitat degradation	Increased turbidity, loss	Arthington,

(Common carp)	aquatic flora	(bioturbation), competition for resources	of macrophyte cover, decreased water quality	1991
Gambusia affinis (Mosquitofish)	Small-bodied native fishes (e.g., Aplocheilus spp.)	Aggression, predation on eggs/larvae	Decline in larvivorous fish, alteration in community structure	Pyke, 2008
Pterygoplichthys spp. (Armored catfish)	Native detritivores and bottom dwellers	Aggressive feeding, nest burrowing, space competition	Bank erosion, decline of bottom-dwelling fishes, alteration in benthic food web	Krishnakumar et al., 2011
Pangasius hypophthalmus (Thai pangas)	Native riverine species	Omnivorous feeding, competition in aquaculture zones	Pressure on native fisheries, escapees impacting natural populations	Singh et al., 2013
Pygocentrus nattereri (Red-bellied piranha)	Small indigenous fishes	Direct predation, ecosystem disruption	Localized depletion of small-bodied fish populations	Raghavan et al., 2008
Ornamental releases (e.g., Pacu, guppy, goldfish)	Multiple native taxa	Accidental release, niche overlap, competition	Establishment of feral populations, threat to biodiversity	Knight, 2010

Empirical evidence and attribution

Robust attribution of native declines to invasives requires multiple lines of evidence BACI designs, space-for-time substitutions, diet and stable-isotope studies, experimental manipulations, and genomic analyses. Recent syntheses urge moving beyond presence/absence to quantitative effect sizes on native richness, abundance, demographic rates, and ecosystem functions (Gozlan et al., 2024). For example, genomic studies in Lake Victoria demonstrate population bottlenecks consistent with strong predation pressure from Nile perch (Sato et al., 2024). In Asia, mesocosm and field studies show reduced growth and survival of native species in the presence of *Pterygoplichthys* and tilapia (Parvez et al., 2023; Roy et al., 2025).

Regional focus: India and tropics

India has experienced introductions of several high-risk fishes: tilapias (*O. mossambicus*, *O. niloticus*), African sharptooth catfish (*Clarias gariepinus*), common carp (*Cyprinus carpio*), mosquitofish (*Gambusia* spp.), and sailfin armoured catfishes (*Pterygoplichthys* spp.). These taxa are associated with documented ecological effects: tilapias altering community composition in reservoirs and wetlands; *Clarias* acting as top predators threatening small natives; and *Pterygoplichthys* causing bank erosion and gear damage in wastewater fisheries (Raghavan et al., 2024; Suresh et al., 2019; Dey et al., 2024). Social media and local reports reveal the rapid, sometimes cryptic, spread of armored catfishes across river basins, underscoring gaps in formal monitoring (Parvez et al., 2023).

Detection and monitoring: role of eDNA

Environmental DNA (eDNA) has emerged as an efficient tool for early detection and range mapping of IFS. Recent studies in India and neighboring regions have developed species-specific qPCR assays to detect *Clarias* and *Pterygoplichthys* DNA in water samples, enabling detection at low densities and prioritizing sites for rapid response (Dey et al., 2024; Prabhakaran et al., 2023). While eDNA excels for presence/absence and early surveillance, linking eDNA concentration to actual abundance remains system-specific and requires calibration (Thomsen & Willerslev, 2015; Hunter et al., 2016).

Management approaches and trade-offs

Prevention and pathway management (regulating aquaculture, live-fish trade, aquarium releases, and inter-basin transfers) provide the highest return on investment. Where invasions occur, integrated responses combine targeted removals, habitat restoration, market incentives (commercializing invasive biomass), and community engagement. Mechanical removals can reduce local densities (particularly for aggregating species), but eradication in open systems is rarely feasible (Shogren et al., 2023). Market-based harvests can help suppress biomass but risk creating perverse incentives if not carefully governed. Adaptive management, guided by quantitative thresholds (e.g., eDNA triggers), offers a pragmatic path forward (Gozlan et al., 2024; Raghavan et al., 2024).

Conclusion

Invasive fishes affect native fish species by a suite of interacting mechanisms predation, competition, habitat alteration, hybridization, and disease often amplified by environmental change and human activities. The evidence base has matured: quantitative effect-size estimates, genomic attribution, and sensitive detection tools (eDNA) now enable earlier, more targeted interventions. For biodiversity conservation especially in invasion-prone regions such as tropical reservoirs and interlinked river basins policy must prioritize pathway controls, standardized monitoring (including eDNA), and integrated socio-ecological management that couples ecological goals with community livelihoods. Future research should emphasize causal attribution with standardized metrics, improve abundance inference from eDNA, and evaluate long-term socio-ecological outcomes of control programs.

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