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Ichthyofaunal diversity and conservation challenges in the Gangetic Plains: A case study from Sheikhpura District, Bihar, India

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ABSTRACT

The Gangetic Plains represent one of the most productive freshwater ecosystems in South Asia, supporting remarkable ichthyofaunal diversity and providing essential ecological, economic, and social services. The middle Gangetic basin, particularly the state of Bihar, encompasses an extensive network of rivers, floodplain wetlands, oxbow lakes, ponds, and irrigation canals that sustain a wide variety of indigenous and commercially important fish species. However, freshwater ecosystems throughout the region are increasingly threatened by anthropogenic activities, including habitat fragmentation, pollution, river regulation, overexploitation of fisheries resources, invasive alien species, and climate change. Sheikhpura District, located within the Kiul-Harohar river system of Bihar, possesses numerous seasonal wetlands, village ponds, and irrigation canals that potentially support diverse freshwater fish assemblages. Despite its ecological significance, comprehensive information on the district's ichthyofaunal diversity remains scarce. This review synthesizes published literature on fish diversity and conservation in the Gangetic Plains with particular emphasis on Bihar and discusses the ecological importance, conservation challenges, and research priorities relevant to Sheikhpura District. The review further proposes integrated conservation strategies, including habitat restoration, sustainable fisheries management, biodiversity monitoring, and community participation, to ensure the long-term conservation of freshwater fish diversity in the middle Gangetic basin.

Key Words - Freshwater biodiversity, Gangetic Plains, Bihar, Sheikhpura, ichthyofauna, conservation, wetlands, fisheries

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1. INTRODUCTION

Freshwater ecosystems occupy less than 1% of the Earth's surface yet support nearly 40% of global fish diversity, making them among the most biodiverse and threatened environments worldwide (Dudgeon *et al.,* 2006; Reid *et al.,* 2019). They provide essential ecosystem services such as nutrient cycling, flood regulation, water purification, and carbon sequestration, while sustaining millions of people through fisheries and agriculture (MEA, 2005; Reid *et al.,* 2019).

The Ganga River, extending ~2,525 km from the Himalayas to the Bay of Bengal, forms one of Asia's largest and most ecologically diverse river systems, draining over one million km² across India and Bangladesh (Das *et al.,* 2023). Its habitat heterogeneity supports a highly diverse ichthyofauna, including endemic, migratory, and commercially important species (Talwar & Jhingran, 1991; Koushlesh *et al.,* 2021). Early documentation by Hamilton (1822) and later taxonomic revisions

by Day (1889) and Menon (1974) highlight its rich historical fish diversity.

Despite its ecological and socioeconomic importance, the Ganga basin is under severe anthropogenic pressure from pollution, dam construction, sand mining, overfishing, and habitat fragmentation, leading to biodiversity loss and disrupted fish migration (Vörösmarty *et al.,* 2010; Sarkar *et al.,* 2017). Invasive species such as *Cyprinus carpio* and *Oreochromis niloticus* further threaten native assemblages through competition and ecosystem alteration (Nelson *et al.,* 2016).

Climate change intensifies these pressures by altering hydrological regimes, temperature patterns, and extreme events, affecting fish reproduction and distribution (IPCC, 2021). Within Bihar's middle Gangetic plains, Sheikhpura District remains poorly studied despite its network of wetlands and tributary systems, particularly the Kiul–Harohar drainage.

This review synthesizes ichthyofaunal diversity in the Gangetic plains, highlights gaps in understudied regions like Sheikhpura, and identifies conservation priorities for sustaining freshwater biodiversity.

2. MATERIALS & METHODS

2.1 Review Design

This study adopted a systematic literature review approach to synthesize existing knowledge on ichthyofaunal diversity, freshwater fish conservation, and anthropogenic pressures in the Gangetic Plains, with emphasis on Bihar and Sheikhpura District. The review followed PRISMA 2020 guidelines to ensure transparency and reproducibility (Page *et al.,* 2021). The objectives were to assess fish diversity in the Ganga basin, identify major ecological threats, evaluate conservation status in Bihar, and highlight research gaps in Sheikhpura District.

2.2 Literature Search Strategy

A comprehensive search was conducted using Google Scholar, Scopus, Web of Science, ScienceDirect, SpringerLink, Wiley Online Library, Taylor & Francis Online, PubMed, and ICAR repositories. Additional records were identified through reference screening. Studies published between 1990 and 2025 were included, along with classical taxonomic literature for historical context.

Keywords included combinations of "ichthyofaunal diversity," "Ganga River," "Gangetic Plains," "freshwater fishes," "Bihar," "floodplain wetlands," "Kiul River," "Harohar River," "aquatic biodiversity," and "Sheikhpura District." Boolean operators (AND/OR) were applied to refine searches and remove irrelevant records. Duplicate studies were excluded.

2.3 Eligibility Criteria

Included studies focused on freshwater fish diversity, ecology, taxonomy, fisheries, or conservation in the Ganga basin or Middle Gangetic Plains, particularly Bihar. Peer-reviewed articles, books, and institutional reports in English were considered. Marine studies, non-scientific publications, and methodologically weak reports were excluded.

2.4 Study Selection and Data Extraction

Studies were screened by title, abstract, and full text following PRISMA principles. Relevant data extracted included author, year, location, ecosystem type, species recorded, richness, dominant families, conservation status, and identified threats. Information was organized thematically for synthesis.

2.5 Quality Assessment and Synthesis

Study quality was evaluated based on sampling design, taxonomic accuracy, methodological clarity, and ecological relevance (Higgins *et al.,* 2022). Due to heterogeneity among studies, meta-analysis was not performed. Instead, a qualitative narrative synthesis was used to identify patterns in biodiversity, threats, and conservation priorities.

2.6 Limitations

Limited availability of studies specific to Sheikhpura District constrained direct analysis. Variations in sampling methods and taxonomic updates reduced comparability across studies. Grey literature was minimally included due to inconsistent quality. Despite these limitations, the review provides a

reliable synthesis of ichthyofaunal diversity in the Gangetic Plains.

3. STUDY AREA

3.1 Geographic Location

Sheikhpura District is located in the south-central part of Bihar, India, between approximately 24°452 –25°152 N latitude and 85°452 –86°152 E longitude. The district was carved out of Munger District in 1994 and covers about 689 km². It is bordered by Lakhisarai, Nalanda, Nawada, Jamui and Patna districts. Situated in the Middle Gangetic Plains, it exhibits typical alluvial floodplain characteristics with fertile soils, low relief, and numerous seasonal and perennial water bodies (Government of Bihar, 2023). The district lies within the Kiul–Harohar sub-basin, which ultimately drains into the Ganga River, forming part of the larger Ganga River system (Sarkar *et al.,* 2017).

3.2 Physiography and Geology

The district consists of gently undulating alluvial plains interspersed with isolated hillocks forming the fringe of the Chotanagpur Plateau. Elevation ranges from 40–80 m above sea level. The region is composed mainly of Quaternary alluvium (sand, silt, clay, gravel) deposited by the Ganga and tributary systems (Valdiya, 2010). These deposits create fertile soils and diverse wetland habitats such as marshes, ponds, and floodplain depressions, supporting freshwater biodiversity (Vörösmarty *et al.,* 2010).

3.3 Climate

Sheikhpura has a subtropical monsoon climate with three seasons: summer, monsoon, and winter. Annual rainfall ranges from 950–1,150 mm, with ~80% during the monsoon (IMD, 2023). Temperatures exceed 40°C in summer and drop to 8–10°C in winter. Seasonal hydrological variation strongly influences fish breeding, migration, and recruitment, as floodplain connectivity increases during monsoon floods (Welcomme *et al.,* 2006; Junk *et al.,* 1989).

3.4 Drainage System

The district is drained primarily by the Kiul and Harohar rivers and their tributaries, which connect to the Ganga basin. Seasonal nalas and irrigation canals enhance hydrological connectivity between rivers, ponds, and wetlands. These flood pulse dynamics are critical for fish migration and productivity but are vulnerable to embankments and water abstraction (Junk *et al.,* 1989; Das *et al.,* 2023).

3.5 Aquatic Habitats

Sheikhpura contains diverse aquatic ecosystems including rivers, floodplain wetlands, village ponds, irrigation canals, and seasonal agricultural water bodies. Rivers act as major migration corridors, wetlands function as breeding and nursery habitats, and ponds support both aquaculture and wild fish populations. Agricultural fields temporarily inundated during monsoon also serve as seasonal fish habitats, increasing habitat heterogeneity and ecological niches (Dudgeon *et al.,* 2006).

3.6 Land Use and Anthropogenic Pressures

Agriculture dominates land use, with intensive cultivation of rice, wheat, maize, pulses, and oilseeds. Expansion of farming has led to wetland drainage and habitat modification. Urbanization increases wastewater discharge, while fertilizers and pesticides contribute to eutrophication. Additional pressures include sand mining, overfishing, groundwater extraction, and wetland encroachment, all of which degrade aquatic habitats and reduce fish diversity (Reid *et al.,* 2019; FAO, 2022).

3.7 Ecological Significance

Despite limited ichthyofaunal surveys, Sheikhpura is expected to support representative freshwater fish assemblages of the Middle Gangetic Plains. Its mosaic of rivers, ponds, wetlands, and canals contributes to fisheries, nutrient cycling, groundwater recharge, and flood regulation. Small indigenous fish species are especially important for rural nutrition and food security (FAO, 2022; Dudgeon *et al.,* 2006). Maintaining these habitats is crucial under increasing anthropogenic pressure and climate variability (IPCC, 2021).

4. ICHTHYOFAUNAL DIVERSITY OF THE GANGETIC PLAINS

4.1 Overview of Ichthyofaunal Diversity

The Gangetic River basin is one of the largest freshwater ecosystems in Asia and among the most biodiverse river systems in India. Originating from the Gangotri Glacier and flowing ~2,525 km to the Bay of Bengal, the River Ganga traverses diverse climatic and ecological zones, generating a wide range of aquatic habitats that support rich freshwater fish diversity, including endemic, migratory, ornamental, and commercially important species (Das *et al.,* 2013; Koushlesh *et al.,* 2021; Gayen, 2021; Das *et al.,* 2023).

Historical ichthyofaunal documentation began with Hamilton (1822), who recorded ~260 fish species from the basin. Subsequent taxonomic works by Day (1889), Menon (1974), Talwar and Jhingran (1991), and Jayaram (2010) refined classification and distributional knowledge. Contemporary assessments, including ICAR–CIFRI studies, report over 190 fish species across the Ganga system, spanning freshwater, estuarine, and migratory forms (Koushlesh *et al.,* 2021). Despite this diversity, long-term monitoring shows shifts in community composition due to anthropogenic stressors (Das *et al.,* 2023).

4.2 Taxonomic Composition

The ichthyofauna is dominated by Actinopterygii, with Cypriniformes being the most species-rich order, followed by Siluriformes, Perciformes, and others (Koushlesh *et al*., 2021). Cyprinidae is the dominant family, including major carps (*Labeo rohita, Catla catla, Cirrhinus mrigala*), which are central to inland fisheries. Siluriformes includes diverse catfishes such as *Wallago attu, Mystus* spp*., Clarias batrachus,* and *Ompok bimaculatus*, occupying rivers, wetlands, and ponds. Perciformes includes snakeheads (*Channa* spp.) and climbing perch (*Anabas testudineus*), which are widely distributed and economically important.

4.3 Dominant Fish Families

Key families include Cyprinidae, Bagridae, Siluridae, Schilbeidae, Sisoridae, Channidae, Mastacembelidae, Notopteridae, Cobitidae, and others. The dominance of Cyprinidae reflects extensive floodplain habitats and high ecological adaptability within the middle Gangetic basin.

4.4 Ecological Guilds

Fish communities include herbivores (*Labeo rohita*), omnivores (*Puntius sophore*), predators (*Wallago attu, Channa striata*), and detritivores. Small indigenous fishes contribute to nutrient cycling, mosquito control, and food web stability, highlighting their ecological significance beyond fisheries value.

4.5 Spatial Variation in Diversity

Fish diversity varies longitudinally. The upper Ganga supports cold-water species such as mahseers (*Tor* spp.) and snow trouts (*Schizothorax spp.*). The middle Gangetic Plains show maximum diversity due to floodplain connectivity and habitat heterogeneity, while the lower reaches transition into estuarine conditions supporting migratory species (Das *et al.,* 2023).

4.6 Commercially Important Species

Important species include *Labeo rohita, Catla catla, Cirrhinus mrigala, Wallago attu, Clarias batrachus, Heteropneustes fossilis, Channa striata,* and *Notopterus notopterus*, which sustain inland fisheries, employment, and food security across the basin.

4.7 Threatened and Endemic Species

Several species, including *Bagarius bagarius, Ompok bimaculatus, Wallago attu,* and *Tor putitora*, are declining due to habitat degradation, overfishing, pollution, and river regulation. Conservation requires maintaining environmental flows, restoring floodplain connectivity, and regulating destructive fishing practices (Das *et al.,* 2023).

4.8 Ecological and Socioeconomic Importance

Freshwater fishes play key roles in nutrient cycling, trophic regulation, and ecosystem stability. They also support livelihoods and provide essential nutrition to millions in the Gangetic basin, contributing significantly to rural food security and economic sustainability.

5. ICHTHYOFAUNAL DIVERSITY OF BIHAR AND SHEIKHPURA DISTRICT

5.1 Freshwater Ecosystems of Bihar

Bihar possesses one of the most extensive inland freshwater networks in India, making it a major centre for ichthyofaunal diversity and inland fisheries. The state is traversed by the River Ganga and several tributaries, including the Gandak, Kosi, Bagmati, Kamla, Mahananda, Punpun, Falgu, Kiul, Harohar, and Sone rivers. In addition, thousands of floodplain wetlands (chaurs and mauns), oxbow lakes, ponds, canals, reservoirs, and seasonally inundated agricultural fields provide highly productive habitats for freshwater fishes (Sarkar *et al.,* 2020; Koushlesh *et al.,* 2021). Floodplain wetlands are particularly important due to their monsoon-driven connectivity with river systems, supporting spawning, feeding, and nursery functions through flood pulse dynamics (Sarkar *et al.,* 2020; Junk *et al.,* 1989). Inland fisheries contribute significantly to rural livelihoods, nutrition, and employment, although habitat degradation and overexploitation have altered fish populations in many regions (Koushlesh *et al.,* 2021).

5.2 Ichthyofaunal Diversity of Bihar

Across Bihar, freshwater ecosystems support high fish diversity dominated by Cyprinidae, followed by Bagridae, Siluridae, Schilbeidae, Channidae, Mastacembelidae, Notopteridae, Cobitidae, Ambassidae, and Clariidae. Recent studies from wetlands and river systems report rich assemblages, including 58 species from Kasaraiya Dhar Wetland (Khagaria), 33 species from Kararia Lake (East Champaran), and 31 species from ponds in Sasaram, consistently showing Cyprinidae dominance (Kumar & Singh, 2013; Kumar & Wanganeo, 2012; Bharti *et al.,* 2025). Surveys in Vaishali and the Baya River also indicate seasonal variation in diversity driven by monsoon hydrology and habitat connectivity (Solanki *et al.,* 2025; Kumar *et al.,* 2025).

5.3 Kiul–Harohar River System

The Kiul River originates in Jharkhand and flows through Jamui, Sheikhpura, and Lakhisarai before joining the Harohar River, ultimately contributing to the Ganga basin. The system includes flowing channels, wetlands, canals, and ponds, which become interconnected during monsoon floods. This hydrological connectivity supports fish migration, breeding, and recruitment, especially for small indigenous species and juvenile stages of commercial fishes (Junk *et al.,* 1989; Koushlesh *et al.,* 2021).

5.4 Expected Ichthyofaunal Diversity of Sheikhpura District

Direct ichthyofaunal studies in Sheikhpura are scarce; however, based on its position in the Kiul–Harohar basin and habitat diversity, it is expected to support typical Middle Gangetic fish assemblages. Likely species include *Labeo rohita, Catla catla, Cirrhinus mrigala, Labeo calbasu, Puntius sophore, Amblypharyngodon mola, Mystus spp., Wallago attu, Ompok bimaculatus, Clarias batrachus, Heteropneustes fossilis, Channa spp., Notopterus notopterus,* and *Mastacembelus armatus*. These species represent multiple trophic guilds and habitat preferences across rivers, ponds, and wetlands (Koushlesh *et al.,* 2021). However, systematic field validation is required.

5.5 Ecological Significance

Fish communities in Sheikhpura contribute to nutrient cycling, food web regulation, and biological control of aquatic insects. Seasonal wetlands provide critical nursery habitats during monsoon flooding. Small indigenous fishes are also important for rural nutrition due to their high micronutrient content. Fisheries from ponds and wetlands support supplementary livelihoods, making aquatic biodiversity essential for both ecological stability and socioeconomic welfare (FAO, 2022; Dudgeon *et al.,* 2006).

5.6 Knowledge Gaps

Major gaps include the absence of a district-level fish checklist, limited seasonal diversity data, and lack of studies on habitat quality, invasive species, and population dynamics in the Kiul–Harohar basin. Future research should focus on standardized surveys, molecular identification, GIS-based habitat

mapping, and long-term ecological monitoring to support evidence-based conservation planning.

6. CONSERVATION CHALLENGES TO ICHTHYOFAUNAL DIVERSITY IN THE GANGETIC PLAINS

The freshwater ecosystems of the Gangetic Plains have experienced substantial ecological degradation over recent decades due to escalating anthropogenic pressures. Although the Ganga River basin remains among the most diverse freshwater systems in South Asia, studies report declining fish diversity, shifting species composition, and population reductions in several ecologically and commercially important fishes (Sarkar *et al.,* 2012; Das *et al.,* 2023). Major threats include habitat degradation, hydrological alteration, pollution, overfishing, invasive species, climate change, sand mining, and loss of floodplain connectivity, often acting synergistically and reducing ecosystem resilience.

6.1 Habitat Degradation and Fragmentation

Habitat loss is a primary driver of biodiversity decline in the basin. Urban expansion, agricultural intensification, wetland conversion, and infrastructure development have significantly reduced natural aquatic habitats. Floodplain wetlands, side channels, and seasonal water bodies that function as spawning and nursery grounds are increasingly isolated or lost (Sarkar *et al.,* 2012). In Bihar, encroachment and eutrophication of wetlands and ponds have further reduced habitat availability for native fishes.

6.2 River Regulation and Hydraulic Structures

Dams, barrages, and embankments have altered natural flow regimes and disrupted longitudinal connectivity. These structures impede fish migration, reduce sediment transport, and modify environmental flows, affecting breeding success of migratory species and altering community structure (Sarkar *et al.,* 2012; Kumar *et al.,* 2023). Reduced flood pulses also diminish spawning cues and habitat availability.

6.3 Water Pollution

Water quality degradation due to untreated sewage, industrial effluents, agricultural runoff, and solid waste disposal is widespread (Das *et al.,* 2023). Nutrient enrichment leads to eutrophication, algal blooms, and oxygen depletion, negatively affecting fish physiology and reproduction. Heavy metals and toxic compounds accumulate in food webs, selectively eliminating sensitive species.

6.4 Overexploitation of Fishery Resources

Unsustainable fishing pressure, driven by livelihood dependence and market demand, has reduced fish populations. Destructive practices include juvenile capture, fine-mesh nets, fishing during breeding seasons, electrofishing, and use of toxic substances (Sarkar *et al.,* 2012). These practices significantly reduce recruitment and long-term population stability.

6.5 Invasive Alien Species

Introduced species such as *Cyprinus carpio*, *Oreochromis niloticus*, *Clarias gariepinus*, *Hypophthalmichthys molitrix*, and *Ctenopharyngodon idella* compete with native fishes for resources and modify aquatic ecosystems (Sarkar *et al.,* 2012). Some invasive species also alter nutrient cycling and introduce pathogens.

6.6 Climate Change

Climate change affects hydrology, temperature regimes, and extreme weather events, influencing fish distribution, breeding cycles, and recruitment success (Reid *et al.,* 2019). Altered monsoon patterns can disrupt floodplain connectivity, while rising temperatures reduce dissolved oxygen levels and favour tolerant or invasive species.

6.7 Sand Mining and Riverbed Alteration

Unregulated sand mining alters channel morphology, increases turbidity, destroys spawning substrates, and destabilizes riverbanks. These changes degrade benthic habitats and negatively affect lithophilic and bottom-dwelling fishes.

6.8 Loss of Floodplain Wetlands

Floodplain wetlands, essential for fish reproduction and nursery functions, are declining due to drainage, siltation, pollution, and hydrological isolation. Loss of connectivity between rivers and wetlands severely affects fish migration and recruitment.

6.9 Conservation Implications

The cumulative impact of these stressors has led to declining freshwater fish diversity across the Gangetic Plains. Effective conservation requires integrated watershed management, restoration of floodplain connectivity, enforcement of fishing regulations, pollution control, invasive species management, and long-term ecological monitoring supported by community participation and scientific governance.

7. RESEARCH GAPS AND FUTURE RESEARCH PRIORITIES

Although substantial progress has been made in documenting freshwater fish diversity in the Ganga River basin, significant knowledge gaps persist, particularly in tributaries, floodplain wetlands, irrigation canals, and village ponds of Bihar. Most studies have focused on the main channel of the Ganga, while medium and small river systems remain poorly studied, leading to incomplete understanding of ichthyofaunal diversity in districts such as Sheikhpura (Sarkar *et al.,* 2012; Koushlesh *et al.,* 2021).

7.1 Lack of District-Level Ichthyofaunal Inventories

A major gap is the absence of comprehensive district-level fish inventories for many parts of Bihar, including Sheikhpura. Existing knowledge is largely derived from regional or adjacent-area studies. This limits accurate assessment of species richness, distribution patterns, and conservation status. Standardized multi-habitat surveys across seasons are required to generate reliable baseline datasets.

7.2 Limited Long-Term Monitoring

Most available studies are short-term in nature and fail to capture long-term ecological changes. Continuous monitoring is essential to understand trends in fish populations under pressures such as climate change, pollution, and river regulation. Establishing permanent monitoring stations in the Kiul–Harohar basin would support trend analysis and predictive modelling (Reid *et al.,* 2019).

7.3 Taxonomic and Molecular Gaps

Fish identification based solely on morphology is challenging due to cryptic diversity and phenotypic variation. Integration of DNA barcoding, environmental DNA (eDNA), and molecular phylogenetics is necessary to improve taxonomic resolution, detect cryptic species, and monitor invasive taxa.

7.4 Ecological and Life-History Data Deficiency

Information on growth, reproduction, migration, feeding ecology, and population dynamics remains limited for many indigenous fishes. Such data are essential for fisheries management and conservation planning (Sarkar & Lakra, 2010).

7.5 Climate Change Impacts

Few studies have quantified climate change impacts on fish communities in the Middle Gangetic Plains. Future research should examine shifts in distribution, breeding cycles, and habitat suitability using ecological niche modelling and long-term datasets.

7.6 River Regulation and Habitat Modification

Impacts of dams, barrages, embankments, and sand mining on tributary ecosystems remain insufficiently studied. Basin-scale assessments are required to evaluate habitat fragmentation, environmental flows, and restoration potential.

7.7 Invasive Species Monitoring

Data on distribution and ecological impacts of invasive fishes in Bihar remain limited. Regular monitoring of species such as *Oreochromis niloticus*, *Cyprinus carpio*, and *Clarias gariepinus* is necessary to assess their effects on native biodiversity and ecosystem processes.

7.8 Socioeconomic and Community-Based Research

Fisheries in the Gangetic Plains are closely linked to rural livelihoods. Integrating ecological studies with socioeconomic research, traditional knowledge, and governance systems is essential for sustainable management. Community-based fisheries management has shown promise in improving both conservation and livelihood outcomes.

Table 1. Ichthyofaunal diversity of the Gangetic Plains by order and family

Order	Family	Representative genera/species	Ecological and economic importance	Key references
Cypriniformes	Cyprinidae	*Labeo rohita*, *Catla catla*, *Cirrhinus mrigala*, *Puntius sophore*	Dominant freshwater fish group; major carps form the backbone of capture fisheries and aquaculture	Koushlesh *et al.,* 2021; Talwar & Jhingran, 1991
	Cobitidae	*Lepidocephalichthys* spp., *Pangio* spp.	Benthic species contributing to sediment turnover and nutrient cycling	Jayaram, 2010
Siluriformes	Bagridae	*Mystus* spp., *Rita* spp.	Commercially important riverine catfishes	Koushlesh *et al.,* 2021
	Siluridae	*Wallago attu*, *Ompok bimaculatus*	Large predatory fishes of high market value; populations declining in several regions	Sarkar *et al.,* 2012
	Clariidae	*Clarias batrachus*	Air-breathing species important in small-scale aquaculture and rural fisheries	Talwar & Jhingran, 1991
	Heteropneustidae	*Heteropneustes fossilis*	High nutritional value; locally important in freshwater fisheries	Koushlesh *et al.,* 2021
	Sisoridae	*Bagarius bagarius*	Habitat-sensitive and threatened species requiring conservation attention	Das *et al.,* 2023
Perciformes	Channidae	*Channa striata*, *Channa punctata*	Apex freshwater predators; high market demand	Jayaram, 2010
	Ambassidae	*Chanda nama*, *Parambassis* spp.	Small-bodied ornamental and wetland-associated fishes	Koushlesh *et al.,* 2021
	Anabantidae	*Anabas testudineus*	Air-breathing, highly stress-tolerant species of commercial value	Talwar & Jhingran, 1991
Synbranchiformes	Mastacembelidae	*Mastacembelus armatus*	Occurs in slow-flowing and stagnant waters; locally consumed species	Jayaram, 2010
Osteoglossiformes	Notopteridae	*Notopterus notopterus*	Economically important featherback species used in fisheries and ornamental trade	Koushlesh *et al.,* 2021
Clupeiformes	Clupeidae	*Tenualosa ilisha*, *Gudusia chapra*	Migratory and small pelagic fishes; *T. ilisha* supports major regional fisheries	Das *et al.,* 2023

Table 2. Ichthyofaunal diversity in selected wetlands and water bodies of Bihar

Location / Water body	District	Species richness	Dominant families	Source
Kasaraiya Dhar Wetland	Khagaria	58 species	Cyprinidae, Bagridae, Channidae	Bharti *et al.,* 2025
Kararia Lake	East Champaran	33 species	Cyprinidae, Siluridae, Channidae	Kumar & Singh, 2013
Eutrophic pond system	Sasaram	31 species	Cyprinidae, Cichlidae, Channidae	Kumar & Wanganeo, 2012
Pond ecosystems	Vaishali	Data unavailable	Cyprinidae, Channidae, Siluridae	Solanki *et al.,* 2025
Baya River	Bihar	Seasonal variation in assemblage	Cyprinidae, Bagridae	Kumar *et al.,* 2025
Sheikhpura District	Sheikhpura	Data deficient (not yet systematically surveyed)	Cyprinidae, Bagridae, Siluridae, Channidae	This study

Table 3. Major conservation challenges affecting ichthyofaunal diversity in the Gangetic Plains

Threat category	Drivers	Impacts on ichthyofauna	Supporting references
Habitat degradation and fragmentation	Agricultural expansion, urbanization, wetland conversion, sand mining	Loss of spawning and nursery habitats; increased sedimentation and habitat fragmentation	Sarkar *et al.,* 2012; Reid *et al.,* 2019
River regulation and hydraulic structures	Dams, barrages, embankments, water abstraction	Disruption of migratory routes; altered flow regimes; reduced floodplain connectivity	Sarkar *et al.,* 2012; Kumar *et al.,* 2023
Water pollution	Sewage discharge, industrial effluents, agricultural runoff	Eutrophication, hypoxia, toxic accumulation in fish tissues	Das *et al.,* 2023; Koushlesh *et al.,* 2021
Overexploitation	Unsustainable fishing practices, juvenile capture, fine-mesh nets	Population decline and recruitment failure	Sarkar *et al.,* 2012; FAO, 2022
Invasive alien species	*Cyprinus carpio*, *Oreochromis niloticus*, *Clarias gariepinus*	Competition, predation, and ecosystem imbalance	Sarkar *et al.,* 2012; Nelson *et al.,* 2016
Climate change	Altered monsoon patterns, temperature rise, extreme events	Distribution shifts, breeding disruption, oxygen stress	Reid *et al.,* 2019; IPCC, 2021
Sand mining	Unregulated extraction of riverbed materials	Channel instability, habitat destruction, spawning substrate loss	Vörösmarty *et al.,* 2010; Das *et al.,* 2023
Wetland loss	Drainage, siltation, hydrological isolation	Decline in breeding and nursery habitats	Junk *et al.,* 1989; Sarkar *et al.,* 2020

Table 4. Research gaps and future priorities for Sheikhpura and Middle Gangetic Plains

Research gap	Priority action	Methods/tools	Key references
Lack of district-level fish inventories	Comprehensive multi-season biodiversity surveys	Standard sampling (nets, traps), taxonomic identification	Sarkar *et al.,* 2012;Koushlesh *et al.,* 2021
Limited long-term monitoring	Establish permanent ecological monitoring sites	Repeated sampling, hydrological monitoring	Reid *et al.,* 2019
Taxonomic uncertainty	Resolve species identity and cryptic diversity	DNA barcoding, eDNA techniques	Koushlesh *et al.,* 2021
Limited life-history data	Study growth, feeding ecology, reproduction,	Otolith analysis, gut content, gonad histology	Sarkar & Lakra, 2010
Invasive species impact data deficiency	Assess ecological effects of alien species	Community structure analysis, field experiments	Sarkar *et al.,* 2012
Climate vulnerability assessment gaps	Predict distribution shifts under climate scenarios	Ecological niche modelling (MaxEnt)	IPCC, 2021; Reid *et al.,* 2019
Socioeconomic knowledge gaps	Integrate fishery ecology with livelihoods	Household surveys, PRA methods	FAO, 2022
Spatial habitat data deficiency	Develop GIS-based habitat mapping	Remote sensing and spatial modelling	Vörösmarty *et al.,* 2010

7.9 Future Research Priorities

Key priorities for future research in Sheikhpura and the Middle Gangetic Plains include:

- Seasonal ichthyofaunal surveys across habitats
- District-level fish biodiversity inventories
- GIS and remote sensing-based habitat mapping
- Molecular taxonomy and eDNA-based monitoring
- Long-term ecological monitoring programs
- Water quality and pollution assessment
- Invasive species impact studies
- Life-history and reproductive biology research
- Climate change vulnerability assessments
- Community-based fisheries management strategies

Addressing these gaps will strengthen the scientific foundation for freshwater biodiversity conservation and support sustainable management of aquatic ecosystems in Sheikhpura District and the wider Gangetic Plains.

8. FUTURE PERSPECTIVES AND CONSERVATION STRATEGIES

Long-term conservation of ichthyofaunal diversity in the Gangetic Plains requires an integrated framework combining ecosystem restoration, scientific research, sustainable fisheries management, policy enforcement, and active community participation. Freshwater ecosystems in this region face multiple interacting threats, including habitat loss, pollution, hydrological alteration, climate change, and invasive species. Therefore, conservation approaches must shift from species-centric protection to ecosystem-based management that maintains ecological integrity while supporting livelihoods (Reid *et al.,* 2019; Sarkar *et al.,* 2012).

8.1 Ecosystem-Based River Basin Management

Effective conservation requires a river basin–level planning approach that recognizes hydrological connectivity among rivers, tributaries, wetlands, and floodplains. Maintaining ecological continuity is essential for fish migration, spawning, and recruitment. Key priorities include restoration of environmental flows, protection of flood pulses, reduction of river fragmentation, and sustainable watershed management. Such approaches enhance resilience and biodiversity conservation (Dudgeon *et al.,* 2006).

8.2 Conservation of Floodplain Wetlands

Floodplain wetlands are biodiversity hotspots that support spawning, nursery, and feeding habitats for many fish species. Conservation measures should focus on wetland restoration, prevention of encroachment, desiltation, and maintenance of hydrological connectivity. Community-managed wetlands can effectively balance fisheries production and biodiversity conservation.

8.3 Sustainable Fisheries Management

Unsustainable fishing practices remain a major threat. Management strategies should include enforcement of mesh size regulations, seasonal fishing bans during breeding periods, protection of broodstock, restriction of destructive gears, and promotion of selective fishing methods. Strengthening fisheries cooperatives and participatory governance is essential for compliance and long-term sustainability (FAO, 2022).

8.4 Species Recovery and Conservation Breeding

Conservation breeding programs may support recovery of threatened species with declining populations. However, such initiatives must maintain genetic diversity and be integrated with habitat restoration. Stock enhancement alone cannot compensate for degraded ecosystems.

8.5 Strengthening Scientific Research

Future research should adopt interdisciplinary approaches integrating taxonomy, molecular biology, ecology, hydrology, and GIS-based modelling. Priorities include biodiversity inventories, eDNA-based monitoring, population genetics, habitat modelling, ecological flow assessment, and climate change vulnerability

studies. These tools will support evidence-based conservation planning.

8.6 Community Participation

Local communities play a critical role in freshwater conservation. Traditional ecological knowledge can provide insights into fish migration, breeding patterns, and ecosystem changes. Participatory monitoring, awareness programs, alternative livelihoods, and capacity building should be promoted to enhance conservation outcomes.

8.7 Policy and Institutional Strengthening

Effective conservation requires stronger institutional coordination and implementation of environmental regulations. Key priorities include biodiversity legislation, regulation of sand mining, pollution control, expansion of aquatic protected areas, and development of district-level conservation action plans.

8.8 Implications for Sheikhpura District

Sheikhpura District, within the Kiul–Harohar river system, holds significant yet underexplored ichthyofaunal potential. Future efforts should prioritize baseline fish diversity surveys, seasonal monitoring, GIS-based habitat mapping, water quality assessment, and conservation of ponds and wetlands. Collaboration among research institutions, government agencies, and local communities is essential for sustainable management.

Table 5. Integrated conservation and management strategies for ichthyofaunal conservation

Strategic pillar	Management actions	Threats addressed	Key stakeholders	Supporting references
River basin management	Maintain environmental flows and floodplain connectivity	Habitat fragmentation, hydrological alteration	Water resources departments, researchers	Dudgeon *et al.,* 2006; Sarkar *et al.,* 2012
Wetland conservation	Prevent encroachment; restore degraded wetlands	Habitat loss and degradation	Forest departments, local communities	Junk *et al.,* 1989; Sarkar *et al.,* 2020
Sustainable fisheries	Mesh-size regulation; closed seasons; broodstock protection	Overexploitation	Fisheries departments, cooperatives	FAO, 2022
Species conservation	Recovery programs and invasive species control	Decline of native species	ICAR-CIFRI, ZSI, research institutes	Sarkar *et al.,* 2012
Scientific research strengthening	Biodiversity monitoring, genetics, climate modelling	All major threats	Academic and research institutions	Reid *et al.,* 2019; Koushlesh *et al.,* 2021
Community participation	Alternative livelihoods and co-management of resources	Unsustainable fishing	Local communities, NGOs	FAO, 2022
Policy enforcement	Pollution control and sand mining regulation	Pollution, habitat degradation	Government agencies	Dudgeon *et al.,* 2006; Vörösmarty *et al.,* 2010
Climate adaptation	Incorporate climate projections into planning	Climate change impacts	Policymakers, scientists	IPCC, 2021

8.9 Concluding Perspective

The Gangetic Plains remain highly productive yet increasingly vulnerable freshwater ecosystems. Conservation success will depend on integrating ecological restoration with socioeconomic development, supported by science-based policy and community engagement. For Sheikhpura District, establishing baseline ichthyofaunal data

and long-term monitoring frameworks is a critical first step toward sustainable freshwater biodiversity conservation.

CONCLUSION

The Gangetic Plains represent one of South Asia's most important freshwater ecosystems, supporting exceptionally high ichthyofaunal diversity across rivers, floodplain wetlands, oxbow lakes, canals, and village ponds. This habitat heterogeneity sustains a wide range of fish species, including commercially important, endemic, migratory, and threatened taxa, and underpins ecosystem functioning, food security, and rural livelihoods (Dudgeon *et al.,* 2006; Sarkar *et al.,* 2012).

Bihar, located within the Middle Gangetic Plains, contains extensive inland water resources that support diverse fish assemblages dominated by Cyprinidae, Bagridae, Siluridae, Channidae, Schilbeidae, and Mastacembelidae. However, increasing anthropogenic pressures—such as habitat degradation, pollution, wetland loss, river regulation, invasive species, overfishing, and climate change—have significantly altered aquatic ecosystems and contributed to declining native fish populations (Reid *et al.,* 2019; Koushlesh et al, 2021). These challenges highlight the need for integrated and ecosystem-based conservation strategies.

Sheikhpura District, within the Kiul–Harohar river system, contains diverse yet under-studied freshwater habitats. Although no comprehensive district-level ichthyofaunal inventory exists, regional evidence suggests the presence of representative Gangetic fish fauna across rivers, wetlands, canals, and ponds. Systematic surveys are urgently required to establish baseline biodiversity data and assess conservation status.

Future research should prioritize standardized fish inventories, long-term ecological monitoring, molecular identification tools (DNA barcoding and eDNA), GIS-based habitat mapping, climate change assessments, and studies on invasive species dynamics. Strengthening interdisciplinary research will improve understanding of fish diversity patterns and ecological processes.

Effective conservation requires restoration of environmental flows, protection of wetlands, regulation of destructive fishing practices, pollution control, and community participation. Developing a district-level fish biodiversity database for Sheikhpura will be essential for guiding sustainable fisheries management and biodiversity conservation in the region.

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