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Assessing ichthyofaunal assemblage structure and diversity of fragile Gomti river ecosystem, Uttar Pradesh, for sustainable conservation and management

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Abstract

Due to human interference, freshwater ecosystems are among the most threatened habitats on the planet. Gomti River is a major tributary of the Ganga River System (GRS). Assessment and exploration of the river were conducted from January to December 2023. In the present study, 76 fish species (70 native and 6 exotic) belonging to 56 genera, 32 families, and 12 orders were recorded from this river. Among these, 64 species belonged to the Least Concern (LC), three species to vulnerable (VU), and six to Near Threatened (NT). However, *Hypophthalmichthys noblis* and *Clarius magur* fall under the Data Deficient (DD) and Endangered (EN) category respectively on the IUCN Red List, 2023. The first time, we listed three fish species (*Tariqilabeo latius, Pseudambassis lala,* and *Aplocheilus panchax)* from this habitat. River Gomti and their ichthyofauna are experiencing tremendous manmade stress such as aquatic pollution, overfishing, illegal fishing activities, exotic invasion, climate change, and infestation of invasive aquatic weeds. Furthermore, the irrational fishing of juveniles and brooders, employing a sophisticated armory of fishing tactics, has threatened native fish populations. Proper implementation of fisheries acts and regulations, use of authorized fishing gear, community-based fisheries management, aquatic sanctuary development, river ranching, and raising public awareness could play a vital role in conserving the fish diversity of this river. This result is expected to contribute skeletal information for future studies in this riverine ecosystem.

Keywords: Anthropogenic threats, Conservation, Indigenous species, Fish diversity, Gomti River, Uttar Pradesh.

Introduction

The Riverine ecosystem is one of the most vulnerable and threatened freshwater habitats (Lakra *et al.*, 2010) because human societies modified them for flood safety, energy production, irrigation, and navigation purposes (Sarkar *et al.*, 2012). Several substantive anthropogenic interventions resulted in habitat loss, fast-changing habitat conditions, fragmentation, species introduction (biological invasions), impaired flows, water extraction, pollution, climate change, indiscriminate fishing, and overexploitation (Dudgeon *et al.*, 2006). Currently, around 59% of the world's major riverine ecosystems face significant impacts from flow regulation activities such as reservoir operation, irrigation, or fragmentation by dams, which alter the natural flow of the rivers (Nilsson *et al.*, 2005). Consequently, freshwater species are declining at an alarming rate of 76% faster than marine, and terrestrial (39%) populations (McLellan *et al.*, 2014).

The fish fauna is one of the largest vertebrate groups with more than 34,000 known species described from varied ecosystems, while 18,075 species (51%) of known fish species are found in freshwater ecosystems (Hughes, 2021). Notwithstanding, freshwater fish are crucial components of freshwater ecosystems but are frequently ignored in conservation efforts (Sarkar *et al.*, 2011). According to Eschmeyer's Catalog of Fishes (Fricke *et al.*, 2024), a total number of approximately 36,953 valid species, of which 18,793 are found in freshwater regions (Fricke *et al.*, 2024). The National Bureau of Fish Genetic Resources (NBFGR) has developed a database on Indian fish diversity comprising information on 3205 indigenous finfishes including 1555 marine, 936 freshwater, and 714 brackish water species (ICAR-NBFGR, 2024). This

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bewildering fish fauna resource of this region has been attracting many ichthyologists and taxonomists from India and abroad. The freshwater fish of the Indian freshwater ecosystems have been the focus of comprehensive studies Hamilton (1822); Hora (1921, 1930, 1937, 1939); Menon (1999); Jayaram (1981); Talwar and Jhingran (1991). Few important literatures of ichthyofaunal diversity have been done in the Himalayan region (Badola, 2009; Agarwal *et al.,* 2011).

Being a landlocked state, Uttar Pradesh boasts a wealth of freshwater resources including rivers, streams, reservoirs, wetlands, pools, tal, and tanks with rivers covering a basin area of 7,20,000 hectares, and traversing 28,500 km (Sahu & Pramila, 2021). These water resources harbour a considerable diversity of aquatic bio-resources that contribute nearly 14.68% of Indian fish diversity and offer good potential for fisheries and aquaculture production. Rivers and tributaries flowing through the state are Ganga, Yamuna, Ghaghra, Rapti, Gandak, Ramganga, Gomti, Hindan, Chambal, Saryu, Sai, Kosi, Betwa, Belan, Dhasan, Tons, and Son, *etc*., which are home to a wide range of genetic diversity (Kanoujiya *et al.,* 2023).

Several researchers investigated fish diversity, composition structures, population dynamics, and conservation status of major important rivers such as Ganga, Yamuna, Ghaghara, Rapti and their several tributaries (Pandey *et al.,* 2010; Jitendra *et al.,* 2013; Pathak *et al.,* 2018; Sahu *et al.,* 2024). The Gomti River is the richest fish germplasm bank, though documentation on its fish resources has been limited to only a few authors (Sarkar *et al.,* 2010; Mishra *et al.,* 2011; Bano & Serajuddin, 2016; Gupta & Tripathi, 2017; Krishna, 2022; Kumar *et al.,* 2023). However, information and considerable knowledge gap on fish groups of this region have not yet been investigated in detail, & scanty and unclear. Also, the lack of definite information on the several threats faced by the fish has hampered the planning and implementation of appropriate conservation and management strategies. So, detailed studies are required to conserve and manage this river ecosystem. Considering this lacuna, this study focuses on the current status of fish, identifying the major threats, and suggesting suitable conservation strategies, which may serve as baseline information for future studies.

Materials and Methods

Description of the study area: The Gomti River originates from a natural lake in the forested area (elevation of about 200 m; North latitude 28°34' and East longitude 80°7')

Table 1. Geo-locational data of the sampling sites in the Gomti River, Uttar Pradesh

Code of Sampling sites	Sampling Sites	Latitude (N)	Longitude (E)	Substratum conditions	Surrounding activities and use of water	Fishing methods
S-1	Daliganj, Lucknow	26° 52' 43.7016" N	80° 54' 35.3268" E	Boulders, Gravels, sand, silt, clay	Fishing, Religious discard (idols, flowers), Recreational activities, Domestic use, Irrigation, Bathing, and washing of chicken cloths	Illegal activities such as juvenile fishing and brooder fishing
S-2	Mehndi Ghat, Lucknow	26° 53' 11.9364" N	80° 53' 57.3828" E	Boulders, sand, silt, clay	Fishing, Religious discard (idols, flowers) Recreational activities, Domestic use, Irrigation, Bathing, and washing of chicken cloths	Illegal activities like juvenile fishing-growth overfishing and recruitment overfishing-brooder fishing
S-3	Golaghat, Sultanpur	26° 16' 15.1356" N	82° 4' 33.7116" E	Cobbles, Gravel, sand, silt, clay	Fishing, Religious discard (idols, flowers), Recreational activities, Domestic use, Irrigation, Bathing	Illegal activities like juvenile fishing-growth overfishing and recruitment overfishing-brooder fishing

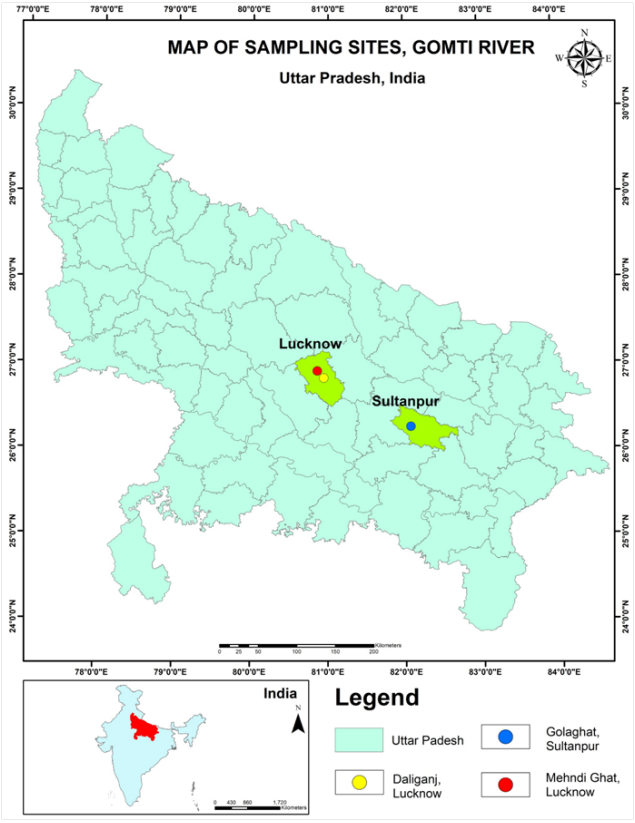


Figure 1. Map of Gomti River showing sampling location.

near Madhoganj Tanda village in Pilibhit dist., UP, about 50 km south of the Himalayan foothills (Sarkar *et al.,* 2010). The river flowing through the central and eastern part of Uttar Pradesh traverses a total distance of about 730 km before finally merging with the Ganga River near Varanasi. The River drains a catchment area of about 25,800 km^2. The major tributaries of the Gomti River are the Kathna, Sarayan, Reth, Luni, Kalyani, and Sai river.

Sampling sites: All details of sampling sites along with geographic coordinates and a map of the study area given in Table 1 and Figure 1. Locations and coordinates of sites were recorded using the Google Earth mobile application.

Sample preservation and photography: We took some glimpses of sampling sites, fresh fish, and a close view of specimens. Generally, live fishes are preferred as they facilitate good photography with original colour patterns and other key traits, which disappear after death. So, a small glass aquarium was used for the photography. All description of the live specimens was noted down because after preservation, the colour will fade and barbles can be broken, etc. For classical taxonomy, specimens were fixed in 5% formalin, kept in a large container, and tagged with serial alphanumeric code, geographical location, collection date, *etc.*

Identification of specimens: Identification of fish was carried out using the standard keys by Day, 1878; Talwar and Jhingran, 1991; Jayaram, 1981; Kottelat, 2001; and Srivastava, 2000. Updated taxonomic framework and nomenclature were collected from the FAO-Fish base database, Eschmeyer's Catalog of Fishes (Fricke *et al.,* 2024), World Register of Marine Species (WoRMS), and Aquatic Genetic Information System of India (AqGRISI, NBFGR). We classified the collected fish species according to Eschmeyer's Catalog of Fishes classification (Fricke *et al.*, 2024).

Estimation of Relative abundance (RA), Diversity indices, and Data analysis: Relative abundance was calculated. Statistical analysis of quantified data was carried out by calculating various indices such as Shannon Weaver diversity index (H'), Margalef richness index (d), Pielou's evenness index (J'), Simpson dominance index (λ), and Simpson diversity index (1- λ). All diversity indices analyses were done by PRIMER-E (Ver. 6.1.6) statistical package (Clarke and Gorley, 2006), Microsoft Excel, and graphs through R v4.3.2 (R Core Team, 2023).

Results

Pattern of Fish Diversity, Composition, and Distribution with IUCN Red List Status

The present study was conducted from January to December 2023. A total of 1020 individuals were enumerated, comprising 76 finfish species belonging to 12 orders, 32 families, and 64 genera, recorded from the Gomti River in Uttar Pradesh. We documented three fish species (*T. latius, P. lala,* and *A. panchax)* from this river that are not listed in previous studies.

Documentation of the conservation status following the IUCN Red List has revealed that among these, 64 species belonged to the Least Concern (LC), three species to Vulnerable (VU), and 6 fishes listed under Near Threatened (NT). However, only one species is under the Data Deficient (DD) and Not Evaluated (NE) category whereas *C. magur* is categorized under the Endangered (EN) category of the IUCN Red List, 2023.

Twelve orders of fishes, Cypriniformes, Cyprinodontiformes, Siluriformes, Perciformes, Anabantiformes, Synbranchiformes, Clupeiformes, Osteoglossiformes, Gobiiformes, Beloniformes, Tetraodontiformes, and Mugiliformes were recorded from the study area. Cypriniformes is the most predominated order, contributing 37.33% of the fish fauna followed by Siluriformes (24%), Perciformes (10.67%), and Anabantiformes (9.33%), whereas Cyprinodontiformes, Gobiiformes, Beloniformes, and Tetraodontiformes formed 1.33% of the total recorded finfish (Figure 2).

The present study revealed that 32 families of finfish are represented in the Gomti River including Cyprinidae, Xenocyprididae, Danionidae, Cobitidae, Botiidae, Nemacheilidae, Aplocheilidae, Siluridae, Pangasiidae, Bagridae, Ritidae, Ailiidae, Sisoridae, Heteropneustidae, Clariidae, Channidae, Sciaenidae, Ambassidae, Anabantidae, Cichlidae, Badidae, Nandidae, Osphronemidae, Mastacembelidae, Synbranchidae, Dorosomatidae, Engraulidae, Notopteridae, Gobiidae, Belonidae, Tetraodontidae, and Mugilidae. Overall, among these Cyprinidae is the most abundant and commercially important family, contributing the highest number of fish species with 21.33% followed by Danionidae (8%), and Bagridae (6.67%) (Figure 3).

Fish diversity and abundance: Species representing the higher economic and commercial value in the Gomti River such as *Labeo catla, L. rohita, L. bata, L. gonius, L. calbasu, Cirrhinus mrigala, C. reba, Cyprinus carpio, Hypophthalmichthys molitrix, H. nobilis, Ctenopharyngodon Idella, Clarias magur, Heteropneustes fossilis, Channa* sp, *Wallago attu, Mystus* sp, *Rita rita, Sperata* sp, *Ompak* sp, *Oreochromis niloticus, Notopterus synurus, Bagarius bagarius* and numerous Small Indigenous Fishes (SIF) like *Ambassis* sp, *Puntius* sp,

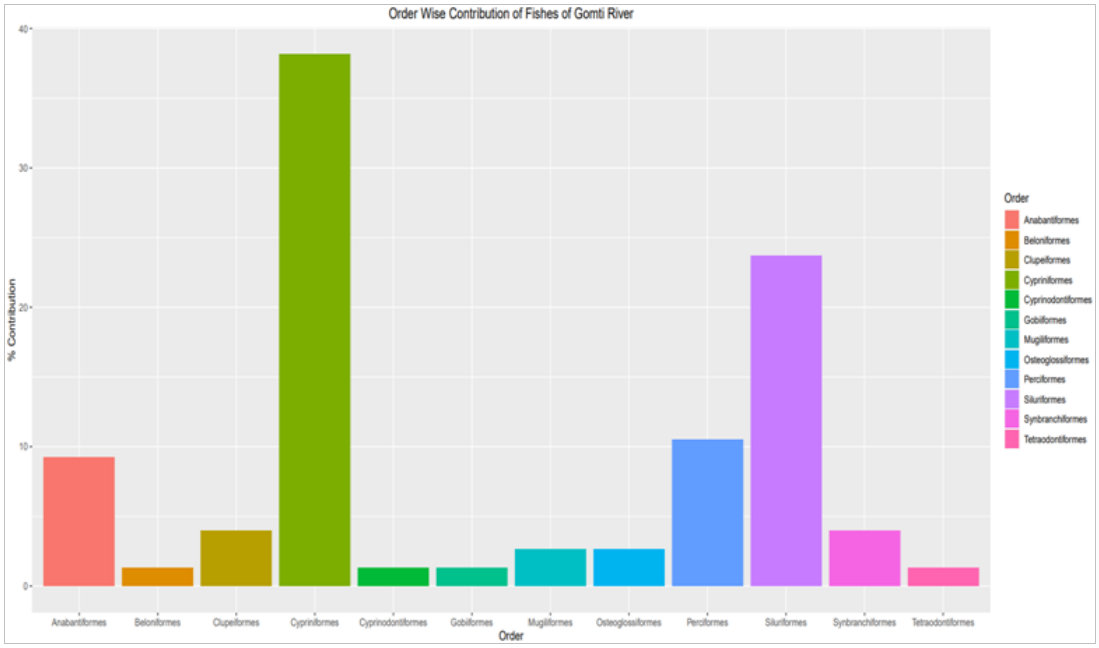


Figure 2. Order-wise contribution of finfishes to the Gomti River Ecosystem.

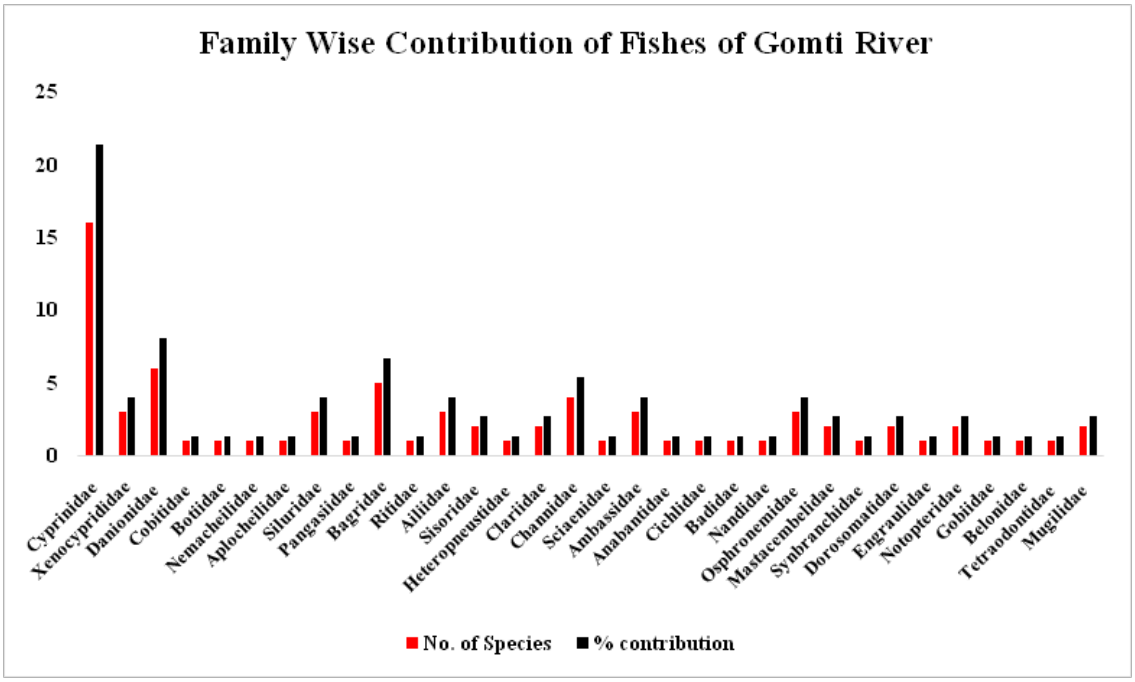


Figure 3. Diagrammatic Representation of the Number of Fish Species of Gomti River Occurring in Each Family.

Pethia sp, *Salmostoma* sp., *Xenentodon sp, Osteobrama* sp, *Nandus* sp, and *Mastacembelus* sp. were recorded (Das *et al.,* 2021). The catch composition represented that the Cypriniformes order, and Cyprinidae family (constituting carps, minnows, and small-sized smiliogastrin barbs) were found to be the most dominant group comprising 37.33%, and 21.33%, respectively. In the case of fish composition, a sharp dominance of catfish and minnow species was observed across all three sites of the Gomti River, in order of abundance. However, the abundance of Indian Major Carp (IMC) decreased compared to catfishes. Moreover, the abundance of fish species also varied according to the site of collection (Figure 4a, b). This could happen due to the presence of different microhabitats within the riverine ecosystem (Kumari *et al.,* 2023).

The overall fish composition of river Gomti was divided into five major groups such as major carps, medium and Minor carps, catfishes, miscellaneous fish groups, and exotic species (Figure 4c). The abundance of major carps was recorded analogous at Gola Ghat, Sultanpur with 10% and has been reduced in river Gomti. Altogether, miscellaneous fish groups were the most abundant group (43.89%) followed by medium and minor carps (24.44%), catfishes (14.44%), and 6.67% contributed by exotic fishes. However, catfish groups and exotic fish did not vary much and constituted a uniform catch percentage in almost all the sites. Menhdi Ghat, Lucknow recorded the least abundance of catfish (11.76%) and exotic fish (7.35%). The number of catfishes was noticed highest in Daliganj, Lucknow, and Golaghat, Sultanpur (15.38% and 16.44% respectively) (Figure 4c).

Diversity index status: The different diversity indices were calculated according to sites (Figure 5). The values of the Shannon diversity index (H') for the three study sites ranged between 2.47 and 2.46. The lowest value was recorded from Daliganj and Mehndi Ghat, Lucknow, Gola Ghat, Sultanpur showing the highest value. The values of the Margalef richness index (d) corresponding to the three stations were found to be varying from 1.99 to 1.85. The highest value was recorded from Daliganj station and the lowest value from Gola ghat. Pielou's evenness index value recorded for all the 3 stations was 0.99. The values of Simpson's dominance index ranged between 0.083 and 0.081. The values of the Simpson diversity index were maximum for Daliganj and lowest for Mehndi Ghat, Lucknow. The findings suggest that Daliganj, despite having the highest species richness, has lower overall diversity due to greater species dominance, while Gola Ghat's more balanced species distribution results in higher

(a)

(b)

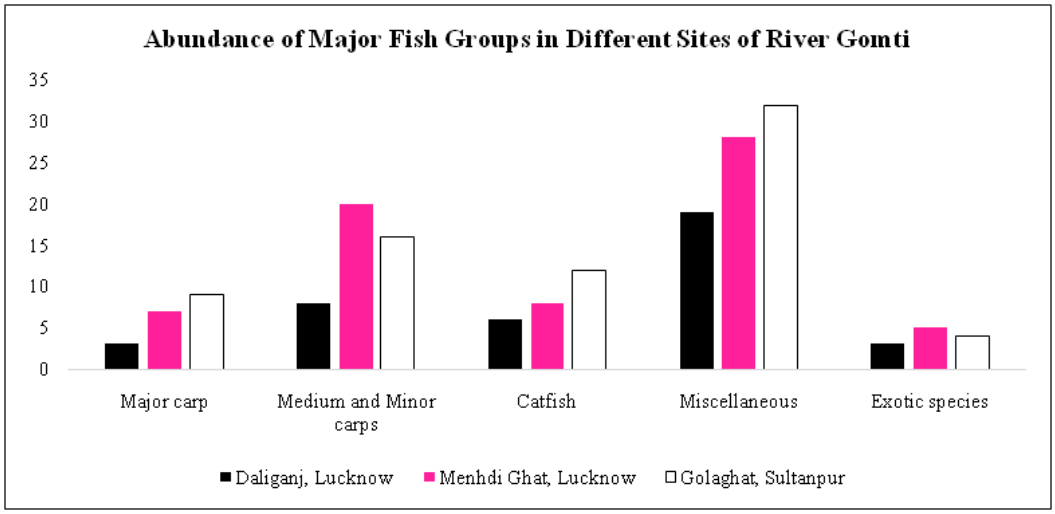
diversity. These differences likely reflect variations in environmental conditions and anthropogenic influences across the sites.

In ongoing ecological studies, changes in diversity indices over time can provide insights into ecosystems' stability, resilience, and health. Any significant changes and fluctuations in biological indices could indicate shifts in species composition, variation in the number of individuals of each fish species caught, biomass, habitat degradation, used fishing gear, or other ecological disturbances, prompting further investigation and management actions. The maximum diversity indices represent the existence of a balance between the total species and the total individuals of each species (Mishra *et al.,* 2011), which signifies a healthy and diverse ecosystem. Maintaining this balance is crucial for preserving biodiversity and ecosystem functioning.

Distribution of Exotic fishes: During the exploration, a total of six exotic species such as Common carp (*Cyprinus carpio*), Grass carp (*Ctenopharyngodon idella*), Silver carp (*Hypophthalmychthys molitrix*), Bighead carp (*Hypophthalmichthys nobilis*), Nile tilapia (*Oreochromis niloticus*) and Thai magur (*C. gareipinus*) were found with moderate to high abundance in Gomti River ecosystem.

Comparison of Current Findings of Finfishes from the Previous Studies

The number of fish species reported in this paper is higher compared to the species reported by previous studies (Figure 6) and indicates the changing scenario of



(c)

Figure 4. **(a)** Heat map showing the month-wise relative abundance of collected fish species (N=1020) along the three different sites of the Gomti River from January to December 2023. **(b)** Heat map representing the relative abundance of collected fish species (N=1020) along the three different sites of the Gomti River from January to December 2023. **(c)** Graph showing the Abundance of Major fish groups in different sites of River Gomti.

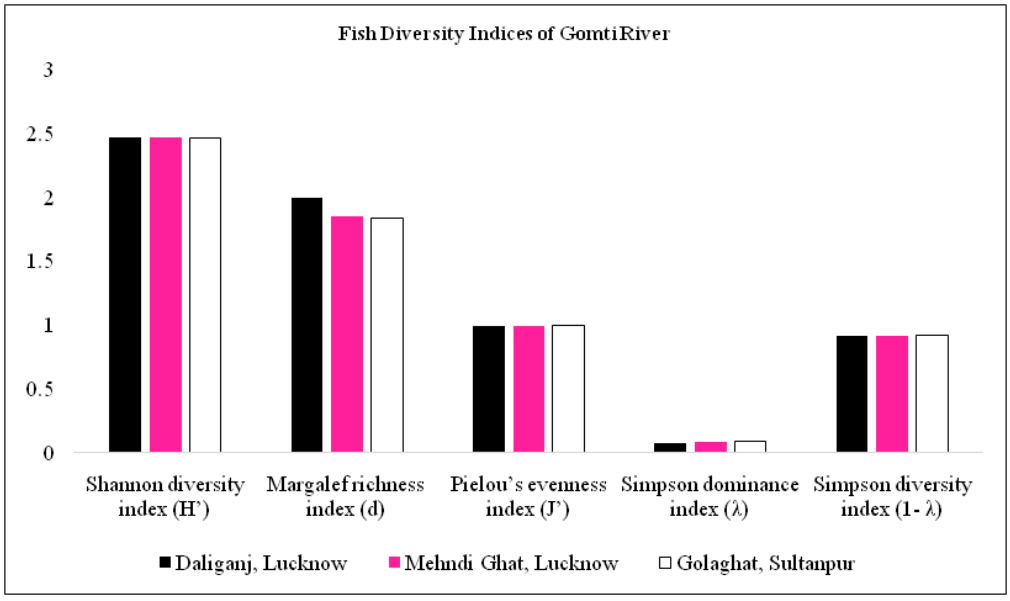


Figure 5. Different fish diversity indices at Gomti River.

the fish diversity structure of the Gomti River. The greater number of the species in the present study may be due to suitable habitat and hydrological parameters in a few sites, heavy rainfall, and more effort in experimental sampling.

Discussion

The present study provides fish diversity with the current IUCN status for Gomti River, UP. Pramod and Rao, (2009) mentioned that previously the Gomti River was home to 265 fish species, and the same statement was given by Singh (2010) in his thesis. However, they reported only 64, and 46 species, respectively. Studies in this region have been conducted over the last few decades, but accurate information regarding fish diversity and assemblage structure is unavailable. Sarkar *et al.*, (2010) reported 56 species from across the river Gomti,

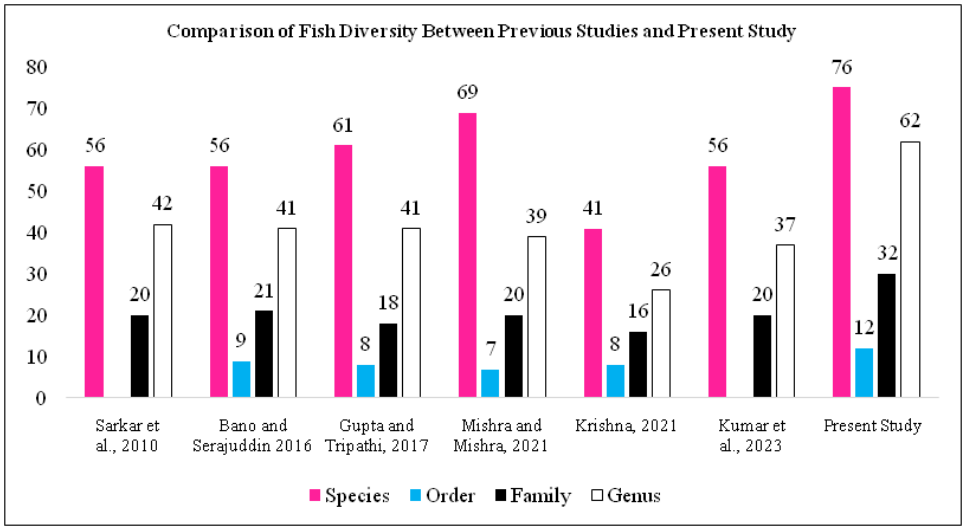


Figure 6. Fish diversity was recorded by various researchers in the Gomti River

and similar results were reported by Bano and Serajuddin (2016) and Kumar *et al.* (2023) from Lucknow region, and Haliyapur and Haidergarh respectively. Gupta and Tripathi (2017) listed 61 species from Lucknow city only as well as Mishra and Mishra (2021) recorded 69 species from the Gomti River. So, we can state that the diversity of the Gomti River is continuously declining and fluctuating due to anthropogenic threats and unmanaged rules and regulations. In the previous studies, the reported finfish species from the Gomti River were low as compared to the current study (Figure 6). These fishes are inclusive of commercially important and several small-size ornamental fish. The changes in the distribution pattern in the Gomti River were observed when compared to earlier reports. The decline of Indian Major Carps in the Gomti River as well as in Indian rivers over the past decade is indeed a concerning issue. This shift in the ecosystem dynamics, with the increasing populations of forage and catfishes, is a cause for concern. These findings are also parallel to the similar observations found in different rivers like Ganga, Ghaghara, Krishna, and Narmada, in which the Cyprinidae family was recorded as the dominating fish family (Sarkar *et al.,* 2010; Arunkumar & Manimekalan, 2018). Additionally, we summarize different Indian river ecosystems with the number of fish species in Table 2.

The largest Gangetic Riverine System (GRS) of India provides habitat for more than 265 fishes and their tributaries (Das *et al.,* 2007) such as Ramganga, Gomti, Ghaghara, Yamuna, Gandak, Kosi, and Damodar Rivers act as reservoirs of different fish stocks, while Das *et al.* (2021) reported 190 species from entire stretches of Ganga River.

Emerging threats and issues to the fish diversity of the Gomti River ecosystem

Fish are crucial components for aquatic ecosystems, providing different ecosystem services and functions such as fishing, commodities, food, and propagule dispersion (Sarkar *et al.,* 2008; Arunkumar *et al.,* 2018). Therefore, the fish decline indicates the current diversity crisis and fishermen of the Gomti River exploiting commercial fish and small native species from the last decade. The Gomti River faces threats to fish diversity, including environmental degradation, overfishing, illegal fishing, siltation, low water depth, increasing fishermen, indiscriminate catch of juveniles and brooders due to unregulated fishing pressure, aquatic pollution, microplastics, creation of barriers and obstacles in the natural movement of fish, new stressors are emerging (*e.g.*, climate change, pandemics), *etc.*, ((Vass *et al.,* 2009; Thilakarathne *et al.,* 2019). The flora and fauna of the Gomti River are also impacted by plastic pollution, which is a major concern. Generally, anthropogenic activities consequently destroy the spawning, feeding, and nursing grounds of many economically important fishes and now these species are facing an extremely high risk of extinction day by day.

Our findings indicate the declining trends of fish assemblage due to over-exploitation which warns of the

Table 2. Current status of freshwater fish diversity of different Indian riverine systems

Riverine ecosystem	No. of fish spp.	References
Ganga	190	Das *et al.*, 2021
Yamuna	143	Sharma *et al.*, 2017
Ghaghara	78	Sahu *et al.*, 2024
Tapti	80	CIFRI, 2020
Godavari	104	CIFRI, 2020
Mahanadi	197	Pathak *et al.*, 2007
Brahmaputra	229	Vishwanath, 2017
Krishna River	127	Das *et al.*, 2017
Cauvery	146	CIFRI, 2019
Narmada	196	Bhakta *et al.*, 2020
Ken	89	Joshi *et al.*, 2017
Kuwano	56	Kanoujiya *et al.*, 2023

gradual fish loss of Gomti River, UP. Sarkar *et al.* (2010) observed similar decline causes of Gomti River diversity and other Indian water bodies, which supports the present results. *Labeo dero, Tor tor*, *Barilius bendelisis, Nangra nangra, Mystus menoda, Chagunius chagunio, Sperata aor, Oxygaster clupeioides, Puntius javanicus,* and *Macrognathus aculeatus* were reported in past studies. However, based on discussions with local fishermen, these species are now locally extirpated from their type locality in the Gomti River. We have also collected only a few specimens of *Pethia ticto, Leiodon cutcutia, Pangasius pangasius, P. lala, A. panchax,* and *L. boggut*. Excessive fishing pressure, often driven by commercial interests, could lead to the depletion of fish stocks, affecting the fish in terms of abundance, diversity, and distribution patterns.

Illegal fishing practices like using non-selective gears (gill net-current Jal and small mesh-sized drag net-mosquito net (locally called *Fardi*), using different dyes or colour, growth overfishing (juvenile catch), recruitment overfishing (brooder catch), catch of all life stages of fish because they don't care the ecosystem, is one of the major issues for diversity loss. Many authors have also stated that the use of poison in the rivers of Kerala (Kurup *et al.,* 2004), Krishna River (Kumbar *et al.,* 2021), and Kosi River of Bihar (Chandra *et al.,* 2020). In our study, we also observed such practices from all selected sites in the study area. These wanton fishing methods are very harmful to the existing fish stocks and adversely affect the fish abundance and recruitment process. Mesh size regulation and a monsoon fishing ban must be practised to ensure the fish recruitment process. Strategically, they use floating objects like logs with branches of trees to attract fish, which are also known as Fish Aggregating Devices (FAD) (Shibu & Krishnan, 2022). The indiscriminate collection of small indigenous fishes by aquarium traders in the summer months (April-August) is a major threat to these fishes. There is hence an urgent need to create awareness among local fishermen communities on the importance of the riverine habitat and its diversity, and the need to conserve them for future generations.

Industrial, agricultural, and domestic water release harmful chemical pollutants, and heavy metals into the river, degrading the water quality index. Khan *et al.* (2020) quantify six heavy metals (As, Fe, Cd, Pb, Mn, and Cr) from River Gomti. Ichthyofauna are fragile to a wide range of stressors because reproduction, growth, and population survival are highly dependent on water quality (Filho *et al.,* 2018). We also observed that several sewage drains have fallen into the river resulting in degraded water quality, destroying the spawning and nursing grounds of fish fauna.

The invasion of exotic fishes has become a great menace to the endemism of fish diversity. It can disrupt the ecosystem and outcompete or prey upon native fish species, leading to declines in native populations. Invasive species could benefit from pollution because they manifest to be more resistant than native species (Gomes-

Silva *et al.,* 2020). In the present study, we found six exotic fishes, which were either intentionally or unintentionally introduced, are now dominant in the Gomti River, our result is supported by Sarkar *et al.* (2010). Among these, early life stages of *O. niloticus* (locally called "*Jalebi*") were observed at Daliganj and Peepe wala pul (Mehndi ghat) sites indicating the possibility of the establishment of a reproductive population. Invasion by exotic aquatic weeds such as *Eichhornia crassipes* (Water hyacinth), Water cabbage/lettuce (*Pistia stratiotes*), *Azolla spp.* (water fen) are causing serious problems to regional and local economies. The fish diversity is especially highly affected and needs to be eradicated. They outcompete native aquatic plants, deoxygenate riverine water, increase flood risks by blocking drainage, and affect fishing practices due to their ability to spread quickly.

Conclusion

The present study suggests that the Gomti River has diverse fish fauna. The availability of a good number of fish species in the river may be linked to the suitable ecological conditions in certain locations, which provide proper breeding grounds for fish. However, due to human activities, several species have become threatened. So, we can say that the fish diversity of Gomti River undoubtedly undergoing a more critical stage than in the past. Based on our research findings and other similar studies of recent times, we can conclude that high attention should be given to the conservation and management of this riverine system and its fisheries. The Gomti River ecosystem, which harbours several fish species, should be declared a fish sanctuary or an aquatic diversity management area.

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