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Fish biodiversity status in the river Mahananda near Katihar (India)

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Abstract
The River Mahananda, a tributary of the Ganga, sustains rich fish biodiversity crucial for the livelihoods and food security of local communities in Katihar, Bihar. There were 61 species in all, including native, food, sport, and decorative fishes, spread throughout 46 genera, 21 families, and 7 orders. According to trophic guild analysis, carnivores predominated, followed by herbivores, detritivores, and omnivores, indicating ecological equilibrium. Sanctuary stretches had better species richness (Shannon-Wiener Index, H = 2.50-2.53) than non-sanctuary zones, demonstrating the importance of protected regions for conservation. Relative abundance analysis revealed that economically significant species including Labeo rohita, Mystus cavasius, and Clupisoma garua were more prevalent. However, overfishing, destructive gear, sand mining, agricultural runoff, household pollutants, and habitat fragmentation pose serious risks to fish diversity. Numerous endangered and near-threatened species have declined as a result of these stresses, calling for immediate conservation action. It is essential to fortify fish sanctuaries, control fishing methods, restore habitats, and encourage community-based co-management. Ecological stability also depends on habitat connectivity and pollution control. The Mahananda River's ichthyological richness must be preserved for the region's socioeconomic stability as well as ecological health.

Keywords: Fish biodiversity, trophic structure, ecological equilibrium, Ichthyological richness, relative abundance, conservation, threats

1. Introduction
Before joining the Ganga at Godagari, Rajshahi (25°04′49″N, 87°51′13″E), the Mahananda River, a tributary of the Ganga, flows ~360 km (80% in India, 20% in Bangladesh) through Darjeeling, Uttar Dinajpur, Malda, Kishanganj, Purnia, and Katihar. It begins near Chimli in the Paglajhora hills, Darjeeling (~2,100 m). The endangered Gangetic dolphin (Platanista gangetica gangetica), artisanal fishing, and a variety of ecosystems are all supported by the Katihar stretch. About 10% of all species on Earth reside in freshwater habitats, which make up less than 1% of the planet's surface. Fish are essential to both ecological equilibrium and human livelihoods (Dudgeon *et al*., 2006; Lévêque *et al*., 2008) [3, 12]. However, overfishing, habitat loss, pollution, and climate change threaten to wipe out more than 20% of species (Collen *et al*., 2008) [1]. These forces are best illustrated by the Ganga basin, which is both environmentally rich and under stress. Destructive equipment, indiscriminate juvenile harvest, sand mining, embankments, runoff, and untreated sewage are among of the serious concerns facing the Mahananda (Hasan, 2017; Sarkar *et al*., 2011) [7, 19]. Indian main carps are being replaced by exotics, which reflects broader developments in India (Manna *et al*., 2014; Nelms *et al*., 2020) [14, 16]. Research limitations were highlighted by the fact that only 20-32 species were recorded in previous surveys (Nandi, 2013; Das *et al*., 2014; Hasan, 2017) [15, 14, 7]. With around 2,500 fish species, including about 800 freshwater taxa, India is a megadiversity hotspot that is experiencing a decline in biodiversity (FishBase, 2019; Ponniah & Gopalakrishnan, 2000) [5, 17]. For ecological stability and socioeconomic security, the Mahananda's ichthyofauna must be preserved.

1.1 Objectives of the Study
- To document the ichthyological biodiversity of the Mahananda River.
- To evaluate physicochemical characteristics of river water.

- To analyze seasonal variation in fish composition.
- To identify threats to fish biodiversity.
- To suggest conservation and management strategies.

1.2 Significance of the Study: In addition to offering a foundation for conservation and sustainable management, this study will aid in the documenting of aquatic biodiversity in the Katihar section of the Mahananda. In line with national and international aims, the results will direct initiatives to preserve artisanal fisheries, safeguard ecologically valuable fish populations, and promote biodiversity conservation (UNCED, 1992; IUCN, 1994) [22, 8].

2. Materials and Methods

2.1. Research Methodology: Six locations were chosen for the study, which encompassed a 95-kilometer section of the Mahananda River in the Katihar region of Bihar: Mahinagar, Jhaua Ghat, Azamnagar Ghat, Durgapur Ghat, Labha Gauripur Ghat, and Trimohani Amdabad (the Ganga confluence, which is known for its rich fish species). GPS coordinates were recorded, and sites (S1-S6) were chosen based on habitat characteristics, accessibility, and closeness to landing centres. At landing centres and with the help of local fishermen, sampling was done every two weeks. Cast nets (16-22 mm), gill nets (32-110 mm), drag nets (4 mm, 15×3 m), scoop nets, and conventional equipment were used to gather both migratory and native species. The specimens were recognised using conventional taxonomic keys and stored in 10% formalin (Dutta Munshi, 1995; Jhingran, 1972; Srivastava, 2014) [4, 11, 20].

2.2. Study Area: The study area includes Mahinagar (25°44'19" N87°48'37"E), Taiyabpur (25°42'55" N87°49'10"E), Bobra Ghat (25°41'25"N 87°48'15"E), Jhaua Ghat (25°44'34"N 87°49'14"E), Salmari (25°35'01.2"N 87°48'53.5"E), Azamnagar Ghat (25°33'04"N 87°49'27"E), Dhoomnagar (25°29'13"N 87°48'40"E), Durgapur Ghat (25°30'43"N 87°44'57"E), Lalganj Teghra English (25°26'13"N 87°45'05"E), New Market Katihar (25°32'35"N 87°34'16"E), Labha (25°26'06"N 87°44'57"E), Gauripur Ghat (25°26'08"N 87°46'16"E), Dilli Diwanganj (25°24'18"N 87°45'33"E), English Dakra (25°23'05"N 87°45'48"E) and Trimohani Amdabad (25°18'31"N 87°48'13"E) in Katihar district.

2.3. Time-Period Sampling: March'2021 to February'2024
Time of sample collection: Early morning 5:30-9:00 AM and Evening 4:00-7:00 PM

2.4. Sampling Sites: I have selected six major fish sampling sites. Following are the details of the fish sampling sites.

Table 2.1: Sampling sites with their GPS Coordinates

Details of the Fish sampling sites		
Site	**GPS Coordinates**	**Locality** (Katihar, Bihar)
S1	25°44'19" N 87°48'37"E	Mahinagar,
S2	25°36'35"N 87°47'20"E	Jhaua Ghat,
S3	25°33'04"N 87°49'27"E	Azamnagar Ghat,
S4	25°30'43"N 87°44'57"E	Durgapur Ghat,
S5	25°25'48"N 87°46'04"E	Labha (Gauripur),
S6	25°18'31"N 87°48'13"E	Trimohani Amdabad,

Fig 2.1: Satellite Image of Sampling Site-1, 2, 3, 4, 5 & 6 (Imagery Google Maps,2023)

2.5. Sampling Methods: Six ecologically different locations (riparian zones, pools, and shallow stretches) were selected based on habitat characteristics, human pressures, and accessibility for a one-year period of fish sampling in the Mahananda River (Jha, 2008) [10]. Species like Tenualosa ilisha, Puntius conchonius, and Mystus bleekeri were captured using standardised equipment, including drag nets, gill nets (10-80 mm), cast nets (4-6 m), and conventional traps (Sarkar & Lakra, 2010) [18]. With the help of fishermen, fishing took place during hours of high activity. For identification purposes, the specimens were sorted, tallied, photographed, and preserved in 10% formalin (Jayaram, 2010; Talwar & Jhingran, 1991) [9, 11]. Following Magurran (2004) [13], data were examined for CPUE, species richness, and diversity indices (Shannon-Wiener H′, Simpson's D). A summary table that included gear kinds, mesh sizes, target species, and seasonal use was presented.

Table 2.2: The summary table of all fishing gear types used in sites S1-S6

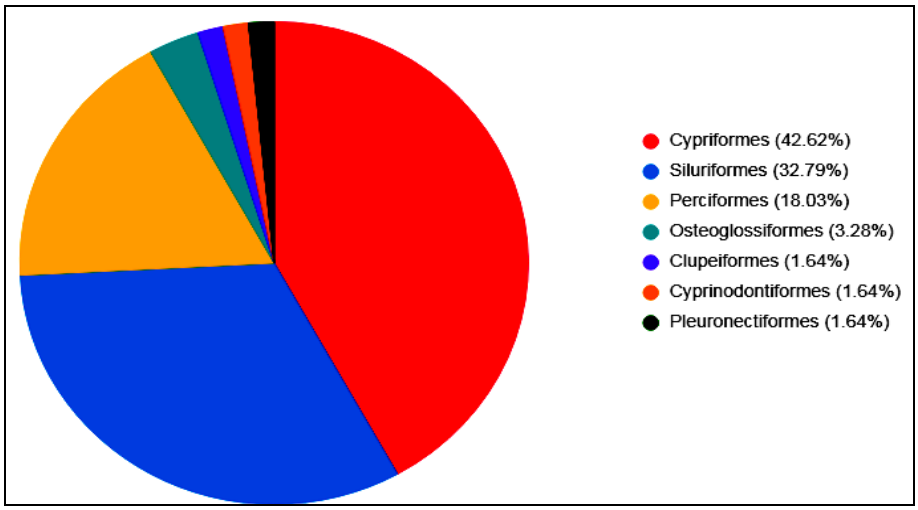
Sl. No.	Gear Type	Operation Type	Preferred Sites	Target Species	Mesh Size (cm)	Best Season
1	Gill Net	Passive	S1-S6	Hilsa, Catfishes, Carps	2-10	Monsoon
2	Cast Net	Active (manual)	S1-S3	SIS, Juvenile Carps	0.5-2	Pre/Post-monsoon
3	Drag Net	Active (dragged)	S2-S5	Mixed species	1-5	Post-monsoon
4	Set Bag Ne	Passive (fixed)	S3-S6	Hilsa, Mystus, Carps	1-5 (tapered)	Monsoon/Post-monsoon
5	Lift Net	Active (lifted)	S1-S3	Small Fish, Puntius	1-2	Pre/Post-monsoon
6	Trap Net	Passive (stationary)	S1-S4	Channa, Crabs, Eels	1-2 or slatted	Dry/Post-monsoon
7	Hook and Line	Passive (manual)	S1-S6	Wallago, Channa, Catfishes	Hook sizes 2-12	Winter/Pre-monsoon

2.6. Identification and Classification: Fishes were identified using standard keys (Jayaram, 2010) [9]. Species were classified into families and orders.

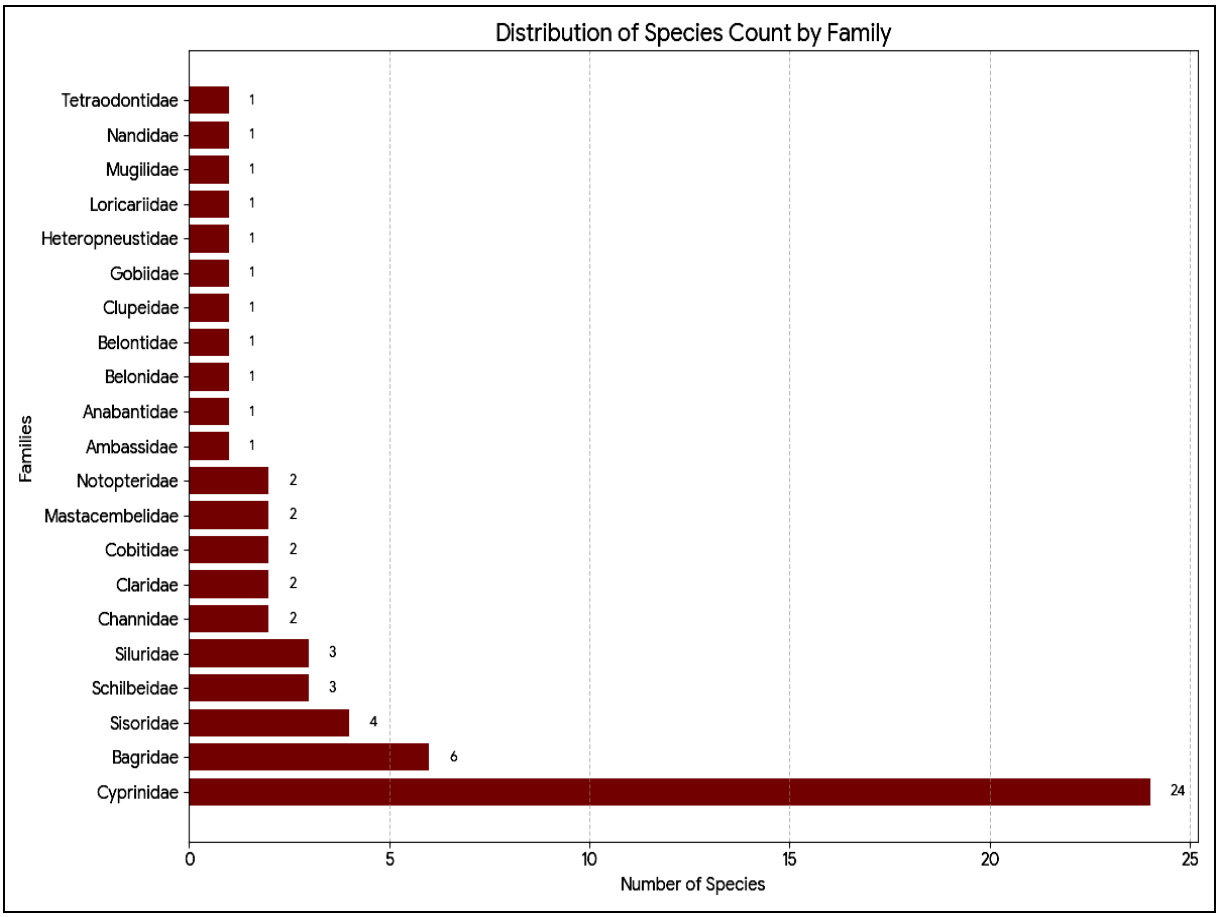
2.7. Data Analysis: Diversity indices (Shannon-Wiener, Simpson's), similarity indices, and correlation analysis were used.

3. Results and Discussion

A total of 61 fish species, representing 46 genera, 21 families, and 7 orders, were recorded from six sampling sites of the Mahananda River. The order Cypriniformes was dominant (42.62%), followed by Siluriformes (32.79%) and Perciformes (18.03%). Other orders such as Osteoglossiformes, Clupeiformes, Cyprinodontiformes, and Pleuronectiformes together contributed less than 6%. Among families, Cyprinidae was most abundant with 24 species (39.34%), followed by Bagridae (9.84%) and Sisoridae (6.56%). Families such as Schilbeidae and Siluridae each contributed 4.92%, while others like Channidae, Claridae, Mastacembelidae, and Cobitidae each accounted for 3.28%. Several families (e.g., Notopteridae, Heteropneustidae, Clupeidae, Tetraodontidae) were represented by a single species (1.64%) (Graph). Relative abundance (RA) analysis (Table 3.2) showed *Salmostoma bacaila* as the most dominant species (16.56%), followed by *Clupisoma garua* (11.0%), *Mystus vittatus* (5.36%), *Puntius ticto* (5.34%), and *Notopterus notopterus* (4.21%). Indian Major Carps were poorly represented: *Catla catla* (0.41%), *Labeo rohita* (0.94%), and moderately for *Cirrhinus mrigala* (1.68%). Medium carp Labeo calbasu showed better distribution (1.97%). Genus-wise, Labeo was most diverse, followed by Puntius, Channa, and Mystus. Conservation-important species such as *Ompok bimaculatus, Clupisoma garua, Notopterus notopterus, Cirrhinus reba, Sperata aor, S. seenghala,* and *Rita rita* were recorded with moderate abundance. In contrast, *Aspidoparia morar, Glyptothorax telchitta, Labeo dero,* and *Anabas testudineus* had the lowest RA (≤0.02%). Five invasive species were also observed: *Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys molitrix, Clarias gariepinus,* and *Pterygoplichthys disjunctivus*. Among these, Cyprinus carpio was well established (RA = 0.71) and widespread across all sites except S1, posing a potential threat to native species. Out of 61 species, 16 were commonly exploited as food fishes across all sites (S1-S6). Of these, eight species have medium resilience (population doubling time: 1.4-4.4 years), while three species exhibit low resilience with long doubling times, raising conservation concerns (Froese & Pauly, 2010) [6].



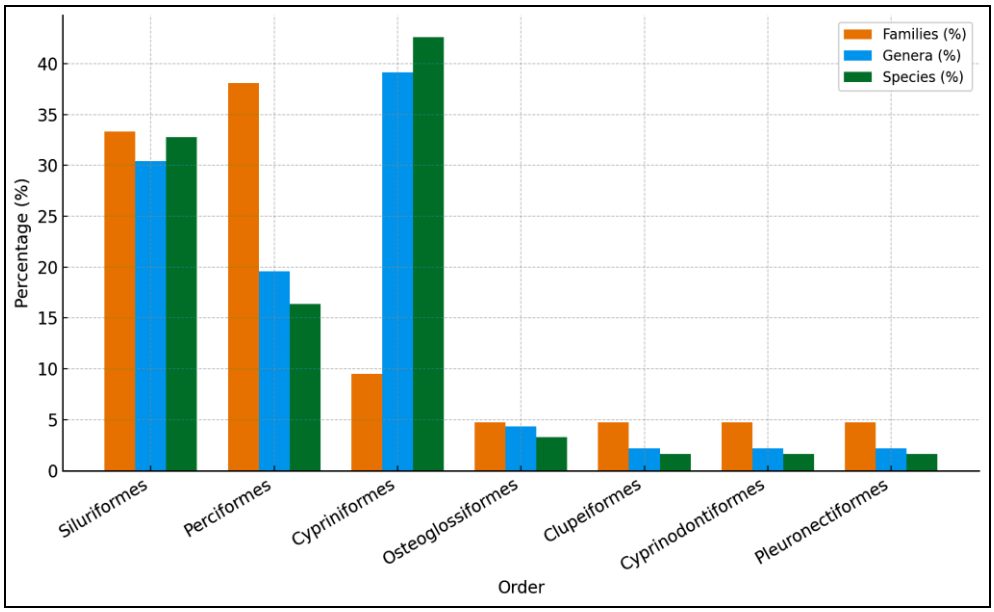
Pie-chart 3.1: Distribution of Fish Order in the river Mahananda



Graph: 3.2: Distribution of Fish species by Family in the Mahananda River

Table 3.1: Percentage contribution of number of Families, Genera and Species under various orders.

S. No.	Order	Families (%)	Genera (%)	Species (%)
1	Siluriformes	33.33	30.43	32.79
2	Perciformes	38.10	19.57	16.39
3	Cypriniformes	9.52	39.13	42.62
4	Osteoglossiformes	4.76	4.35	3.28
5	Clupeiformes	4.76	2.17	1.64
6	Cyprinodontiformes	4.76	2.17	1.64
7	Pleuronectiformes	4.76	2.17	1.64
Total	7	100	100	100



Graph 3.3: Percentage distribution of Families, Genera and species by Order

3.1. Relative Abundance of Fish Species: Dominant species (RA% > 5%) included *Salmostoma bacaila* (17.82%), *Puntius ticto* (9.01%), *Clupisoma garua* (7.5%), *Mystus vittatus* (5.12%), and *Ompok bimaculatus* (5.08%), indicating strong ecological adaptability and key roles in food-web stability. Moderately abundant species (≤5%) such as *Notopterus notopterus* (3.95%), *Puntius sophore* (3.78%), *Channa punctatus* (3.3%), *Osteobrama cotio* (3.14%), and *Rita rita* (2.96%) significantly contributed to community diversity and ecological balance. Low abundance species (≤2%), including *Labeo calbasu* (1.98%), *L. bata* (1.97%), *L. gonius* (1.74%), *Macrognathus pancalus* (1.39%), and *Ompok pabda* (1.36%), were less represented but still important for maintaining trophic integrity. Rare species (≤1%) comprised over 40 taxa, such as *Sperata aor* (0.98%), *Wallago attu* (0.97%), *Channa marulius* (0.85%), *Cirrhinus reba* (0.74%), *Catla catla* (0.41%), *Bagarius yarrelli* (0.37%), along with invasive *Cyprinus carpio* (0.72%) and *Clarias gariepinus* (0.03%). These distributional patterns highlight both the ecological dominance of select species and the conservation urgency for low-abundance and rare taxa.

Table 3.2: Diversity of Fish Species, threats status, total mean length and their relative abundance (RA %)

Sl. No.	Species name	Local name	Threat status	Total nos.	Total length (cm)		RA (%)
					Min	Max	
Notopteridae							
1.	*Chitala chitala*	Moi	EN	36	30	56.0	0.16
2.	*Notopterus notopterus*	Patra	LRnt	958	7.8	25.0	3.95
Clupeidae							
3.	*Gudusia chapra*	Suhia,Chapla	LRlc	356	6.2	15.5	0.70
Cyprinidae							
4.	*Amblypharyngodon mola*	Moya	LRlc	18	11.5	16.5	0.06
5.	*Aspidoparia morar*	Pirohia	LRnt	3	12.5	16.3	0.02
6.	*Catla catla*	Katla,Bhakur	VU	85	35.0	42.6	0.41
7.	*Chagunius chagunio*	Chaguni	EN	23	14.0	26.4	0.12
8.	*Chela laubuca*	Chelwa	LRlc	16	2.9	4.3	0.06
9.	*Cirrhinus mrigala*	Naine,mrigal	LRnt	710	20.5	47.7	2.46
10.	*Cirrhinus reba*	Rewabata	VU	212	13.5	22.3	0.74
11.	*Ctenopharyngodaon idellus**	Grasscarp	NE	50	35.5	19.3	0.20
12.	*Cyprinus carpio**	Chinarahu	NE	170	9.5	55.7	0.72
13.	*Devario devario*	Danio	LRnt	112	4.6	8.0	0.45
14.	*Esomus danricus*	Danrika	LRlc	76	7.5	10.6	0.32
15.	*Hypophthalmichthys molitrix**	Silvercarp	NE	82	46.5	13.7	0.33
16.	*Labeo bata*	Bata	LRnt	411	15.5	31.4	1.97
17.	*Labeo boggut*	Bhagan	NE	17	6.5	13.8	0.08
18.	*Labeo calbasu*	Calbasu	LRnt	419	7.5	53.0	1.98
19	*Labeo dero*	Arangi	VU	3	13.5	15.2	0.02
20.	*Labeo gonius*	Kursha	LRnt	297	16.0	29.6	1.74
21.	*Labeo rohita*	Rohu	LRnt	305	8.5	45.5	1.18
22.	*Osteobrama cotio*	Mutheri,Gurda	LRnt	592	8.4	14.2	3.14
23.	*Puntius sarana sarana*	Pothi	VU	112	5.9	18.9	0.45
24.	*Puntius sophore*	Pothi	LRnt	800	7.5	12.0	3.78
25.	*Puntius ticto*	Pothi	LRnt	2002	6.0	9.4	9.01
26.	*Rasbora daniconius*	Dendua	NE	276	8.5	9.8	1.20
27.	*Salmostoma bacaila*	Chelwa	LRnt	3956	6.8	16.5	17.82
Cobitidae							
28.	*Botia lohachata*	Bagha	EN	76	8.5	16.9	0.31
29.	*Lapidocephalus guntea*	Guntea	NE	29	5.4	7.6	0.12
Bagridae							
30.	*Sperata aor*	Tengan	VU	219	9.6	45.2	0.98
31.	*Sperata seenghala*	Ari,Tengan,	LRnt	234	18.5	84.7	0.83
32.	*Mystus cavasius*	Tengra	LRnt	595	10.7	22.0	2.56
33.	*Mystus tengara*	Tengra	LRlc	603	11.5	17.5	2.66
34.	*Mystus vittatus*	Tengan	VU	1135	5.5	18.7	5.12
35.	*Rita rita*	Ritha,Hunna	LRnt	701	6.7	26.3	2.96
Siluridae							
36.	*Ompok bimaculatus*	Pabda	EN	1127	9.5	25.6	5.08
37.	*Ompok pabda*	Pabda,Jalkapoor	EN	305	7.8	21.0	1.36
38.	*Wallago attu*	Parhen,Buari	LRnt	236	23.4	80.0	0.97
Loricariidae							
39	*Pterygoplichthys disjunctivus**	Sailfin	NE	2	-	28.5	0.02
Schilbeidae							
40.	*Ailia coila*	Banspati,Patasi	VU	168	10.0	14.1	0.67
41.	*Eutropiichthys vacha*	Vachwa	VU	273	15.8	33.5	1.22
42.	*Clupisoma garua*	Bakeri	VU	1608	11.4	46.5	7.50

Sisoridae							
43.	*Glyptothorax telchitta*	Tilchatta	VU	2	9.3	9.5	0.02
44.	*Bagarius yarrelli*	Baghar	VU	93	15.5	130.5	0.37
45.	*Nangra nangra*	Balsohani	EN	5	9.2	11.5	0.03
46.	*Gagata cenia*	Baghi	NE	73	6.5	10.6	0.30
Claridae							
47.	*Clarias batrachus*	Mangur	VU	58	16.5	25.0	0.23
48.	*Clarias gareipinus**	ThaiMangur	NE	5	14.5	41.6	0.03
Heteropneustidae							
49.	*Heteropneustes fossilis*	Singhi	VU	191	22.5	27.5	0.72
Belonidae							
50.	*Xenentodon cancila*	Gotla	LRnt	372	15.9	33.5	1.20
Ambassidae							
51.	*Chanda nama*	Chanari	LRlc	287	4.0	5.5	1.21
Gobiidae							
52.	*Glossogobius guiris*	Bulla	LRnt	20	6.4	9.0	0.06
Mugilidae							
53.	*Rhinomugil corsula*	Parsibata	VU	17	6.5	14.3	0.07
Nandidae							
54.	*Nandus nandus*	Dhebari	LRnt	83	16.3	19.0	0.37
Anabantidae							
55.	*Anabas testudineus*	Koi,Kawai	VU	4	13.7	18.4	0.02
Belontidae							
56.	*Colisa fasciatus*	Khosti	VU	606	7.5	9.5	2.80
Channidae							
57.	*Channa marulius*	Souri	VU	197	22.5	57.5	0.85
58.	*Channa punctatus*	Girohi	LRnt	767	15.8	27.8	3.3
Mastacembelidae							
59.	*Macrognathus pancalus*	Baam	NE	306	11.0	20.0	1.39
60.	*Mastacembelus armatus*	Baam	LRlc	274	26.8	77.0	1.2
Tetraodontidae							
61.	*Tetrodon cutcutia*	Galphulani	LR-nt	19	4.5	7.0	0.06

VU = Vulnerable; **EN** = Endangered; **LRnt** =Lower risk near threatened; **LRlc** = Lower risk least concern; **NE** = Not evaluated. a, b, c, represents commonly exploited species and resilience value high (a), medium (b), low (c).*Exotic specie

3.2. Trophic Status of Fishes in the Mahananda River

Carnivorous fishes dominate the Mahananda River, making up about 58.5% of the species. Omnivores constitute 24.6%, feeding on both plants and animals, while herbivores account for 10.8%, primarily consuming algae and aquatic plants. Detritivores represent 6.2%, playing a role in organic matter recycling (Pie-chart: 3.5). This diverse trophic composition supports a balanced and healthy river ecosystem.

3.3. Valuation of Fish Diversity

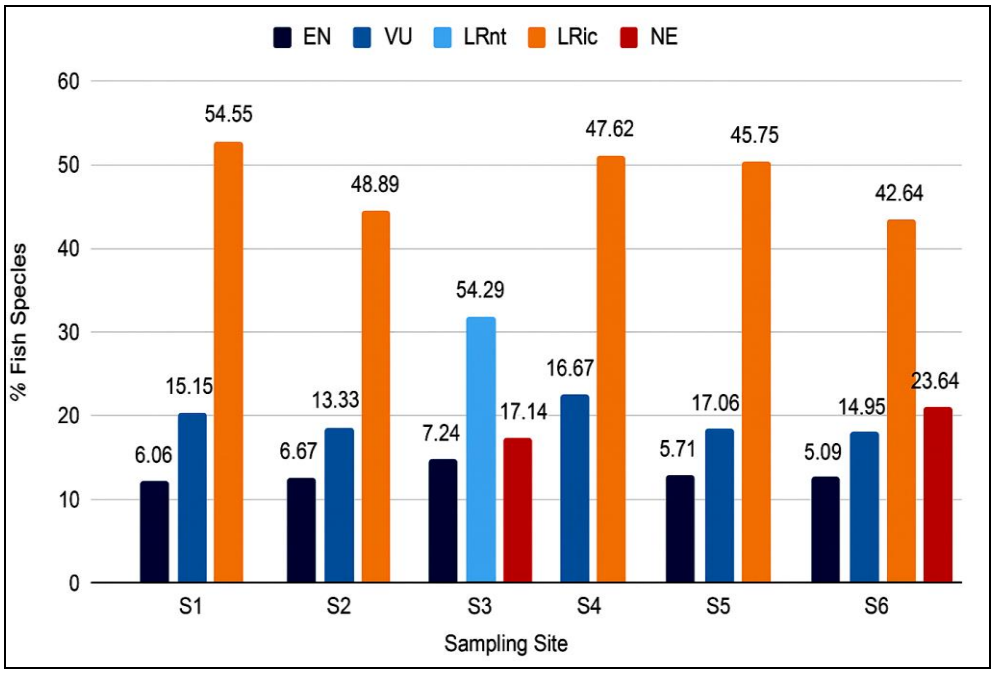
Approximately 89.5% of the fish fauna in the Mahananda River were food fishes. In all, 47 species were found to have the potential to be food fish, 28 species to be aquarium fish, and 4 species to be sport fish. Nine of the food fish species were appropriate for aquaculture and cultivation, whereas 31 of the species had a high economic value (Graph 3.6). These results highlight the Mahananda River's importance as a resource for aquaculture development, livelihoods, and fisheries.

3.4. Diversity indices

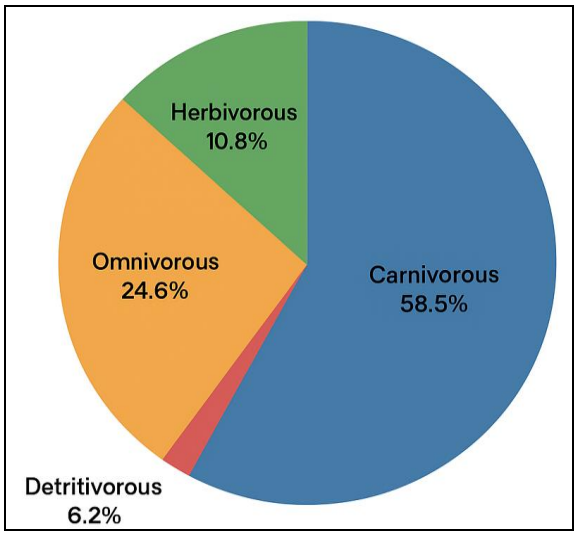
The diversity indices reveal consistently high fish biodiversity across all six sites of the Mahananda River. Species richness peaked at S6 (54 species), followed by S5 (45 species), indicating greater variety in downstream stretches. The Shannon-Wiener index (2.50-2.55) and Simpson index (0.8851-0.8925) values suggest stable and moderately high diversity throughout, with S6 showing the highest Shannon value (2.55) and S4 the highest Simpson value (0.8925)**.** The species dominance index (0.2378-0.2559) remained low, implying no single species dominated, while evenness (0.8662-0.8810) was uniformly high, with S6 exhibiting the most even distribution**.** Overall**,** S6 emerged as the most diverse and balanced site, while S4 showed the least dominance and highest ecological stability (Graph: 3.7).

Table: 3.3 Fish diversity indices of Mahananda River

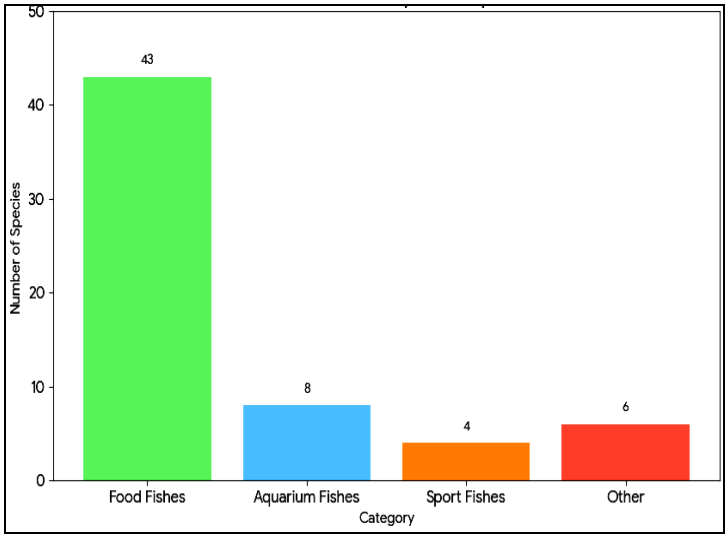
Diversity indices	S1	S2	S3	S4	S5	S6
Species richness	35	41	40	36	45	54
Number of individuals	2540	2720	2626	2823	2725	2840
Shannon- Weiner index (H)	2.50	2.53	2.52	2.54	2.54	2.55
Simpson index (D)	0.8851	0.8910	0.8882	0.8925	0.8920	0.8911
Species dominance index (d)	0.2559	0.2418	0.2483	0.2378	0.2429	0.2474
Evenness_eˆH/S	0.8662	0.8765	0.8717	0.8785	0.8804	0.8810



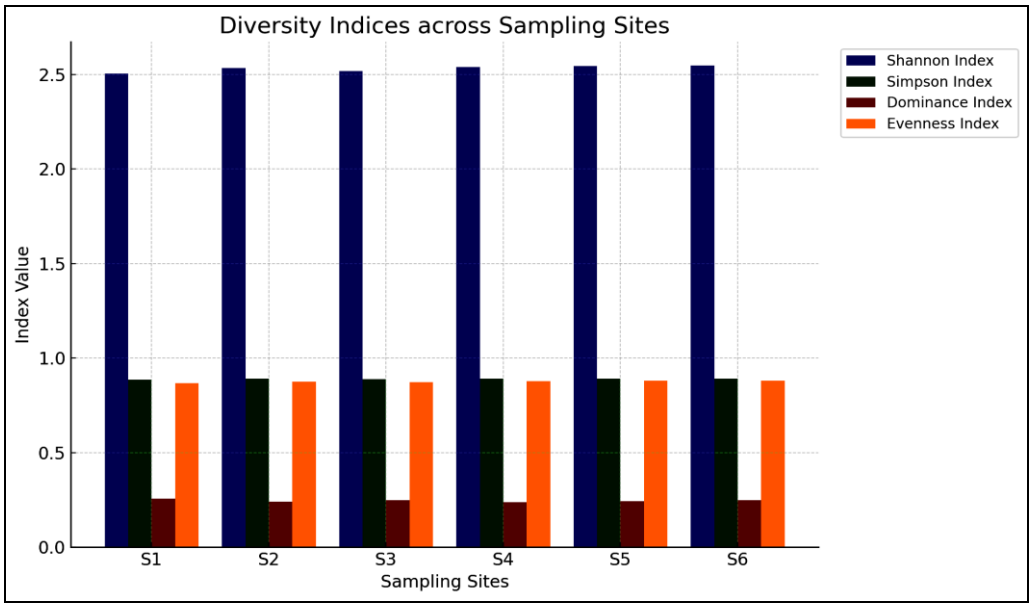
Graph 3.4: Assessment of threat status of fish species at six different sampling sites.



Pie-chart 3.5: Trophic level status of fishes.



Graph 3.6: Valuation of fish diversity



Graph: 3.7-Diversity indices at Mahananda river sites

4. Conclusion

A total of 61 fish species (46 genera, 21 families, 7 orders) were recorded from six sites in the Mahananda River. Cypriniformes dominated (42.62%), followed by Siluriformes (32.79%) and Perciformes (18.03%), while other orders contributed <6%. Cyprinidae was the most speciose family (24 spp.; 39.34%), with Bagridae (9.84%) and Sisoridae (6.56%) also important; several families were represented by single species (1.64%). Relative abundance (RA) analysis identified *Salmostoma bacaila* (16.56%) as most dominant, followed by *Clupisoma garua* (11.0%), *Mystus vittatus* (5.36%), *Puntius ticto* (5.34%), and *Notopterus notopterus* (4.21%). Indian Major Carps were poorly represented (*Catla catla* 0.41%, *Labeo rohita* 0.94%, *Cirrhinus mrigala* 1.68%), while *Labeo calbasu* was more common (1.97%). The genus *Labeo* was most diverse, followed by *Puntius*, *Channa*, and *Mystus*. Conservation-important taxa (*Ompok bimaculatus*, *C. garua*, *N. notopterus*, *C. reba*, *Sperata spp.*, *Rita rita*) occurred at moderate levels, whereas *Aspidoparia morar*, *Glyptothorax telchitta*, *Labeo dero*, and *Anabas testudineus* showed very low RA (≤0.02%). Five invasives were present, notably *Cyprinus carpio* (RA = 0.71), widespread across sites except S1. Sixteen species were commonly exploited as food fishes, of which eight had medium and three low resilience (Froese & Pauly, 2010) [6], underscoring the need for long-term conservation strategies and sustainable management. The study highlights multiple anthropogenic and climatic threats to fish biodiversity in the Mahananda River. Major concerns include pollution (78-82%) from untreated sewage and runoff, causing eutrophication and loss of sensitive species; overfishing (56-67%) with destructive gears, depleting stocks of Catla catla and Labeo rohita; and habitat degradation (32-45%) through sand mining and embankments, reducing spawning grounds and affecting keystone species. Additionally, invasive species (25-29%) such as Clarias gariepinus threaten native fish, while irregular monsoons and flooding linked to climate change further destabilize recruitment and migration. To address these threats, integrated conservation strategies are essential: strengthening pollution control, enforcing sustainable fishing practices, and promoting habitat restoration. Management of invasive species, creation of community fish sanctuaries, and climate adaptation measures will safeguard biodiversity. Research on population dynamics of threatened species and co-management with local fishers will ensure long-term sustainability of the river ecosystem.

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