Eco. Env. & Cons. 31 (4) : 2025; pp. (1798-1811)
Copyright@ EM International
ISSN 0971–765X

DOI No.: **http://doi.org/10.53550/EEC.2025.v31i04.070**
Website: www.envirobiotechjournals.com

Fish Biodiversity and its Environmental Correlates in River Sai, a lesser-known tributary of Ganga River, Central India

Kadam Bihari[1], Chandra Pal Singh[1], Radhakrishnan K.V.[1]*, Jyoti Saroj[1], Dinesh Kumar[2], Lavkush[1], Jay Kumar[1], Satyendra Kumar[1] and Gaurav Mishra[1]

[1] Department of Fisheries Resource Management, College of Fisheries, ANDUA and T, Kumarganj, Ayodhya 224 229, India
[2] Department of Aquaculture, College of Fisheries, ANDUA and T, Kumarganj, Ayodhya 224 229, India

(Received 11 July, 2025; Accepted 18 September, 2025)

ABSTRACT

The study investigates the ichthyofaunal diversity and environmental correlations of the Sai River in Uttar Pradesh, India, focusing on spatial and seasonal variations in fish composition and abundance. Increasing anthropogenic pressures and the presence of exotic species have raised concerns about biodiversity loss, making regular monitoring and conservation strategies essential for sustaining the ecological balance of river. Fish samples were collected from three sites along the Sai River and analyzed for taxonomic composition across orders, families, and genera. Diversity was quantified using indices such as Shannon's Diversity Index, Margalef's Index, Simpson's Index, Dominance Index, and Evenness Index. Seasonal variations were assessed across winter, pre-monsoon, and monsoon periods, while correlation analyses were used to evaluate relationships between fish abundance and environmental parameters including rainfall, relative humidity, minimum temperature, water transparency, and total dissolved solids (TDS). A total of 39 fish species representing 8 orders, 16 families, and 28 genera were identified, with Cypriniformes as the dominant order and Cyprinidae as the largest family. Diversity indices indicated a highly diverse and evenly distributed fish community, with Shannon's Index (3.56), Margalef's Index (7.97), Simpson's Index (0.96), Dominance Index (0.076), and Evenness Index (0.90). Species richness was highest during winter and pre-monsoon, while monsoon flooding and habitat disturbances reduced diversity. Correlation analysis showed that rainfall had the strongest positive influence on fish abundance (0.396–0.553), followed by relative humidity and minimum temperature, while water transparency (0.70-0.85) and TDS (0.52-0.56) were also strongly correlated. The occurrence of exotic species and anthropogenic disturbances underscore the need for immediate conservation interventions to protect the river's biodiversity.

Key words: *Fish Biodiversity, Conservation, Sustainable Fisheries, Sai River, Freshwater Ecosystem, Water Quality*

Introduction

Fish are critical as keystone species and bioindicators within freshwater systems, helping regulate populations of other aquatic organisms and supporting overall biodiversity (Karr, 1991; Power *et al*., 1996). As consumers of algae and detritus, and through their own decomposition, fish contribute to nutrient cycling essential for ecosystem function (Holmlund and Hammer, 1999; Flecker, 1996). Migratory fish such as Salmon also transport nutrients across ecosystems, benefitting terrestrial riparian zones (Naiman *et al*., 2002). Fish's sensitivity to water quality, habitat conditions, and hydrological regimes makes them effective indicators of freshwater health species declines or absences often signal broader ecosystem disruption and degradation (Karr, 1981; Metcalfe, 1989). Some fish also reveal impacts of overfishing or altered food web dynamics, while their presence highlights ecosystem resilience (Pauly *et al*., 1998; Jackson *et al.,* 2001). The deteriorating freshwater ecosystems have drastic impact on the fish life. Specifically, populations of migratory freshwater fish have witnessed an average 81% decrease between 1970 and 2020 (WWF, 2022; Deinet *et al*., 2020). Overfishing, fuelled by high demand and unsustainable practices, increasingly threatens fish populations and ecosystem stability (Welcomme *et al*., 2014; Cooke and Cowx, 2004). Habitat loss and degradation, including river fragmentation by dams and conversion of wetlands for agriculture, account for about half the threats to migratory fish, followed by overexploitation and increasing pollution (Grill *et al*., 2019; Winemiller *et al*., 2016).

India, a megadiverse nation and one of the world's biodiversity hotspots including the Himalayas, Western Ghats, Indo-Burma region, and Sundaland (Andaman and Nicobar Islands) is not exempt from this global trend (Mittermeier, 2005; Praveen *et al*., 2017). Its extensive network of rivers, lakes, and wetlands supports an exceptional array of aquatic biodiversity: India boasts nearly 3250 documented fish species, with 964 inhabiting freshwaters, fish biodiversity, ranking third in global fisheries production and second in aquaculture (Jayaram, 2010; FAO, 2022; Sarkar *et al.,* 2010). However, these vital ecosystems now face intense pressures. The discharge of untreated wastewater amounting to more than 38,000 million liters daily into Indian rivers exemplifies the severity of pollution, leading to dangerous levels of organic matter, pathogens, and heavy metals in water bodies (CPCB, 2022; Mishra *et al*., 2018). The escalating impacts of climate change particularly rising water temperatures and altered flow regimes are most acute in tropical regions, further aggravating the vulnerability of India's freshwater fish populations (Heino *et al*., 2009; Xenopoulos *et al.,* 2005). Agricultural runoff compounds pollution with nutrient loads and toxic pesticides, causing eutrophication and oxygen depletion that threaten aquatic life (Yu *et al.,* 2022; Garno *et al*., 2025). Ongoing scientific research remains vital for deepening our understanding of freshwater fish ecology, tracking species declines, and adapting management practices to evolving environmental conditions (Cooke *et al*., 2016; Dudgeon *et al.,* 2006). Only through coordinated, evidence-based action can India and the world hope to arrest the decline of freshwater biodiversity and preserve the critical ecosystem services upon which humanity depends (Reid *et al*., 2019).

The Sai River, a lesser-known tributary of the Gomti River which merges into the mighty river Ganga, flows through the fertile plains of Uttar Pradesh, India **(**Arya *et al*., 2020).The river holds significant cultural and ecological importance in eastern Uttar Pradesh, being referred to as the Aadi Ganga and revered in Hindu scriptures, serving as a vital lifeline for local rural communities (Arya *et al*., 2020; Praveen *et al*., 2017). Originating near the village of Hardoi, it traverses key districts including Raebareli, Amethi, Pratapgarh, and Jaunpur before merging with the Gomti River. (Kumari and Chaurasia, 2015) The river supports numerous agricultural activities by providing irrigation water for the predominantly agrarian populations along its course (Mdadheshiya *et al*., 2023; 2024). Additionally, it sustains local livelihoods through fishing, contributes to groundwater recharge, and plays a crucial role in biodiversity conservation**.** The river harbors a diverse range of freshwater species, including fish, aquatic plants, and invertebrates (Praveen *et al*., 2017). Its floodplains and adjoining wetlands serve as vital habitats for migratory birds and indigenous fauna (Arya *et al*., 2020; Praveen *et al*., 2017). However, scientific studies on fish diversity in Sai River are very scarce. Besides, increasing anthropogenic interventions have been causing severe biodiversity loss in Sai River (Dutta *et al.,* 2015). Hence proper documentation of fish diversity of this important ecosystem is imperative for conservation and sustainable exploitation of its fish resources. The present study was undertaken under this background with the objectives, 1. To study the distribution and abundance, pattern of fishes in Sai River. And 2. To correlation of fish diversity with environmental parameters to bring out critical environmental variables on fish diversity.

Materials and Methods

Site Selection: This study was conducted along an approximately 300 km stretch of the Sai River flowing through Lucknow, Raebareli, and Pratapgarh districts. For detailed ecological assessment, three sampling sites (Sites A, B, and C) were selected, each covering roughly 100 km to represent different ecological zones within the river system. A map of the river system with the locations selected for sampling is given in Fig. 1.

Fish sample collection and taxonomic identification

The fish specimens were collected from fishermen from the sampling sites along the river seasonally during July 2024 to March 2025. Preserved fish specimens were then transported to the laboratory for detailed identification and confirmation of their taxonomic status. Identification was primarily based on morphological characteristics following standard taxonomic references such as Nelson (2016) and Jayaram (2010). Additional verification utilized the online database Fish Base (Froese and Pauly, 2013) to corroborate species identification and nomenclature.

Relative Abundance

The abundance of the different fish species was estimated by quantifying the number of individuals caught at each sampling site. These data were extrapolated proportionally to estimate population abundance across the entire surveyed water body. Relative abundance of individual species was computed as the proportion of each species' count relative to the total fish population sampled (Williams *et al*., 2023).

Biodiversity Indices

Fish community diversity and structure are being assessed using several established indices to capture species richness, evenness, and dominance. Fish species diversity subjected to diversity analysis using different indices like Shannon Weiner index (H) (1963); Simpson Dominance index (D); Simpson index of diversity (1-D) (1949) Pielous Evenness (1966) and Margalef's index (1958). These indices provide quantitative measures of the ecological status of the fish assemblages sampled (Hossain *et al.,* 2017).

Assessment of Conservation Status of the fishes

The conservation status of each fish species was evaluated following the International Union for Conservation of Nature (IUCN) Red List categories and criteria (IUCN, 2023).

Physico-Chemical Parameters of Water

Water quality parameters such as temperature, electrical conductivity (EC), pH, and salinity were measured *in situ* at all sampling sites using a calibrated Hanna Combo HI98129 multi parameter meter (Hanna Instruments, 2020; APHA, 2023). Transparency was recorded with a Secchi disc, and total dissolved solids (TDS) were measured onsite by an IONIX TDS meter (Wetzel and Likens, 2000). Monthly water samples were collected in sterilized bottles and analyzed in the laboratory following standard protocols for dissolved oxygen (DO) (Winkler, 1888; Boyd, 2020), free carbon dioxide (CO_2) (Wetzel and Likens, 2000), Alkalinity, (APHA, 2023).

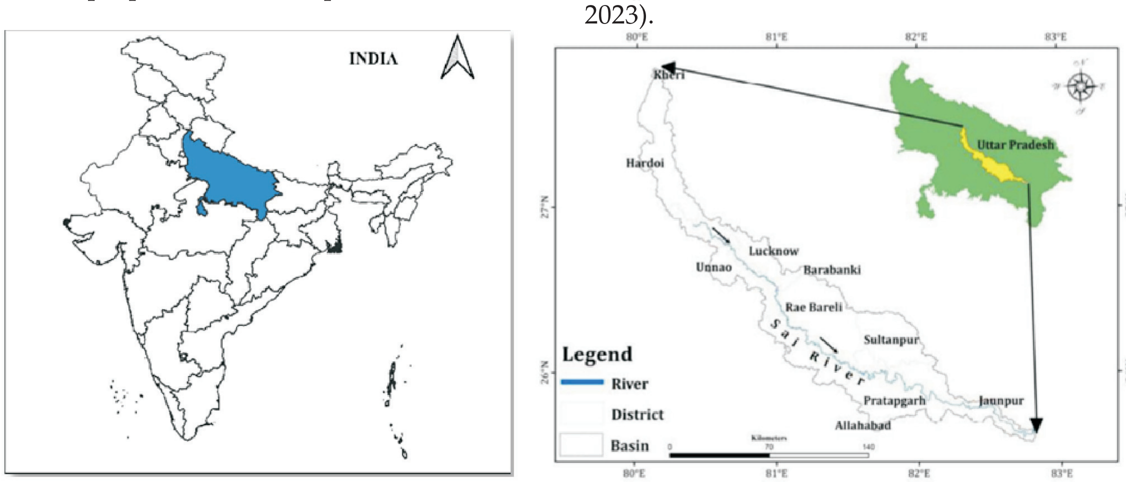

Fig. 1. Map showing the Sai River with the Sampling Sites

Meteorological data (air temperature, precipitation, wind speed, relative humidity, and solar radiation) were obtained from the Indian Meteorological Centre at Lucknow to know environmental factors influencing fish distribution.

Statistical Analysis

All physico-chemical data were analyzed using Microsoft Excel and SPSS software, while fish diversity indices were calculated with PAST software version 4.02 (Hammer *et al*., 2001; Hossain *et al*., 2017). This integrated approach enabled comprehensive assessment of water quality dynamics and their relationship with aquatic biodiversity in the Sai River.

Results and Discussion

Fish Biodiversity of Sai River

A total of 39 fish species belonging to 8 orders, 16 families, and 28 genera were collected from the three sampling sites of the Sai River. Among the orders, Cypriniformes was the largest with 15 species, followed by Siluriformes with 12 species. Other orders included Anabantiformes (4 species), Perciformes (3 species), Synbranchiformes (2 species), and single species from Clupeiformes, Osteoglossiformes, and Beloniformes (Table 1; Fig. 2). Cyprinidae was the most dominant family with 14 species, followed by Bagridae (6 species), Siluridae (3 species), while other families had one or two species each (Fig. 3). This pattern aligns with previous studies reporting Cyprinidae as the richest family in the Sai River (Daisy and Kumar, 2020).

Comparatively, Prakash (2021) reported 58 fish

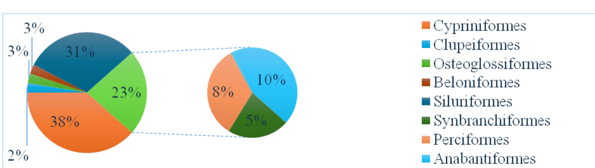

Fig. 2. % Distribution of Orders of Fish Species collected from the Sai River during the study period

species from various water bodies in Uttar Pradesh, while Sahu *et al*. (2024) recorded 76 species from the rivers and streams of the state, representing about 14.11% of India's freshwater fish diversity. Kumar *et al*., (2013) documented 62 species in Faizabad district. The current study's tally of 39 species reflects a

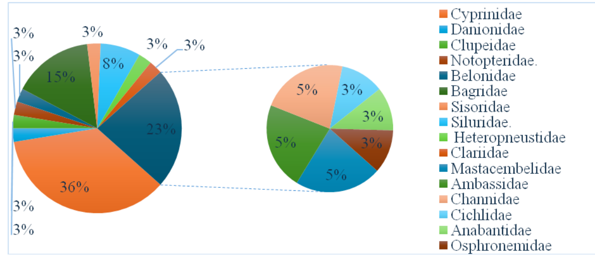

Fig. 3. % Distribution of Families of fish Species collected from the Sai River during the study period.

localized snapshot of fish diversity in the Sai River system.

Threat Status of Fishes

Based on IUCN (2024) criteria, most species (35) in the Sai River were classified as Least Concern (LC), with three Near Threatened (NT) and two Vulnerable (VU), indicating emerging conservation concerns. Similar patterns have been reported in Indian rivers such as the Ganga and Western Ghats systems, where studies by Raghavan *et al*., (2011) and Dahanukar *et al*., (2011) highlighted the growing number of threatened freshwater fishes due to habitat loss, pollution, and overexploitation. Although a majority of species remain LC, the presence of NT and VU species suggests localized environmental pressures. As noted by Lakra *et al*., (2010), continuous monitoring and region-specific conservation measures are essential to prevent further declines in native fish populations.(Table 1).

Abundance and Distribution

The assessment of 39 fish species across the three sites of the Sai River revealed distinct patterns of abundance and distribution reflecting both environmental stability and localized pressures. Dominant species such as *Puntius chola* (Relative Abundance, RA 7.67), *Salmostoma bacaila* (RA 7.13), and *Cyprinus carpio* (RA 4.84) were consistently abundant across all sites, indicating their ecological adaptability. Similar patterns were noted by Sarkar *et al*. (2010) in the Gomti River, where cyprinids, especially Puntius species dominated moderately impacted habitats. Moderately abundant species like *Mystustengara*, *Rita rita*, and *Xenentodon cancila* likely reflect habitat preferences for submerged vegetation and deeper pools, paralleling findings from the Ganga River system (Lakra *et al*., 2010). Conversely, species with low abundance such as *Bagariusbagarius* and *Parambassislala* might have affected by overfish-

Table 1. List of fish species collected from the Sai River along with Common name, local name, threat status and the fin formula

Sl. No.	Scientific name	Order	Family	Common name	Local name	Relative abundance	IUCN status	Fin formula
1.	*Labeo rohita*	Cypriniformes	Cyprinidae	Rohu	Rohu	1.54	LC	D. 11-12 (3/8-9); P1. 17; P2. 9 (1-8); A. 7(2/5)
2.	*Labeo calbasu*	Cypriniformes	Cyprinidae	Orange finlabeo	Karaunchi	1.97	LC	D. 17-18 (3/14-15); P1. 16 18; P2.9 (1/8); A. 7(2/5)
3.	*Labeo bata*	Cypriniformes	Cyprinidae	Bata	Bata	0.98	LC	D 3/7; P1 1/17; P2 1/7; A 2 3/12-14
4.	*Labeo gonius*	Cypriniformes	Cyprinidae	Kuria labeo	kursha	1.35	LC	D. 17-18 (3/14-15); P1. 16 18; P2.9(1/8); A.7(2/5)
5.	*Cirrhinusreba*	Cypriniformes	Cyprinidae	Reba carp	Raiya	1.65	LC	D. 32-39/74-90; A. 3/75 88; P. 23
6.	*Cirrhinusmrigala*	Cypriniformes	Cyprinidae	Mrigal	Nain	1.03	LC	D. 16; P1. 17; P2. 9; A. 8
7.	*Puntius chola*	Cypriniformes	Cyprinidae	Swamp barb	Pothi	7.67	LC	D. 10 (2/8); P1. 15; P2; 9-10; A.33-36(3/30-33)
8.	*Salmostomaphulo*	Cypriniformes	Cyprinidae	Finescalerazorbelly minnow	Chelwa	1.01	LC	D. 9 (2/7); P 1. 11; P 2. 8; A. 18-20 (2/16-18)
9.	*Puntius sophore*	Cypriniformes	Cyprinidae	Pool barb	Pothi	5.41	LC	D.3/8;A.3/5;P.15;V.19
10.	*Chaguniuschagunio*	Cypriniformes	Cyprinidae	Chaguni	Chaguni	1.30	LC	D-18(3/15),P-19,V-9,A-8(3/5),C-19,LL-40-43
11.	*Catlacatla*	Cypriniformes	Cyprinidae	Catla	Bhakur	0.93	LC	D-18(3/15),P-19,V-9, A 8(3/5),C-19,LL-40-43
12.	*Cyprinus carpio*	Cypriniformes	Cyprinidae	Common carp	Chinarahu	4.84	LC	D-18(3/15),P-19,V-9, A 8(3/5),C-19,LL-40-43
13.	*Ctenopharyn godonidella*	Cypriniformes	Cyprinidae	Grass carp	grass	2.38	LC	D. 3/7, P1. 1/17 P2. 1/8, A. 3/7-8
14.	*Osteobramacotio*	Cypriniformes	Cyprinidae	Cotio	Mutheri, Gurda	2.68	LC	D. 15-16 (3/12-13); P1. 16 17; P2.9; A. 7(2/5)
15.	*Salmostomabacaila*	Cypriniformes	Danionidae	Chela	Chelwa	7.13	LC	D.10(2/8);P1.12 13; P2.9;A. 14-15(2/12 13)
16.	*Gudusiachapra*	Clupeiformes	Clupeidae	Indian River Shad	Suhia,Chapla	1.20	LC	D. 14-15 (3/11-12); P1. 13(1/12);P2.7;A.23 25(2/21 23)
17.	*Notopterusnotopterus*	Osteoglossiformes	Notopteridae.	Feather Back	Patra	3.02	LC	D.7-8;P1.15-17;P2.5 6;A. 99-104.
18.	*Xenentodoncancila*	Beloniformes	Belonidae	Freshwater garfish	Kawwamachli	4.08	LC	D.15-16; P1.10 11; P2. 6; A. 17-18
19.	*Sperataaor*	Siluriformes	Bagridae	Long whiskered catfish	Tengan	1.84	LC	D. I/7; P1. I/9-10; P2. I/5; A.12-13
20.	*Mystuscavasius*	Siluriformes	Bagridae	Gangetic mystus	tengna	2.04	LC	D. I/7; P1. I/8; P2. 6; A. 11
21.	*Mystus vittatus*	Siluriformes	Bagridae	Striped dwarf catfish	Tengra	2.41	LC	D I 7; A ii-iii 7-9; P I 9; V i 5

Table 1. *Continued ..*

Sl. No.	Scientific name	Order	Family	Common name	Local name	Relative abundance	IUCN status	Fin formula
22.	*Mystustengara*	Siluriformes	Bagridae	Tengara catfish	Tengan	3.47	LC	D. I/7; P1. I/8; P2.6; A. 10 139
23.	*Rita rita*	Siluriformes	Bagridae	Rita	Belgadra	4.13	LC	D. 11/6; P1. 1/10; P2. 8; A. 11-13
24.	*Sperataseenghala*	Siluriformes	Bagridae	Giant river-catfish	Tengra	3.29	LC	D.I/7;P1.I/9;P2.I/5; A.11- 12
25.	*Bagariusbagarius*	Siluriformes	Sisoridae	Goonch	Gonch	0.49	VU	D1. I/6; D2. 0; P. I/12; V. 6; A. 3/10-12; C. 17
26.	*Ompokpabda*	Siluriformes	Siluridae.	Pabdah catfish	Pabda, Jalkapoor	1.16	NT	D. 4-5; P. I/1113; V. 8; A. 2/ 52-60; C. 18
27.	*Wallago attu*	Siluriformes	Siluridae.	Wallago	Parhen, Barari	1.72	VU	D. 5; P1.1/13-14; P2. 10; A. 85-89.
28.	*Ompokbimaculatus*	Siluriformes	Siluridae.	Butter catfish	Pabda	0.69	NT	D. 4; P1.12-15(1/11 14); P2.8; A.66-73.
29.	*Heteropneustesfossilis*	Siluriformes pneustidae	Hetero-	Stinging catfish	Singhi	1.23	LC 70	D. 6-7; P1. 1/6-7; P2. 6;A. 62-
30.	*Clarias batrachus*	Siluriformes	Clariidae	Magur	Mangur	1.47	LC	D. 64-70; P1. 1/9-10; P2. 6. A.45-52
31.	*Macrognathuspancalus*	Synbranchiformes	Mastacem-belidae	Barred spiny eel	Baam	2.46	LC	D.XXIV-XXVI/35-37; P1. 19-20; A. III/37-40
32.	*Macrognathus armatus*	Synbranchiformes	Mastacem-belidae	Spinyeel	Baam	0.37	LC	D.XXXVII-XXVIII/78 84, P1.25-26,A.III/77-85
33.	*Chanda nama*	Perciformes	Ambassidae	Elongate glass-perchlet	Chanari	0.47	LC	D.XXIV-XXVI/35- 37; P1. 19-20; A. III/37-40
34.	*Oreochromis niloticus*	Perciformes	Cichlidae	Nile tilapia	Tilapia	1.70	LC	D. XVI-XVIII 10-14, P1. 1/15-17, P2. 1/5-6 A. III 7-11
35.	*Parambassislala*	Perciformes	Ambassidae	Highfin glassy perchlet	glass fish	0.10	NT	D. 21–22 (VIII/13–14), P 1. 8–10 (2/6–8), P 2. 6 (I/5),A. 17-18 (III/14–15),C. 20–22 (4/16–18)
36.	*Channa punctatus*	Anabantiformes	Channidae	Spotted snakehead	Girohi	2.85	LC	D.29-32;P1.15- 18; P2.6; A. 20-22
37.	*Channa striatus*	Anabantiformes	Channidae	Striped snakehead	Souri	3.32	LC	D. 42-46; P1. 15-17; P2. 6; A. 24-27
38	*Anabas testudineus*	Anabantiformes	Anabantidae	Climbing perch	Koi, Kawai	2.88	LC	D.26-28(XVI-XVIII1- 2/7-10) P1.13-15(1- 2/11-14) P2
39.	*Trichogaster fasciata*	Anabantiformes	Osphronemidae	Banded gourami	Khosti	2.85	LC	D. XV-XVII/10-14,Pc. 9-10, Pv. 1, A. XV-XVIII/ 15-19, C. 18-20,

Where,
LC = Least Concern, NT = Near Threatened, VU = Vulnerable D= Dorsal, P1 = Pectoral, P2 = Pelvic, A = Anal

ing and habitat degradation, akin to trends documented in the Mahanadi River in Odisha where siltation and pollution reduced diversity (Das *et al*., 2023). Site C exhibited the highest species abundance, possibly due to more heterogeneous habitats or reduced anthropogenic disturbance. The presence of exotic species like *Oreochromis niloticus* aligns with ecological shifts seen in other North Indian rivers due to aquaculture escapees (Prakash, 2021; Sarkar *et al*., 2010).

Biodiversity Indices

The Simpson's Diversity Index values remained consistently high (~0.96) across all sampling sites (Fig. 4), indicating a healthy, diverse fish assemblage. Slight seasonal declines during the monsoon (July-August) likely reflect flooding and habitat disturbance impacting species distribution, with diversity rebounding post-monsoon and peaking in March, possibly due to pre-spawning behavior and food availability (Hossain *et al.,* 2017; Rao *et al.,* 2024; Sarkar *et al*., 2013). Simpson's index ranged from 0 (low) to 1 (high diversity), and values close to 1 denote ecological stability (Magurran, 2004).

Similarly, the Shannon Diversity Index (H) showed obvious seasonal variation, with the lowest values (~2.83) during monsoon and highest (~3.50) in late winter to spring (Fig. 5). This indicates reduced richness and evenness under monsoon stress and more balanced communities in stable periods, mirroring observations in other Indian rivers (Sreekanth *et al*., 2016; Tremain and Adams, 1995). Shannon's index values above 3.5 reflect very high diversity (Hossain *et al*., 2017).

The Dominance Index (D) values were generally low (0.031–0.076), implying no overwhelming species dominance and a well-balanced fish community (Fig. 6). An increase during monsoon indicates a temporary rise of hardy species dominance due to environmental stress (Rao et al., 2024; Jhingran, 1991).

Evenness Index values ranged between 0.76 and 0.90, with peak evenness in March, showing equitable distribution of individuals among species (Fig. 7), supported by stable water quality and less disturbance in cooler months. Slight decreases post-monsoon suggests ecological readjustments (Bhatt *et al.*, 2012; Cassey *et al*., 2004**;** Shukla and Bhat, 2017).

Margalef's Richness Index fluctuated from 4.75 to 7.96, peaking post-monsoon and early spring, reflecting flourishing fish richness when river conditions stabilize (Fig. 8). Richness dropped during monsoon due to flooding and habitat disruption, consistent with patterns reported for major Indian

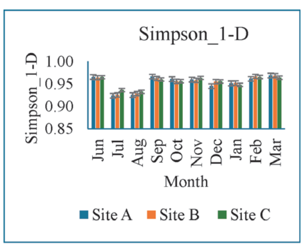

Fig. 4. Simpson Diversity Index of Fish Diversity in Sai River at selected sites

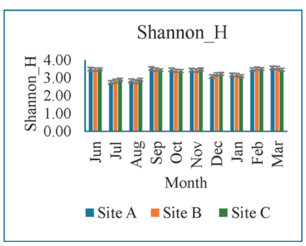

Fig. 5. Shannon Diversity Index of Fish Diversity in Sai River at selected sites

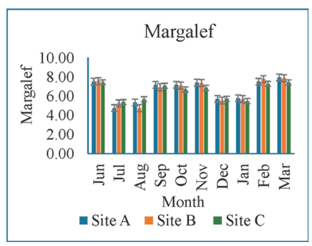

Fig. 8. Margalef Diversity index of Fish Diversity in Sai River at selected sites

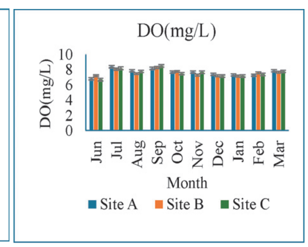

Fig. 9. Dissolved oxygen of water recorded at different study sites of Sai River

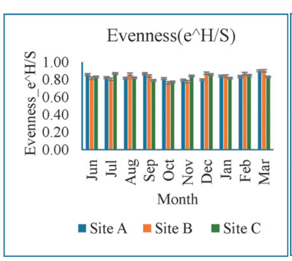

Fig. 6. Dominance Index of Fish Diversity in Sai River at selected sites

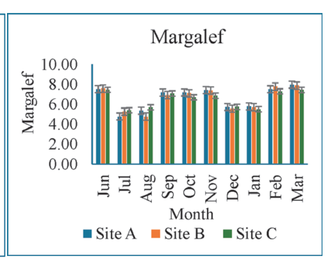

Fig. 7. Evenness Index of Fish Diversity in Sai River at selected sites

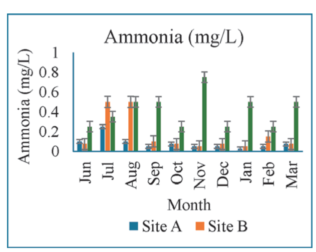

Fig. 10. Ammonia of water recorded at different study sites of Sai River

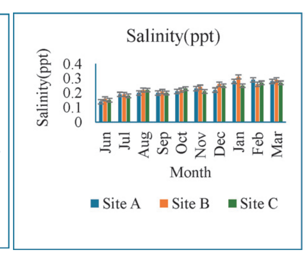

Fig. 11. Salinity of water recorded at different study sites of Sai River

rivers like Godavari and Brahmaputra (Rao *et al*., 2024; Poddar *et al*., 2025; Nimasow *et al*., 2025).

Water Quality

The physico-chemical characteristics of water are critical for aquatic ecosystem health, influencing biodiversity and productivity (Wetzel, 2001). In this study, dissolved oxygen (DO) levels across Sites A, B, and C ranged from 6.7 to 8.5 mg/l (Fig. 9), remaining within the optimum range for aquatic life (Sargaonkar and Deshpande, 2003). Seasonal fluctuations showed lower DO during pre-monsoon months due to elevated temperatures and reduced mixing, consistent with findings from Mishra *et al.* (2009) and Singh and Saxena (2025) in Indian rivers. Post-monsoon increases in DO, linked to enhance aeration and cooler temperatures, support ecosystem recovery (Sharma *et al.*, 2014). Salinity was low (<0.5 ppt) but exhibited seasonal variation, with minimum during monsoon and maxima in dry months (Fig. 11), attributed to evaporation and ion concentration during low flows (Mariu *et al*., 2023). Such fluctuations can affect fish physiology and immune function as discussed by *Wu et al.* (2025) and Das *et al*. (2025). Electrical conductivity followed a similar seasonal trend (0.29–0.63 mS/cm), reflecting ion concentration changes (Fig. 12); these variations influence fish habitat suitability as reported in other northern Indian rivers (Venkatesharaju *et al.*, 2010; Nidhi *et al*., 2025; Verma *et al.*, 2025).

pH values fluctuated seasonally (7.01-9.1) (Fig. 15), with higher alkalinity corresponding to increased photosynthetic activity and lower CO_2 concentrations (Fig. 14) in winter (Mishra *et al*., 2023; Mahajan *et al.*, 2024). These findings align with observations by Trivedi and Goel (1984) and Singh *et al*. (2021). Water temperature showed typical seasonal variation (17.9–31.3 °C), affecting dissolved oxygen and metabolic rates (Fig. 13), consistent with Sharma *et al*. (2014) and Pandey *et al.* (2025).

Total dissolved solids (TDS) ranged from 230 to 444 mg/l, peaking in dry months due to evaporation and anthropogenic inputs (Fig. 16), impacting fish Osmoregulation as noted by Kumar and Dua (2009). Free carbon dioxide exhibited seasonal peaks in early summer because of decomposition and respiration, influencing pH balance and biological activity (Wetzel, 2001; Das and Acharya, 2003). Transparency varied seasonally, lowest during monsoon due to runoff and turbidity (Fig. 17), affecting light penetration and primary productivity (Kalff, 2002; Kundu *et al*., 2017). Ammonia concentrations

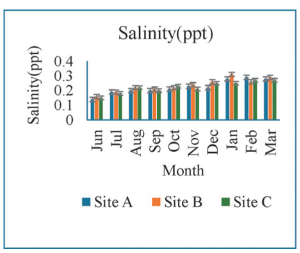

Fig. 12. Electrical conductivity of water recorded at different study sites of Sai River

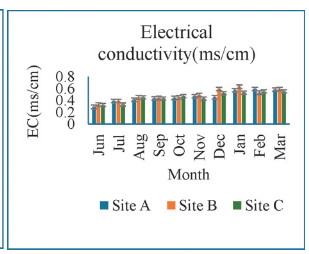

Fig. 13. Water temperature ofwater recorded at different study sites of Sai River

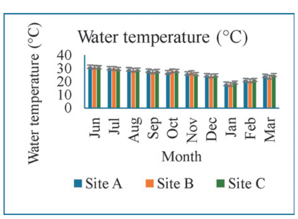

Fig. 14. Free Carbon Dioxide of water recorded at different study sites of Sai River

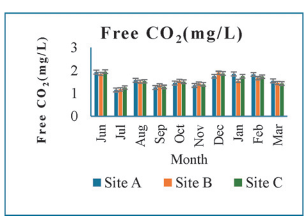

Fig. 15. pH of water recorded at different study sites of Sai River

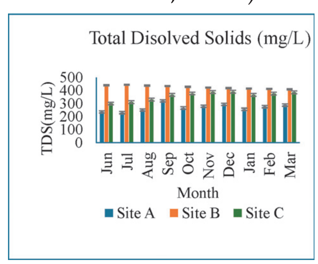

Fig. 16. Total Dissolved Solids of water recorded at different study sites of Sai Rive

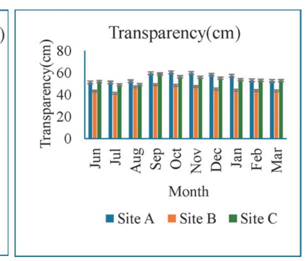

Fig. 17. Transparency of water recorded at different study sites of Sai River

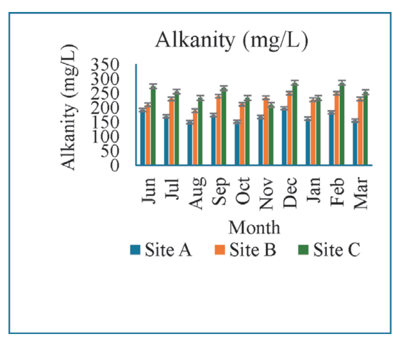

Fig. 18. Alkalinity of water recorded at different study sites of Sai River

showed seasonal spikes linked to temperature and organic loading (Fig. 10), posing potential toxicity risks (Camargo and Alonso, 2006; Sharma *et al.*, 2025). Alkalinity was highest in winter (Fig. 18), reflecting mineral dissolution and microbial decomposition, important for buffering capacity (Kannel *et al.,* 2007; Li *et al.,* 2025).

Correlation between the water quality parameters and fish abundance

In this study, correlations between water quality parameters and fish abundance showed varied pattern across the three sites of the Sai River, reflecting environmental influences on fish distribution. At Site A, fish abundance had a strong positive correlation with water transparency (0.70) and free CO_2 (0.56), suggesting that clearer, moderately mineral-rich waters promote fish presence. Weak positive correlation with temperature (0.09) was also noted, while ammonia (-0.57), total dissolved solids (TDS) (-0.25), pH (-0.35), and alkalinity (-0.19) negatively affected fish abundance (Vass *et al.,* 2009; Sarkar *et al*., 2010). Dissolved oxygen, salinity, and electrical conductivity showed weak or negligible correlations.

Site B showed moderate positive correlation with transparency (0.62) and weaker positive correlations with alkalinity (0.21), free CO_2 (0.19), dissolved oxygen (0.10), and pH (0.10). Fish abundance correlated strongly negatively with ammonia (-0.78), underscoring ammonia's toxicity even at low concentrations, impairing fish respiration and osmoregulation (Randall and Tsui, 2002). Negative correlations with

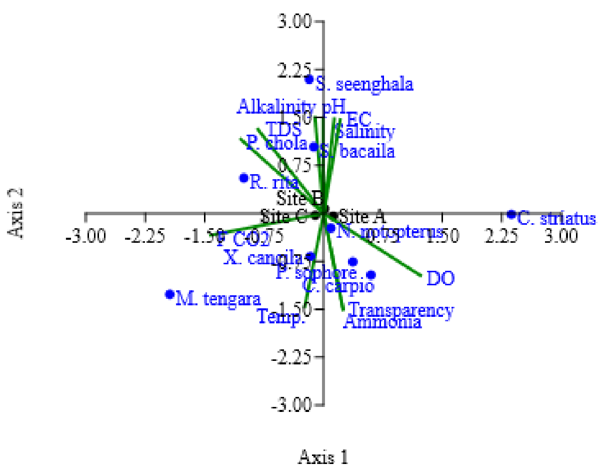

Fig. 19. CCA biplot showing the relationship between the fish abundance and environmental variable for different study sites of Sai River

EC, salinity, and TDS were weak but consistent with trends reported in polluted systems disrupting habitats (Sharma *et al*., 2025; Kelkar *et al.,* 2022).

At Site C, fish abundance correlated strongly with transparency (0.85) and moderately with TDS (0.52), indicating clearer water and balanced dissolved solids enhance habitat quality (Sugunan, 1995). Weakly positive correlations with EC and salinity were observed, while negative correlations with pH (-0.27) and free CO_2 (-0.01) suggested higher alkalinity and carbon dioxide levels may suppress fish abundance (Sharma *et al*., 2025; Kelkar *et al.,* 2022). These findings overall align with studies across Indian freshwater ecosystems linking water clarity and lower pollution levels with healthier fish communities (Sarkar *et al*., 2010; Vass *et al*., 2009).

The **Canonical Correspondence Analysis (CCA)** biplot (Fig. 19) illustrates the multivariate relationship between fish species, water quality parameters, and sampling sites (A, B, C) in the Sai River ecosystem. It also revealed how environmental gradients shape food chain structure by influencing species distribution across different trophic levels. Fish species like *Channa striatus*, located far along the positive side of Axis 1, show a strong positive correlation with dissolved oxygen (DO) and moderate transparency. As a top predator, *C. striatus* depends on clear, well-oxygenated waters for effective hunting, primarily feeding on smaller fishes and insects, highlighting its apex position in the aquatic food chain. On the opposite side of the biplot (negative Axis 1 and Axis 2), species like *Mystustengara* and *Xenentodon cancila* align with higher free CO and elevated water temperature. These environmental conditions are typically associated with organic decomposition and benthic productivity, indicating that these mid-level carnivores feed on macro invertebrates and larval fish in nutrient-enriched zones. Fish such as *Sperataseenghala*, *Rita rita*, and *Salmostoma bacaila* cluster near alkalinity, pH, salinity, TDS, and EC parameters linked to more ion-rich, mineralized waters. These omnivores and bottom-feeders thrive on detritus, benthic invertebrates, and plant matter, representing the mid-to-lower trophic levels and acting as important links between decomposers and higher predators.

Cyprinus carpio and *Puntius sophore* are located near ammonia, transparency, and moderate DO, suggesting tolerance for moderately impacted habitats. These are omnivorous species, feeding on algae, detritus, and small organisms, thus forming a vital component of nutrient cycling in the aquatic food web. The sampling sites A, B, and C are closely clustered near the origin, indicating overlapping ecological conditions but subtle differences that support species diversity across trophic guilds. For example, Site A is slightly closer to DO and *Channa striatus*, implying better oxygenated, predator-favorable waters, while Site C leans toward free CO_2 and *M. tengara*, suggesting slightly more eutrophic conditions. Sarkar *et al.* (2013) reported that fish distribution in Indian rivers responds significantly to gradients in DO, TDS, and pH, shaping food web roles and biodiversity. Bhatt *et al.* (2012) observed that predator species like *Channa* were abundant in clearer, oxygen-rich Himalayan rivers, while benthic feeders were tied to high nutrient zones. Dudgeon (2000) highlighted that monsoon-driven nutrient pulses promote base-level productivity, triggering trophic cascades up to top predators. Jhingran (1991) emphasized that environmental tolerance defines ecological niches and food chain positions, especially under seasonal shifts in Indian rivers. Lakra *et al.* (2010) found that habitat heterogeneity supports different feeding guilds, contributing to fish community resilience and stability.

Conclusion

The Sai River, as revealed through this study, harbours a vibrant and seasonally responsive fish community. Species richness and ecological balance were clearly evident, especially during cooler months. Site C stood out as the most biologically rich location, likely benefiting from less human disturbance and more diverse habitats. Fish populations here are deeply influenced by environmental parameters, Particularly DO, CO2, ammonia, PH etc.These elements promote favourable conditions for feeding and breeding. At the same time, pollution indicators like ammonia and CO_2 pose threats that need close monitoring. The findings also highlighted the fringed balance of this river system. Regular water quality assessments, habitat protection, and pollution control are essential to safeguard the biodiversity of the Sai River. This study is the first authentic attempt which provide the status of fish diversity and environmental health of Sai River, but also it needs further rigorous research towards habitat prediction and conservation of fish biodiversity, for sustainable utilisation of resources of this important river in Central India

Acknowledgements

The authors like to acknowledge the Department of Fisheries Resource Management, College of Fisheries, ANDUAT, Kumarganj, Ayodhya for providing the infrastructural facility for carrying out this research study. The first author also would like to thank to Indian Meteorological Department (IMD), Lucknow for providing the meteorological data for conducting the research.

Conflict of Interest- None

References

American Public Health Association, American Water Works Association, and Water Environment Federation 2023. *Standard Methods for the Examination of Water and Wastewater* (24^{th} ed.). APHA.

Arya, A.K., Singh, A.P. and Agarwal, K.K 2020. A multi criteria approach for morpho-tectonic evaluation of Sai River Basin in Uttar Pradesh. *Journal of the Geological Society of India.* 96(2): 171-179.

Berkes, F. 2009. Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management.* 90(5): 1692-1702.

Bhatt, J.P., Manish, K. and Pandit, M.K. 2012. Elevational gradients in fish diversity in the Himalaya: water discharge is the key driver of distribution patterns. *PLOS ONE.* 7(9): e46237.

Boyd, C.E. 2020. *Water Quality: An Introduction*. Springer.

Camargo, J.A. and Alonso, A. 2006. Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: A global assessment. *Environment International.* 32(6): 831-849.

Cassey, P., Blackburn, T.M. Russell, G.J. Jones, K.E. and Lockwood, J. L 2004. Influences on the Transport and Establishment of Exotic Bird Species: An Analysis of the Parrots (*Psittaciformes*) of the World. *Global Change Biology.* 10: 417-426.

Cooke, S.J. and Cowx, I.G. 2004. The role of recreational fishing in global fish crises. *Bio Science.* 54(9): 857-859.

Cooke, S.J., Allison, E.H. Beard, Jr T.D. Arlinghaus, R. Arthington, A.H. Bartley, D.M. and Welcomme, R.L 2016. On the sustainability of inland fisheries: Finding a future for the forgotten. *Ambio.* 45(7): 753-764.

Cowx, I.G. and Portocarrero, Aya, M. 2011. Paradigm shifts in fish conservation: moving to the ecosystem services concept. *Journal of Fish Biology.* 79(6): 1663-1680.

CPCB, 2019. *Comprehensive Assessment of Riverine Pollution in India*. Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, Govt.

of India.

CPCB, 2022. *Status of Water Quality in India: Annual Report* 2021-2022. Central Pollution Control Board. Cuttack City, India. *Water, Air, and Soil Pollution.* 150: 163-175.

Dahanukar, N., Raghavan, R., Ali, A., Abraham, R. and Shaji, C.P. 2011. The status and distribution of freshwater fishes of the Western Ghats. *The Status and Distribution of Freshwater Biodiversity in the Western Ghats India.* 3: 21-48.

Daisy, R. and Avinash, K. 2020. Fish Diversity of Sai River flowing through Raebareli District of Uttar Pradesh (India*). International Journal of Fisheries and Aquatic Studies*. 8(5): 182-185.

Das, J. and Acharya, B.C. 2003. Hydrology and assessment of lotic water quality in Cuttack City, India. *Water, Air, and Soil Pollution.* 150(1): 163-175.

Das, P., Landge, A.T. Nayak, B.B. Ramteke, K. Das, B.K. Majhi, S.K. and Borah, S. 2025. Fish Community Structure and Environmental Drivers in a Tropical River Wetland Continuum: A Study from Brahmaputra Basin in the Eastern Himalayan Region. *Ecohydrology.* 18(3): e70041.

Deinet, S., Scott-Gatty, K. Rotton, H. Twardek, W.M. Marconi, V. McRae, L. and Berkhuysen, A. 2020. The living planet index (LPI) for migratory freshwater fish: University of *Groningen Technical report.*

Dudgeon, D. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews.* 81(2): 163-182.

Dutta, V., Kumar, R. and Sharma, U. 2015. Assessment of human-induced impacts on hydrological regime of Gomti river basin, India. *Management of Environmental Quality: An International Journal.* 26(5): 631-649.

FAO, 2022. *The State of World Fisheries and Aquaculture 2022.* Food and Agriculture Organization of the United Nations. https://www.fao.org/3/cc0461en/cc0461en.pdf

Flecker, A.S. 1996. Ecosystem engineering by a dominant detritivore in a diverse tropical stream. *Ecology.* 77(6): 1845-1854.

Froese, R. and Pauly, D. (Eds) 2013. *FishBase*. World Wide Web electronic publication. Retrieved from https://www.fishbase.org

Galib, S.M., Rashid, M.A. Chaki, N. Mohsin, A.B.M. and Joadder, M.A.R. 2016. Seasonal variation and community structure of fishes in the Mahananda River with special reference to conservation issues, India. *Journal of Fisheries.* (4): 325-334.

Garno, Y.S., Prayogo, T. Dewa, R.P. Widodo, L. Riyadi, A. Susanto, J.P. and Tresnadi, H. 2025. Impact of Anthropogenic Activities on Water Quality, Pollutant Diffusion in Lake Waters, and the Level of Eutrophication: the Case of Batur Lake, Indonesia. *Polish Journal of Environmental Studies*. (10): 1-15.

Grill, G., Lehner, B. Thieme, M. Geenen, B. Tickner, D. Antonelli, F. and Zarfl, C. 2019. Mapping the world's free-flowing rivers. *King Research Portal.* 569(7755): 215-221

Hammer, Ø. and Harper, D. A. 2001. Past: paleontological statistics software package for educaton and data anlysis. *Palaeontologia electronica.* 4(1): 1.

Heino, J., Virkkala, R. and Toivonen, H. 2009. Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions. *Biological Reviews.* 84(1): 39-54.

Holmlund, C. M. and Hammer, M. 1999. Ecosystem services generated by fish populations. *Ecological economics.* 29(2): 253-268.

Hossain, M. A., Akter, M. and Iqbal, M.M. 2017. Diversity of fish fauna in kusiara river (fenchungonjupazilla), northeast Bangladesh. *Journal of Aquaculture in the Tropics 32*(1): 1-13 International. 32(6): 831-849.

Jackson, J. B., Kirby, M.X. Berger, W.H. Bjorndal, K.A. Botsford, L.W. Bourque, B.J. and Warner, R.R 2001. Historical overfishing and the recent collapse of coastal ecosystems. *Science.* 293(5530): 629-637.

Jayaram, K.C. 2010. The Freshwater Fishes of the Indian Region. 2nd Edition, Narendra Publishing House, Delhi616 p.

Jhingran, V. G. 1991. *Fish and Fisheries of India*. Hindustan Publishing Corporation.

Kalff, J. 2002. Limnology: inland water ecosystems. New Jersey: Prentice Hall 592.

Kannel, P.R., Lee, S. Kanel, S.R. Khan, S.P. and Lee, Y.S. 2007. Spatial temporal variation and comparative assessment of water qualities of urban river system: a case study of the river Bagmati (Nepal), *Environmental Monitoring.* 129: 433-459.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. *Fisheries.* 6(6): 21-27

Karr, J.R. 1991. Biological integrity: a longneglected aspect of water resource management. *Ecological Applications.* 1(1): 66-84.

Kelkar, N. and Arthur, R. I. 2022. A Review of Governance and Tenure in Inland Capture Fisheries and Aquaculture Systems of India, *FAO Fisheries and Aquaculture Circular,* 2022.

Kumar, A. and Dua, A. 2009. Water Quality Index for Assessment of Water Quality of River Ravi at Madhopur (India), *Global Journal of Environmental Sciences.* (8):1, 2009: 49–57.

Kumar, J., Pandey, A.K. Dwivedi, A.C. Naik, A.K. Mahesh, V. and Benakappa, S. 2013. Ichthyofaunal diversity of district Faizabad (Uttar Pradesh), India. *Journal of Experimental Zoology.* 16(1): 149-154.

Kumar, P., Khar, S., Dwivedi, S. and Sharma, S.K. 2015. An overview of fisheries and aquaculture in India. *Agro-Economist.* 2(2): 1-6.

Kumari, V. and Chaurasia, G.L. 2015. Study of water quality status of Sai River in Uttar-Pradesh with Reference to Water Quality Index assessment.

Internat.Journal of Innovative Research in Science, Engineering and Technology. 4(1): 18614-18623.

Lakra, W.S., Sarkar, U.K. Kumar, R.S. Pandey, A. Dubey, V.K. and Gusain, O.P. 2010. Fish diversity, habitat ecology and their conservation and management issues of a tropical River in Ganga basin, India. *The Environmentalist.* 30(4): 306-319.

Li, Y., Yan, C. Ju, P. Liu, B. Wang, J. Zhang, C. and Wang, Y. 2025. How the fish community structure change with seasons in Zhoushan Fishing Ground, China? *Frontiers in Marine Science.* 11: 1511121.

Maddheshiya, S.K., Jha, M. Tignath, S. and Singh, N. 2023. Hydrogeomorphic and Spatio-Temporal analysis of riverine wetlands in the interfluvial zone of Ganga and Sai rivers, Uttar pradesh, India. *Wetlands.* 43(1): 9.

Maddheshiya, S.K., Jha, M. Tignath, S. and Singh, N. 2024. Study of riverine wetlands of Bakulahi River in the interfluvial zone of Ganga and Sai Rivers, Uttar Pradesh, India. *Environmental Earth Sciences.* 83(8): 242.

Magurran, A.E. 2013. *Measuring biological diversity*. John Wiley and Sons. Blackwell Science Ltd, a Blackwell Publishing Company.

Mahajan, D., Thakur, K. Kumari, H. and Kumar, R. 2024. A comprehensive study of assessing water quality and phytoplankton communities in the river Ravi (India). *Transylvanian Review of Systematical and Ecological Research.* 26(2):31-56.

Margalef, R.D. 1978. Information theory in ecology. *International Journal of General Systems*. 3 pp36-71.

Metcalfe, J.L. 1989. Biological water quality assessment of running waters based on macroinvertebrate communities: history and present status in Europe. *Environmental Pollution.* 60(1-2):101-139.

Mishra, A., Mukherjee, A. and Tripathi, B.D 2009. Seasonal and temporal variations in physico-chemical and bacteriological characteristics of River Ganga in Varanasi, *International Journal of Environmental Research.* 3(3): 395-402.

Mishra, M., Singhal, A. and Srinivas, R. 2023. Effect of urbanization on the urban lake water quality by using water quality index (WQI). *Materials Today: Proceedings*.

Mishra, S., Bharagava, R.N. More, N. Yadav, A. Zainith, S. Mani, S. and Chowdhary, P. 2018. Heavy metal contamination: an alarming threat to environment and human health. In *Environmental biotechnology: For sustainable future* (pp. 103-125). Singapore: Springer Singapore.

Mittermeier, R. 2005. Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions. *Monitoring and Assessment.* 131: 423-435.

Naiman, R.J., Bilby, R.E. Schindler, D.E. and Helfield, J.E. 2002. Pacific salmon, nutrients, and the dynamics of freshwater and riparian ecosystems. *Ecosystems*. 5(4): 399-417.

Nelson, J.S., Grande, T.C. and Wilson, M.V. 2016. *Fishes of the World*. John Wiley and Sons.

Nimasow, G., Mahato, R. Abujam, S. and Das, D.N. 2025. Spatio-temporal dynamics of fish communities and habitat conditions in the Bichom River Basin. *Environmental Monitoring and Assessment.* 197(5): 1-19.

Niu, M., Lu, F. Zuo, T. Wang, J. Li, Y. Cheng, Z. and Sun, J. 2025. Spatiotemporal distribution of ichthyoplankton and their relationship with environmental factors in the waters around the Yellow River estuary, China. *Frontiers in Marine Science.* 12:1523007.

Pandey, P.C., Srivastava, P.K. and Srivastava, S.K. 2025. Introduction to Aquatic Ecosystems Editorial Message. In *Aquatic Ecosystems Monitoring* (pp. 3-10). CRC Press.

Pauly, D., Christensen, V. Dalsgaard, J. Froese, R. and Torres, Jr.F 1998. Fishing down marine food webs. *Science.* 279(5352): 860-863.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology.* 13pp. 131-144.

Poddar, V.K., Srivastava, A. Kumar, A. Farheen, A. Abbas, K. and Alam, M. 2025. Seasonal variation in Indian river ecosystems influence fish biodiversity and nutritional composition. *Munis Entomology & Zoology.* 20(2): 2962-2981.

Poff, N.L., Richter, B.D. Arthington. A.H. Bunn, S.E. Naiman, R.J. Kendy, E. and Warner, A. 2010. The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. *Freshwater Biology.* 55(1):147-170.

Power, M.E., Tilman, D. Estes, J.A. Menge, B.A. Bond, W.J. Mills, L.S. and Paine, R.T. 1996. Challenges in the quest for keystones: identifying keystone species is difficult but essential to understanding how loss of species will affect ecosystems. *Bio Science.* 46(8): 609-620.

Prakash, S. 2021. Present status of fish diversity of Davipatan Division of Uttar Pradesh, India. *International Journal of Zoological Investigations.* 7(2): 629-636.

Praveen, A., Uttam Kumar, S. Naresh Sahebrao, N. Rahsya Mani, M. Ravindra, K. Abhishek, A. and Brijesh Kumar, P. 2017. Dynamics of reproductive ecology of the fish Ompokbimaculatus (Siluriformes: Siluridae) in six tropical rivers of the Ganges basin, India. *Cuadernos de Investigación UNED.* 9(1):73-85.

Raghavan, R., Dahanukar, N. Tlusty, M.F. Rhyne, A.L. Kumar, K.K. Molur, S. and Rosser, A.M. 2013. Uncovering an obscure trade: threatened freshwater fishes and the aquarium pet markets. *Biological Conservation.* 164:158-169.

Rahel, F.J. and Olden, J.D. 2008. Assessing the effects of climate change on aquatic invasive species. *Conservation Biology.* 22(3): 521-533.

Randall, D.J. and T.K.N. Tsui 2002. "Ammonia Toxicity in Fish." *Marine Pollution Bulletin.* 45 no. 1-12: 17-23.

Rao, N.V., Jawahar, P. Jayakumar, N. Sujathkumar, N.V. Rani, V. Rathod, R. and Mohale, H.P. 2024. An Annotated Checklist of Ichthyofaunal Diversity of the Godavari River, Andhra Pradesh, *India, Pakistan Journal of Zoology.* pp 1-12, 2024.

Reid, A.J. 2019. Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews.* 94(3): 849-873.

Sahu, A., Singh, M. Kumar, S. and Sarkar, U.K. 2024. Assessing ichthyofaunal assemblage structure and diversity of fragile Gomti river ecosystem, Uttar Pradesh, for sustainable conservation and management. *Records of the Zoological Survey of India.* 24(2): 169-181.

Sargaonkar, A. and Deshpande, V. 2003. Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. *Environmental Monitoring and Assessment.* 89(1): 43-67.

Sarkar, U.K. and Lakra, W.S. 2010. Small indigenous freshwater fish species of India: significance, conservation and utilization. *Aquac Asia.* 15(3): 34-35.

Sarkar, U.K., Gupta, B.K. and Lakra, W.S. 2010. Biodiversity, ecohydrology, threat status and conservation priority of the freshwater fishes of river Gomti, a tributary of river Ganga India. *The Environmentalist.* 30(1): 3-17.

Saunders, D.L., Meeuwig, J.J. and Vincent, A.C. 2002. Freshwater protected areas: strategies for conservation. *Conservation Biology.* 16(1):30-41.

Shannon, C.E. and Wiener, W. 1963. The mathematical theory of communication. Urbana: University of Illinois Press.

Sharma, A. and Manhas, N.S. 2025. Environmental Security Complex in the Hindu-Kush Himalayas: A Regional Perspective. *Strategic Analysis*. 1-13.

Sharma, J.G., Singh, S.P. Mittal, P. and Chakrabarti, R. 2014. Impact of temperature gradient on the Indian major carp Catlacatla larvae. Proceedings of the National Academy of Sciences, India Section B: *Biological Sciences*. 86: 269-273.

Sharma, R., Kumar, V. and Tyagi, S.K. 2025. Chemical characterization of textile industry effluents in the northern Ganga basin: a comparative study of Yamuna and non-Yamuna basin discharges. *International Journal of River Basin Management*. 1-13.

Singh, R., Mehra, A. and Kulkarni, V. 2021. *Seasonal dynamics of pH and temperature in Indian freshwater ecosystems*. *Journal of Environmental Sciences.* 39(3): 210-218.

Shukla, R. and Bhat, A. 2017. Environmental drivers of á-diversity patterns in monsoonal tropical stream fish assemblages: a case study from tributaries of Narmada basin, India. *Environmental Biology of Fishes.* 100(7): 749-76.

Simpson, E.H. 1949. Measurement of diversity. Nature. 163(4148), pp.688-688.

Singh, K.P. and Saxena, A. 2025. Seasonal variations and correlation analysis of water quality parameters in the Chambal River, Rajasthan, India. *Water Environment Research.* 97(2): e70035.

Singh, N. and Tung, S. 2025. Assessment of Water Quality of Gomti River at Lucknow. *Air, Soil and Water Research. 18*, p.11786221251328589.

Sreekanth, G.B., Manju Lekshmi, N. Chakraborty, S.K. Jaiswar, A.K. Zacharia, P.U. Vishnuradhan, R. and Pazhayamadom, G. 2016. Effect of monsoon on coastal fish diversity of Goa: an example from the gillnet fishery. *Indian Journal of Fisheries.* 63(2):8-18.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. and Polasky, S. 2002. Agricultural sustainability and intensive production practices. *Nature.* 418(6898): 671-677.

Tremain, D.M. and Adams, D.H. 1995. Seasonal variations in species diversity, abundance, and composition of fish communities in the northern Indian River Lagoon, Florida. *Bulletin of Marine Science.* 57(1):171-192.

Trivedy, R.K. and Goel, P.K. 1984. Chemical and biological methods for water. *Environmental Publications.*

Vass, K.K., Das, M.K., Srivastava, P.K. and Dey, S. 2009. Assessing the impact of climate change on inland fisheries in River Ganga and its plains in India. *Aquatic Ecosystem Health and Management.* 12(2): 138-151.

Venkatesharaju, K., Somashekar, R.K. and Prakash, K.L 2010. Study of seasonal and spatial variation in surface water quality of Cauvery River stretch in Karnataka. *J. Ecol. Nat. Environ*. 2(1): 1-9.

Verma, H.O., Agarwal, A. and Gopal, K. 2015. Fish diversity of Lucknow district (Uttar Pradesh), India. *Journal of Ecophysiology and Occupational Health*. 15(1 and 2): 65–71.

Vishwanath, W. and Linthoingambi, I. 2010. Emerging trends in taxonomy research and evolutionary systematics of fish fauna of North-East India. *Indian Journal of Animal Sciences.* 80(4):16-25.

Vorosmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P. and Davies, P. 2010. Global threats to human water security and river biodiversity. *Nature.* 467(7315):555-561.

Welcomme, R.L., Valbo-Jørgensen, J. and Halls, A.S. 2014. Inland fisheries evolution and management. *Case studies from four continents. FAO fisheries and aquaculture technical paper.* (579).

Wetzel, R.G. and Likens, G.E. 2000. Limnological Analyses, 3rd. Printed by Springer Sciences, Business Media. *INC. New York, USA*.

Williams, B.L., O'Donnell, P.M. Kendall, M.S. Winship, A.J. and Jessen, B. 2023. How are man-made changes in freshwater flow related to the abundance of juvenile estuarine fishes? *Estuaries and Coasts.* 46(6):1632-165.

Winemiller, K.O., McIntyre, P.B., Castello, L., Fluet-Chouinard, E., Giarrizzo, T., Nam, S. and Saenz, L. 2016. Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. *Science.* 351(6269): 128-129.

Winkler, L.W. 1888. Die Bestimmung des im Wasser gelösten Sauerstoffes. *Berichte der deutschen chemischen Gesellschaft*. 21(2):2843-2854.

Wu, J., He, S. and Lu, L. 2025. Multi-scale effects of topography and landscape pattern on riverine nitrogen and phosphorus nutrients in an agricultural watershed. *Landscape Ecology.* 40(6): 112.

WWF, 2018. *Living Planet Report 2018: Aiming Higher*. Worldwide Fund for Nature.

WWF, 2022. *Living Planet Report 2022: Building a Nature-Positive Society*. Worldwide Fund for Nature.

Xenopoulos, M.A., Lodge, D.M. Alcamo, J. Märker, M. Schulze, K. and Van Vuuren, D.P. 2005. Scenarios of freshwater fish extinctions from climate change and water withdrawal. *Global Change Biology.* 11(10): 1557-1564.

Yu, S., Rose, P.M. Bond, N.R. Bunn, S.E. and Kennard, M.J 2022. Identifying priority aquatic refuges to sustain freshwater biodiversity in intermittent streams in eastern Australia. *Aquatic Conservation: Marine and Freshwater Ecosystems.* 32(10): 1584-1595.