Indian J. Fish., 71 (3): 29-37, 2024
doi:10.21077/ijf.2024.71.3.136111-04
Available online at: epubs.icar.org.in/index.php/IJF

Fish community structure in relation to habitat variables in a seasonally open floodplain wetland of the Yamuna River basin of India

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Abstract

The study was carried out in Alwara wetland, a seasonally open floodplain wetland connected to the Yamuna River in the Kaushambi District of Uttar Pradesh, to estimate the fish community structure in relation to habitat variables across three seasons. Altogether, 62 fish species comprising 9 orders, 23 families and 50 genera were recorded, including 5 exotic species. As per IUCN categorisation, 5 species *viz., Wallago attu*, *Ompok bimaculatus*, *O. pabda*, *Chitala chitala* and *Ailia coila* are near threatened and *Clarias magur* is endangered. Cypriniformes (40.32%) were the most dominant order, followed by Siluriformes (22.58%), Perciformes (19.35%), Synbranchiformes (4.84%), Clupeiformes and Mugiliformes (3.23%), Tetraodontiformes and Beloniformes (1.61%). The Shannon-Wiener diversity index (H') ranged from 3.421 (post-monsoon) to 3.877 (monsoon) with an uneven abundance of fishes as indicated by the evenness index (post-monsoon = 0.6951 to monsoon = 0.8186). Water quality parameters were significantly ($p<0.05$) different across the seasons except specific conductivity, silicate-Si, phosphate-P, and dissolved organic matter (DOM). Certain sediment quality parameters differed significantly ($p<0.05$) across the seasons. Canonical correspondence analysis (CCA) was used to study the association of 27 commercially important fish species with 6 important water quality parameters and provided the baseline information on fish community structure. We observed growth and recruitment overfishing, which may affect fish diversity and its sustainable utilisation to support fishers' livelihoods.

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Keywords:
Alwara wetland, Diversity indices, Endangered, Fish community, Overfishing

Received : 08.05.2023
Accepted : 26.06.2024

Introduction

In India, wetlands are distributed across various climatic regions and terrains, which maintain enormous diversity and special habitats. Wetlands are among the most productive and dynamic aquatic habitats, which support livelihoods and nutritional security for the huge populace of the world. These wetlands are regarded as very important parts of the hydrological cycle and provide a wide range of goods and ecosystem services (MoEF, 2010). These water bodies are also being used for irrigating farms, fish culture, domestic and recreational purposes. They have important roles in raising groundwater levels, regulating floods, sequestering carbon and reducing pollution loads (Bassi *et al*., 2014). Ichthyofaunal diversity in open inland ecosystems plays a crucial role in supporting the livelihoods and ensuring nutritional security of the impoverished communities residing nearby. These ecosystems harbour rich ichthyofaunal diversity and are facing ecological degradation due to irrational human interference and unsustainable developments. The Indian subcontinent is endowed with rich piscine diversity, comprising 2,500 fish species, of which 930 belong to freshwaters (Talwar and Jhingran, 1991). The total area of wetlands, locally called "*bheels*" in the state of Uttar Pradesh is 1.54 million ha, which is around 42% of the wetland area in the country (Das *et al.,* 2017). The actual fish yield from the wetlands of the state ranges between

43-357 kg ha^{-1} yr^{-1} with a mean of 160.4 kg ha^{-1} yr^{-1} (Pathak *et al.*, 2004; Kumar and Watal, 2006). Wetlands in India are home to 14.68% of the total national fish fauna (Lakra, 2010). As per the utilisation hierarchy, the fishery has been assigned the least priority among a long chain of stakeholders (Joshi and Kumar, 2009). During the last 150 years, 50% of wetlands around the globe have been degraded (O'Connell, 2003). The Ministry of Environment, Forests and Climate Change (MoEF&CC), Government of India, has identified 115 wetlands that require urgent conservation and management interventions, and the Alwara wetland in Uttar Pradesh is one of them (NWCP, 2009). Pathak *et al.* (2004) estimated the actual and potential fish production of the wetland as 142 and 792 kg ha^{-1} yr^{-1}, respectively. Uneconomical miscellaneous fish species and tertiary consumers feeding at higher trophic levels utilised most of the energy reserves, resulting in a lower average harvest (Kumar and Watal, 2006). Humans are stressing aquatic organisms by deteriorating water quality (Das *et al.* 2014; 2020; 2022a,b). The ecology and productivity of the floodplain wetlands in India have been studied by various workers (Pathak *et al.*, 1985; Jha, 1989; Pathak 1989, 1990; Sugunan, 1995, 1997; Jha, 1997; Pathak *et al.*, 2002, 2004; Kumar and Joshi, 2008; Joshi and Kumar, 2009; Bhattacharjya *et al.*, 2015; Alam *et al.*, 2017; Das *et al.*,2017). A comprehensive study on fish community structure and the conservation status needs to be assessed for undertaking fisheries management in wetlands. In this backdrop, during the present study, importance was given to assessing seasonal fish community structure, diversity indices and high-value fish species assemblage patterns in association with selected important water quality parameters and their conservation status. The study therefore provides baseline information for the conservation and management of fish from the wetland.

Materials and methods

Description of study area

Alwara is a seasonally open floodplain wetland located near Paurkashi-Rampur Village in Kaushambi District of Uttar Pradesh, that is connected to the river Yamuna during the monsoon. It is located at latitude 25°24'05" S-25°25'10"N and longitude 81011'39"E- 81012'57"W and has a water spread area of nearly 1250 ha. Fish, sediment and water samples were collected from eight sites (Table 1) of the wetland across three seasons *i.e.*, pre-monsoon (February to May), monsoon (June to September) and post-monsoon (October to January) during 2014-2015 (Fig. 1).

Table 1. Location of the different sites along with average depth in Alwara wetland

Site	Location	Average depth (m)
Site 1	25°24'45.76"N; 81°11' 36.42"E	0.65
Site 2	25°24'59.43"N; 81°11' 16.95"E	0.75
Site 3	25°24'53.85"N; 81°12' 53.48"E	0.8
Site 4	25°24'32.61"N; 81°12' 02.44"E	1.2
Site 5	25°24'37.36"N; 81°12' 41.68"E	1.3
Site 6	25°24'10.58" N; 81°11' 41.74"E	1.11
Site 7	25°24'13.93" N; 81°12' 24.37"E	0.75
Site 8	25°24'15.62" N; 81°13' 03.28"E	0.8

Sampling of sediment and water for physico-chemical variables

Sediment and water samples were collected from eight sites in the wetland across the three seasons. Physico-chemical parameters *viz*. Dissolved oxygen (DO), Total alkalinity (TA), Chloride, Total hardness (TH), Silicate-Si, Phosphate-P and Dissolved organic matter (DOM), were analysed according to the APHA (2005). The transparency of the water was assessed using a Secchi disc having 20 cm diameter. Air temperature (AT), water temperature (WT), pH, Specific conductivity (Spc) and total dissolved solids (TDS) were analysed using a portable water quality probe (EUTECH Cyber scan series 600, Singapore). Other soil and water quality parameters were analysed in the laboratory following standard procedures, preferably within 24 h after collection of the labelled samples kept in ice box or refrigerated.

Fish diversity

Information on piscine diversity and composition was collected through experimental fishing conducted at eight locations across three seasons employing cast nets (1.5 m dia and 2.0 × 2.0 mm mesh size), gill nets (10-40 mm mesh size) and drag nets. Details of fish caught by local fishers using traditional gear such as hook and line as well as multiple pronged spears were also collected during samplings. Fish specimens sampled were identified up to the species level in the field. Unidentified specimens were preserved in 10% formaldehyde, brought to the laboratory and identified with the help of standard manuals/keys (Talwar and Jhingran, 1991; Jayram, 2006). The latest scientific names of all the fish species were checked following the online version of Eschmeyer's catalogue of fishes, California Academy of Sciences.

Data analysis

The Paleontological STatistics (PAST) software, version 2.6 (Hammer *et al.*, 2001), was used to assess diversity indicators such as species richness, Shannon-Wiener diversity index (Shannon and Wiener, 1964) and evenness index (Pielou, 1966). A dominance curve following Lambshead *et al.* (1983) was used to compare dominance across seasons using the R add-on package "Vegan". Basic descriptive statistics of observed data were calculated using Excel 2013. The ANOVA (Analysis of Variance) was used to find the seasonal variation of water and sediment quality parameters. Interactions and relationships between habitat variables and fish species abundance were studied using Canonical Correspondence Analysis (CCA). Since different water quality parameters have different units of measurement, all ecological data were standardised to make it unit-free to normalise the data for CCA analysis. The statistical analyses were performed using SAS, R and XLSTAT (trial version) softwares. Based on higher correlations, six water quality parameters out of fourteen, *viz.* Depth (dep), Water temperature (WT), DO, pH, Spc and TA and 27 commercially important fish species out of 62 species, were used for the CCA analysis to find the influence of ecological parameters on the abundance of fish species in the wetland.

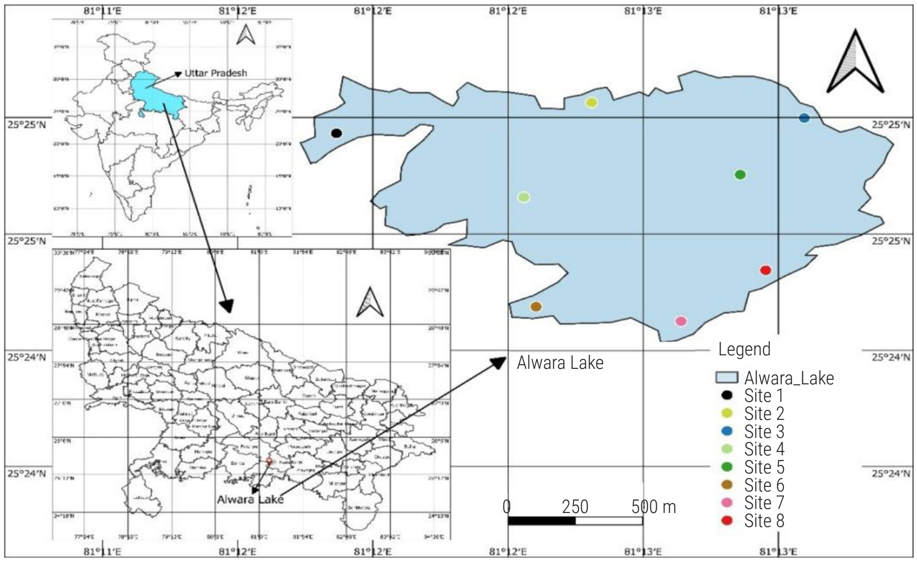

Fig. 1. Sampling sites in Alwara Wetland, Uttar Pradesh, India

Results and discussion

Physico-chemical factors

The mean seasonal values and standard errors (SE) of important sediment and water quality variables of the wetland are shown in Table 2. The wetland has an alkaline pH (7.5-8.0) with DO content in the range 6.3 to 10.4 mg l^{-1}. The mean seasonal value of physico-chemical parameters such as TA, TH, Spc, TDS and chloride were in the range of, 200.5-212.00 mg l^{-1}, 170.00-184.00 mg l^{-1}, 656.00-764.9.0 µsiemen cm^{-1}, 374.20-434.70 mg l^{-1} and 51.20-97.98 mg l^{-1} respectively. Organic carbon (1.72-4.64%), available nitrogen (53.2-41.4 mgN l00g-^{1}) and available phosphorous (3.0-4.1 mgP l00g^{-1}) were at moderate levels in the soil. ANOVA showed that the selected water quality parameters of the wetland were significantly ($p<0.05$) different across the seasons, except Spc, silicate-si, phosphate -p and DOM. Similarly, some sediment quality parameters (*viz.,* available nitrogen, available phosphorus, organic carbon, free calcium carbonate and Spc) were significantly ($p<0.05$) different across the seasons. In any water body, quality is controlled by its biological, chemical and physical factors, which interact with one another, to influence its productivity (Keke *et al.*, 2015). Water with a total alkalinity of more than 90 mg l^{-1}, favourable oxygen content (>5 mg l^{-1}), specific conductance above 200 µ siemen cm^{-1}, TDS and total hardness above 100 mg l^{-1} are considered to be productive in nature (Moyle, 1949; Northcote and Larkin, 1956). In the present study, the values of most of the water quality parameters were conducive to fish production (Boyd, 1982).

Fish diversity and community structure

There was a total of 62 fish species comprising, 9 orders, 23 families and 50 genera recorded from the wetland of which 27 species sustained fishery of commercial importance because of their high-value. The details of fish diversity are presented in (Table 3). The Order Cypriniformes (40.32%) was the most dominant order, followed by the Siluriformes (22.58%), Perciformes (19.35%), Synbranchiformes (4.84%), Clupeiformes and Mugiliformes (3.23%) and Tetraodontiformes and Beloniformes (1.61%) each. Cyprinidae was the most dominant family, represented by 24 species belonging to 17 genera (Fig. 2). During the present investigation, a total of 2206 fish individuals were caught and the highest number of individuals were observed in the monsoon months (1123) followed by pre-monsoon (616), and post-monsoon (467). The values of the Shannon-Wiener diversity index (H') was highest (3.898) during monsoon as compared to pre-monsoon (H': 3.719) and post-monsoon (H': 3.452). It might be due to the ingress of primarily riverine fish species (*e.g., Rhinomugil corsula*) from the feeding river Yamuna, as reported by Das *et al.* (2017). It may also be due to the aggregation of fish in small areas of the wetland during pre-monsoon caused by evaporation/percolation. Similar observations

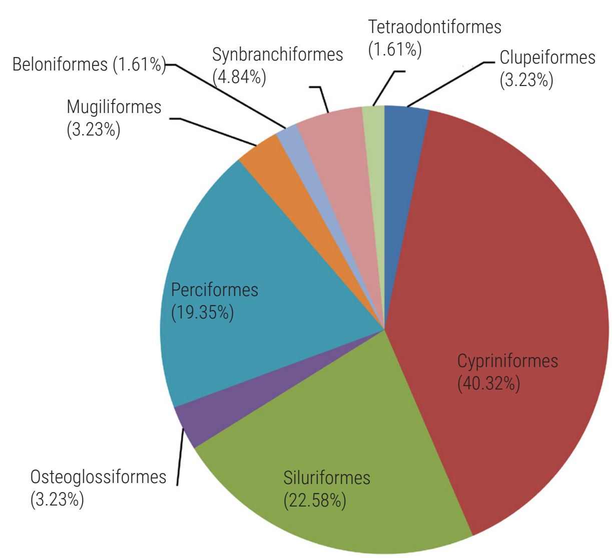

Fig. 2. Percentage strength of fish Orders in Alwara Wetland

Table. 2. Seasonal water and sediment quality of Alwara wetland (mean±SE)

Parameters	Premonsoon (Feb-May)	Monsoon (June-Sept)	Post monsoon (Oct-Jan)	p value
Depth (m)	0.733^b	1.203^a	0.85^b	0.0337
Air temperature (°c)	30.5±0.59^b	39.5±1.07^a	29.0±0.88^b	0.0002
Water temperature (°c)	25.5±0.26^b	35.5±0.55^a	26.0±0.35^b	0.001
Transparency (cm)	73.0±2.08^b	35.0±1.73^a	73.0±2.52^b	0.0013
Dissolved oxygen (mg l^{-1})	9.68±0.12^a	6.3±0.09^b	10.4±0.23^c	0.0001
pH	8.0±0.06^b	7.5±0.06^b	8.0±0.10^a	0.0033
Free carbon dioxide (mg l^{-1})	ND*	80.0± 1.15	ND*	ND*
Total alkalinity (mg l^{-1})	200.5±1.15^b	212.0±3.21^b	210.0±2.37^a	0.0048
Chloride (mg l^{-1})	97.98±0.57^a	51.2±0.17^b	92.3±1.27^c	0.0001
Total hardness (mg l^{-1})	170±4.50	178.0±3.51	184.0±4.98	0.1566
Total dissolved solids (mg l^{-1})	374.8±2.90^b	434.7±2.60^a	374.2 ±3.02^b	0.001
Sp. Conductivity (µsiemen cm^{-1})	656.8±6.03^a	764.9±2.74^b	656.0 ±4.73^b	0.0003
Phosphate (mg l^{-1})	0.05±0.01	0.05±0.01	0.03±0.06	0.1262
Silicate (mg l^{-1})	0.5±0.10	0.5±0.06	0.7±0.12	0.6373
Dissolved organic matter (mg l^{-1})	5.78±0.06	6.3±0.09	5.85.0±0.06	0.1509
Sediment quality				
Soil texture (%)				
Sand	54.33±1.15	57.0±1.20	52.67±1.20	0.1886
Silt	33.7±0.57	31.0±1.00	34.33±0.88	0.2929
Clay	12.0±1.0	12.0±0.33	13.0±0.577	0.33
pH	6.7±0.058	6.73±0.10	6.57±0.06	0.1383
Av. Nitrogen (mg N per 100 g)	53.2±0.52^b	53.4±0.56^b	41.4±0.51^a	0.0071
Av. Phosphate (mg P per 100 g)	4.1±0.058	3.20±0.03	3.0±0.12	0.0037
Organic carbon (%)	1.77±0.06^b	4.64±0.05^a	1.72±0.06^b	0.0001
Free Calcium carbonate (%)	5.75±0.14^b	5.75±0.01^b	7.0±0.10^a	0.043
Sp. Conductivity (µsiemen cm^{-1})	593.0±1.45^a	667.3±2.51^b	667.3±2.67^b	0.0158

*ND: Not detectable; Mean seasonal values with same superscript do not differ significantly

were noticed in a wetland in Cooch Behar District, West Bengal, India (Das, 2018). The evenness index at three seasons (pre-monsoon = 0.792, monsoon = 0.8186, post-monsoon = 0.6951) indicates uneven abundances of different fishes in this wetland. Fig. 3 depicts the dominance curve estimated from the ichthyofaunal species abundance from the wetland. Each curve is produced using the average abundance from the three sampling seasons. There is minimal to no overlap in species structure between samples obtained over three seasons. The pre-monsoon curve was higher than the monsoon and post-monsoon seasons, which clearly shows that samples obtained during the post-monsoon season is the most diverse, followed by the monsoon and pre-monsoon seasons. A total of five exotic species namely-*Oreochromis niloticus, Cyprinus carpio, Clarias gariepinus, Hypophthalmichthys molitrix* and *H. nobilis* were recorded from the wetland. As per the IUCN Red data book and Fishbase, among the 62 fish species recorded from the wetland, five species *viz., Wallago attu, Ompok bimaculatus, O. pabda, Chitala chitala* and *Ailia coila* are near threatened (NT) which account for a combined contribution of 8.06%. Of total number of fish species in the wetland. One species *i.e., Clarias magur* is endangered, contributing 1.61%. The rest of the species are either not evaluated (NE), data deficient (DD) or least concerns (LC) contributing 90.33%. All 62 species of fish observed in the wetland were also reported from the river Yamuna and reflected the fish diversity of the feeding river (Joshi *et al*., 2016).

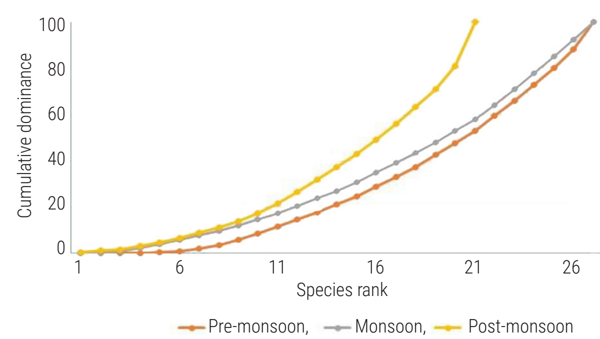

Fig 3. Cumulative dominance curve of fish species abundance in three seasons

Wetlands are home to wild germplasm of a number of flora and fauna, including fishes. It also acts as a nursery for the larvae, fry and young fishes of the major carps that provide them with food and shelter. The shallowness and the submerged vegetation in the wetlands provide a conducive environment for successful spawning. The rheophilic species *viz. A. coila*, *Johnius coitor, Pachypterus atherinoides*, *Nandus nandus, Rhinomugil corsula, Minimugil cascasia, Gagata cenia* and *Gogangra viridescens* were documented during the monsoon season and it indicates the importance of the wetland in terms of habitat heterogeneity and fish biodiversity. The nursery and the breeding grounds of the

Table 3. Fish diversity of Alwara Wetland

Sl no.	Family	Scientific name	Common/Local name	Habitat	Abbreviation	IUCN Status
Order: Beloniformes						
1	Belonidae	*Xenentodon cancila* (Hamilton, 1822)	Kauwa/Freshwater garfish	R + W	XeCA	LC
Order: Clupeiformes						
2	Clupidae	*Gudusia chapra* (Hamilton, 1822)	Khaira/ Indian river shad	R+ W	GuCh*	LC
3		*Gonialosa manmina* (Hamilton, 1822)	Suhiya/ Ganges river gizzard shad	R+ W	GoMa	LC
Order: Cypriniformes						
4	Cyprinidae	*Labeo catla* (Hamilton, 1822)	Bhakur/Catla	R+ W	GiCa*	LC
5		*Cyprinus carpio* Linnaeus, 1758	China rohu/Common carp	R+ W	CyCa*	EX/VU
6		*Cirrhinus mrigala* (Hamilton, 1822)	Nain/Mrigal	R+ W	CiMr*	LC
7		*Cirrhinus reba* (Hamilton, 1822)	Raiya/Reba carp	R+ W	CirRe*	LC
8		*Osteobrama cotio* (Hamilton, 1822)	Gurdha/Chela	R+ W	OsCo	LC
9		*Labeo rohita* (Hamilton, 1822)	Rohu/Roho labeo	R+ W	LaRo*	LC
10		*Labeo calbasu* (Hamilton, 1822)	Karouch/Orangefin labeo	R+ W	LaCA*	LC
11		*Labeo gonius* (Hamilton, 1822)	Bhagna/Kuria labeo	R+ W	LaGo*	LC
12		*Labeo bata* (Hamilton, 1822)	Bata	R+ W	LaBa*	LC
13		*Hypophthalmichthys molitrix* (Valenciennes, 1844)	Silver carp	R+ W	HyMo*	EX/NT
14		*H. nobilis* (Richardson, 1845)	Bighead	R+ W	HyNo*	EX/DD
15		*Puntius sophore* (Hamilton, 1822)	Puthiya/Pool barb	R+ W	PuSo	LC
16		*Pethia conchonius* (Hamilton, 1822)	Puthiya/Rosy barb	R+ W	PeCo	LC
17		*Pethia ticto* (Hamilton, 1822)	Puthiya/Ticto barb	R+ W	PeTi	LC
18		*Systomus sarana* (Hamilton, 1822)	Olive barb	R+ W	SySa*	LC
19		*Salmophasia bacaila* (Hamilton, 1822)	Chelwa/Large razorbelly minnow	R+ W	SaBa	LC
20		*Salmophasia phulo* (Hamilton, 1822)	Chelwa/Finescale razorbelly minnow	R+ W	SaPh	LC
21		*Amblypharyngodon mola* (Hamilton, 1822)	Dhawai/Mola carplet	R+ W	AmMo	LC
22		*Cabdio morar* (Hamilton, 1822)	PirkiChelwa/Morari	R+ W	CaMo	LC
23		*Rasbora daniconius* (Hamilton, 1822)	Chelwa/Slender rasbora	R+ W	RaDa	LC
24		*Chela cachius* (Hamilton, 1822)	Chelwa/Silver hatchet chela	R+ W	ChCa	LC
25		*Barilius barila* (Hamilton, 1822)	Chelwa/Chedra	R+ W	BaBa	LC
26		*Securicula gora* (Hamilton, 1822)	Chelwa/Gora chela	R+ W	SeGo	LC
27		*Esomus danrica* (Hamilton, 1822)	Chelwa/Flying barb	R+ W	EsDa	LC
28	Nemacheilidae	*Paracanthocobitis botia* (Hamilton, 1822	Mottled loach	R+ W	AcBo	LC
Order: Mugiliformes						
29	Mugilidae	*Rhinomugil corsula* (Hamilton, 1822)	Edwar/Corsula	R+ W	RhCo	LC
30		*Minimugil cascasia* (Hamilton, 1822)	Banna/Yellowtail mullet	R+ W	SiCa	LC
Order: Osteoglossiformes						
31	Notoptiridae	*Notopterus notopterus* (Pallas, 1769)	Moy/Bronze featherback	R+ W	NoNo*	LC
32		*Chitala chitala* (Hamilton, 1822)	Chiwetland/Clown knifefish	R+ W	ChCh*	NT
Order: Perciformes						
33	Ambassidae	*Chanda nama* Hamilton, 1822	Chanda/Elongate glass-perchlet	R + W	ChNa	LC
34		*Parambassisr anga* (Hamilton, 1822)	Chanda/Indian glassy fish	R + W	PaRa	LC
35	Sciaenidae	*Johnius coitor* (Hamilton, 1822)	Pattarchatti/Coitorcroaker	R + W	JoCo	LC
36	Nandidae	*Nandus nandus* (Hamilton, 1822)		R + W	NaNa	LC
37	Cichlidae	*Oreochromis niloticus* (Linnaeus, 1758)	Tilapia/Nile tilapia	R + W	OrNi*	EX/NV
38	Anabantidae	*Anabas testudineus* (Bloch, 1792)	Kawai/Koi/Climbing perch	R + W	AnTe*	DD
39	Osphronemidae	*Trichogaster fasciata* Bloch and Schneider, 1801	Banded gourami	R + W	TrFa	LC
40		*T. lalius* (Hamilton, 1822)	Dwarf gourami	R+ W	TrLa	LC
41	Channidae	*Channa marulius* (Hamilton, 1822)	Saur/Great snakehead	R+ W	ChMa*	LC
42		*C. striata* (Bloch, 1793)	Saura/Striped snakehead	R+ W	ChSt*	LC
43		*C. punctata* (Bloch, 1793)	Saura/Spotted snakehead	R+ W	ChPu*	LC
44	Gobidae	*Glossogobius giuris* (Hamilton, 1822)	Gulla/Tank goby	R+ W	GlGi	LC

Contd..............................

Order: Siluriformes						
45	Sisoridae	*Gogangra viridescens* (Hamilton, 1822)	Tinkatiya/Huddah nangra	R+ W	GoVi	LC
46		*Gagata cenia* (Hamilton, 1822)	Tinkatiya/Indian gagata	R+ W	GaCe	LC
47	Siluridae	*Wallago attu* (Bloch and Schneider, 1801)	Padhin/Wallago	R+ W	WaAt*	NT
48		*Ompok bimaculatus* (Bloch, 1794)	Pabda/Butter catfish	R+ W	OmBi*	NT
49		*O. pabda* (Hamilton, 1822)	Pabda/Pabdah catfish	R+ W	OmPa	NT
50	Bagridae	*Sperata aor* (Hamilton, 1822)	Tengan/Long-whiskered catfish	R+ W	SpAo*	LC
51		*S. seenghala* (Sykes, 1839)	Tengan/Giant river-catfish	R+ W	SpSe*	LC
52		*Mystus cavasius* (Hamilton, 1822)	Tengra/Gangetic mystus	R+ W	MyCa	LC
53		*M. tengara* (Hamilton, 1822)	Tengra/Tengara catfish	R+ W	MyTe	LC
54	Claridae	*Clarias magur* (Hamilton, 1822)	Magur	R+ W	ClMa*	EN
55		*C. gariepinus* (Burchell, 1822)	Mongra/North African catfish	R+ W	ClGa	EX
56	Heteropneustidae	*Heteropneustes fossilis* (Bloch, 1794)	Singhi/Stinging catfish	R+ W	HeFo*	LC
57	Schilbeidae	*Ailia coila* (Hamilton, 1822)	Suthi/Gangetic ailia	R+ W	AiCo	NT
58		*Pachypterus atherinoides*(Bloch, 1794)	Misraila/Indian potasi	R+ W	PaAt	LC
Order: Synbranchiformes						
59	Mastacembelidae	*Mastacembelus armatus* (Lacepede, 1800)	Baam/Zig-zag eel	R+ W	MaAr*	LC
60		*Macrognathus pancalus* Hamilton, 1822	Banchulla/Barred spiny eel	R+ W	MaPa*	LC
61	Synbranchidae	*Monopterus cuchia* (Hamilton, 1822)	Bamach/Cuchia	R+ W	MoCu	LC
Order: Tetradontiformis						
62	Tetradontidae	*Leiodon cutcutia* (Hamilton, 1822)	Petfuliya/Ocellated puffer fish	R+ W	LeCu	NE

Habitat: R: river; W: wetland; * Fish species taken for CCA analysis

commercially important fishes need to be identified and protected to avoid overfishing of the commercially important major carp brooders and their juveniles. A few exotic fishes like *H. molitrix* and *H. nobilis* have been deliberately stocked in the wetland for enhancement of their fish yield. Exotic fish species (*C. gariepinus*, *C. carpio* and *O. niloticus*) occurring in river Yamuna also apparently found their way into wetland through the flood waters of the river (Joshi *et al.*, 2016). *O. niloticus* and *C. carpio* compete with the valuable and the commercially important major carps (*L. rohita*, *G. catla*, *L. calbasu* and *C. mrigala*) for both food and space (Alam *et al.*, 2015). Their invasion and successful establishment can have a deleterious effect on the native population (Joshi *et al.*, 2014; Alam *et al.*, 2015; Das *et al.*, 2019; Das *et al.*, 2020) resulting in the contamination of the endemic gene pool, hybridisation, inception of a new disease and decline of biodiversity (Peeler *et al.*, 2011; Alam *et al.*, 2015; Hata *et al.*, 2019).

Influence of habitat parameters on the structure of fish community

The influence of the physic-chemical parameters on fish community structure is shown in CCA biplot (Fig. 4). The output of the CCA shows that the constrained CCA has 90.23% of inertia of constrained CCA explaining 90.23% of variability present in the data while 9.77% variability is unexplained. So it indicates that the CCA is informative in capturing the variability with selected variables under study. Further, eigen values showed that the first two CCA

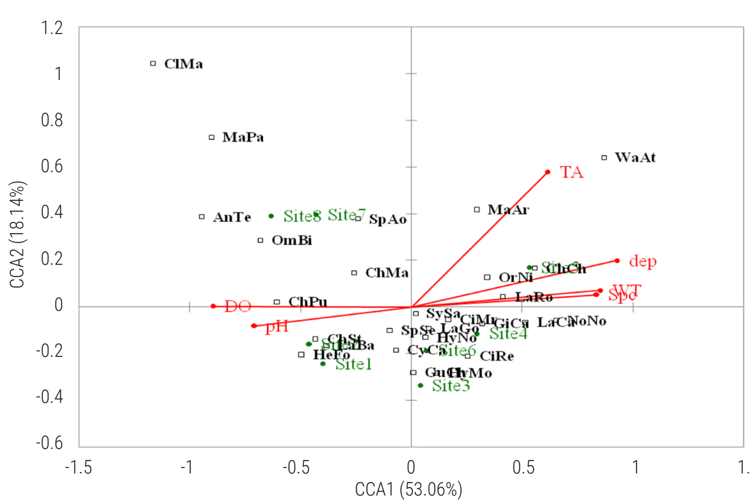

Fig. 4. Relationship between water quality, fish species and sites of the wetland

axis explained more than 71% of the variability present in the data. The CCA1 axis explains 53.06% of the variability, while the CCA2 axis explains 18.137% of the variability. Therefore, for fish species showing species abundance, water parameters, and sites, the horizontal axis is more important than the vertical axis. The CCA clearly showed a significant correlation between the fish species abundance and habitat parameters. The water quality parameters like TA, dep, WT and Spc had more impact on the abundance of fish species like *L. rohita, C. chitala, O. niloticus* and *W. attu* .Site 5 was more suitable for these species, while DO and pH were negatively associated or had less impact on these species. The results of the CCA showed that the physico-chemical characteristics had a major impact on fish species abundance. Similar kinds of results were also observed in the reservoir ecosystem (Alam *et al.,* 2024). Fishes like *Channa marulius, C. punctata, O. bimaculatus, Anabas testudineus, Macrognathus pancalus* and *C. magur* were abundant at Sites 7 and 8 and were more influenced by DO and pH while less influence was exerted by TA, dep, WT, and Spc. Sites 1 and 2 were favourable for species like *Channa striata, H. fossilis, Sperata seenghala* and *C. carpio,.* that were abundant at these sites and were more influenced by DO and pH and less influenced by TA, dep, WT and Spc. Fish Species like *Systomus sarana, H. nobilis, H. molitrix, C. mrigala, L. calbasu, Gudusia chapra, G. catla* and *N. notopterus* were more abundant at sites 3, 4 and 6. Dep, WT and Spc had more positive impacts on the abundance of these species than TA, while DO and pH had a negative impact on abundance. The CCA analysis revealed that sites 3, 4 and 6 are more suitable for rearing highly demanded Indian major carps in pen enclosures with appropriate measures like macrophytes control and bottom raking. The findings from the present study are in agreement with results from Orinoco floodplain lakes, in which fish community structure was linked to some environmental parameters such as depth (Rodríguez and Lewis, 1997).

The wetland was moderately infested with aquatic macrophytes (50-70%). The dominant macrophytes were *Najas, Nymphea* sp., *Vallisneria* sp., *Hydrilla* sp., *Eicchornia crassipes, Nelumbo nucifera* and *Ceratphyllum* sp. (Pathak *et al.,* 2004; Das *et al.,* 2017). These species have a high growth rate and clog waterways, which hinders fishing, boating and other water-related activities. The rich nutrient status of the soil was not reflected in the water phase with large amounts of nutrients being taken up by the growing macrophytes, which remained locked in the bottom deposits following the death of these macrophytes and effectively removed from the water circulation for longer duration (Alam *et al.,* 2017). The current yield of 202.4 $kg^{-1}\ ha^{-1}\ yr^{-1}$ was observed to be higher than the 142 $kg^{-1}\ ha^{-1}\ yr^{-1}$ reported by Pathak *et al.* (2004). The gap between the potential and the present fish yield is almost 590 $kg^{-1}\ ha^{-1}\ yr^{-1}$. This can be achieved by stocking the fingerlings of the major carp species (*L. rohita, L. calbasu, G. catla* and *C. mrigala*). The auto-recruitment of these major carp species could be promoted by a total ban on fishing during the breeding season. The wetland needs to be stocked with grass carp, *Ctenopharyngodon idella* to enhance the fish yield, which can utilise submerged aquatic weeds (*Hydrilla* sp. and *Vallisneria* sp.). The excessive growth of aquatic vegetation in the wetland needs to be controlled to optimise the fish yield through appropriate methods (manual/ mechanical). They hinder the fishing process, reduce phytoplankton growth, worsen the limno-chemical quality of the water by altering the DO and limit the movement of fishes (Pathak *et al.,* 2004). Removal of the macrophytes from the Kulia showed that fish production increased sharply (Pathak, 1990). The large expanse of the shallow areas along the margin, the ecological environment of the wetland and its association with the river, all suggest adoption of the strategies of pen culture in the shallow areas and capture fisheries in deeper areas (Pathak *et al.,* 2004; Alam *et al.,* 2017; Das *et al.,* 2017). Fishing gears used in this wetland were cast nets, gill nets, drag nets, hook and line along with some traditional methods. Multiple pronged spear are prevalent in the wetland during the post-monsoon season only for capture of singhi (*H. fossilis*), which fetches a good price in the market. We also observed that a significant number of brood fishes were invariably killed in the monsoon season and large numbers of juvenile fishes were caught with different gears of smaller mesh sizes (less than 10 mm). Such practices will lead to growth and recruitment overfishing in the wetland, which is a concern for conservation of wild fishes and the sustainability of capture fisheries. In addition to the conservation of indigenous fish diversity from the wetland, the propagation of threatened fish needs to be addressed.

The present study revealed that the wetland harbours a rich fish diversity, which is significantly correlated with seasons. The gap between the potential and the present fish yield is almost 590 $kg^{-1}\ ha^{-1}\ yr^{-1}$. This can be achieved by stocking the fingerlings of the major carp species. Possible management interventions like prevention of indiscriminate fishing to reduce growth and recruitment overfishing, control of aquatic macrophytes, declaration of closed season during spawning seasons of major fishes, development of fishers' cooperative societies, culture-based capture fisheries, pen culture in marginal areas and awareness creation among different stakeholders need to be addressed for sustainable utilisation of rich fish diversity while protecting the livelihood and nutritional security of poor fishers of the wetland.

Acknowledgements

The authors acknowledge the Indian Council of Agricultural Research, New Delhi for financial grants under the Institutional Research Project No**.** REF/NE/12/02/01**.**

References

Alam, A., Joshi, K. D., Das, S. C. S., Jha, D. N., Srivastava, K., Vijay, K. and Bhattacharjya B. K. 2017. Enhancing fish productivity through pen culture: A case study in Sareni wetland of Uttar Pradesh. *Indian J. Fish.,* 64: 8-13. https://doi.org/10.21077/ijf.2017.64.special-issue.76184-02.

Alam, A., Chadha, N. K., Joshi, K. D., Chakraborty, S. K., Sawant, P. B., Kumar, T., Srivastava, K., Das, S. C. S. and Sharma, A. P. 2015. Food and feeding ecology of the non-native Nile Tilapia *Oreochromis niloticus* (Linnaeus, 1758) in the river Yamuna, India. *Proc. Natl. Acad. Sci. India Sect B Biol Sci.*, 85(1): 167-174.

Alam, A., Kumar, J., Sarkar, U. K., Jha, D. N., Sahu, S. K., Das, S. C. S., Srivastava, S.K., Kumar, V. and Das, B. K. 2024. Linking ecological characteristics with fish diversity, assemblage patterns and feeding guilds, and GIS applications along the temporal and spatial gradients in a large subtropical reservoir, India, for sustainable management. *Journal of Water and Climate Change*, 15(2): 607-627.

APHA 2005. *Standard methods for examination of water and wastewater*, 21st edn. American Public Health Association (APHA), American Water Works Association (AWWA) and Water Pollution Control Federation (WPCF), Washington DC, USA.

Bassi, N., Kumar, M. D., Sharma, A. and Saradhi, P. P. 2014. Status of wetlands in India: A review of extent, ecosystem benefits, threats and management strategies. *J. Hydrol. Reg.. Stud.,* 2: 1-19. https://doi.org/10.1016/j.ejrh.2014.07.001.

Bhattacharjya, B. K., Yengkokpam, S., Gogoi, P., Sarma, K. K. and Dipesh, D. 2015. Rearing of carried over carp seed in Pen enclosure in a closed floodplain wetland of Assam, India. *J. Inland Fish. Soc. India,* 47(1): 43-48. https://doi.org/10.47780/jifsi.47.1.2015.110497.

Boyd, C. E. 1982. *Water quality management for pond fish culture*, Elsevier, Amsterdam, The Netherlands, 301 p.

Das, R. K. 2018. Fish diversity and the conservation status of a wetland of Cooch Behar District, West Bengal, India. *J. Threatened Taxa*, 10(3): 11423-11431. https://doi.org/10.11609/jott.3404.10.3.11423-11431.

Das, S. C. S., Joshi, K. D., Alam, A., Jha, D. N., Srivastava, K., Kumar, V. and Mishra, S. S. 2014. Impact assessment of massive anthropogenic activities during Maha-Kumbh-2013 on biotic and abiotic parameters at Allahabad, Uttar Pradesh, India, *J. Kalash Sci.,* 2(2): 1-8.

Das, S. C. S., Alam, A., Jha, D. N., Kumar, V., Srivastava, K. and Bhattacharjya, B. K. 2017. Raising of stocking materials in pen enclosure in a floodplain wetland of Uttar Pradesh. *J. Inland Fish. Soc. India*, 49(1): 15-21.

Das, S. C. S., Joshi, K. D., Chakraborty, S. K., Panda, D. and Jaiswar, A. K. 2019. Length-weight relationship and condition factor of *Cyprinus carpio* Linnaeus, 1758 from the river Ganga at Allahabad. *J. Entomol. Zoo. Stud.,*7(3): 1420-1424.

Das, S. C. S., Khan, A., Alam, A., Dubey, V. K. and Joshi. K. D. 2020. Piscine diversity, community structure and distributional patterns of the west Ramganag River: A mid Himalayan tributary of river Ganga. *Indian J. Anim Sci.,* 90(1): 109-115. https://doi.org/10.56093/ijans.v90i1.98240.

Das, S. C. S., Jha, D. N., Alam, A., Borah, S., Kumar, V., Srivastava, K., Thakur, V. R., Sahoo, A. K. and Das, B. K. 2022a. Assessing assemblage pattern, health status and environmental drivers of macrobenthic invertebrate community structure for sustainable management in a tropical tributary of River Ganga, India. *Sustainable Water Resources Management*, 8(5): 1-11.

Das, S. C. S., Jha, D. N., Kumar, V., Alam, A., Srivastava, K., Sahoo, A. K. and Das, B. K. 2022b. Fish diversity, community structure and environmental variables of river Tamas, a tributary of River Ganga, India. *Aquat. Ecosyst. Health. Manag.,* 25(2): 62-69.

Hammer, O., Harper, D. A. T. and Ryan, P. D. 2001. PAST: Paleontological statistics software package for educaton and data anlysis. *Palaeontologia electronica,* 4(1): 1-9. http://palaeo-electronica.org/2001_1/past/issue1_01.htm.

Hata, H., Uemura, Y., Ouchi, K. and Matsuba, H. 2019. Hybridization between an endangered freshwater fish and an introduced congeneric species and consequent genetic introgression. *PLoS One*, 14(2): e0212452. https://doi.org/10.1371/journal.pone.0212452.

Jayram, K. C. 2006. *The freshwater fishes of the Indian Region*. Narendra Publishing House, New Delhi, India

Jha, B. C. 1989. Beel fishery resource in Bihar and Uttar Pradesh. *CIFRI Bull. No. 63*. ICAR-Central Inland Fisheries Research Institute, Kolkata India.

Jha, B. C. 1997. Salient ecological features of the mauns and chaurs of Bihar and their fisheries. *CIFRI Bull. No. 75,* ICAR-Central Inland Fisheries Research Institute, Kolkata, India, pp 167-174.

Joshi, K. D., Jha, D. N., Alam, A., Das, S. C. S., Srivastava, S.K. and Kumar, V. 2014. Massive invasion of resilient exotic fishes in the river Ganga: A case study at Allahabad stretch. *J. Inland Fish. Soc. India,* 46(1): 92-95.

Joshi, K. D., Alam, A., Jha, D. N., Srivastava, S. K. and Kumar, V. 2016. Fish diversity, composition and invasion of exotic fishes in river Yamuna under altered water quality conditions. *Indian J. Animal Sci.,* 86(8): 957-963. https://doi.org/10.56093/ijans.v86i8.60837.

Joshi, K. D. and Kumar, D. 2009. Status of fishery, its management and scope for enhancement in a terai Wetland of Uttar Pradesh, India. *Asian Fish. Sci.,* 22: 229-234. https://doi.org/10.33997/j.afs.2009.22.1.021.

Keke, U. N., Arimoro, F. O., Ayanwale, A. V. and Aliyu, S. M. 2015. Physicochemical parameters and heavy metals content of surface water in downstream Kaduna River, Zungeru, Niger state, Nigeria. *Appl. Sci. Res. J.,* 3: 46-57.

Kumar, A. and Watal, G. 2006. Flow of chemical energy in Alwar Jheel of Yamuna basin near Allahabad. *J. Environ. Biol.,* 27(3): 545-549.

Kumar, D. and Joshi, K. D. 2008. Status of fishery and its management in certain wetlands of Uttar Pradesh. *J. Inland Fish. Soc. India,* 40(2): 56-60.

Lakra, W. S. 2010. Fish biodiversity of Uttar Pradesh: Issues of livelihood security, threats and conservation. In: *Proceedings of the National conference on biodiversity, development and poverty alleviation* 22 May 2010, Uttar Pradesh State Biodiversity Board, Lucknow, India, pp. 40-45.

Lambshead, P. J. D., Platt, H. M. and Shaw, K. M. 1983.The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. *J. Nat.Hist.,* 17(6): 859-874. https://doi.org/10.1080/00222938300770671.

Moyle, J. B. 1949. Some indices of lake productivity. *Trans. Amer. Fish. Soc*., 76: 323-334.

Northcote, T. G. and Larkin, P. A. 1956. Indices of productivity in Columbia lakes. *J. Fish Res. Bd. Canada,* 13: 515-540. https://doi.org/10.1139/f56-032.

NWCP 2009. National Wetland Conservation Programme.*Guidelines for conservation and management of wetlands in India*. Conservation and survey Division, Ministry of Environment and Forests, Government of India, New Delhi, India, 45 p.

O'Connell, M. J. 2003. Detecting, measuring and reversing changes to wetlands. *Wetlands ecology and management*, 11(6): 397-401. https://doi.org/10.1023/B:WETL.0000007191.77103.53.

Pathak, V. 1989. Limnological features in beels - Abiotic factors. *CIFRI Bulletin No. 63*. ICAR-Central Inland Fisheries Research Institute, Kolkata, India, pp 43-53.

Pathak, V. 1990. A comparative study of energy dynamics of open and closed beels in Ganga and Brahmaputra basins. *J. Inland Fish. Soc. India*, 22(1&2): 26-30.

Pathak, V., Saha, S. B. and Bhagat, M. J. 1985. Pattern of energy utilisation and productivity in beel ecosystem. *J. Hydrobiol*., 1(2): 47-52.

Pathak, V., Singh, B., Mahavar, L. R. and Saroj, B. D. 2002. A comparative study of hydrological status and energy dynamics of *beels* in eastern Uttar Pradesh. *Proc. Nat. Acad. Sci. India*, 72B(1): 47-57.

Pathak, V., Tyagi, R. K. and Singh, B. 2004. Ecological status and production dynamics of wetlands of Uttar Pradesh*. CIFRI Bull.,* 131: 44.

Peeler, E. J., Oidtmann, B. C., Midtlyng, P. J., Miossec, L. and Gozlan, E. R. 2011. Non-native aquatic animals introductions have driven disease emergence in Europe. *Biol. Invasions,* 13: 1291. https://doi.org/10.1007/s10530-010-9890-9.

Pielou, E. C. 1966. Shannon's formula as a measure of specific diversity: Its use and misuse. *The American Naturalist,* 100(914): 463-465. https://doi.org/10.1086/282439.

Rodríguez, M. A. and Lewis, M. L. 1997. Structure of fish assemblages along environmental gradients in floodplain lakes of the Orinoco River. *Ecological Monographs*, 67(1): 109-128. https://doi.org/10.1890/0012-9615(1997)067[0109:SOFAAE]2.0.CO;2.

Shannon, C. E. and Wiener, W. 1964. *The mathematical theory of communities.* The University of Illinois Press, Urbana, USA, 126 p.

Sugunan, V. V. 1995. Floodplain wetlands - A fisheries perspective. *Conservation and sustainable use of floodplain wetlands*. *AWB publication No. 113,* Asian Wetland Bureau, Kualalumpur, Malaysia, pp. 13-15.

Sugunan, V. V. 1997. Floodplain wetlands, small water bodies, culture-based fisheries and enhancement - Conceptual framework and definition. *CIFRI Bull. No. 75*. ICAR-Central Inland Fisheries Research Institute, Kolkata, India, pp. 13-22.

Talwar, P. K. and Jhingran, A. 1991. *Inland fishes of India and adjacent countries*. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, India

MoEF 2010. *Wetlands Rules, Conservation and Management).* Ministry of Environment and Forests, Government of India, New Delhi, India.