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A Study on the Present Status of Fish Population, Abundance, and Anthropogenic Stressors Affecting the Ichthyofaunal Diversity in Deepor Beel, Assam, India

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ABSTRACT: The study examines the fish population and abundance in Deepor Beel, a Ramsar site in Assam, India. A total of 45 fish species were recorded, including 42 native species, 3 exotic species, and 1 each of endangered and vulnerable species. Native species predominantly belonged to the Cypriniformes and Siluriformes orders. The post-monsoon season exhibited higher Shannon diversity and species evenness compared to the monsoon season. *Amblypharyngodon mola* had the highest relative abundance (35.62%), while 10 species showed minimal abundance (0.0009%). Based on catch frequency, 12 species were extremely rare, 5 were rare, and 1 was abundant, with *Puntius terio* being the most abundant. A questionnaire survey revealed significant anthropogenic impacts on the wetland, with 69.51% of respondents reporting a decline in fish abundance. Pollution, invasive species like water hyacinth, and habitat degradation were identified as major threats. The findings underscore the need for urgent restoration and sustainable management to protect biodiversity and ecosystem services of Deepor Beel wetland.
Keywords: Fish diversity, anthropogenic stressors, Deepor Beel, Assam.

INTRODUCTION

Wetlands are among the most productive ecosystems, providing a wide range of environmental services, including provisioning, regulating, cultural, and supporting functions, which offer numerous vital benefits to both humans and wildlife (Gokce, 2019; Sofia and Nurlianti 2019). Assam wetlands are some of the most biologically diverse and productive ecosystems in India, supporting various fish species, including endemic and economically valuable ones (Bassi *et al.*, 2014). Deepor Beel, a Ramsar Wetland, is a perennial freshwater lake and channel of the River Brahmaputra located south of the river in Kamrup District, Assam. The actual extent of Deepor Beel is 4.1 km², with its depth varying seasonally from approximately 6 m to 1.5 m (Pandit, 2016). It supports a diverse population of fish fauna and is the only major stormwater storage basin for Guwahati (Rongpi, 2024). Deepor Beel plays a crucial role in maintaining regional biodiversity. It is home to a wide variety of aquatic species and supports 200 different species of birds, including 70 migratory species (Nikita *et al.*, 2024). Additionally, the wetlands sustain numerous reptiles, amphibians, and plant species, contributing to its reputation as a biodiversity hotspot in Assam (Saikia, 2005).

Bhattacharjya *et al.* (2017) reported that fish landings in the closed wetlands of the Brahmaputra Valley, Assam, were predominantly comprised of Barbs (*Puntius* spp.), Rasboras (*Danio* spp., *Rasbora* spp., and *Devario* spp.), small catfishes (*Mystus* spp.), Murrels (*Channa* spp.), *Notopterus notopterus*, *Wallago attu*, among others. Species requiring flowing waters for spawning, such as major and minor carps (*Cirrhinus* spp., *Labeo* spp.), *Bagarius bagarius*, *Pangasius pangasius*, *Chitala chitala*, *Ompok* spp., and *Aspidoparia* spp., were notably absent in these wetlands. They further reported that, due to the lack of significant recruitment from rivers, these habitats are primarily inhabited by fish species that spawn in stagnant waters, typically small and economically significant fishes. The natural fishery of closed wetlands is dominated (50–90%) by small economic fish species such as *Puntius* spp., *Rasbora* spp., *Trichogaster* spp., *Mystus* spp., and *Notopterus notopterus*. Additionally, macrophyte-choked wetlands exhibited higher abundances of insectivorous and air-breathing fishes, including *Channa* spp., *Anabas testudineus*, *Clarias magur*, *Heteropneustes fossilis*, and *Notopterus notopterus*. According to the RIS (Information Sheet on Ramsar Wetlands) report, updated in August 2002, 50 fish species were found in Deepor Beel. Saikia (2005) reported 61 fish species in Deepor Beel, of which 5 species were exotic, 54 were indigenous, and 8 were endangered. They identified species such as *Cirrhinus reba*, *Ompok bimaculatus*, *Ompok pabda*, *Botia dario*, *Nandus nandus*, *Megarasbora elanga*, *Channa barca*, and *Brachydanio rerio* during their study of Deepor Beel. While a total of 46 species from 17 families *viz.*, Notopteridae, Clupeidae, Anabantidae, Cyprinidae, Cobitidae, Bagridae, Siluridae, Schilbeidae, Clariidae, Heteropneustidae, Synbranchidae, Chandidae,

Gobiidae, Belontiidae, Channidae, Mastacembelidae, and Tetraodontidae, have been recorded in Deepor Beel by another group of researchers (Acharjee *et al.*, 2009). Medhi *et al.* (2019) found the fish diversity in two other wetlands within the Brahmaputra Basin of Assam, documenting 54 fish species across 38 genera, 8 orders, and 21 families in Chatla Beel, and 52 fish species spanning 37 genera, 8 orders, and 21 families in Urmal Beel. The order Cypriniformes was the most dominant in both wetlands, represented by 23 species in Chatla Beel and 22 species in Urmal Beel.

However, during the past few years, numerous studies have highlighted the threats wetlands face globally due to anthropogenic stressors (Nath and Deka 2012; Sultana *et al.*, 2017; Kumar *et al.*, 2018; Butt *et al.*, 2021). Baruah and Goswami (2022) highlighted that the only Ramsar site of Assam, Deepor Beel is struggling to survive due to human interventions, unchecked pollution, and the violation of critical environmental regulations. The severe pollution of this vital water body has caused adversely impacts biodiversity, ecological balance, and threat to the local livelihoods of the communities. Rongpi (2024) reported that rapid urban development is putting the wetland and its ecosystem at risk of shrinking. Additionally, the establishment of the city's garbage disposal center in the Boragaon area has significantly polluted the waters of Deepor Beel and threatening the biodiversity of the wetland. The deterioration and overexploitation of wetlands reduce their ability to support life and provide essential services. The Ramsar Convention was established to combat wetland loss through global cooperation and promote sustainable development. Despite efforts to raise awareness, wetlands continue to face rapid decline due to overexploitation (Daryadel and Talaei 2014). Duarah and Das (2019) reported that fish diversity of the wetlandsare under tremendous threats due to environmental degradation and its associated problems. Unsustainable land-use practices and development activities are placing tremendous pressure on Deepor Beel (Saikia, 2019). Fish production in the wetland is rapidly declining due to siltation, the dumping of solid waste, and the release of hazardous chemicals through inlet channels. These factors have considerably reduced the wetland's carrying capacity, causing many fishermen's families to lose their livelihoods. Bhattacharjya *et al.* (2021) also documented a decline in fish species due to threats faced by Deepor Beel and emphasized possible conservation strategies, such as regulating pollution, preventing/control of siltation, enacting and enforcing appropriate legislation, and other related conservation measures.

Over time, anthropogenic activities have caused the area of the wetland to shrink. Deka *et al.* (2011) on the monitoring of spatial changes in Deepor Beel indicated that the total area of open water bodies diminished by 2.904 sq. km from 1991 to 2010. Mandal *et al.* (2024) reported an increase in built-up areas around Deepor Beel, from 9.07 to 32.19 sq. km between 2008 and 2018, with increasing built-up areas within a 500-meter buffer of the wetland. A study on the estimation of water pixel frequency from 1988 to 2019 revealed that the aerial extent of high, moderate, and low-frequency water presence areas were approximately 4.81, 3.48, and 2.76 km², respectively, from 1988 to 2000. From 2001 to 2018, the rapid expansion of the railway network further reduced the wetland area by about 58%, 33%, and 52% in high, moderate, and low water presence frequency zones, respectively (Das *et al.*, 2024). The Beel is gradually converting from swamp to grassland. Its ability to absorb floodwaters has decreased, resulting in artificial waterlogging throughout the city. The wetland's self-purification capacity is also compromised due to pollution. Moreover, water quality in most areas of Deepor Beel was found to be in poor condition, a critical factor for fish diversity (Roy and Majumder 2022; Das *et al.*, 2024; Sharma *et al.*, 2024). The water quality has deteriorated due to the release of pollutants from several industries and waste disposal sites. Recent studies have revealed significant quantities of heavy and trace metals, which threaten the aquatic flora and fauna diversity, while lower dissolved oxygen levels in the Beel put aquatic life in a hypoxic state (Fatima *et al.*, 2020; Sengupta and Deb 2022).

Bhattacharjya *et al.* (2017) emphasized that the scientific management of floodplain wetlands could significantly enhance fish production. These wetlands, often transitioning to marshlands, provide critical habitats for migratory and resident species, while supporting diverse aquatic flora and fauna, including plankton, macrophytes, benthic organisms, and various macrophyte-associated species. They are also vital for conserving threatened air-breathing and small-sized fish species. Fish act as an indicator species, regulating the distribution and abundance of other organisms within their ecosystems. They also serve as key indicators of water quality and overall ecosystem health (Moyle and Leidy 1992; Nath *et al.*, 2015; Malakar and Boruah 2017; Mamun and An 2022). Studies on relationship of anthropogenic activities and the abundance of fish species can clarify the overall wetland health and its associated ecosystems. However, limited studies exist on the current fish diversity of Deepor Beel and the possible anthropogenic stresses that affect fish abundance. Therefore, the present study aims to investigate the current status of fish populations and abundance in Deepor Beel, along with an exploration of possible anthropogenic stresses that have impacted the fish diversity, utilizing a questionnaire survey based on the perceptions of the 'sons of the soil'.

MATERIALS AND METHODS

Study area. The study was conducted in the Deepor Beel, Assam, India that located in lower Brahmaputra valley zone of Assam. Deepor Beel, is a large natural freshwater wetland situated southwest of Brahmaputra River near Guwahati City and is recognized as a Ramsar site. It extends between 26º03′26″ and 26º09′26″ N to 90º36′39″ 90º41′25″ E. The fish markets selected for fish sampling during the study are located near Deepor Beel. The market survey was carried out directly from local fish markets and from fishermen in

the Deepor Beel fish market and Godhuli Bazar at Azara.

Sampling methods. The fishermen employed various fishing gears, including gill nets (with different mesh sizes), drag nets (fry nets), and hook and line. Sampling at the fish markets in Godhuli Bazar and the Deepor Beel area took place in the morning between 7:00 AM and 9:30 AM from July-November, 2024. Fish samples were identified based on their morphometric and meristic characteristics. Each species was categorized according to its respective IUCN Red List status (2024). The relative abundance of each fish species (% of the catch) was calculated using the method outlined by Sarkar *et al.* (2012), applying the following formula:

$$\text{Relative abundance of a fish species (\% by number)} = \frac{\text{Total number of samples of the particular species} \times 100}{\text{Total number of samples of all species found during the survey}}$$

The frequency of occurrence of each species was calculated based on the number of occasions the species was collected during the samplings. The status was determined with the help of a standard catch frequency chart presented by Tamang *et al.* (2007) (Catch frequency: 91–100 % = Common, 81–90 % = Abundant, 61–80 % = Frequent, 31–59 % = Occasional, 15–30 % = Sporadic, 05–14 % = Rare, Less than 5% = extremely rare).

Shannon-Weinner index and species evenness was calculated by following May, (1993) and used following diversity indices:

Shannon-Weinner Index $H = -\{ni/N \log^2 ni/N\}$

Where N = Total species and ni = Numbers of individual species

The species evenness ratio is the ratio of the observed species diversity (H') to the maximum possible for the same number of species in the sample (log S).

It is expressed as: J'=H'/log S. If J'=1, the biomasses of the individual species are evenly distributed among all of the species in the sample

A questionnaire survey was conducted to analyze the anthropogenic activities that influence the health of fish diversity in Deepor Beel. The sample questions of the questionnaire are furnished in Table 1. Random sampling was conducted and a total of 15 fishermen from each village were surveyed, making a total of 165 fishermen.

Table 1: Questionnaire format used during the survey at Deepor Beel area, Assam.

Date:	**Location:**	**GPS coordinates:**
(I) General details:		
Name of respondent:		Contact number:
Gender (male/female)		
Age (yrs):		
Fishing experience (yrs):		
(II) Anthropogenic climate change perception/belief:		
Do you feel any change in climate over the last 10-20 years: Yes/No/Can't say		
(III) What anthropogenic activities influences fish diversity		
a) Developmental activities: most/moderate/low		
b) Waste dumping site: most/moderate/low		
c) Invasive species: most/moderate/low		
(IV) Anthropogenic influences on fish diversity:		
Abundance change: increase/moderate/decrease		
Taste change: Yes/No/can't say		
(V) Details of fishes found: Indigenous/exotic		
(VI) Livelihood of fishermen: fishing/ others/both		
Any shift in livelihood (from fishery to others or vice versa)? Yes/No		
If yes, reason for shift:		

Statistical analysis. Descriptive statistical analysis was performed with MS-office excel (version 2021).

RESULTS AND DISCUSSION

Fish diversity. In the present study, a total of 107875 fish individuals belonging to 45 species, representing 11 orders (one order is not assigned) and 22 families, were recorded from the Deepor Beel wetland (Table 2, Fig. 1). Photographs of the fish species recorded during the present study are presented in Plate I. Literature surveys revealed that more than 60 fish species were present in the Deepor Beel (Saikia, 2005; Bhattacharjya *et al.*, 2021). Present study included 42 native species and three exotic species (Fig. 2) *viz.*, *Piaractus brachypomus* from the order Characiformes and family Serrasalmidae, and *Cyprinus carpio*, belonging to the order Cypriniformes and family Cyprinidae, and *Oreochromis mossambicus* under the order Cichliformes and family Cichlidae (Table 3). These exotic species are known for their rapid growth and ability to consume a wide variety of foods from various

sources, including sometimes the juveniles of other fish species (Erarto and Getahun 2020). Some fish culturists have introduced these species to achieve quick economic returns. During floods, these species can escape from ponds and enter into Beels and rivers, posing a significant threat to native fish species and natural water bodies. The relative abundance (%) of fish species identified during the survey is detailed in Table 3. Among the fish species, *Amblypharyngodon mola* was found with more relative abundance (35.62%) and 10 fish species were found with lower relative abundances (0.0009%) in the Deepor Beel. Based on Tamang *et al*., (2007) catch frequency status, the survey categorized 12 fish species as extremely rare, 5 as rare, 5 as sporadic, 15 as occasional, 7 as frequent, and 1 as abundant. The study concluded that, although a moderate number of fish species were found, their catch frequency status raises significant concerns. Several species, such as *Mystus cavasius*, *Rita rita*, *Sperata seenghala*, *Pachypterus atherinoides*, *Pangasius pangasius* from the Siluriformes order, *Xenentodon cancila* from the Beloniformes order, *Chitala chitala* from the *Osteoglossiformes* order, *Channa gachua* from the *Anabantiformes* order, *Lepidocephalichthys guntea* from the Cypriniformes order, and *Mastacembelus armatus* from the Synbranchiformes order were observed at lower levels of relative abundance during the study period. However, *Puntius terio* species belonging to the family Cypriniformes were found abundant, and *Mystus tengara, Heteropneustes fossilis* from Siluriformes order, *Gudusia chapra* from Clupeiformes order, *Channa punctata* from Anabantiformes order *Macrognathus pancalus* from Synbranchiformes order *and Notopterus notopterus* from Osteoglossiformes order were found frequent during the study period in Deepor Beel (Table 3). Fishermen reported that species such as the Zig-zag eel, Corsula, Gangetic leaf fish, Flying barb, Mottled loach, Bengal loach, Pabo catfish, Freshwater garfish, and some of the Puntius species have not been found abundantly and have gradually declined in recent years. Malakar and Boruah (2017) reported that the uncontrolled harvesting of brood and juvenile fish, combined with the overexploitation of commercially important local species during the breeding season, is leading to a notable decline in fish diversity in several other wetlands of Assam, including Sol Beel, Etila Beel, and Duani Beel. In the current survey, the fish species *Nandus nandus*, *Leiodon cutcutia*, and *Ompok pabda* were notably absent. This absence could be attributed to a decline in their population or perhaps seasonal fluctuations, as the survey was conducted across only two seasons. Most of the native fish species obtained during the survey belonged to the Cypriniformes and Siluriformes orders (Fig. 1). The contribution of fish species by order and family is detailed in Table 1 and illustrated in Fig. 1. The present study found the Cyprinidae family to be most abundant among the recorded fish families (Table 2), aligning with the findings of Nikita *et al*. (2024) who utilized an eDNA approach to study fish diversity in Deepor Beel. The IUCN Red List status of the fish species recorded in this survey is shown in Fig. 3. Most species were classified as Least Concern (LC), while one species, *Wallago attu* from Siluriformes order was found to be Vulnerable (VU), *Clarias magur* from Siluriformes order was found to be endangered and another species *Chitala chitala* from *Osteoglossiformes* order was found to be Near Threatened (NT).

Table 2: Order and family-wise fish species contribution recorded during the present study from Deepor Beel, Assam, India.

Order	Family	Species	Order wise species contributions
Anabantiformes	Anabantidae	1	7
	Channidae	4	
	Osphronemidae	2	
Beloniformes	Belonidae	1	1
Characiformes	Serrasalmidae	1	1
Clupeiformes	Dorosomatidae	1	1
Cypriniformes	Botiidae	1	18
	Cyprinidae	13	
	Danionidae	3	
	Cobitidae	1	
Osteoglossiformes	Notopteridae	2	2
Siluriformes	Bagridae	4	9
	Heteropneustidae	1	
	Siluridae	1	
	Clariidae	1	
	Schilbeidae	1	
	Pangasiidae	1	
Synbrachiformes	Synbranchidae	1	3
	Mastacembelidae	2	
Cichliformes	Cichlidae	1	1
Gobiiformes	Gobiidae	1	1
Not assigned	Ambassidae	2	2
Total species= 45			

Source: field survey (July-November, 2024)

The study identified one endangered, one vulnerable and one near-threatened fish species, and emphasizes the urgent need for conservation efforts to protect the wetland and its associated faunal diversity. Although most fish species were classified as being of least concern, their low relative abundance raises urgent concerns about the conservation of indigenous fish, which is essential for maintaining the health of the wetland ecosystem. Nayak and Biswas (2020) underscored that ecological restorations of the wetlands are very crucial to conserve the indigenous fishes of Assam. The present study showed Shannon diversity index and species evenness of fish species in monsoon and post-monsoon seasons (Table 4). The post-monsoon season showed higher Shannon diversity and species evenness in comparison to monsoon season during the survey period, which might be due to the favorable environment for their growth and movement that increases the fish diversity in the Deepor Beel. In the post-monsoon season, there may be favorable water conditions that allow fish populations to flourish, attracting both resident and migratory species from Brahmaputra river, which boosts overall fish diversity. In monsoon season, heavy rains bring an influx of nutrients into freshwater bodies like rivers, and lakes. This nutrient enrichment supports the growth of phytoplankton and other primary producers, creating a more productive environment that promotes food availability for fish species (Madhupratap *et al.*, 2001; Sreekanth *et al.*, 2019). In the post-monsoon season, the lower rate of surface runoff and evaporation support higher species diversity (Saha *et al.*, 2021). Monsoon rains causes fluctuations in water levels, which can lead to changes in water parameters, including pH, TDS levels that may be stressful for some fish species or may temporarily reduce the diversity (Sreekanth *et al.*, 2019; Saha *et al.*, 2021).

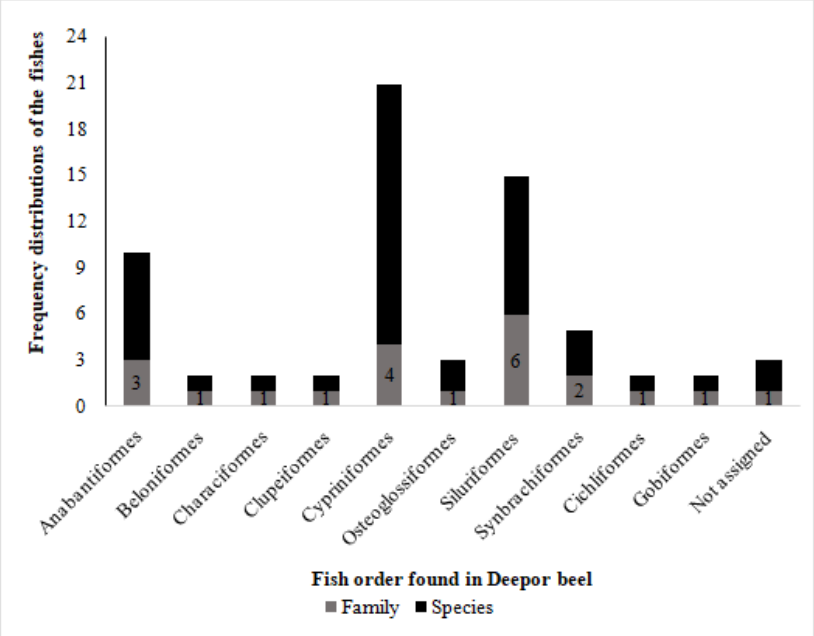

Fig. 1. Order-wise family and species distribution of fish recorded during the study in Deepor Beel, Assam, India.

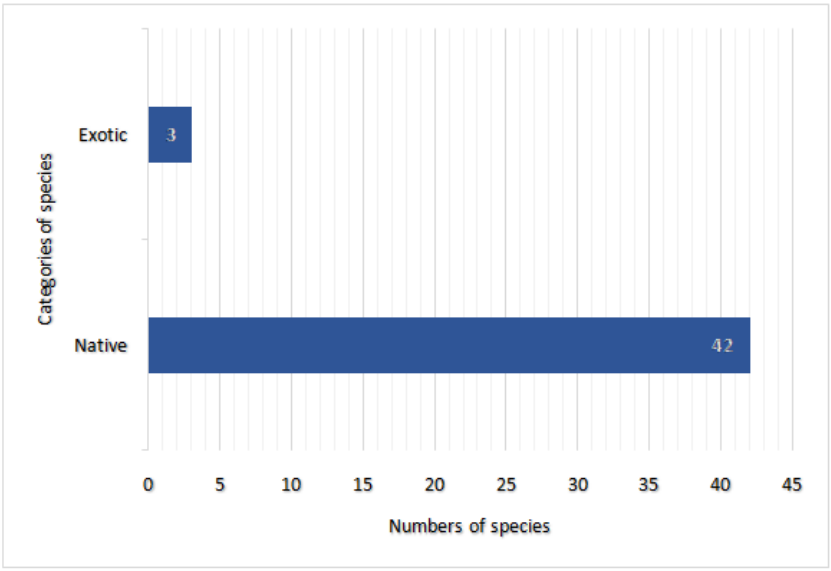

Fig. 2. Graphical representation of categories of fish species found during the survey in Deepor Beel, Assam, India.

Table 3: Details of the fish species recorded during present study in Deepor Beel, Assam, India.

Sr. No.	Species	Order	Family	Common name	Vernacular name	Catching frequency (%)	Status	Relative abundances (%)	IUCN red list status
1	*Anabas cobojius* (Hamilton, 1822)	Anabantiformes	Anabantidae	Gangetic Koi	Kawaoi	50	Occasional	0.246	DD
2	*Channa marulius* (Hamilton, 1822)		Channidae	Great snakehead	Shaal	11.90	Rare	0.007	LC
3	*Channa punctata* (Bloch, 1793)			Spotted snakehead	Goroi	73.81	Frequent	1.283	LC
4	*Channa striata* (Bloch, 1793)			Stripped snakehead	Sol	14.29	Rare	0.011	LC
5	*Channa gachua* (Bloch & Schneider 1801)			Walking snakehead	Chengali	7.14	Rare	0.007	LC
6	*Trichogaster bejeus* (Hamilton, 1822) (formerly *Trichogaster fasciata*)		Osphronemidae	Banded gourami	Kholihona	54.76	Occasional	0.596	LC
7	*Trichogaster fasciata* (Bloch & Schneider, 1801) (formerly *Trichogaster lalia*)			Dwarf gourami	Kholihona	23.81	Sporadic	0.058	LC
8	*Xenentodon cancila* (Hamilton, 1822)	Beloniformes	Belonidae	Freshwater garfish	Kokila	2.38	Extremely rare	0.001	LC
9	*Piaractus brachypomus* (Cuvier, 1818)*	Characiformes	Serrasalmidae	Red-Bellied Pacu	Rupchanda	2.38	Extremely rare	0.001	
10	*Gudusia chapra* (Hamilton, 1822)	Clupeiformes	Dorosomatidae	Indian river shad	Koroti	76.19	Frequent	5.054	LC
11	*Botiadario* (Hamilton, 1822)	Cypriniformes	Botiidae	Bengal loach	Gethu	11.90	Rare	0.005	LC
12	*Cirrhinus mrigala* (Hamilton, 1822)		Cyprinidae	Mrigal	Mirika	26.19	Sporadic	0.025	LC
13	*Cirrhinusreba* (Hamilton, 1822)			Reba carp	Lachim	40.48	Occasional	1.345	LC
14	*Cyprinus carpio* (Linnaeus, 1758)*			Common carp	Common carp	2.38	Extremely rare	0.001	
15	*Labeo bata* (Hamilton, 1822)			Bata	Bhagun	28.57	Sporadic	0.296	LC
16	*Labeo calbasu* (Hamilton, 1822)			Orangefinlabeo	Kalbasu	59/52	Occasional	0.319	LC
17	*Labeo catla* (Hamilton, 1822)			Catla	Bhokuwa	33.33	Occasional	0.054	LC
18	*Labeo gonius* (Hamilton, 1822)			Kurialabeo	Kurhi	33.33	Occasional	0.051	LC
19	*Labeo rohita* (Hamilton, 1822)			Rohu	Rohu	50.00	Occasional	0.112	LC
20	*Osteobrama cotio* (Hamilton, 1822)			Cotio	Hafu mash	52.38	Occasional	0.522	LC
21	*Puntius sophore* (Hamilton, 1822)			Pool barb	Puthi	61.90	Frequent	4.914	LC
22	*Puntius terio* (Hamilton, 1822)			One spot barb	Puthi	88.10	Abundant	10.651	LC
23	*Esomus danricus* (Hamilton, 1822)			Flying barb	Dorikona	2.38	Extremely rare	0.002	LC
24	*Bangana dero* (Hamilton, 1822)			Kalabans	Narowa	40.48	Occasional	0.024	LC
25	*Amblypharyngodon mola* (Hamilton, 1822)		Danionidae	Molacarplet	Mowa	38.10	Occasional	35.616	LC
26	*Salmostoma bacaila* (Hamilton, 1822)			Large razorbelly minnow	Selkana, Chela	38.10	Occasional	0.127	LC
27	*Lepidocephalichthys guntea* (Hamilton, 1822)		Cobitidae	Guntea loach	Botia	2.38	Extremely rare	0.001	LC
28	*Chanda nama* (Hamilton, 1822)	Not assigned (formerly classified in the order Perciformes)	Ambassidae	Elongate glass-perchlet	Chanda	57.14	Occasional	30.677	LC
29	*Parambassis lala* (Hamilton, 1822)			Highfin glassy perchlet	Chanda	38.10	Occasional	0.461	LC
30	*Notopterus notopterus* (Pallas, 1769)	Osteoglossiformes	Notopteridae	Bronze featherback	Kandhuli	66.67	Frequent	0.160	LC
31	*Chitala chitala (Hamilton, 1822)*			Clown knifefish	Citol	2.38	Extremely rare	0.001	NT

32	*Mystus cavasius* (Hamilton, 1822)	Siluriformes	Bagridae	Gangeticmystus	Bar singora, Gulsa	19.05	Sporadic	0.054	LC
33	*Mystus tengara* (Hamilton, 1822)			Tengara catfish	Singora, Tengna	78.57	Frequent	3.253	LC
34	*Rita rita* (Hamilton, 1822)			Rita	Ritha	2.38	Extremely rare	0.001	LC
35	*Sperata seenghala* (Sykes, 1839)			Giant river-catfish	Aari	2.38	Extremely rare	0.001	LC
36	*Heteropneustes fossilis* (Bloch, 1794)		Heteropneustidae	Stinging catfish	Singi	76.19	Frequent	2.086	LC
37	*Wallago attu* (Bloch & Schneider, 1801)		Siluridae	Wallago	Borali	35.71	Occasional	0.047	VU
38	*Clarias magur* (Hamilton, 1822)		Clariidae	Walking catfish	Magur	11.90	Rare	0.019	EN
39	*Pachypterus atherinoides* (Bloch, 1794)		Schilbeidae	Indian potasi	Bordia	4.76	Extremely rare	0.002	LC
40	*Pangasius pangasius* (Hamilton, 1822)		Pangasiidae	Pangas catfish	Basa	2.38	Extremely rare	0.001	LC
41	*Ophichthys cuchia* (Hamilton, 1822)	Synbrachiformes	Synbranchidae	Gangaticmudeel	Cuchia	35.71	Occasional	0.779	LC
42	*Macrognathus pancalus* (Hamilton, 1822)		Mastacembelidae	Barred spiny eel	Turi	69.05	Frequent	1.102	LC
43	*Mastacembelus armatus* (Lacepède, 1800)			Zig zag eel	Bami	2.38	Extremely rare	0.001	LC
44	*Oreochromis mossambicus* (Peters, 1852)*	Cichliformes	Cichlidae	Tilapia	Japanikawoi	2.38	Extremely rare	0.001	
45	*Glossogobius giuris* (Hamilton, 1822)	Gobiiformes	Gobiidae	Tank goby	Patitmutura	28.57	Sporadic	0.020	LC

* Exotic species; EN: Endangered; VU: Vulnerable; NT: Near Threatened; LC: Least Concern; DD: Data Deficient

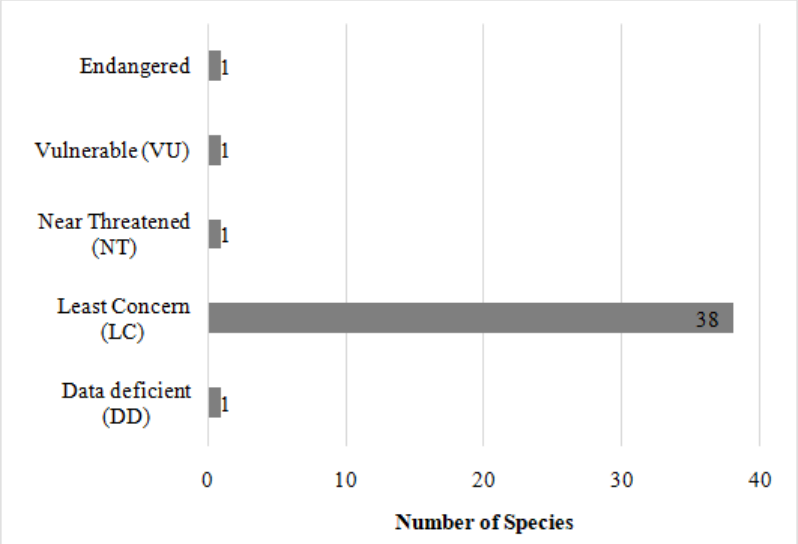

Fig. 3. Graphical representation of the IUCN Red List status of fishes found during the survey in Deepor Beel, Assam, India.

Table 4: Diversity of fish species at Deepor Beel in the study period (July-November).

	Monsoon (July-September)	Post-monsoon (October-November)	Study period (July-November)
Shannon-Weiner index	1.52	1.84	1.86
Species evenness	0.42	0.51	0.49

Source: field survey (July-November, 2024)

Social parameters of respondents. Out of the 165 respondents, 81.10% were male and 18.90% were female (Table 5). The average age of the respondents was approximately 48 years, with an average of 33 years of fishing experience. The majority of respondents were in the 41-60 age group, with 26-45 years of fishing experience (Table 5). Most of the fishermen (96.97%) were also involved in other livelihood activities (such as daily wage labor and business) alongside fishing, to support their livelihoods (Table 5), due to the decline in fish catch in the wetland, which has directly or indirectly affected their income.

Table 5: Social parameters of the fishermen in the study area at Deepor Beel, Assam, India.

Variables	Categories	Numbers of respondents
Gender (%)	Male	81.10
	Female	18.90
Age (yrs)	Average	48.46
	20-40	47
	41-60	101
	61-80	16
Experience (yrs)	Average	33.46
	5-25	47
	26-45	101
	46-55	16
Livelihood (%)	Fishing	3.03
	Fishing+ Others	96.97

Source: field survey (July-November, 2024)

Anthropogenic stresses to the fish diversity in Deepor Beel. Wetlands of Assam play an important role in the local economy, benefiting thousands of people, particularly through fisheries and supporting agriculture (Gogoi *et al.*, 2015). Literature survey revealed that the spatial extent of Deepor Beel has been shrinking due to anthropogenic activities, such as developmental activities, unsustainable land use, extension of railway network, and waste dumping site near the Deepor Beel (Deka *et al.*, 2011; Das *et al.*, 2024; Mandal *et al.*, 2024). To find out the anthropogenic stresses that prevail in the Deepor Beel and its influences on fish diversity, a questionnaire survey was conducted among local fishermen to understand about their perception of anthropogenic activities that influences or impacted the wetland's health. The survey found that around 69.51% of the fishermen reported a decline in some native fish species, with certain species no longer found in the Beel (Table 6). Meanwhile, 83.54% of respondents noted that the taste of the fish in the Beel may have changed over time (Table 6). In view of the anthropogenic stressors, around 59.76% of the respondents observed moderate levels of influences due to developmental/construction activities such as unsustainable land use, establishment of railway lines and numerous warehouses (Fig. 4). 60.98% of respondents reported moderate levels of impact of invasive species, particularly water hyacinth on fish populations and their growth (Figure 4). Whereas some of them reported that extensive growth of water hyacinth in the Deepor Beel affects spawning ground and limits the movement and migration of fish within the wetland. The rapid proliferation of water hyacinth (*Eichhornia crassipes*) has emerged as a major threat to Deepor Beel's ecosystem. The present observations are in alignment with the findings of Omondi and Merceline (2023), who reported that water hyacinth, an invasive species, forms dense mats on the water's surface, blocking sunlight from reaching submerged plants and reducing oxygen levels in the water, which further exacerbates eutrophic conditions. Moreover, the high infestation of water hyacinth leads to an increase in evapotranspiration, which decreases the water level of the wetland (Getahun and Kefale 2023). Invasive species, water hyacinth competes aggressively with native plants, such as bamboo grass and fox nut plants, both of which are crucial sources of food, breeding ground and sheltering ground for local fish species in the wetland (Villamagna and Murphy 2010; Kirim *et al.*, 2014; Segbefia *et al.*, 2019). The displacement of these native plants by water hyacinth leads to a significant reduction in available food resources for herbivorous and omnivorous fish species, undermining the food web that sustains a diverse fish population. Furthermore, the presence of water hyacinth restricts the growth of phytoplankton, which is the primary producers and base of the aquatic food chain. Phytoplankton are critical not only as a direct food source for many fish but also because they help maintain balanced nutrient levels in the water (Das *et al.*, 2012). As water hyacinth spreads, it reduces phytoplankton populations, leading to a cascade effect in which less food is available for higher trophic levels, including fish and other aquatic animals (Basaula *et al.*, 2023). However, 92.68% of respondents reported the waste dumping site located at Boragaon near Deepor Beel as the most detrimental activity, as it leads to the release of polluted water or leachate into nearby water bodies which may influence fish abundance and growth (Fig. 4). The present findings were in line with those of (Gohain and Bordoloi 2021; Sharma *et al.*, 2024) who stated that Boragaon, the waste dumping site, located in close proximity to the wetland, releases polluted water laden with harmful chemicals, heavy metals, and other contaminants into the Beel. The leachate from the dumping site has led to high levels of nutrient pollution, particularly an excess of nitrogen and phosphorus compounds. This nutrient enrichment fuels eutrophication, a process characterized by excessive algae and plant growth (Sánchez-Carrillo *et al.*, 2011). The resulting algal blooms consume large amounts of dissolved oxygen in the water, creating hypoxic conditions (low oxygen) that make survival challenging for most fish species. This oxygen-depleted environment can result in large-scale fish kills, altering fish diversity and causing a decline in indigenous fish

populations (Oh *et al.*, 2023; San Diego McGlone *et al.*, 2024). The eutrophic conditions also impact other aquatic organisms, leading to broader ecosystem imbalances that further stress the wetland's health (Ballut-Dajud *et al.*, 2022; Datta *et al.*, 2022; Niu *et al.*, 2022). Similarly, Vyas and Vishwakarma (2013) and Maibam *et al.* (2015) observed a significant decline in fish species abundance in Jammer river, a tributary of Narmada, Madhya Pradesh and Loktak Lake, Manipur respectively, compared to earlier studies. They reported that this decline could be attributed to changes in the physicochemical properties of water and various anthropogenic activities. They emphasized the need for effective policies, appropriate interventions, and proper implementation to ensure the lake's sustainability for future generations, which is also relevant to the context of Deepor Beel. The ongoing degradation of Deepor Beel's ecosystem through pollution and eutrophication has serious implications for its potential designation as a Ramsar site- a recognition reserved for wetlands of international importance. Achieving and maintaining Ramsar status is essential for Deepor Beel, as it would not only recognize the wetland's ecological importance but also ensure stronger conservation measures and international support for its protection. Due to various anthropogenic stressors, the wetland has experienced a marked decline in fish diversity with indigenous fish species, some of which are already vulnerable or near-threatened. These indigenous fish species are essential for the wetland's ecological balance and contribute to the region's cultural and economic heritage, as many local communities rely on them for sustenance and livelihood (Ekka *et al.*, 2024; Ghosh *et al.*, 2024; Sinha *et al.*, 2024). The indigenous fish species are also rich sources of nutrients and are consumed for their medicinal importance by various ethnic tribes of Assam (Duarah and Das 2019). The combined pressures of habitat degradation, pollution, invasive species, and food scarcity create a challenging environment for fish populations, with potential long-term consequences for biodiversity in the Beel. The deterioration in fish diversity and overall ecosystem health further emphasizes the need for immediate conservation measures to restore Deepor Beel and mitigate the effects of these various stressors. Biological techniques, including phytoremediation, phycoremediation, biomembranes, and ecological floating beds, can play a crucial role in enhancing the population of aquatic organisms and improving the ecological health of aquatic ecosystems (Chawla *et al.*, 2024). Overall, a thorough comprehensive approach is essential to mitigate the harmful effects of pollutants and ensure the sustainability of ecosystem services provided by water bodies for future generations. Hoque and Sharma (2020) suggested that government restoration policies and initiatives would be more beneficial with the active participation of local communities.

Table 6: Percentage distributions of fishermen' responses related to fish species diversity in Deepor Beel, Assam, India.

Variables	Categories	Percentage of responses
Fish species abundances	Increase	0%
	Moderate	30.49%
	Decrease	69.51%
Taste changed	Yes	83.54 %
	No	0%
	Can't say	16.46%

Source: field survey (July-November, 2024)

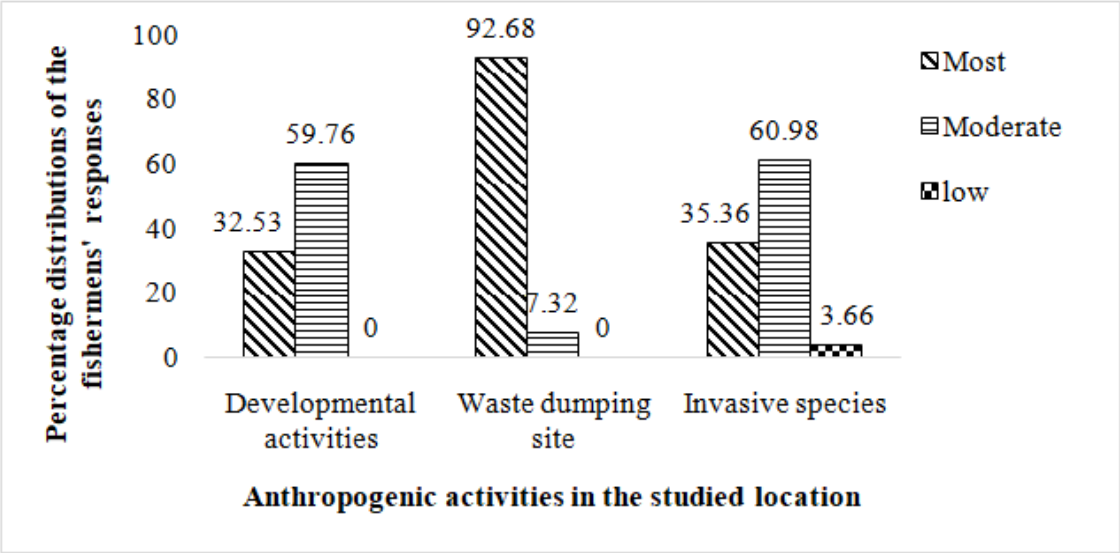

Fig. 4. Percentage distributions of the respondents on studied anthropogenic activities recorded during the study period (July-November, 2024) in Deepor Beel, Assam, India.

Plate I: Fish species found during the survey in Deepor Beel, Assam. 1. *Osteobrama cotio*, 2. *Labeo bata*, 3. *Salmostoma bacaila*, 4. *Anabas cobojius*, 5.*Trichogaster fasciata*, 6. *Trichogasterbejeus*, 7. *Labeo calbasu*, 8. *Labeo rohita*, 9. *Puntius sophore*, 10. *Puntiusterio*, 11. *Parambassis lala*, 12. *Chandanama*, 13. *Botia Dario*, 14. *Cirrhinusreba*, 15. *Amblypharyngodon mola*, 16. *Ophichthys cuchia*, 17. *Xenentodon cancila*, 18. *Macrognathus pancalus*, 19. *Mystus tengara*, 20. *Mystus cavasius*, 21. *Esomus danricus*, 22. *Gudusia chapra*, 23. *Heteropneustes fossilis*, 24. *Labeo gonius*, 25. *Sperata seenghala*, 26. *Cirrhinus mrigala*, 27. *Rita rita*, 28. *Channamarulius*, 29. *Channa punctata*, 30. *Labeocatla*, 31. *Pachypterus atherinoides*, 32. *Glossogobius giuris*, 33. *Lepidocephalichthys guntea*, 34. *Mastacembelus armatus*, 35. *Banganadero*, 36. *Pangasius pangasius*, 37. *Notopterus notopterus*, 38. *Chitala chitala*, 39. *Wallago attu*, 40. *Channa gachua*, 41. *Channa striata*, 42. *Clarias magur*, 43. *Piaractus brachypomus*, 44. *Cyprinus carpio*, 45. *Oreochromis mossambicus*.

CONCLUSIONS

Assam is blessed with a rich diversity of indigenous fish species, many of which thrive in the state's extensive network of wetlands, including the ecologically significant Deepor Beel. These wetlands are naturally abundant in resources, providing ideal habitats that support a wide array of fish species uniquely adapted to the region's specific environmental conditions. The presence of these indigenous fish species is essential not only for maintaining the ecological balance of Assam's aquatic ecosystems but also for supporting the cultural heritage, economy, and livelihoods of local communities. Deepor Beel provides critical habitats for fish species by offering a complex ecosystem comprising shallow waters, submerged vegetation, and ample food sources that meet the diverse needs of various fish species. The wetlands of Assam, particularly Deepor Beel, serve as vital sources of sustenance for local fishing communities who rely on traditional fish species for food, income, and cultural practices. The study provides the current status of the fish abundance and diversity in Deepor Beel, offering an overview of the perception of local fishermen regarding the decline in fish abundance and identifying major anthropogenic activities that threaten the health of the wetland. Despite the richness of indigenous fish diversity, Assam's wetlands, including Deepor Beel, face threats from pollution, habitat loss, and invasive species such as water hyacinths. These factors place stress on native fish populations, reducing their abundance and threatening the survival of sensitive species. Efforts to conserve and restore wetlands like Deepor Beel through sustainable management practices are essential not only for safeguarding Assam's unique indigenous fish diversity for future generations but also for enhancing the overall ecological health of these wetlands. Comprehensive management and restoration initiatives could prevent further degradation, conserve biodiversity, and potentially qualify Deepor Beel for Ramsar status. Such initiatives would ensure stronger protection and long-term sustainability of Assam's wetlands and their resources.

FUTURE SCOPE

Future research should focus on comprehensive water quality parameter testing, to better understand how water degradation impacts fish health and biodiversity in Deepor Beel. Additionally, longitudinal studies on fish population dynamics and the effects of anthropogenic activities, such as pollution and habitat destruction, are crucial to identifying specific threats to the wetland's ecosystem. Exploring the effectiveness of conservation strategies, including habitat restoration and sustainable fishing practices, will be vital for ensuring the long-term sustainability of the fish populations and the socio-economic and cultural heritage of local communities. These efforts will provide a deeper understanding of the causes of habitat degradation and guide more effective management and restoration practices for Deepor Beel.

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