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Research Article

Fish and Shellfish Diversity of Malam *Beel*, Bangladesh: Status, Trends, and Management Strategies

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ABSTRACT

Most of the waterbodies in Bangladesh's north-eastern *haor* basin have seen a gradual decline in their biodiversity, but little study has been done to determine their current condition. To address this issue, this research was conducted in the Malam beel under the Hakaluki *haor* – one of the largest wetland resources of the country. The study was conducted using a pre-tested questionnaire and a direct catch assessment survey in the *beel*. From 11 orders and 32 families, a total of 69 fish and shellfish species were identified. Of the species documented, 15.94% were classified as abundant, 39.13% were common, 27.54% were moderately available, and 17.39% were rare. Among the orders, Cypriniformes accounted for 37.68% of the total fish recorded. The most prevalent family was Cyprinidae found in Malam *beel*. Based on the findings, it can be concluded that Malam *beel* is a highly valuable inland open water body that has the potential to function as a key source of fishery resources as well as a gene bank for various fish species. However, some manmade and natural threats such as fishing by dewatering, brush pile fishing, illegal/destructive fishing and siltation were identified during the present study. Therefore, to ensure the sustainable maintenance of these water bodies, ecosystem-based fisheries management involving the local community is strongly advised.

Keywords: Biodiversity, threats, conservation, management

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INTRODUCTION

Fisheries and aquaculture are of paramount importance for ensuring global food security. These sectors are instrumental in supplying essential animal protein to billions of individuals across the globe, while also serving as a source of livelihood for 10-12% of the world's population (FAO, 2012). Bangladesh is rich in Inland and marine fisheries that make up the country's diverse fisheries resources. Bangladesh boasts abundant water resources, which host a diverse array of aquatic ecosystems that serve as habitats for a wide variety of species of fish (Sultana et al., 2016; Islam & Sultana, 2016). The biodiversity is extremely abundant, with about 260 freshwater fish species (DoF, 2018; Khan et al., 2018). In terms of inland open water capture production, Bangladesh secured the third position globally. The most popular animal source food in Bangladesh is fish, which is consumed at an average rate of 14 kg per year across all societal categories, meeting up to 60% of the country's demand for animal protein (FAO, 2022; DoF, 2018; Khan et al., 2018). Following China and India, Bangladesh is the third-ranked country in Asia for its diverse range of aquatic fish species. The country is home to around 800 species that can be found in freshwater, marine water, and brackish waters (Shamsuzzaman et al., 2017). However, a notable downward trend of fish diversity within Bangladesh's freshwater resources has become evident, with many freshwater species experiencing decreasing population trends (Hanif et al., 2015; Kamal et al., 2022; Das et al., 2022). About a quarter of these species are categorized as threatened, with 25 vulnerable, 30 endangered, and 9 severely endangered species. Also, 27 species have been listed as being near threatened (IUCN Bangladesh, 2015).

The term '*beel*,' which originates from the Bengali language, pertains to a substantial surface water body that is equipped with internal drainage channels for the purpose of collecting surface runoff water (Banglapedia, 2021; Kunda et al., 2022). Bangladesh has thousands of *beels*, and indigenous fishes used the *beel* as a natural habitat for food and shelter (Rahman et al., 2019). Malam *beel* is an important *beel* in the Hakaluki *haor*. It is 45 km away from Kulaura bazar. During the monsoon season, the *beel* is flooded yet remains dry for over six months. It is home to different fauna and flora. Moreover, the *beel* serves as a source of livelihood for thousands of people, providing them with income as well as food, fuelwood, recreational opportunities, and aesthetic benefits.

However, several human interventions, including the building of drainage systems, sluice gates, and flood control embankments, as well as the conversion of waterlogged area to cropland, have led to a reduction in the water area of the *beel* ecosystems, thereby posing a severe threat to aquatic life. Additionally, the careless application of herbicides is also contributing to the degradation of the *beel* ecosystem. Pollution from household, industrial, and agrochemical wastes, as well as mining runoff, has resulted in the demise of many aquatic organisms (Chakraborty, 2011; Pandit et al., 2023). Physicochemical characteristics, climatic parameters, industrial pollutants, municipal wastes, agricultural run-off, and irregular floods are all contributing to the decline of biodiversity in the Malam *beel*. Therefore, it is essential to implement practical management measures to enhance the biodiversity status of the *beel*, upon which local communities depend. However, to devise effective management strategies, understanding the current situation, patterns, and dangers to the aquatic biodiversity of the *beel* is essential. Due to a scarcity of existing research in this area, our study endeavors to fulfill a vital purpose. Specifically, our investigation aims to evaluate the current state of aquatic biodiversity within Malam *beel*. By identifying discernible trends and potential threats, we seek to contribute to a comprehensive understanding of this vital water body. Furthermore, our study strives to generate comprehensive guidelines that facilitate effective management strategies for sustaining the ecological balance of the Malam *beel*.

MATERIALS AND METHODS

Study site and duration

The study was conducted in the Malam *beel* which is a notable *beel* of Hakaluki *haor* (Figure 1), is situated 45 km away from Kulaura bazar. The total area of the Malam *beel* is around 400 acres during the rainy season and 70 acres in the dry season. A geographically suitable coverage that would include a range of fish biodiversity was one of the main selection factors for the study area, as well as the involvement of local fishers who rely on the *beel* for their livelihood. Four villages were selected for interview surrounding the *beel* named Borni, Khutaura, Kazirbond and Golapnagar. The research was done over a span of six months, from October 2017 to March 2018. But the catch assessment of fish was done only in the dry season (December, January, and February). Fishing in the Malam *beel* is exclusively conducted during the dry season. In the rainy season, the *beel* becomes submerged underwater, rendering fishing activities impractical during that period.

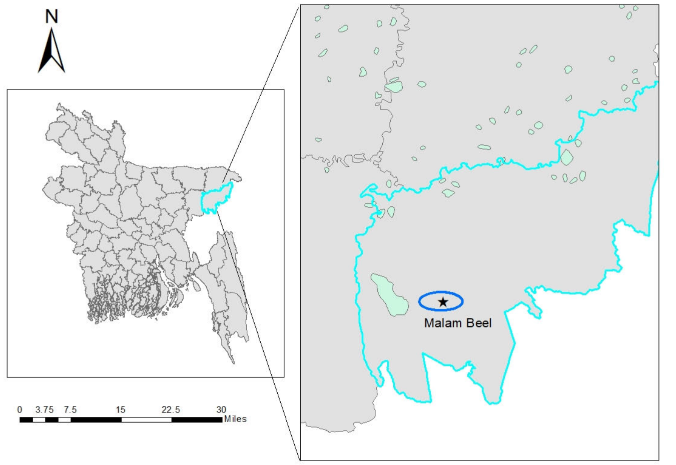

Figure 1. Malam *beel*.

Data collection methods

In this study, 80 fishers, 10 aratdars (fish trader), and 10 fish retailers from four chosen villages made up the total for the questionnaire interviews (QIs). Four focus group discussions (FGDs) were conducted in these villages, with participants from different age groups of fishers. Following the collection of data through FGDs and QIs, key informant interviews (KIIs) were conducted with experienced fishers, Upazila Fisheries Officers (UFO), District Fisheries Officers (DFO), community leaders, and NGO personnel.

Collection of fish samples

Fish and shellfish samples were taken during the catch from previously known fishers and local fish landing sites at 15 day intervals throughout the study period. In the study region, local fishers employ a variety of fishing equipment, such as seine nets, gill nets, lift nets, hooks, and traps. Each of these methods is designed to capture specific species and sizes of fish, and their efficiency varies, as outlined in Kundu et al.'s (2020) study. The sampling methods used in data collection were consistent in the dry season.

Identification of the collected fish samples

Based on their distinctive morphological traits, the collected fish and shellfish were divided into distinct categories. If a species proved challenging to identify during fieldwork, it was preserved in a buffered formalin solution of 10% and later transported to the Fisheries Biology and Genetics laboratory at Bangladesh Agricultural University for in-depth examination. The process of identification encompassed analyzing the specimens' morphometric and meristic traits, as well as their coloration. The taxonomic evaluation adhered to the methods detailed by Rahman (2005), Talwar & Jhingran (1991), and IUCN Bangladesh (2015), while the classification of fish species aligned with the system established by Nelson (2006).

Determination of availability status

The fish and shellfish were identified in terms of the respondent's opinion, their frequency of occurrence and finally, categorized into four classes based on their availability status (Pandit et al., 2020,2021). The categories were defined as: abundantly available (AA) - species consistently observed year-round, repeating over 75% of the time; commonly available (CA) - species frequently seen but in smaller quantities, repeating 51-75% of the time; moderately available (MA) - species encountered occasionally, with a repetition rate ranging from 26 to 50%; and rarely available (RA) - species observed infrequently, repeating in small amounts at a repetition rate equal to or less than 25% (Pandit et al., 2020,2021; Kamal et al., 2022; Kunda et al., 2022).

Statistical analysis

The gathered data underwent input, preprocessing, and analysis using V25.0 of the Statistical Package for the Social Sciences (SPSS) software. A map of the study area was crafted by integrating ArcGIS 10.0 software with the assistance of a global positioning system (GPS).

RESULTS AND DISCUSSION

Fish and shellfish diversity status

In Malam *beel*, 69 species of fauna were identified, including 67 species of finfish and 2 species of prawns, which belonged to 11 different orders and 32 families (Table 2). Although there were no previous studies on fish and shellfish diversity in this *beel* for comparison, the current study provides a baseline for future fish assemblage assessments. Previous studies on fish diversity and richness in the surrounding areas supported the findings of this study. Numerous studies have examined fish species diversity in various water bodies across Bangladesh (Table 1).

The study's findings revealed a distribution of fish and shellfish species availability as follows: 15.94% were abundantly available, 39.13% were commonly available, 27.54% were moderately available, and 17.39% were rarely available. Respondents attributed this pattern to a diminishing fish biodiversity. Kamal et al. (2022) mirrored this trend in Kawadighi *haor*, with 18% abundantly available, 20% commonly available, 42% moderately available, and 20% rarely available species. Parallel results have emerged from studies focused on fish diversity in river and *haor* ecosystems. For instance, Pandit et al. (2020) found that the Gurukchi River displayed a predominance of rarely available fish species (29.82%), followed by commonly available (28.07%), moderately available (22.81%), and abundantly available (19.30%). Similarly, Pandit et al. (2021) documented 17.4% abundantly available, 27.5% commonly available, 31.9% moderately available, and 23.1% rarely available fish species in the Dhanu River and its surrounding *haor* ecosystems. These collective findings highlight the consistent distribution of fish species across different water bodies within the region.

Cypriniformes, Siluriformes, and Anabantiformes were discovered to be the most prominent orders among the eleven recognized orders, contributing for 37.68%, 23.19%, and 11.59% of the total fish population in Malam *beel*, respectively (Figure 3). Other eight orders were constituted by Perciformes, Synbranchiformes, Clupeiformes, Osteoglossiformes, Beloniformes, Decapoda, Tetraodontiformes, and Cyprinodontiformes. Many studies have consistently shown that Siluriformes and Cypriniformes are the most common orders in Bangladesh (Rahman, 2005; Iqbal et al., 2015; Hossain et al., 2016; Mondol et al., 2015; Sultana et al., 2018, 2019; Debnath et al., 2020; Talukder et al., 2021), which is like the current study. Sulta-

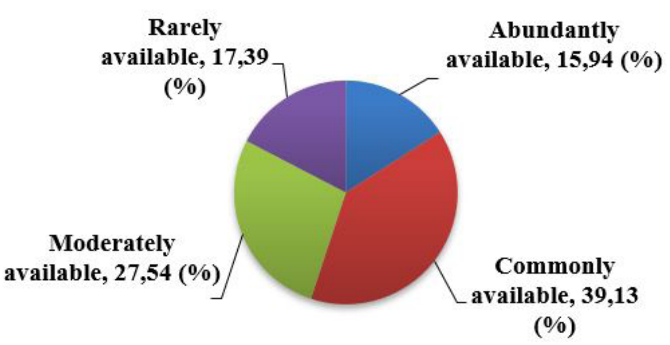

Figure 2. Pie chart for percentage of availability status of fish and shellfish species in Malam *beel*.

Table 1. Comparison of fish and shellfish diversity with other studies.

Sl. No.	Study Area	Order	Family	No. of Species	References
1	Malam *beel*	11	32	69	Present Study
2	Hakaluki *haor*	10	28	83	Iqbal et al. 2015
3	Hakaluki *haor*	12	27	63	Aziz et al. 2021
4	Bhawal *beel*	10	23	56	Sultana et al. 2019
5	Chalan *beel*	10	26	78	Siddique et al. 2016
6	Basurabad *beel*	6	-	33	Rahman et al. 2019
7	Banar River	10	24	62	Sultana et al. 2018
8	Juri River	-	25	75	Islam et al. 2019
9	Basuakhali *beel*,	10	21	38	Rahman et al. 2019
10	Shari-Goyain River	9	27	66	Talukder et al. 2021

Table 2. Recorded fish and shellfish species from the Malam *beel*.

SL No.	Order	Family	Scientific Name	English Name	Local Name	Present Status	Conservation Status		Native status	Major Fishing Gear	Catch Preference
							BD	GL			
1	Anabantiformes	Osphronemidae	Trichogaster fasciata (Bloch & Schneider 1801)	Banded gourami	Baro khlisha	CA	LC	LC	Native	CN	BC
2	Anabantiformes	Osphronemidae	Trichogaster fasciata (Bloch & Schneider 1801)	Honey gourami	Lal khalisha	CA	LC	LC	Native	CN	BC
3	Anabantiformes	Anabantidae	Anabas testudineus (Bloch, 1792)	Climbing perch	Koi	MA	LC	LC	Native	CN	TC
4	Anabantiformes	Channidae	Channa marulius (Hamilton, 1822)	Giant snakehead	Gozar	RA	EN	LC	Native	H	TC
5	Anabantiformes	Channidae	Channa striata (Bloch, 1793)	Snakehead murrel	Shol	CA	LC	LC	Native	H	TC
6	Anabantiformes	Channidae	Channa orientalis (Bloch & Schneider, 1801)	Asiatic snakehead	Cheng	CA	LC	VU	Native	H	TC
7	Anabantiformes	Channidae	Channa punctata (Bloch, 1793)	Spotted Snakehead	Taki	CA	LC	LC	Native	H	TC
8	Anabantiformes	Nandidae	Nandus nandus (Hamilton, 1822)	Gangetic leaffish	Meni/Veda	CA	NT	LC	Native	SN	TC
9	Beloniformes	Belonidae	Xenentodon cancila (Hamilton, 1822)	Freshwater garfish	Kankila	CA	LC	LC	Native	SN	BC
10	Beloniformes	Hemiramphidae	Hyporhamphus limbatus (Valenciennes, 1847)	Congaturi halfbeak	Ekthutia	CA	LC	LC	Native	SN	BC
11	Clupeiformes	Dorosomatidae	Gudusia chapra (Hamilton, 1822)	Indian river shad	Chapila	AA	VU	LC	Native	GN	TC
12	Clupeiformes	Dorosomatidae	Corica soborna (Hamilton, 1822)	The Ganges River sprat	Kachki	AA	LC	LC	Native	CN	TC
13	Cypriniformes	Cobitidae	Lepidocephalichthys guntea (Hamilton, 1822)	Guntea loach	Gutum	CA	LC	LC	Native	SN	TC
14	Cypriniformes	Botiidae	Botia dario (Hamilton, 1822)	Bengal loach	Bou/Rani	CA	EN	LC	Native	SN	BC
15	Cypriniformes	Cyprinidae	Labeo rohita (Hamilton, 1822)	Rohu	Rui	MA	LC	LC	Native	SN	TC
16	Cypriniformes	Cyprinidae	Labeo catla (Hamilton, 1822)	South Asian carp	Catla	RA	LC	NE	Native	SN	TC
17	Cypriniformes	Cyprinidae	Cirrhinus mrigala (Bloch, 1795)	Mrigal carp	Mrigal	MA	NT	VU	Native	SN	TC
18	Cypriniformes	Cyprinidae	Cirrhinus reba (Day, 1878)	Reba carp	Lachu	CA	NT	LC	Native	SN	TC
19	Cypriniformes	Cyprinidae	Cyprinus carpio (Linnaeus, 1758)	Common carp	Carpio	MA	NT	VU	Native	SN	TC

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SL No.	Order	Family	Scientific Name	English Name	Local Name	Present Status	Conservation Status		Native status	Major Fishing Gear	Catch Preference
							BD	GL			
20	Cypriniformes	Xenocyprididae	Hypophthalmichthys molitrix (Valenciennes, 1844)	Freshwater cyprinid fish	Silver carp	RA	LC	NT	Non-native	SN	TC
21	Cypriniformes	Xenocyprididae	Ctenopharyngodon idella (Valenciennes, 1844)	Ray-finned fishes	Grass carp	MA	NT	NE	Non-native	SN	TC
22	Cypriniformes	Cyprinidae	Labeo gonius (Hamilton, 1822)	Kuria labeo	Gonia	MA	NT	LC	Native	SN	TC
23	Cypriniformes	Cyprinidae	Pethia ticto (Hamilton, 1822)	Ticto barb	Tit punti	AA	VU	LC	Native	CN	TC
24	Cypriniformes	Cyprinidae	Puntius sophore (Hamilton, 1822)	Spotfin swamp barb	Jat punti	AA	LC	LC	Native	CN	TC
25	Cypriniformes	Cyprinidae	Pethia phutunio (Hamilton, 1822)	Spottedsail barb	Phutanio punti	MA	LC	LC	Native	CN	TC
26	Cypriniformes	Cyprinidae	Systomus sarana (Hamilton, 1822)	Olive barb	Shorputi	MA	NT	LC	Native	CN	TC
27	Cypriniformes	Danionidae	Amblypharyngodon mola (Hamilton, 1822)	Mola carplet	Mola	AA	LC	LC	Native	CN	TC
28	Cypriniformes	Cyprinidae	Osteobrama cotio (Hamilton, 1822)	Cotio	Dhela	RA	NT	LC	Native	CN	TC
29	Cypriniformes	Danionidae	Esomus danrica (Hamilton, 1822)	Stripped flying barb	Darkina	CA	DD	NE	Native	CN	BC
30	Cypriniformes	Danionidae	Securicula gora (Hamilton, 1822)	Chela gora	Ghora chela	CA	NT	LC	Native	CN	BC
31	Cypriniformes	Danionidae	Salmostoma acinaces (Valenciennes, 1844)	Silver razor belly minnow	Chela	MA	DD	LC	Native	CN	BC
32	Cypriniformes	Cyprinidae	Puntius terio (Hamilton, 1822)	One spotted barb	Teri punti	CA	LC	LC	Native	CN	TC
33	Cypriniformes	Cyprinidae	Pethia guganio (Hamilton, 1822)	Glass-barb	Mola punti	AA	LC	LC	Native	CN	TC
34	Cypriniformes	Danionidae	Salmostoma phulo (Hamilton, 1822)	Finescale razorbelly min-now	Phulo-chela	RA	NT	LC	Native	CN	TC
35	Cypriniformes	Cyprinidae	Pethia gelius (Hamilton, 1822)	Golden barb	Jelly puti	AA	NT	LC	Native	CN	TC

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SL No.	Order	Family	Scientific Name	English Name	Local Name	Present Status	Conservation Status		Native status	Major Fishing Gear	Catch Preference
							BD	GL			
36	Cypriniformes	Cyprinidae	Labeo bata (Hamilton, 1822)	Bata labeo	Bata	MA	LC	LC	Native	SN	TC
37	Cypriniformes	Cyprinidae	Labeo calbasu (Hamilton, 1822)	Orange Fin labeo	Kalibaus	MA	LC	LC	Native	SN	TC
38	Cypriniformes	Psilorhynchidae	Psilorhynchus balitora (Hamilton, 1822)	Balitora Minnow	Balichata	MA	LC	LC	Native	CN	TC
39	Cyprinodontiformes	Aplocheilidae	Aplocheilus panchax (Hamilton, 1822)	Blue panchax	Kanpona	CA	LC	NT	Native	CN	BC
40	Decapoda	Soleniceridae	Solenocera crassicornis (H. Milne Edwards, 1837)	Red prawn	Gura chingri	AA	LC	NE	Native	T	TC
41	Decapoda	Palaeomonidae	Macrobrachium rosenbergii (De Man, 1879)	Giant river prawn	Golda chingri	CA	LC	LC	Native	T	TC
42	Osteoglossiformes	Notopteridae	Notopterus notopterus (Pallas, 1769)	Bronze featherback	Foli	CA	VU	LC	Native	SN	TC
43	Osteoglossiformes	Notopteridae	Chitala chitala (Hamilton, 1822)	Clown knifefish	Chital	RA	EN	NT	Native	CN	TC
44	Perciformes	Ambassidae	Chanda nama (Hamilton, 1822)	Elongate glass perchlet	Lamba chanda	MA	LC	LC	Native	SN	BC
45	Perciformes	Ambassidae	Parambassis ranga (Hamilton, 1822)	Highfin glassy perchlet	Gol chanda	CA	LC	LC	Native	GN	BC
46	Perciformes	Cichlidae	Oreochromis mossambicus (Peters, 1852)	Hawaiian perch	Tilapia	MA	LC	VU	Non-native	SN	TC
47	Perciformes	Badidae	Badis badis (Hamilton, 1822)	Blue perch	Napit koi	MA	NT	LC	Native	GN	TC
48	Perciformes	Gobiidae	Glossogobius giuris (Hamilton, 1822)	Tank goby	Bele	CA	LC	LC	Native	T	BC
49	Siluriformes	Siluridae	Wallago attu (Bloch & Schneider, 1801)	Freshwater shark	Boal	CA	VU	VU	Native	H	TC
50	Siluriformes	Siluridae	Ompok pabo (Hamilton, 1822)	Pabo catfish	Pabda	CA	CR	NT	Native	GN	TC
51	Siluriformes	Siluridae	Ompok pabda (Hamilton, 1822)	Butter catfish	Modhu pabda	RA	EN	NT	Native	SN	TC
52	Siluriformes	Pangasiidae	Pangasius pangasius (Hamilton, 1822)	Pungas catfish	Deshi pan-gus	RA	EN	LC	Native	SN	TC
53	Siluriformes	Ailiidae	Eutropiichthys vacha (Hamilton, 1822)	Batchwa vacha	Bacha	CA	LC	LC	Native	CN	TC
54	Siluriformes	Horabagridae	Pachypterus atherinoides (Bloch, 1754)	Indian potasi	Batashi	AA	LC	NE	Native	CN	TC

Table 2. Recorded fish and shellfish species from the Malam *beel*.

SL No.	Order	Family	Scientific Name	English Name	Local Name	Present Status	Conservation Status		Native status	Major Fishing Gear	Catch Preference
							BD	GL			
55	Siluriformes	Bagridae	Sperata aor (Hamilton, 1822)	Long-whiskered catfish	Air	CA	VU	LC	Native	H	TC
56	Siluriformes	Sisoridae	Bagarius bagarius (Hamilton, 1822)	Gangetic goonch	Baghair	RA	CR	NT	Native	H	TC
57	Siluriformes	Bagridae	Mystus bleekeri (Day, 1877)	Bleeker's mystus	Gulsha tengra	AA	LC	LC	Native	CN	TC
58	Siluriformes	Bagridae	Mystus vittatus (Bloch, 1794)	Asian striped catfish	Tengra	AA	LC	LC	Native	CN	TC
59	Siluriformes	Bagridae	Rita rita (Hamilton, 1822)	Rita	Rita	MA	EN	LC	Native	CN	TC
60	Siluriformes	Bagridae	Sperata seenghala (Sykes, 1839)	Giant river-catfish	Guizza air	RA	LC	LC	Native	SN	TC
61	Siluriformes	Bagridae	Mystus tengara (Hamilton, 1822)	Striped dwarf catfish	Bujuri tengra	CA	LC	LC	Native	CN	TC
62	Siluriformes	Clariidae	Clarias batrachus (Linnaeus, 1758)	Walking catfish	Magur	MA	LC	LC	Native	H	TC
63	Siluriformes	Heteropneustidae	Heteropneustes fossilis (Bloch, 1794)	Stinging catfish	Shing	CA	LC	LC	Native	H/T	TC
64	Siluriformes	Bagridae	Mystus cavasius (Hamilton, 1822)	Gangetic mystus	Kabasi tengra	CA	NT	LC	Native	H/T	TC
65	Synbranchiformes	Mastacembelidae	Mastacembelus pancalus (Hamilton, 1822)	Striped spiny eel	Guchi baim	RA	LC	LC	Native	T	TC
66	Synbranchiformes	Mastacembelidae	Mastacembelus armatus (Lacepede, 1800)	Zig-zag eel	Baim	MA	EN	NE	Native	T	TC
67	Synbranchiformes	Mastacembelidae	Macrognathus aculeatus (Bloch, 1786)	Lesser spiny eel	Tara baim	MA	DD	LC	Native	T	TC
68	Synbranchiformes	Synbranchidae	Ophichthys cuchia (Hamilton, 1822)	Gangetic mudee	Kuchia	RA	VU	VU	Native	T	TC
69	Tetraodontiformes	Tetraodontidae	Leiodon cutcutia (Hamilton, 1822)	Ocellated puffer fish	Potka	CA	LC	LC	Native	LN	BC

BD – Bangladesh, GL – Global, LC - Least concern, NT - Near threatened, NE - Not evaluated, DD - Data deficient, VU - Vulnerable, EN - Endangered, and CR - Critically endangered (IUCN Bangladesh, 2015); AA - Abundantly available, CA - Commonly available, MA - Moderately available, RA - Rarely available; SN – Seine Net, GN – Gill Net, LN – Lift Net, CN – Cast Net, H – Hooks, T – Traps; TC – Target Catch, BC – Bycatch.

na et al. (2019) revealed the order-based percentage analysis of the existing aquatic fauna from Bhawal *beel* and found as Cypriniformes (33.93%), Siluriformes (21.43%) and Perciformes (19.65%).

In Malam *beel*, the prevailing family was identified as Cyprinidae, contributing to 23.19% of the overall fish diversity (Figure 3b). While smaller proportions were attributed to families like Bagridae, Anabantidae, and others, their presence was observed. These outcomes parallel the conclusions drawn from earlier investigations by Sultana et al. (2019) on Bhawal *beel* and Islam et al. (2019) on Juri River, both of which underscored the dominance of Cyprinidae as the primary family in terms of fish population.

According to IUCN Bangladesh (2015), 21.74% of the identified fish and shellfish in Malam *beel* were classified as endangered, while 18.84% were near threatened (Figure 3c). However, most of the fish populations (55%) were categorized as least concern (LC). When considering the global IUCN status, most fish species in Malam *beel* were categorized as least concern (LC), constituting 73.90% of the total. Following this, near threatened (NT), data deficient (DD), and not evaluated (NE) species accounted for 8.70% each (IUCN Bangladesh, 2015).

The investigation unveiled that within Malam *beel*, there existed a collective of 15 fish species categorized as threatened. Among these, 6 were deemed vulnerable, 7 as endangered, and 2 as critically endangered, as per the IUCN Bangladesh (2015) classification (Figure 6). In comparison, previous studies conducted in

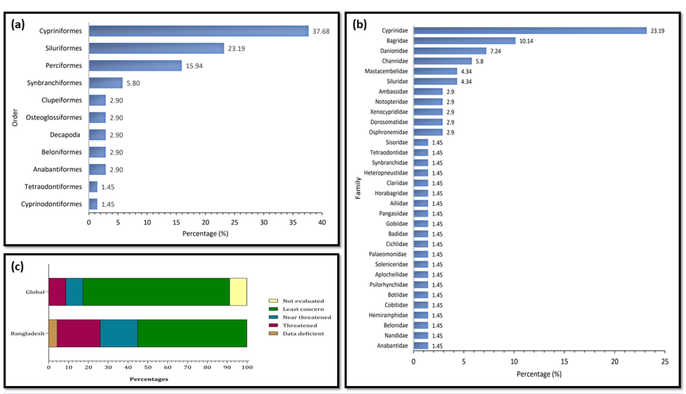

Figure 3. Recorded fish and shellfish species distribution according to their (a) orders, (b) families and (c) conservation status.

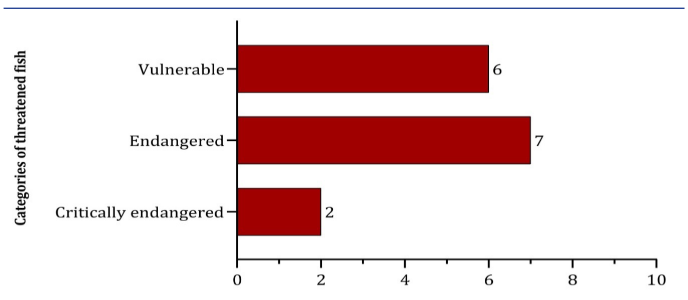

Figure 4. Threatened fish species found in Malam *beel*.

Hakaluki *Haor* and Bhawal *beel* identified 41 and 13 threatened species, respectively, with varying levels of vulnerability. Similarly, the Juri River study found 19 threatened species, with 10 being vulnerable, 8 endangered, and 1 critically endangered, which aligns with the present study's findings.

Threats to fish biodiversity of Malam beel

The fish and shellfish species diversity of Malam *beel* is affected by both natural and anthropogenic factors. The major threats identified by respondents were overfishing, fishing by dewatering, and brush pile fishing, which were reported by 85%, 77.5%, and 72.5% of the respondents, respectively. Additionally, the use of illegal/destructive fishing equipment, the unregulated use of insecticides, pesticides and chemical fertilizers on agricultural lands, siltation and sedimentation, and water abstraction for irrigation were identified as factors affecting fish biodiversity, with 65%, 56.25%, 51.25%, and 47.5% of respondents reporting these as issues. The conversion of *beel* to agricultural fields and habitat loss due to siltation were also mentioned. Climate change was identified as a natural cause of impact on the *beel*'s biodiversity due to changes in water temperature and extreme rainfall events. The lack of awareness and fishing by poor and illiterate individuals were also mentioned as contributing factors. Furthermore, *Oreochromis mossambicus*, *Hypophthalmichthys molitrix*, and *Ctenopharyngodon idella* are non-native fish species that have been introduced to various aquatic environments for different purposes. While they are not traditionally considered invasive species in the sense of causing significant harm to native ecosystems in Bangladesh. These findings highlight the urgent need to take measures to address the identified threats to fish biodiversity in Malam *beel*. Details shown in Table 3.

The decrease in fish and shellfish abundance observed in Hakaluki *haor* in northeast Bangladesh can be attributed to several factors such as the drying up of *beel*s, flooding, siltation, overfishing, use of harmful fishing tools, temperature fluctuations, and the use of inorganic fertilizers to catch fish. Similar trends

Table 3. Threats to fish biodiversity of Malam *beel*.

Factors affecting fish biodiversity	Percentage of respondents
Overfishing	85.0%
Fishing by dewatering	77.5%
Brush pile fishing	72.5%
Use of illegal/destructive fishing gears	65.0%
Unregulated application of pesticides, insecticides, chemical fertilizers on agricultural lands.	56.25%
Siltation and sedimentation	51.25%
Water abstraction for irrigation	47.5%
Climate change (altered pattern in temperature and rainfall)	31.25%
Construction of developmental infrastructure	26.25%
Water pollution	10.0%

have been identified as catalysts for the decline in biodiversity in various other investigations conducted by Rahman et al. (2019), Sultana et al. (2019), Das et al. (2022), Tasnim et al. (2022), and Sultana et al. (2022). Additionally, the conversion of *beel* fringes into agricultural fields remains an ongoing process in the region. Overfishing stands out as a prominent contributor to the decline in fisheries, while the application of pesticides, known for their high toxicity, poses a substantial threat to aquatic organisms, impacting the integrity and function of ecosystems (Parveen and Faisal, 2002). The sedimentation of water bodies also emerges as a significant factor contributing to the deterioration and degradation of aquatic ecosystems (Craig et al., 2004). In the context of Kawadighi *haor*, crucial drivers that have led to a reduction in species diversity within the *beel* encompass dewatering, overfishing, the usage of destructive fishing equipment, intensified agricultural activities, road and embankment construction, pesticide utilization, sediment deposition, barrage establishment, improper fish farming, and drought (Kamal et al., 2022).

Management options

Preventing overfishing, illegal fishing equipment usage, and the destruction of fish eggs and seeds through illegal fishing methods and tools is crucial. Enforcing minimum mesh size requirements for various gears will help accomplish this and prohibiting the use of monofilament nets.

The unregulated building of bridges, culverts, sluice gates, and flood control embankments has disrupted the natural migration patterns of fish during their spawning, breeding, and feeding activities. To counteract the adverse effects on fishery resources, it has become imperative to establish and uphold fish-friendly migration pathways.

To safeguard fish biodiversity, it is essential to prevent the complete draining of *beel*s, and the withdrawal of water from *beel*s for irrigation in the dry season should be managed or discouraged. To ensure a minimum water depth in the *beel*, the extraction of water needs to be regulated.

It is important to limit the widespread use of inorganic fertilizers and insecticides through integrated pest management programmes.

To keep a sustainable year-round production, stock enhancement programs should be implemented. Species like thai sarpunti, silver carp, common carp, catla, mrigal, kalibaus, and rui can be introduced in the *beel*.

Fish sanctuaries should be established, and brush pile fishing should be stopped to conserve the existing fish species for sustainable fish production.

Existing fisheries rules and regulations should be strictly enforced.

To achieve sustainable management of the *beel* ecosystem, it is vital to formulate ecosystem-based management strategies that engage various stakeholders, such as researchers, policymakers, resource managers, governmental bodies, and non-governmental organizations. These strategies should focus on balancing the ecological, economic, and social aspects of the *beel*'s management while preserving its biodiversity and ecosystem functions. These plans ought to focus on increasing production, sustainably preserving biodiversity, and enhancing local fishermen's incomes. Further research is necessary in this area to enhance biodiversity, production patterns, and conserve resources.

CONCLUSION

The study conducted in Malam *beel*, nestled within the expansive Hakaluki *Haor*, addresses the lack of understanding about the current state of aquatic biodiversity. Across eleven orders and 32 families, the research meticulously recorded 69 distinct fish and prawn species. Notably, Cypriniformes emerged as a key contributor, constituting 37.68% of the total fish population, with Cyprinidae being the dominant family. This study shines a spotlight on the remarkable potential of Malam *Beel* as a valuable inland water body. It holds promise as a critical fishery resource and a repository for preserving genetic diversity. Amidst this promise, the study also uncovers threats, from human-induced activities like dewatering and destructive fishing to natural processes such as siltation, posing significant challenges to the ecosystem's sustainability. These findings underscore the call for ecosystem-based fisheries management that actively involves local communities. The importance of conserving diverse fish populations has become evident. Balancing the availability of resources with conservation emerges as a vital consideration, necessitating comprehensive and adaptable management strategies. By embracing an ecosystem-based approach, we can harness the potential of these water bodies while safeguarding their vitality for the well-being of current and future generations.

Conflicts of interest: The authors assert the absence of any conflicts of interest.

Ethics committee approval: Ethical approval was granted by the "Bangladesh Agricultural University Ethical Committee" for all experiments involving human subjects and animals (fish). The procedures employed adhered to the established ethical standards. Furthermore, informed consent was obtained from all survey respondents, ensuring compliance with ethical principles governing research involving human participants.

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