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Biodiversity assemblages and conservation necessities of ecologically sensitive natural wetlands of north-eastern Bangladesh

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North-Eastern region of Bangladesh is very promising for freshwater capture fisheries, nevertheless, comprehensive assessment on faunal composition and diversity assemblages of natural wetlands are scant.This study identifies the occurrence, different biodiversity indices and composition of fish with various gear types by means of qualitative and quantitative approaches in Tanguar*haor* and Dekar*haor*. A total of 75 fish species were identified, of which 53 % were Cypriniformes, followed by Siluriformes (15 %), Perciformes (14 %), Channiformes (7 %) and Clupeiformes (4 %). Among the identified taxa 42 species were not threatened, 12 vulnerable, 11 endangered and 8 critically endangered. The values of diversity indices explicitly Shannon-Weiner **(***H'*), Pielou evenness (J'), Margalef richness (d) and Simpson dominance (c) indices indicated that Tanguar*haor*wasmore diversified and evenly distributed than Dekhar*haor*. For effective management of the *haors*comprehensive stock assessment, establishment of fish sanctuaries, and combination of input and output control is suggested.

[Keywords: Conservation;*Haor* basin; Management; Natural wetlands; Species diversity;

Introduction

Bangladesh is a riverine country of Southeast Asian region having a total area of 147,570 km^2 and a population of about 140 million[1,2]. The country is divided into 8 administrative divisions (Dhaka, Chittagong, Khulna, Barisal, Rajshahi, Rangpur, Sylhet and Mymensingh). Bangladesh has endowed with 4.92 million hectares (ha) of inland waters of which 230 large and small rivers[3] and their estuaries constitute approximately 1.03 million ha[4]. Fish plays an important role in the diet of the people of Bangladesh and among all the division Sylhet (North-Eastern region) is very promising for freshwater capture fisheries due to abundance of a number of rivers, *beel* (static lake), *baor* (oxbow lake), canal and *haor* (bowl or saucer shape shallow depression) etc. *Haor*is a diversified aquatic habitat with the combination of river, streams, *beels*, irrigation canals and seasonally cultivated plains[5]. There are 411 *haors*in Bangladesh covering about 8000 km^2 area in the district of Netrakona, Kishoreganj, Brahmanbaria, Hobiganj, Moulvibazar, Sylhet and Sunamganj district[6]. Tanguar*haor*(ecologically critical area since 1999 and Ramsar site since 2000) is one of the largest wetland systems in the northeast region of Bangladesh that is situated in the Tahirpur and Dharmapasha Upazilla of the Sunamganj district under Sylhet division which covers approximately 10,000 hectares of land[7]. During monsoon whole area becomes inundated and flows through the Bulai-Surma river but in winter only 30 % area remain underwater. Tanguar*haor* is said to be a part of world's largest geosynclines. Dekhar*haor*is another important wetland of Sylhet division. It covers Sunamganj Sadar, DakhinSunamganj, Chatak and Dawrabazar Upazilla of Sunamganj district[6].

*Haors*ecosystems are very potential for fisheries resources and act as a breeding, feeding and nursery ground of numerous fish species. These wetlands play a vital role inthe country's economic, industrial, ecological, socio-economic, and cultural context[8]. Moreover, it supports a rich biodiversity of flora and fauna and contributes to the sustainability of the socio-economic life of millions of people of rural Bangladesh by providing employment opportunities, irrigation, food and nutrition, fuel, fodder and transportation[9,10] but the fish production from the fresh waters has declined to less than 40 %[11,12]. Major causes of declining fish catch from the waters include increased fishing pressure, habitat destruction along with many other anthropogenic drivers (e.g. pesticides, agricultural wastes, pollutants, siltation, diseases, non-compliance of laws and regulations etc.) and natural drivers like changes in the pattern of temperature, rainfall and other climatic elements due to climate change[13-15]. Moreover, species diversity has also dramatically declined due to introduction of lease system (*Ijarah* of *Jalmohal*), indiscriminate use of gears, overfishing, destruction of spawning grounds and catching of fish during their downstream migration from floodplains to rivers[7,15]. In order to thrive in such threatening pressure, these natural wetlands are known to play a significant contribution to the food security and support millions of rural livelihood and thus playing a vital role for the sustainable economic development, management and conservation perspectives.

Although fisheries resources of natural wetlands of Sylhet are very promising for providing food, nutrition and significant contribution to capture fisheries[7] its inconsistency in production and declining trends of biodiversity suggest the necessity of proper management. To suggest a best possible management strategy research is very important to find out the problems and expectations of the dependent communities but there are very few studies focused on the fish biodiversity and ecological status of these *haors*. Nevertheless, concurrent comprehensive assessment study on faunal composition and diversity assemblages of natural wetlands of north-eastern Bangladesh are scant. Therefore, this study aimed to assess the composition, biodiversity status and diversity indices of fish species of ecologically sensitive natural wetlands explicitly Tanguar*haor* and Dekar*haor* in the Sylhet division of Bangladesh.

Materials and Methods

Profile of the study sites

The study was conducted in two fishing communities of Dekhar*hoar* (24°34′N to 25°12′N, 90°56′E to 91°49′E) and Tanguar*haor*(25^{0}09$^{'}$-25^0-12$^{'}$ N, 91^{0}04-91^0-07$^{'}$ E) of Sunamganj district (Fig. 1). The communities were Uttar Sreepur of Tanguar*haor* of TahirpurUpazilla and Dakkhingaon of Dekhar*haor* of Sunamaganj Sadar Upazilla under Sunamganj District; whose livelihoods were mainly depended on fisheries (90 %), small scale fishing (main livelihood), fish drying, fish trading, net mending, boat making and repairing activity. Other livelihood activities were agriculture, small business and daily labour.

Data collection and sampling

To collect empirical data (representing both qualitative and quantitative), household survey and field observation during fishing was conducted and a number of qualitative tools such as interviews, focus group discussions, oral history, cross-check key informants interviews were employed. This study identifies the status of fish biodiversity, livelihoods strategies that fishers follow to maintain their livelihood and possible ways to enhance their capacity to improve their living condition and as well as governance and management. Both sampling and field survey was conducted simultaneously among the local fishing communities, operator of fishing boats and fish markets and landing centres situated in the adjacent area of these two wetlands. The sampling of the fish taxa was conducted on the quarterly basis among the fishermen during fishing operations and in the nearby fish market and landing centre situated in the adjacent area of the wetlands to get real scenario about the species composition and diversity of the taxa. The taxa were then identified based on expert knowledge sharing, secondary document consultation according to Froese and Pauly (2017)[16], Siddiqui et al. (2007)[17], Rahman (2005)[18] and IUCN (2000)[19]. Identification of the taxa was fine-tuned by cross-checking with the Catalogue of Life 2017 Annual Checklist (Roskov et al. 2017)[20] and IUCN Red List of Threatened Species (Version 2017 -1, IUCN 2017)[21] with the IUCN global status and trends of each available taxa.

Questionnaire interviews

Exploratory interviews (a total of 90 interviews where 45 in each study sites) were conducted in two

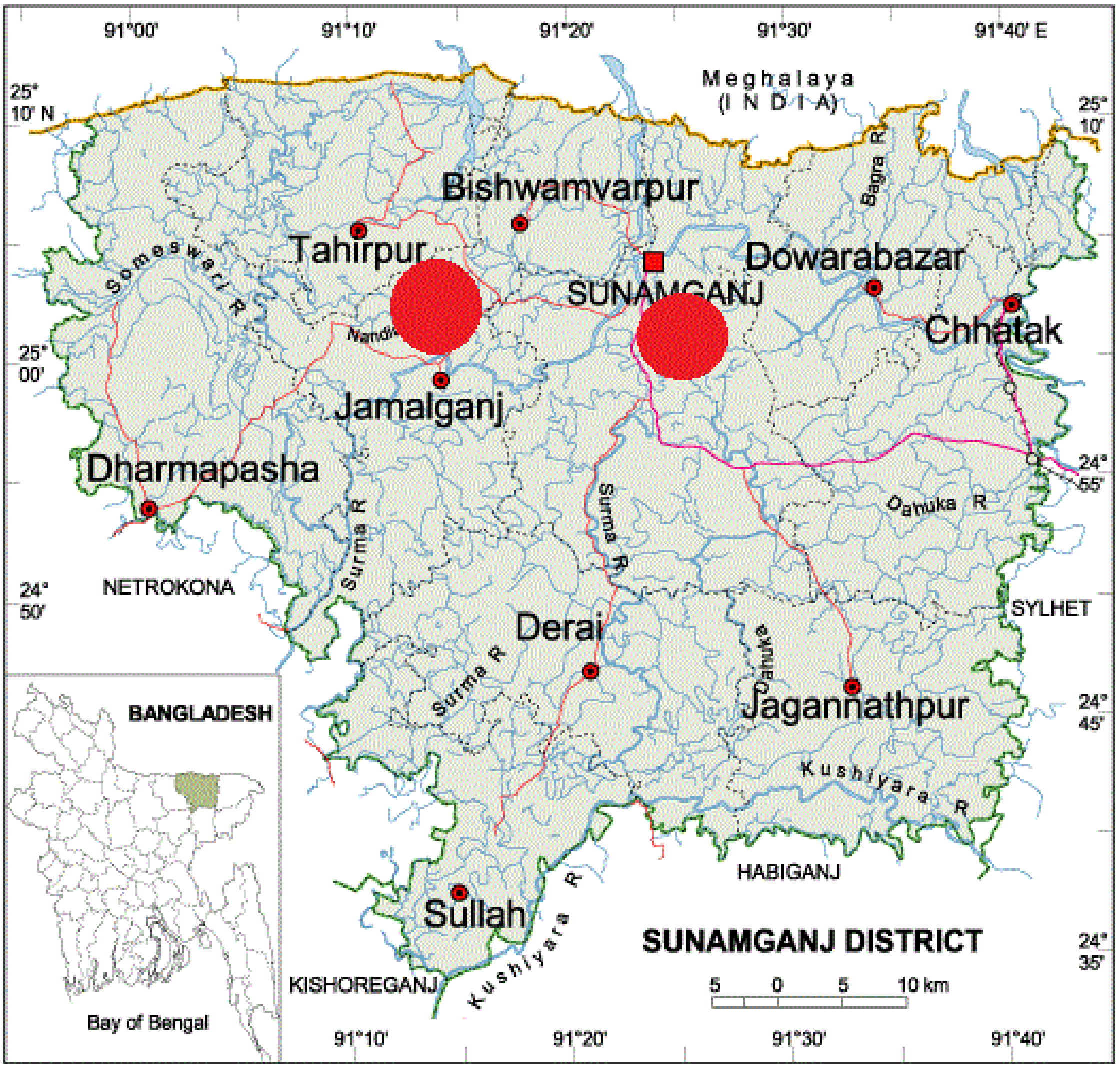

Fig. 1 — Location of the study areas in north-eastern Bangladesh

areas to collect the necessary information. Fishers, community people were interviewed on the boat, bank of the *beel*, fishers' houses, fish markets, paddy field and where participants could sit and feel comfortable. The interviews took approximately one hour, focused on the present status of fisheries resources, status of very available fishes, available fishes and less available fishes, monthly income, fishing time, types of gear, and mesh size of gears, catching rate and constraints of fishing.

Data analysis

Collected data from questionnaire interviews were entered and analyzed into a database system with using the programs: Microsoft Excel (MS Excel) and *PRIMER 5* (Plymouth Routines in Multivariate Ecological Research). The value of Shannon-Wiener index (H'), species richness was measured by Margalef index (d), evenness was measured by Pielou's index (J') and dominance was measured by Simpson index (c) that were calculated by using the following formula[22]:

Shannon-Weiner diversity index (H'): $H' = \sum [Pi \times Ln(Pi)]$

where, $Pi = ni/N$

ni = No. of individuals of a species

N = Total number of individuals

Margalef species richness (d): $d = (S-1)/\log(N)$

where, S = Total species

N = Total individuals.

Pielou's evenness index (J'): $(J') = \frac{H(S)}{H(\max)}$

where, H (s) = The Shannon-Wiener information function.

H (max.) = The theoretical maximum value for H(s) if all species in the sample were equally abundant.

Simpson dominance index (c): $c = \sum_{i=1}^{s}\left(\frac{ni}{N}\right)^2$

whereni = Number of individuals in the 'each' species

N = Total number of individuals

S = Total number of species

Results and Discussion

Species abundance and catch composition

In this study, more than 53 % of the total catch comprised of Cypriniformes, followed by Siluriformes (15 %), Perciformes (14 %), Channiformes (7 %), Clupeiformes (4 %) while the remaining 7 % included other fish, prawn, crab and mollusk (Fig. 2). During 2003 Paik and Chakrabortyn[23] recorded that among all the fish species, 44% were cypriniformes followed by Channiformes, Siluriformes and Perciformes[23]. Among the 43 species from semi-closed Tawa reservoir 62 % was cypriniformes followed by Siluriformes, Perciformes and Channiformes which also supported the findings of this present study[24].

Bangladesh has an important wetland ecosystem having global significance with approximately 289 indigenous freshwater species but the biodiversity of different waters are decreasing day by day[3,25]. Though natural wetlands of Bangladesh are rich in freshwater fishery species diversity and *haors* are considered as major mother fishery. However, lower count of different species and getting only 75 finfish might be associated with the limited study area coverage, short and periodic sampling effort mostly during (post-monsoon and winter) rather continuous year-round monitoring to the study sites. The number of available species composition could be more if continuous sampling effort is employed throughout the year and extend the coverage of study sites which was beyond the capacity of the present study. Nevertheless, the results of a number of studies were more or less convincing with the present findings. Rahman and Hasan (1992) recorded 54 species of fish from the Kaptai lake[26]. A similar number of fish species were recorded 43, 58 and 60 fish species from different types of oxbow lake[27]. Total 40 species of fish including exotic species was observed in Chanda *beel* and Salda*beel* [28]. Comparatively number of fish species were found in the *haor*s of Sunmaganj (north-eastern region) than other regions of the country[19]. In the present study, a total of 75 species of fishes were recorded which was much better than the biodiversity of the wetland of other region. *Barbodessarana, Puntius chola, Puntius sophore, Labeorohtia, Cirrhinuscirrhosus, Labeocalbasu, Labeogonius, Cirrhinusreba, Tetraodon cutcutia, Xenentodoncancila, Aplocheil uspanchax, Channastriatus, Channa punctatus, Chanda nama, Chanda beculis*, were dominant species of the *haor*s. Although a number of crustaceans e.g. prawns, crabs, and molluscans e.g. snail, mussels faunas were also available however, that were not included for counting as their attribute were beyond the scope of the present study. Omitting the exotic species (mostly escaped from aquaculture

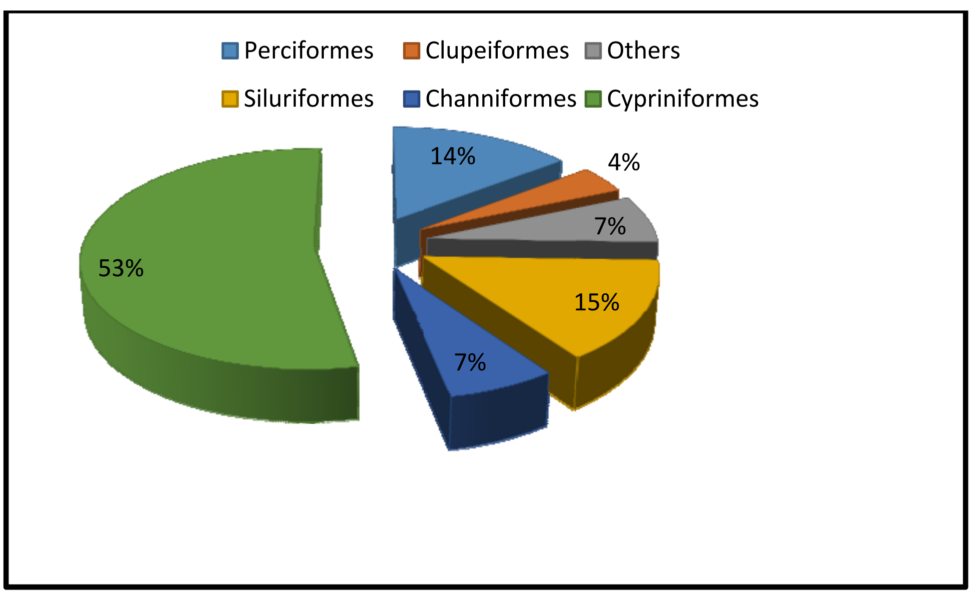

Fig. 2 — Contribution of different groups of fish to total catches of the studied natural wetlands of north easten Bangladesh

farms during floodings to the natural wetlands), crustaceans and molluscans faunas may be the main cause of this lower count of the taxa in the present study. Relatively less number of fish species than this investigation was found in Chenderon reservoir, India[29]. In the Narmada river, 57 fish species were reported which was also less than the findings of the present study. About 100 species are commonly found in Chinese reservoir that was higher than the findings of this study[30]. Nevertheless, findings of the present studies were more or less convincing with the results of Chowdhury and Iqubal (2007)[31], Rahman et al. (2013)[32] and Pandit et al. (2015)[6] and Sultana et al. (2017) [33]. A total of 46 taxa were recorded by Rahman et al. (2010)[34] in Katar *Beel* of Mymensing district, Bangladesh whereas comparatively higher numbers were noted in Sunamganj district explicitly 56 species in Soma nadi *Jalmohal*[6] and 71 taxa in the wetlands of Chhatak[33].

Conservation status of fishery species

Although the biodiversity of both studied *haors* was very rich. Nevertheless, according to the IUCN conservation status of fish species 56 % were not threatened, 16 % were vulnerable, 15 % were endangered, 10 % were critically endangered (Fig. 3). Among the 75 species, 42 species were not threatened, 12 species were vulnerable, 11 species were endangered, 8 species were critically endangered, 1 species was near to threatened according to IUCN (2000). Apart from these, the global status of most of the species was designated as Least Concern (LC) with global trends as unknown or decreasing (Table 1) that called for further research-based conservation necessities for the fishery species of the studied *haors*. This study findings were more or less convincing when compared with the findings of Iqbal et al. (2015)[35] who recorded 83 fishery species where 49.40 % were threatened (more precisely with vulnerable (14.46 %), endangered (21.69 %), and critically endangered (13.25 %) species in the Hakaluki*haor*, the largest haor in Bangladesh situated in Moulvibazar district.

Dominancy status of fishery taxa

From Tanguarhaor, a total of 69 species were recorded, among them, 31 species were not threatened, 8 species were endangered, 5 species were critically endangered, 5 species were vulnerable, 1 species was near to threatened (Table 1). A total of 56 species were found in Dekhar*haor* where 31 species were not threatened, 8 species were endangered, 8 species were critically endangered and 9 species were vulnerable (Table 1). Minnows were the most abundant group of fishes in the catches of *beels* of Mymensingh and Sylhet regions and *Puntius* spp.

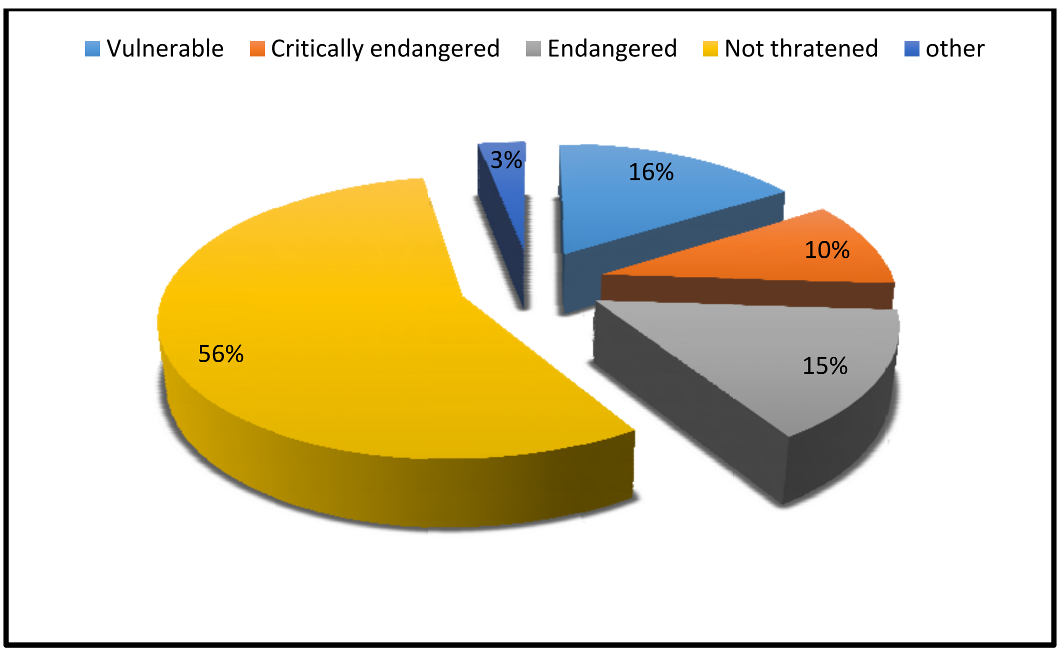

Fig. 3 — Conservation status of fish species according to IUCN, Bangladesh (2000) in the studied natural wetlands of north easten Bangladesh

Table 1 — List of different fishery taxa with their order, scientific identity, local or vernacular Bengali and common English name, IUCN status and trends, availability and (%) of individual species in two study sites explicitly UttorSreepur in Tanguar*Haor*(TH) and Dakkhingaon in Dekhar*hoar*s (DH)

Sl. No.	Order	Scientific identity of the taxonwith the author	Vernacular or local Bengaliname	Common English name	Availability of taxa		Taxa (%) individual		IUCN Status in BD[1]	IUCN global Status[2]	IUCN global trends[2]
					TH	DH	TH	DH			
1.	Anguilliformes	*Anguilla bengalensis* (Gray, 1831)	Bamos	Indian mottled eel	√	√	1.20	1.90	VU	NT	Unknown
2.	Cypriniformes	*Salmostomaphulo*(Hamilton, 1822)	Fulchela	Flying barb	√	√	3.24	3.50	NT	LC	Unknown
3.	Cypriniformes	*Esomusdanrica* (Hamilton, 1822)	Darkina	Flying barb	√	√	3.50	2.40	EN	LC	Stable
4.	Cypriniformes	*Rasborarasbora* (Hamilton, 1822)	Darkina	Flying barb	√	-	2.70	-	EN	LC	Unknown
5.	Cypriniformes	*Chela labuca* (Hamilton, 1822)	Labuca	Hatchet fish	-	√	-	1.80	VU	NE	-
6.	Cypriniformes	*Psilorhynchussucatio* (Hamilton, 1822)	Titari	River stone carp	√	√	1.20	0.40	NT	LC	Stable
7.	Cypriniformes	*Bengalaelanga* (Hamilton, 1822*)*	*Sephatia*	Bengala barb	√	√	0.57	0.37	NT	NE	-
8.	Cypriniformes	*Bariliusbendelisis* (Hamilton, 1807)	Joia	Hamilton's barila	√	-	1.14	-	EN	LC	Stable
9.	Cypriniformes	*Danio rerio* (Hamilton, 1822)	Anju	Zebra danio	-	√	-	0.40	NT	LC	Decreasing
10.	Cypriniformes	*Osteobramacotio* (Hamilton, 1822)	Dhela	Cotio	√	√	2.40	1.14	EN	LC	Unknown
11.	Cypriniformes	*Systomussarana* (Hamilton, 1822)	Sarpunti	Olive barb	-	√	-	0.30	CR	LC	Unknown
12.	Cypriniformes	*Puntius chola* (Hamilton, 1822)	Chalapunti	Chola barb	√	√	3.50	1.75	NT	LC	Unknown
13.	Cypriniformes	*Pethiaguganio* (Hamilton, 1822)	Molapunti	Glass-barb	√	√	3.40	3.0	NT	LC	Unknown
14.	Cypriniformes	*Puntius conchonius* (Hamilton, 1822)	Kanchanpunti	Rosy barb	√	√	3.20	3.20	NT	LC	Unknown
15.	Cypriniformes	*Puntius ticto* (Hamilton, 1822)	Tit punti	Ticto barb	√	√	2.70	0.50	VU	LC	Unknown
16.	Cypriniformes	*Puntius sophore* (Hamilton, 1822)	Jatpunti	Pool barb	√	√	3.24	3.24	NT	LC	Unknown
17.	Cypriniformes	*Puntius terio* (Hamilton, 1822)	Teri punti	One spot barb	-	√	-	0.40	NT	LC	Unknown
18.	Cypriniformes	*Oreichthyscosuatis* (Hamilton, 1822)	Kosuati	Sortfinner barb	√	-	1.20	-	NT	LC	Unknown
19.	Cypriniformes	*Garra* gotyla (Gray, 1830)	Gharpoia	Sucker head, Gotyla	√	√	1.70	0.37	NT	LC	Unknown
20.	Cypriniformes	*Acanthocobitiszonalternans* (Blyth, 1860)	Bilturi	River loaches	√	-	0.43	-	NT	LC	Unknown
21.	Cypriniformes	*Schisturacorica* (Hamilton, 1822)	Koikra	Stone loach	√	√	0.45	0.57	NT	LC	Unknown
22.	Cypriniformes	*Schisturascaturigina (*McClelland, 1839)	Dari	Stone loach	√	-	1.30	-	NT	LC	Unknown
23.	Cypriniformes	*Schisturabeavani* (Gunther, 1868)	Shavonkhokra	Greek loach	√	√	1.32	0.40	NT	LC	Unknown
24.	Cypriniformes	*Somileptesgongota* (Hamilton, 1822)	Poia	Gongota loach	√	√	1.70	0.37	NT	LC	Unknown
25.	Cypriniformes	*Botiadario* (Hamilton, 1822)	Rani	Stripped loach	√	-	0.45	-	EN	LC	Unknown
26.	Cypriniformes	*Lepidocephalusguntea* (Hamilton, 1822)	Gutum	Guntea loach	-	√	3.70	2.20	NT	LC	Stable
27.	Cypriniformes	*Labeorohita* (Hamilton, 1822)	Rui	Rohu	√	√	3.50	3.30	NT	LC	Decreasing
28.	Cypriniformes	*Catlacatla* (Hamilton, 1822)	Catla	Catla	√	√	1.80	1.70	NT	LC	Decreasing
29.	Cypriniformes	*Cirrhinuscirrhosus* (Bloch, 1795)	Mrigal	Mrigal carp	√	√	2.50	3.20	NT	VU	Decreasing
30.	Cypriniformes	*Labeocalbasu* (Hamilton, 1822)	Kala Baush	Karnataka labeo	√	√	3.50	3.40	EN	LC	Unknown

(*contd.*)

Table 1 — List of different fishery taxa with their order, scientific identity, local or vernacular Bengali and common English name, IUCN status and trends, availability and (%) of individual species in two study sites explicitly Uttar Sreepur in Tanguar*Haor*(TH) and Dakkhingaon in Dekhar*hoar*s (DH) (*contd.)*

Sl. No.	Order	Scientific identity of the taxonwith the author	Vernacular or local Bengaliname	Common English name	Availability of taxa	Taxa (%) individual	IUCN Status in BD[1]	IUCN global Status[2]	IUCN global trends[2]	Sl. No.	Order
31.	Cypriniformes	*Labeobata* (Hamilton, 1822)	Bata	Bata labeo	√	√	2.67	1.90	EN	LC	Unknown
32.	Cypriniformes	*Chaguniuschagunio* (Hamilton, 1822)	Jarua	Minor carp	√	√	3.33	2.70	NT	LC	Unknown
33.	Cypriniformes	*Labeoangra* (Hamilton, 1822)	Angrot/kharas	Angralabeo	√	√	2.70	3.0	NT	LC	Stable
34.	Cypriniformes	*Labeogonius* (Hamilton, 1822)	Ghainna	Kuria labeo	√	√	1.60	3.10	EN	LC	Unknown
35.	Cypriniformes	*Labeonandina* (Hamilton, 1822)	Nandina	Nandi labeo	√	√	0.40	2.30	CR	NT	Decreasing
36.	Cypriniformes	*Labeopangusia* (Hamilton, 1822)	Ghoramach	Pangusialabeo	-	√	-	0.40	CR	NT	Decreasing
37.	Cypriniformes	*Cirrhinusreba* (Hamilton, 1822)	Bhagna	Reba carp	√	√	1.60	3.0	VU	LC	Stable
38.	Cypriniformes	*Amblypharyngodonmola* (Hamilton, 1822)	Mola	Molacarplet	√	√	3.50	3.30	NT	LC	Stable
39.	Cypriniformes	*Danio devario* (Hamilton, 1822)	Debari	Bengal danio	√	-	0.30	-	NT	NE	-
40.	Cypriniformes	Raiamas bola (Hamilton, 1822)	Bhol	Trout barb, Indian trout	√	√	1.40	0.37	EN	LC	Unknown
41.	Siluriformes	*Eutropiichthysvacha* (Hamilton, 1822)	Bacha, Bhacha	Schilbi	√	√	1.20	0.57	CR	LC	Decreasing
42.	Siluriformes	*Clariasbatrachus* (Linnaeus, 1758)	Magur	Walking catfish	√	√	2.12	3.0	NT	LC	Unknown
43.	Siluriformes	*Wallago attu* (Bloch & Schneider, 1801)	Boal	Freshwater shark	√	√	1.20	1.30	NT	NT	Decreasing
44.	Siluriformes	*Heteropneustesfossilis* (Bloch, 1794)	Shing	Stinging catfish	√	√	1.20	1.30	NT	LC	Stable
45.	Siluriformes	*Pangasiuspangasius* (Hamilton, 1822)	Pangus	Pangas catfish	√	√	0.40	0.50	CR	LC	Decreasing
46.	Siluriformes	*Ailiacoila* (Hamilton, 1822)	Kajuli	Gangetic catfish	√	√	0.43	0.50	NT	NT	Decreasing
47.	Siluriformes	*Rita rita* (Hamilton, 1822)	Rita	Rita, Striped catfish	√	√	0.57	0.57	CR	LC	Decreasing
48.	Siluriformes	*Sperataaor* (Hamilton, 1822)	Ayre	Long-whiskered catfish	√	√	3.70	1.70	VU	LC	Stable
49.	Siluriformes	*Mystuscavasius* (Hamilton, 1822)	GolshaTengra	Gangetic mystus	√	√	3.33	1.30	VU	LC	Decreasing
50.	Siluriformes	*Mystusbleekeri* (Day, 1877)	Tengra	Catfish	√	√	2.70	2.38	NT	LC	Unknown
51.	Siluriformes	*Mystustengara*(Hamilton, 1822)	BazariTengra	Stripped dwarf catfish	√	-	1.20	-	NT	NE	-
52.	Siluriformes	*Clupisomagarua* (Hamilton, 1822)	Garua	River catfish	√	√	0.30	1.75	CR	LC	Decreasing
53.	Tetraodontifomes	*Tetraodon cutcutia* (Hamilton, 1822)	Potka	Ocellated pufferfish	√	√	3.30	2.87	NT	LC	Unknown
54.	Beloniformes	*Xenentodoncancila* (Hamilton, 1822)	Kakila	Freshwater garfish	√	√	3.33	2.90	NT	LC	Unknown
55.	Beloniformes	*Hyporhamphuslimbatus* (Valenciennes, 1847)	Ekthota	Congaturi Halfbeak	√	√	3.30	2.40	NT	LC	Stable
56.	Cyprinodontiformes	*Aplocheiluspanchax* (Hamilton, 1822)	Kanpona	Blue Panchax	√	√	3.36	3.20	NT	LC	Unknown
57.	Channiformes	*Channastriatus* (Bloch, 1793)	Shol	Snakehead murrel	√	√	3.40	1.72	NT	NE	-
58.	Channiformes	*Channamarulius* (Hamilton, 1822)	Gajar	Giant snakehead	√	√	2.70	2.50	EN	LC	Unknown
59.	Channiformes	*Channabarca* (Hamilton, 1822)	Piplashol	Barca snakehead	√	√	0.57	0.30	CR	DD	Unknown
60.	Channiformes	*Channa punctatus* (Bloch, 1793)	Taki	Spotted snakehead	√	√	3.30	2.40	EN	NE	-

(*contd.*)

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61.	Channiformes	*Channaorientalis* (Bloch & Schneider, 1801)	Raga/Cheng	Walking snakehead	√	-	1.70	-	VU	NE	-
62.	Clupiformes	*Chitalachitala* (Hamilton, 1822)	Chital	Clown knifefish	√	√	1.75	0.37	EN	NT	Decreasing
63.	Clupiformes	*Notopterusnotopterus* (Pallas, 1769)	Foli	Bronze featherback	√	√	0.57	0.57	VU	LC	Unknown
64.	Clupiformes	*Coricasoborna* (Hamilton, 1822)	Kachki	The Ganges River Sprat	√	-	1.40	-	NT	LC	Unknown
65.	Perciformes	*Macrognathusaculeatus* (Bloch, 1786)	Tara baim	Lesser spiny eel	√	√	2.70	1.86	VU	NE	-
66.	Perciformes	*Mastacembelusarmatus* (Lacepede, 1800)	Baim	Spiny eel	√	-	0.57	-	EN	LC	Unknown
67.	Perciformes	*Mastacembeluspancalus* (Hamilton, 1822)	Guchibaim	Spiny eel	-	√	-	1.70	VU	NE	-
68.	Perciformes	*Colisafasciatu*(Bloch & Schneider, 1801)	Khalisha	Banded gourami	√	√	2.40	1.72	NT	NE	-
69.	Perciformes	*Colisalalia*(Hamilton, 1822)	Lalkholisha	Dwarf gourami	√	-	0.37	-	NT	NE	-
70.	Perciformes	*Anabas testudineus* (Bloch, 1792)	Koi	Climbing perch	√	√	1.70	1.50	NT	DD	Unknown
71.	Perciformes	*Chanda nama* Hamilton, 1822	NamaChanda	Elongate Glass Perchlet	√	-	3.20	-	VU	LC	Decreasing
72.	Perciformes	*Parambassislala* (Hamilton, 1822)	LalChanda	Highfin Glassy Perchlet	√	√	0.57	0.37	-	NT	Decreasing
73.	Perciformes	*Parambassisranga* (Hamilton, 1822)	Rangachanda	Indian glassy fish	√	-	2.50	-	VU	LC	Stable
74.	Perciformes	*Chanda beculis* (Hamilton, 1822)	Chanda	Himalayan glassy perchlet	-	√	-	3.40	NT	NE	-
75.	Perciformes	*Glossogobiusgiuris* (Hamilton, 1822)	Bele	Freshwater goby	√	√	1.75	1.40	NT	LC	Unknown

[1]IUCN Threatened status categories in Bangladesh (BD) according to (IUCN, 2000),Not threatened (NO), Near threatened (NT), Vulnerable (VU),Endangered (EN), Critically Endangered (CR). [2]Global IUCN status of the species and global population trends representing here are according to the IUCN Red List of Threatened Species (IUCN 2017). Categories of IUCN status: Data Deficient (DD), Not Threatened (NO), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR). Not evaluated (NE): Taxon has not yet been assessed for the IUCN Red List.

were the most dominant genera[28]. It was also considered as rich species in Dighali*beel*, India[36]. On spot catch result from the fishermen indicated that *haors* were comprised with 28.23 % minnows followed by 22.66 % carps and *Puntius sophore*was found to be most abundant species (24.33 %) among minnows that is similar to the previous study (Table 2). Saha and Hossain (2002) also found that Boro*beel* was dominated by minnows (25.97 %) in his research during 2002 that also agreed with this study[37].

Fishing gears

A total of 14 different fishing gear belonging 8 categories like *koiajal, current jal, patijal, berjal, dubajal, tuna or tana jal, kunijal, thelajal, moiyajal, chip or borshi, teta, koach, anta, chai* were found in both Tanguar and Dekhar*hoar* (Table 3). Nineteen (19) different fishing gears under nine (9) categories were found under operation in the Pagla river of Kishoregonj, like gill net, seine net, lift net, set bag net, push net, hook and line, long line, spears and traps where current jal, *patajal*, *moiyajal* and dharma jal were found to be operated in every month, and rest of the nets were seasonally used[38]. Nonetheless, findings also more or less coincided with the results of Katar *Beel* (13 fishing gear of 3 types) of Mymensing district, Bangladesh[34].

Status of species diversity

The value of H' is dependent on sample size, on species richness and evenness[39-41]. Shannon-Wiener diversity index (H') ranged from 3.72 (Dekhar*haor*) to 3.74 (Tanguar*haor*) which indicated that the Tanguar*haor* is more diversified than the Dekhar*haor.*A more or less similar value of H' was found in the range of 1.017534 – 4.6494 from the Bakkhali river, Cox's Bazar[39].

Pielou's evenness index (J') was recorded as 0.891 from, Madras, India[42]. J' was found to be 0.708295

Table 2 — On spot catch composition of different groups of fishery taxaby using different fishing netsby the fishermen of the Tanguar and Dekhar*hoar*s (compilation of the catches of both *haors*)[1]

Sl. No.	Group	Scientific identity fo the taxon	The average number of catch				Caught individual of each species (no)	Catch weight of each taxon (kg)	Caught individuals of each group (no)	Caught individuals of each group (%)[1]	Catch weight of each group (kg)	Catch weight of each group (%)[2]
			Gill net	Seine net	Cast net	Push net						
1.	Carps	*Labeocalbasu*	-	2	1	-	4	2.05				
2.	Carps	*Labeorohita*	-	2	1	-	4	2.00				
3.	Carps	*Labeogonius*	-	3	1	-	2	0.59				
4.	Carps	*Labeobata*	-	1	1	-	1	0.45				
5.	Carps	*Catlacatla*	-	2	2	-	4	1.00				
6.	Carps	*Labeoangra*	-	2	1	-	3	1.02				
7.	Carps	*Cirrhinuscirrhosus*	1	2	1	-	3	1.05	21	2.05	8.17	22.59
8.	Minnows	*Puntius guganio*	6	25	-	5	36	0.71				
9.	Minnows	*Puntius conchonius*	-	20	8	-	28	0.98				
10.	Minnows	*Amblypharyngodonmol a*	-	150	30	10	190	2.58				
11.	Minnows	*Osteobramacotio*	-	45	15	6	64	0.79				
12.	Minnows	*Puntius sophore*	22	200	20	13	255	3.10				
13.	Minnows	*Puntius ticto*	-	42	20	9	69	1.29				
14.	Minnows	*Esomusdanricus*	-	103	18	4	123	1.24				
15.	Minnows	*Xenentodoncancila*	-	-	-	3	3	0.05	771	75.15	11	30.41
16.	Snakehead	*Channa punctatus*	6	17	-	2	25	1.91				
17.	Snakehead	*Channastriatus*	1	4	-	-	5	1.89				
18.	Snakehead	*Channaorientalis*	2	5	2	1	10	1.58				
19.	Snakehead	*Channamarulius*	2	4	-	-	5	1.88	45	4.39	7.30	20.18
20.	Catfish	*Mystuscavasius*	4	3	4	1	12	0.24				
21.	Catfish	*Mystusvittatus*	6	5	3	2	16	0.31				
22.	Catfish	*Mystustengara*	4	4	3	1	12	0.36				
23.	Catfish	*Pangasiuspangagisus*	-	3	1	-	4	0.12				
24.	Catfish	*Ailiacoila*	1	1	-	-	2	0.10				
25.	Catfish	*Rita rita*	-	6	-	-	6	0.53				
26.	Catfish	*Wallago attu*	-	2	-	-	2	0.80				
27.	Catfish	*Mystusaor*	-	4	-	-	4	1.19				
28.	Catfish	*Clupisomagarua*	-	1	-	-	1	0.20				
29.	Catfish	*Heteropneustesfossilis*	-	2	2	-	4	0.20				
30.	Catfish	*Clariasbatrachus*	-	2	-	-	2	0.15	65	6.34	4.20	11.61
31.	Eels	*Macrognathusaculeatu s*	-	2	3	2	7	0.30				
32.	Eels	*Mastacembelusarmatus*	-	4	3	2	9	0.56				
33.	Eels	*Mastacembeluspancalu s*	-	4	4	4	12	0.58	26	2.53	1.50	4.15
34.	Perches	*Chanda baculis*	-	2	1	3	6	0.02				
35.	Perches	*Chanda ranga*	2	4	1	3	10	0.08				
36.	Perches	*Chanda nama*	6	7	2	4	17	0.16				
37.	Perches	*Colisafasciatus*	5	10	5	4	24	0.33				
38.	Perches	*Tetradoncutcutia*	-	1	3	-	4	0.07	61	5.95	2.10	5.81
39.	Others	*Aplocheiluspanchax*	-	4	2	-	6	0.30				

(*contd.*)

Table 2 — On spot catch composition of different groups of fishery taxaby using different fishing netsby the fishermen of the Tanguar and Dekhar*hoar*s (compilation of the catches of both *haors*)[1]

Sl. No.	Group	Scientific identity fo the taxon	The average number of catch				Caught individual of each species (no)	Catch weight of each taxon (kg)	Caught individuals of each group (no)	Caught individuals of each group (%)[1]	Catch weight of each group (kg)	Catch weight of each group (%)[2]
			Gill net	Seine net	Cast net	Push net						
40.	Others	*Glossogobiusgiuris*	06	10	-	4	20	1.40				
41.	Others	*Lapidocephalusgun tea*	-	4	4	-	8	0.20	37	3.61	1.90	5.25
		Total							1026	100	36.17	100

[1]Only catch of gill, sein, cast and push netswere considered for the represented calculation. Though many of the species caught by dragnet, hook and line, spears and traps however,catch were exculded due to inconsistency in fishing mehods (e.g. bait, expertise/ skill, timing of operation) and catch compostion (large variationin size, weight, number of speciesper traps per operation etc.)and unintentsional error during recording of the data.Counting of the small specimens were done as: Number of small fish (N)= {Total catch weight of small fish (Wt)/ ((weight of subsample (Ws) × Number of individual of small fish in each subsample (Ns))}.[2]Caught individuals of each group (%)=Caught individuals of each group (no)×100/1026; [3]Catch weight of each group (%)=Catch weight of each group (kg)×100/36.17.

Table 3 — Different types of fishing gears used in the Tanguar and Dekhar*hoar*s of the north-eastern Bangladesh

No	Category/Gear type	Local name	Length (m)	Width (m)	Mesh size (cm)	Operating manpower
1.	Gillnet	Koiajal	50-65	1-1.5	0.5-1	1-3
		Current jal	105-110	1.2-1.5	1-1.5	1-3
		Patijal	80-90	1.5-2	2.5-4	1-3
2.	Seine net	Berjal	100-220	2.3	0-0.5	4-10
		Dubajal	100-150	25-35	0.5-0.8	4-10
		Tuna/tana jal	7-8	3.5-5	0.5-1.2	4-10
3.	Cast net	Kunijal	1.2-3.6	1-3	1-1.5	1
4.	Push net	Thelajal	3-5	2-3	0.5-1.2	1
5.	Dragnet	Moiyajal	5-7.5	4-4.5	0.3-0.4	1-3
6.	Hook andline	Chip/Borshi	-	-	-	1
7.	Spears	Teta	-	-	-	1
		Koach	-	-	-	1
8.	Traps	Anta	-	-	-	1-2
		Chai	-	-	-	1-2

from the Bakkhali muddy beach of Cox's Bazar[39]. In the present study, the highest mean evenness value (0.95) was observed in Tanguar*haor* while the lowest mean value (0.9) was observed in Dekhar*haor* which indicates that the fish species is more evenly distributed. Though Margalef species richness (d) index (Max) is dependent on sample size[40] however, the minimum Margalef richness index was observed in Dekhar*haor* (4.3), while the highest value was observed in Tanguar*haor*(4.6) depicted in figure 4. The value of d may deviate from actual diversity value to some extent because; it does not confound the evenness and species richness value properly[40]. The highest mean value of Simpson dominance index (c) was observed in Tanguar*haor* (0.027) while (0.025) was observed in Dekhar*haor* (Fig. 4).With exception of fishery species diversity indices values of evenness (0.66) and dominance indices (0.081), more or less similar findings were recorded by Iqbal et al. (2015) with the values of H' (2.53) and d (5.94) in the Hakaluki*haor*[35], the largest haor in Bangladesh situated in Moulvibazar district.

Nevertheless. the *haors* are rich in fish diversity but concerns arise about the long term sustainability of the fish biodiversity due to poor institutional and organizational support. Lack of alternating income generating activities induces overfishing, fishing during the breeding season, siltation, agricultural pollutants (pesticides, insecticides), conversion to agricultural lands and habitat destruction reduce the biodiversity (Fig. 5). Introduction of revenue based *Ijarah* of *Jalmohal* leasing system (since 1932) for major *beels*is one of the main threat for the biodiversity and fishing community. High dependenceon natural resources, lack of alternating income-generating activities and seasonal

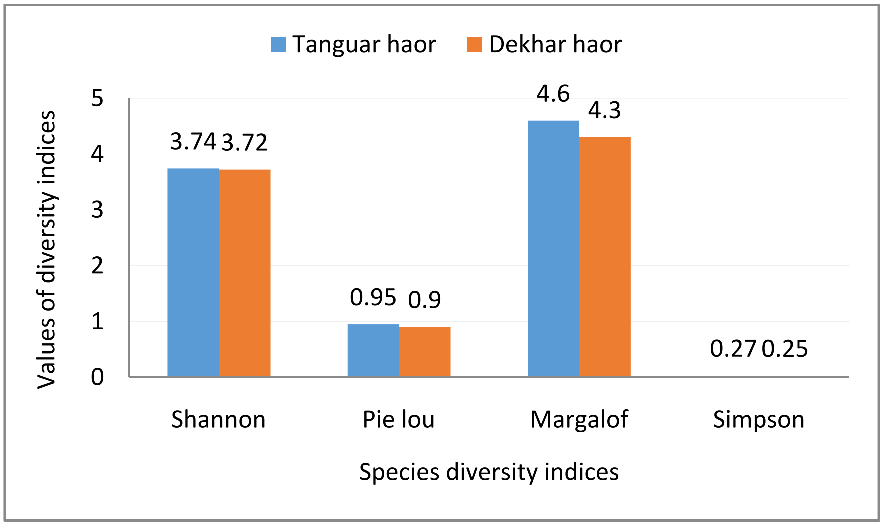

Fig. 4 — Comparison of the fishery species diversity indices explicitly Shannon-Weiner (*H'*), Pieloueveness (J'), Margalefrichness (d) and Simpson dominance (c)indices of the studied wetlands

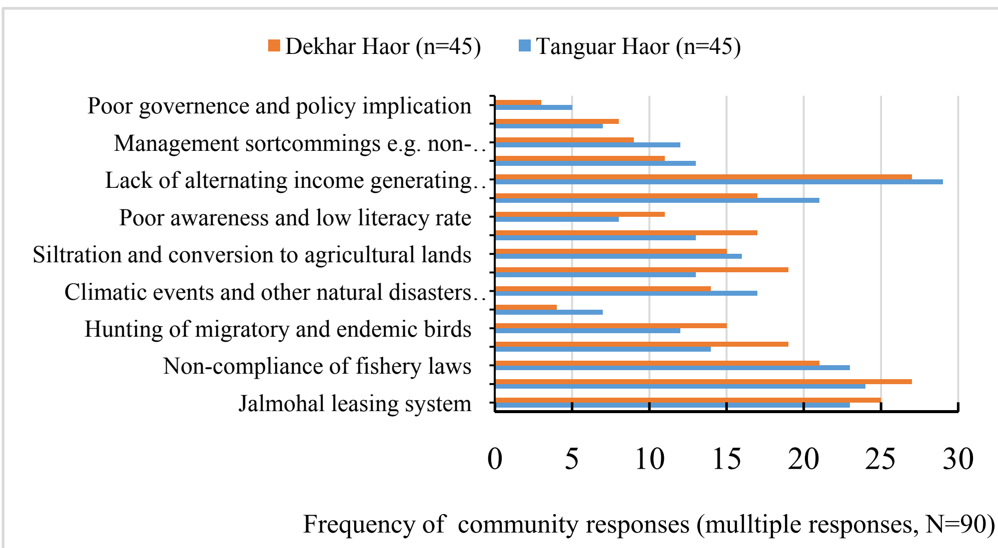

Fig. 5 — Identified threats and stressors based on community perception regarding the causes of aquatic biodiversity losses in the studied natural wetlands of north-eastern Bangladesh

unemployment with intense poverty induced overfishing[43-45], non-compliance of fishery laws and regulation e.g. fishing during breeding seasons, e.g. use of fine-meshed mono filamentous net, current jal, extreme fishing pressure, indiscriminate use of agricultural pollutants[45,46], conversion to agricultural lands, habitat destruction, irresponsible tourism practice, hunting of migratory and endemic birds, extreme climatic events and other natural disasters e.g. flash flood, heavy rain, drought, erosion, river bed siltation etc. are the focal causes for the loss of biodiversity[47]. These scenarios also aligned with the current management regime of natural wetlands in Sundarbans mangrove ecosystems in Bangladesh[48-50] as well as the management settings of greater *haor*basins of north-eastern Bangladesh including Tanguar*haor*[7].

Poor governance with top-down policy implication e.g. unplanned construction of dam, bridge, Flood Control Drainage (FCD) structures, inter conflict regarding ownerships, non-transparent socio-political representation of managerial roles among the different departments and administrative body of the Government of Bangladesh (GoB) i.e. Ministry of Land, Ministry of Environment & Forests, Department of Forest, Department of Environment, Department of Fisheries (DoF), Bangladesh Water Development Board, Local Government Engineering Department (LGED), legislative bindings of district public administration, poor linkages with lack of support along with existed non-synchronize collaborative efforts, make the scenario more complex. Moreover, political obstacles with the dominancy of influential and political misconduct, lack of intelligent and honest local leader and negligible community participation in the discussion and decision making; low literacy rate, poor health, hygiene and sanitation facilities, lack of effective rules for managing risks and conflict resolution with ever-increasing population pressure accelerated the risk towards sustainable management of these ecologically sensitive natural wetlands. It should be introduced to the local people as common property, also discussing its importance and community rights.

Conclusion

Hoar is an ecologically important wetland with high fish diversity, but it is a matter of concern that it is under severe threat of gradual depletion. Training and the motivational program should arrange to increase awareness among the resource users and improve their skill for sustainable use of natural resource and monitoring wildlife to prevent catch of fish during the breeding season. Community-based fisheries management can improve the situation with the help of different government organizations, NGOs, donor organization, research organization, other national and international organizations. For effective management of the studied wetlands, this study submits urgent and effective initiatives concerning conservation necessities while interventions like comprehensive stock assessment, the establishment of fish sanctuaries, combination of input and output control, comply with the Ecologically Critical Area (ECA) and RAMSAR guidelines are suggested. The findings of the present study could also be helpful to draw a guideline for planning and management of the studied *haors*as well as other ecologically sensitive wetlands in Bangladesh.

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