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FISH DIVERSITY IN THE ANDHARMANIK RIVER SANCTUARY IN BANGLADESH

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ABSTRACT

Loss of fish biodiversity, especially in the inland and coastal areas, is a major concern in sustainable fish production. Indiscriminate fish catch, climate change and many other anthropogenic activities synergistically affect fish biodiversity. To formulate a sustainable fish biodiversity conservation plan, fish biodiversity in the Andharmanik River, a 40-km-long Hilsa shad sanctuary in the southern part of Bangladesh, was assessed. The study was conducted to understand the status of fish species diversity through sampling in three sampling stations between December 2014 and November 2015. A total of 93 fish species were found belonging to 66 genera, 45 families and 14 orders. Perciformes (27.65%) was found to be the most dominant order, followed by Cypriniformes (20.21%), Siluriformes (21.28%) Clupeiformes (7.45%) Mastacembeliformes (4.26%) and Channiformes (4.26%). Out of the 93 fish species of the river, the percentage compositions of the vulnerable, endangered, critically endangered and not threatened were found to be 14%, 11%, 6% and 59%, respectively. Four population indices viz. Shannon-Wiener's diversity index (H), Simpson's dominance index (D), Simpson's index of diversity (1-D) and Margalef's index (d) were applied to demonstrate species diversity, richness and evenness of fish species in sampling areas, and the overall values of the indices were 2.70-3.51, 0.10-0.12, 0.88-0.90 and 7.84-8.19, respectively. The main threats to fish biodiversity were reviewed and the measures for fish biodiversity conservation of the river recommended. Indiscriminate fishing using biodiversity destructive gears, as well as losing hydrological and ecological connectivity with the surrounding habitats, were identified as major threats to biodiversity in the Andharmanik River. Effective sanctuary-based co-management, immediate actions for habitat enhancement to conserve and improve fish biodiversity in the river were recommended. Necessary steps to improve hydrological and ecological connectivity for habitat protection and elimination of all destructive fishing gears in order to conserve biodiversity in the Andharmanik River were also suggested.

Keywords:
Andharmanik River
Sanctuary
Fish diversity
Biodiversity index

How to Cite

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INTRODUCTION

Loss of biodiversity and food insecurity are two major concerns in the 21st century. In many inland and coastal areas this concern focuses sharply on the demise of fishery resources. Indiscriminate fish catch, climate change and many other anthropogenic activities synergistically affect fish biodiversity (Nagelkerken et al., 2017). Given the ever-growing demand of fish consumption for over 160 million people in Bangladesh, fish biodiversity and fisheries sustainability are identified as key concerns, but management solutions to address food security and biodiversity are few and far between.

Bangladesh is known as a riverine country because of the large number of rivers distributed across it (Banglapedia, 2012; Rahman, 2015; USAID, 2016). It has various biodiversity-rich inland bodies of water. About 800 rivers, including tributaries and distributaries, flow through the country, constituting a waterway of a total length of approximately 24,140 km, with massive potential for fish biodiversity (Banglapedia, 2012; Department of Fisheries (DoF), 2013). It has the third highest aquatic fish biodiversity in Asia, after China and India, with about 800 species in fresh, brackish and marine waters (Hussain and Mazid, 2001). Among these species, Bangladesh contains 260 freshwater fish species; minnows, catfish, eels, perch, gobies, clupeids, carps, snakeheads and prawns constitute the majority (DoF, 2009).

The Andharmanik River is one of five sanctuaries declared by the Government of Bangladesh where fishing is restricted for a certain period of time, especially to protect the juvenile Hilsa shad called 'Jatka'. The entire catchment of the 40-km-long Andharmanik River is an important Hilsa shad sanctuary in southern Bangladesh (Wahab and Golder, 2016).

The role of fisheries in the national economy has always been significant and has been the main source of animal protein, employment opportunities, food security, foreign income and socio-economic improvement (Siddiq et al., 2013; Ali et al., 2014a, 2014b, 2014c; Ali et al. 2015a, 2015b). This sector contributes 3.65% of the total GDP and 23.81% of agricultural GDP. More than 2% of export earnings come from this sector as well. About 60% of a person's daily animal protein intake is supplemented by fish. About 11% of the population is dependent directly and indirectly on fisheries for their livelihood (DoF, 2016). Southern Bangladesh is rich in fisheries resources. Among the 58 rivers in the Barisal Division in southern Bangladesh, the Andharmanik is predicted to be the future economic hub of the region (Banglapedia, 2012). The productivity and enrichment of a body of water is dependent on its biodiversity. The species diversity of a body of water is generally influenced by both human activity and natural calamity. The most impactful human activities include, but are not limited to, the construction of dams, bridges and roads, pollution and the use of different type of illegal gears. At the same time, natural causes that can affect fish biodiversity include flood, indiscriminate fluctuation of temperature and salinity, other natural disasters, phytoplankton bloom and siltation. It is very important to conserve the biodiversity of a body of water, and it is not too late to take initiatives for the conservation of biodiversity of coastal rivers and maintain optimum utilization level (Fu et al., 2003; Eros and Scmera, 2010; Rao et al., 2014, Ali et al., 2015a).

Though a number of studies on the biodiversity of fishes have been conducted around the world (Goswami et al., 2012; Rixon et al., 2005; Shinde et al., 2009; William et al., 2010), such studies have been more limited in Bangladesh (Rahman et al., 2012; Hossain et al., 2012; Siddiq et al., 2013; Ali et al., 2014c; Hossain et al., 2014; Ali et al., 2015a, 2015b; Hanif et al., 2015). Except for the studies by Hossain et al. (2014) and Hanif et al. (2015), most research efforts in Bangladesh lack analyses of diversity indices, which many studies have used in different parts of the world (Penczak et al., 1994; Nyanti et al., 2012). As the Andharmanik River is a vital river of the southern region of Bangladesh and a sanctuary of the most important fishery - the Hilsa, the study of biodiversity assessment and conservation is very important for the fisheries sector. The present article focuses on the assessment of fish biodiversity, reviews the main threats to fish biodiversity and provides recommendations for fish biodiversity conservation in the Andharmanik River, Bangladesh.

MATERIALS AND METHODS

Study area

The study was conducted in the Andharmanik River, located in Kalapara Upazila, Patuakhali district of southern Bangladesh (Fig. 1).

This 40-km-long coastal river is a confluence of freshwater, brackish water and marine waters. It is connected to another large coastal river, the Galachipa, on one end and joins the Bay of Bengal at the Kuakata beach point. Additionally, there are many freshwater canals that join the rivers. The water becomes nearly fresh in the rainy season, and in the dry season it transforms to estuarine and marine water (up to 16 ppt salinity). Therefore, fish species of all three habitats are available in the river depending on the seasons. To collect fish species specimens, the study area was divided into three sampling stations (Figure 1): Kalapara (S1, 21°55'35.65''N 90°08'21.70''E), Hajipur (S2, 21°54'06.37''N 90°06'58.88''E) and Alipur (S3, 21°52'22.68''N 90°05'52.97''E) areas of the river. The fish samples were periodically collected from these three sites starting from December 2014 to November 2015.

Fig 1. Map showing the Andharmanik River, indicating three sampling sites (S1- Kalapara, 21°55'34.65''N 90°08'21.70''E; S2- Hajipur, 21°54'06.37''N 90°06'58.88''E and S3- Alipur, 21°52'22.68''N 90°05'52.97''E of Kalapara Upazila, Patuakhali, Bangladesh)

Sampling

Fish samples were collected from the catch of fishermen in the Andharmanik River. A total of 15 seine net fishermen were chosen for data collection from the spots. Fish were usually caught by means of the traditional fishing gears such as seine net (Sutar jal), cast net (Jhaki jal), square lift net (Tar jal), conical trap (Dughair), fish angles (Borsi), monofilament fixed gill net (Current jal) and fish barrier (Thaga). Samples were also collected from fish-landing centres and fish markets. The specimens thus collected during the field visit were identified primarily in the field. Those which appeared difficult to identify were marked properly. All the identified and unidentified fish samples were preserved with a 10% formalin solution in plastic jars.

Primary data on the concerned species were collected from the fishermen, fish traders, local people and also from on the spot locations. Relevant data such as the local name of the collected fish samples, source, distribution and availability of the species were collected from the study sites. Secondary data was also collected from the District Fisheries Offices, Department of Fisheries (DoF), Statistical Yearbook of Bangladesh, etc. Along with these data, relevant published documents were also collected from various government agencies, autonomous bodies and NGOs. Research papers on the freshwater fish fauna of Bangladesh were also consulted in order to compile past data of abundance and availability for assessing biodiversity status.

Identification of the collected samples

The collected fish samples were identified by evaluating their morphometric and meristic characteristics, as well as the colour of the specimens, by referring to books such as Fish Base. The taxonomic guides were followed as described by Eschmeyer (2014) and Rahman (2005). Additionally, fish species were systematically classified based on Nelson's (2006) classification.

Data analysis

Species diversity was assessed using different indices viz. Shannon-Wiener diversity index (*H*), Simpson's dominance index (*D*), Simpson's index of diversity (*1-D*), Margalef's index (*d*) and the Evenness index (*E*) (Shannon, 1949; Shannon and Weaver, 1963; Margalef 1968; Ramos et al., 2006).

RESULTS

Fish species abundance

The river acts as an asylum for an immense number of aquatic organisms, fish in particular. The present study represented a total of 93 species of fishes belonging to 66 genera, 45 families and 14 orders. Scientific names, number of specimen under each of the species and International Union for Conservation of Nature (IUCN), as well as the Bangladeshi red list status, are presented in Table 1.

Table 1. Fish species abundance, distribution and conservation status in the Andharmanik River, southern Bangladesh

Scientific Name	Number of Species				Conservation Status	
	S1	S2	S3	Total	Bangladesh	Global
Congresox talabon (Cuvi-er, 1829)	120	80	58	258	NO	NA
Harpadon nehereus (Hamilton, 1822)	2531	1945	2456	6932	NO	NA
Anodontostoma chacunda (Hamilton, 1822)	385	391	389	1165	NO	NA
Tenualosa ilisha (Hamil-ton, 1822)	15078	11908	13876	40862	NA	NA
Tenualosa toli (Valenci-ennes, 1847)	1291	1626	1432	4349	NA	NA
Ilisha megaloptera (Swainson, 1839)	5311	4308	5325	14944	NO	NA
Setipinna phasa (Hamil-ton, 1822)	2185	2134	2356	6675	NO	LC
Coilia neglecta (White-head, 1967)	3434	3856	4534	11824	NO	NA
Setipinna taty (Valenci-ennes, 1848)	1138	1324	1435	3897	NO	NA
Amblypharyngodon mola (Hamilton, 1822)	1124	908	1376	3408	NO	LC
Amblypharyngodon mi-crolepis (Bleeker, 1853)	246	223	236	705	NO	LC
Chela cachius (Hamilton, 1822)	289	189	198	676	NO	LC
Esomous danricus (Hamil-ton, 1822)	405	384	678	1467	NO	LC
Labeo bata (Hamilton, 1822)	46	23	35	104	EN	LC
Labeo boga (Hamilton, 1822)	0	0	6	6	CR	LC
Puntius gonionotus (Bleeker, 1849)	0	0	2	2	EX	LC
Puntius ticto (Hamilton, 1822)	69	78	81	228	VU	LC
Pethia guganio (Hamilton, 1822)	53	64	84	201	NO	LC
Puntius sophore (Hamil-ton, 1822)	67	34	85	186	NO	LC
Puntius sarana (Hamilton, 1822)	9	2	4	15	CR	LC
Osteobrama cotio (Hamil-ton, 1822)	67	85	66	218	NO	LC
Pethia conchonius (Hamil-ton, 1822)	34	39	48	121	NO	LC
Salmophasia bacaila (Hamilton, 1822)	76	65	86	227	NO	LC
Acanthocobitis zonalter-nans (Blyth, 1860)	0	41	28	69	NA	LC
Botia dario (Hamilton, 1822)	0	1	4	5	EN	LC
Lepidocephalichthys gun-tea (Hamilton, 1822)	64	41	65	170	NO	LC
Lepidocephalichthys ir-rorata (Hora, 1921)	16	0	27	43	DD	LC
Channa marulius (Hamil-ton, 1822)	11	13	17	41	EN	LC
Channa orientalis (Bloch & Schneider, 1801)	14	13	18	45	VU	NA
Channa punctatus (Bloch, 1794)	19	23	29	71	NO	LC
Channa striatus (Bloch, 1794)	13	4	12	29	NO	LC
Chanda nama (Hamilton, 1822)	78	23	59	160	VU	LC
Chanda ranga (Hamilton, 1822)	19	22	36	77	VU	LC
Pseudoambassis lala (Hamilton, 1822)	31	43	48	122	NO	NT
Anabas testudineus (Bloch, 1792)	26	27	34	87	NO	DD
Trichogaster fasciata (Bloch & Schneider, 1801)	207	203	190	600	NO	LC
Nandus nandus (Hamil-ton, 1822)	56	43	49	148	VU	LC

Scientific Name	Number of Species				Conservation Status	
	S1	S2	S3	Total	Bangladesh	Global
Badis badis (Hamilton, 1822)	4	0	3	7	EN	LC
Drepane punctata (Lin-naeus, 1758)	204	192	182	578	NO	NA
Eleotris fusca (Forster, 1801)	57	52	43	152	NA	LC
Apocryptes bato (Hamil-ton, 1822)	504	459	608	1571	NO	NA
Glossogobius giuris (Ham-ilton, 1822)	407	430	389	1226	NO	LC
Taenoides anguillaris (Linnaeus, 1758)	309	334	323	966	NO	LC
Lates calcarifer (Bloch, 1790)	78	67	89	234	NA	NA
Lutjanus madras (Valen-ciennes, 1831)	19	16	14	49	NO	NA
Nemipterus japonicas (Bloch, 1791)	67	45	76	188	NO	NA
Polynemus paradiseus (Linnaeus, 1758)	34	0	33	67	NO	NA
Scatophagus argus (Lin-naeus, 1766)	2309	2298	2531	7138	NO	NA
Euthynnus affinis (Cantor, 1849)	29	0	18	47	NO	NA
Katsuwonus pelamis	37	28	31	96	NO	LC
Pampus chinensis *(Lin-naeus, 1758)*	67	58	66	191	NO	LC
Sillaginopsis panijus (Hamilton, 1822)	145	134	241	520	NO	NA
Acanthopagrus chinshira (Kume & Yoshino, 2008)	708	653	751	2112	NA	NA
Trichiurus mutica (Gray, 1831)	3497	4133	3765	11395	NO	NT
Panna microdon (Bleeker, 1849)	407	379	490	1276	NO	NA
Otolithoides pama (Hamil-ton, 1822)	7980	6754	8905	23639	NO	NA
Johnius coitor (Hamilton, 1822)	2398	2690	2467	7555	NO	NA
Arius gagora (Hamilton, 1822)	178	167	184	529	DD	NT
Sperata aor (Hamilton, 1822)	34	29	23	86	VU	LC
Mystus tengara (Hamilton, 1822)	30	58	57	145	VU	LC
Mystus gulia (Hamilton, 1822)	341	378	398	1117	NO	LC
Mystus vittatus (Bloch, 1794)	1423	1156	1287	3866	NO	LC
Rita rita (Hamilton, 1822)	0	1	5	6	CR	LC
Batasio batasio (Hamilton, 1822)	3	0	2	5	CR	LC
Hemibagrus menoda (Hamilton, 1822)	62	56	34	152	NO	LC
Clarias batrachus (Linne-aeus, 1758)	37	21	54	112	NO	LC
Plotosus canius (Hamil-ton, 1822)	14	7	9	30	VU	NA
Heteropneustes fossilis (Bloch, 1794)	32	24	13	69	NO	LC
Ailia coila (Hamilton, 1822)	27	14	11	52	VU	NT
Ailia punctata (Day, 1872)	127	76	113	316	VU	DD
Clupisoma garua (Hamil-ton, 1822)	3	0	4	7	CR	LC
Silonia silondia (Hamilton, 1822)	7	4	0	11	EN	LC
Wallago attu (Bloch & Schneider, 1801)	23	18	25	66	NO	NT
Ompok pabda (Hamilton, 1822)	5	3	3	11	EN	NT
Ompok bimaculatus (Bloch, 1794)	0	2	6	8	EN	NT

Scientific Name	Number of Species				Conservation Status	
	S1	S2	S3	Total	Bangladesh	Global
Bagarius bagarius (Hamil-ton, 1822)	0	0	3	3	CR	NT
Glyptothorax cavia (Ham-ilton, 1822)	11	9	0	20	NO	LC
Macrognathus aral (Bloch & Schneider, 1801)	28	19	9	56	VU	LC
Macrognathus pancalus (Hamilton, 1822)	49	64	58	171	NO	LC
Mastacembelus aculeatus (Cuvier, 1832)	67	87	76	230	NO	NA
Mastacembelus armatus (Lacepède, 1800)	3	2	5	10	EN	LC
Monopterus cuchia (Ham-ilton, 1822)	44	39	51	134	VU	LC
Tetraodon cutcutia (Ham-ilton, 1822)	56	47	38	141	NO	LC
Liza parsia (Hamilton, 1822)	13	15	14	42	NO	LC
Rhinomugil corsula	12	4	17	33	NO	LC
Notopterus chitala (Hamil-ton, 1822)	0	8	3	11	EN	NT
Notopterus notopterus (Pallas, 1769)	14	3	11	28	VU	LC
Xenentodon cancila (Ham-ilton, 1822)	24	21	19	64	NA	LC
Hyporhamphus limbatus (Valenciennes, 1847)	11	17	6	34	NO	LC
Brachirus pan (Hamilton, 1822)	23	21	25	69	NO	LC
Brachirus orientalis (Bloch & Schneider, 1801)	13	11	9	33	NO	NA
Cynoglossus arel (Bloch & Schneider, 1801)	71	49	67	187	NO	NA
Cynoglossus cynoglossus (Hamilton, 1822)	76	46	56	178	NO	NA

LC = Least Concern, NT = near Threatened, DD = Data Deficient, NO = Not Threatened, CR = Critically Endangered, EN = Endangered, EX= Extinct, VU= Vulnerable, NA = Not Assessed

Out of 14 orders, Perciformes was the most dominant order and contributed 27.65%, followed by Cypriniformes (20.21%), Siluriformes (21.28%), Clupeiformes (7.45%), Mastacembeliformes, (4.26%) and Channiformes (4.26%), whereas Anguilliformes, Aulopiformes, Tetradontiformes, Synbranchiformes were least dominant and constituted 1.06% each (Fig. 2).
Out of the 93 fish species, a maximum of 90 fish species were recorded at sampling station S3, followed by S1 and S2 areas where 87 and 86 fish species were found, respectively. The highest number of individuals (59,271) was recorded at S3 area, followed by S1 and S2 areas where 56,716 and 51,417 individuals were recorded, respectively. Compared to the other two stations, S3 station showed the highest species richness.
Among 93 fish species, 30 IUCN red-listed species were

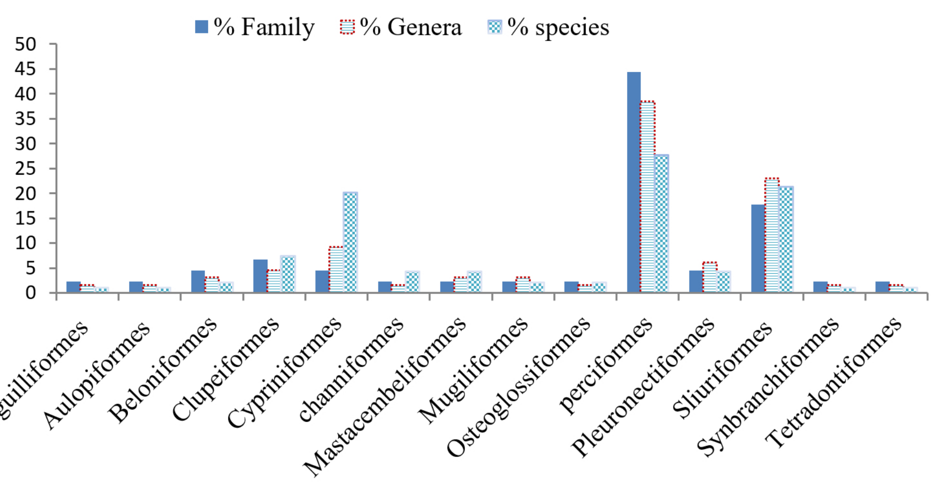

Fig 2. Percentage composition of families, genera and species under various orders of the fish species found in the Andharmanik River between December 2014 and November 2015

recorded from the studied areas, of which 6 species were found to be Critically Endangered, 10 species reported as Endangered, 13 species were found Vulnerable (IUCN, 2015). The percentage composition of the vulnerable, endangered, critically endangered and not threatened categories were found to be 14%, 11%, 6% and 59%, respectively (Fig. 3). Most of the threatened species were recorded at sampling site S3, followed by S1 and S2 (Fig. 4).

Biodiversity status

The values of Shannon-Wiener index (*H*), Simpson's dominance index (*D*), Simpson's index of diversity (*1-D*) and Margalef's index (*d*) of selected areas are shown in Fig. 5. From the studied area, the highest Shannon-Wiener index value (3.51) was observed in S2 area and the lowest value (2.70) was observed in S3 area. The highest value of Simpson's dominance index (0.12) was estimated from S1 area, followed by 0.11 in S3 and 0.10 in S2 areas, respectively. The highest Simpson's index of diversity (0.90) was recorded from S2 area and the lowest value (0.88) was recorded from S1 area. The highest Margalef's index value was 8.19 at S3 site, whereas the lowest value was 7.84 at S2 site. The highest Gibson's Evenness value (0.07) was found at the S3 location, and the lowest value (0.03) was recorded from the S2 station (Fig. 6).

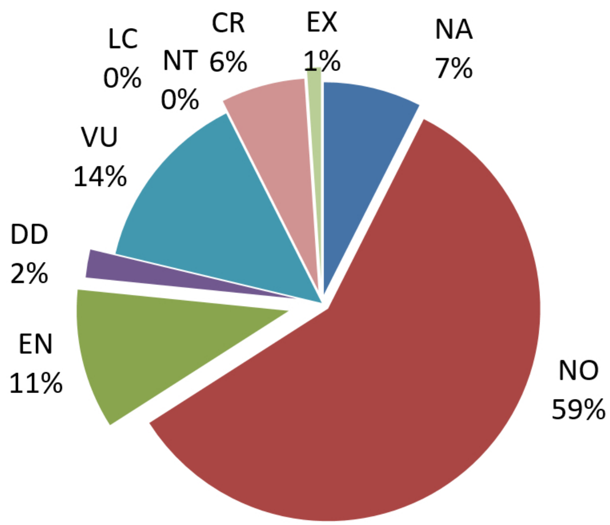

Fig 3. Conservation status of available fish species found in the Andharmanik River between December 2014 and November 2015 *(VU= Vulnerable, EN= Endangered, CR= Critically Endangered, EX= Extinct, DD= Data Deficient, NA= Not Assessed)*

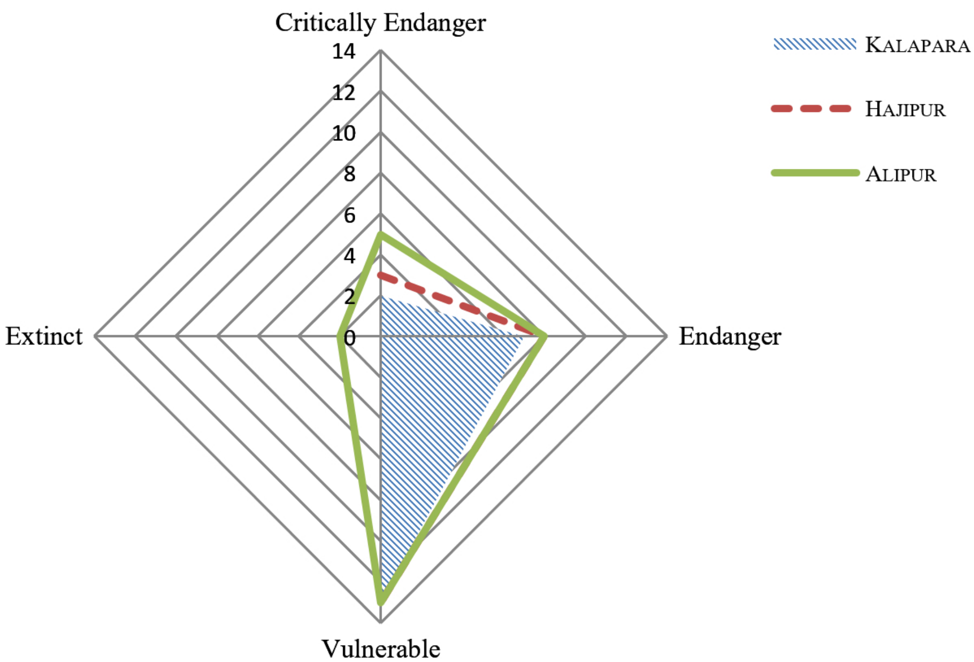

Fig 4. Number of species under different categories of threat as per IUCN 2013 found in the Andharmanik River between December 2014 and November 2015

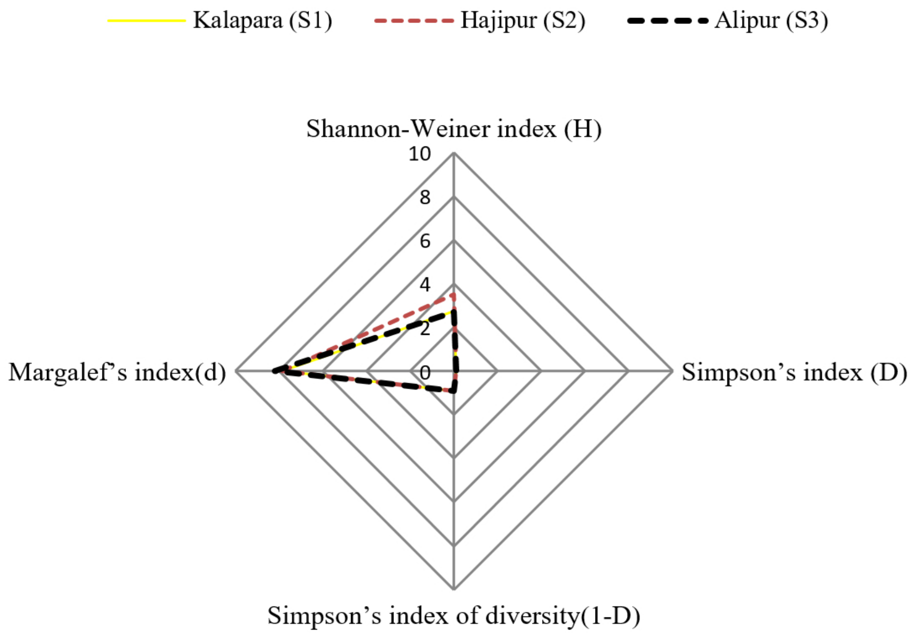

Fig 5. Different fisheries diversity indexes at sampling sites of the Andharmanik River

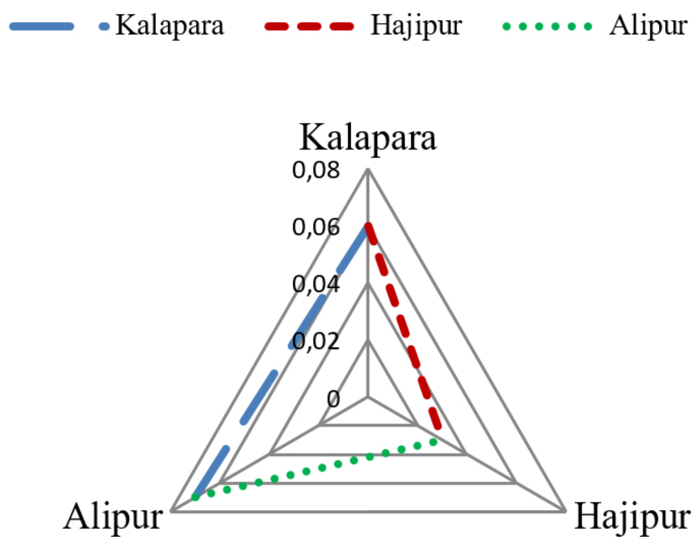

Fig 6. Evenness of fish diversity in different areas of the Andharmanik River

DISCUSSION

This study recorded 93 fish species from the Andharmanik River, representing 35.47% of the country's total fish species (Table 2). The species composition indicated a combination of marine, estuarine and freshwater species as the river is a confluence of freshwater, brackish-water and marine waters. In the rainy season, it becomes almost fresh and in the dry season it becomes estuarine to marine waters. Mohsin et al. (2014) studied the fish fauna of the Andharmanik River for a period of one year between March 2011 and February 2012 and found a total of 53 fish species under 28 families, indicating improvement in biodiversity in the last few years. In fact, due to some recent incentive-based management measures, the abundance of fish species has remarkably increased and fishers get more species in their catches (Islam et al., 2016; Islam et al., 2017).

However, the recorded fish species was much lower than some other rivers of Bangladesh (Bhuiyan et al., 2008; Rahman et al., 2012; Hossian et al., 2014). Hossian et al., 2014 found 128 species belonging to 12 orders and 35 families from the flood plain area of greater Noakhali areas, so the species richness was much higher than that of the present findings. Higher species richness was also reported by some other researchers. Hossain et al. (2007) reported 161 species collected by different types of nets from the Naaf River estuary. Nabi et al. (2011) identified finfish species from the following areas: Chittagong coast (48), Moheskhali Channel (76), Karnaphuli River

Table 2. Studies on the diversity of fish species in Bangladesh waters

Number of Species	Number of Family	Study Area	References
94	45	Patuakhali	Present study (2016)
57	28	Paira River; Patuakhali	Rahman et al. (2016)
53	26	Lohalia River, Patuakhali	Ali et al. (2015a)
98	48	Pirojpur, Bhola, Patuakhali and Barguna	Hanif et al. (2015)
53	28	Andharmanik River	Mohsin et al. (2014)
128	34	Noakhali	Hossain et al. (2014)
251	61	Bangladesh	Siddiqui et al. (2007)
265	55	Bangladesh	Rahman (2005)
133	32	Rajshahi	Bhuiyan et al. (1992)
106	34	Mymensingh and Tangail	Doha (1973)
71	25	Dhaka	Bhuiyan (1964)
63	23	The Choto Jamuna River	Galib, et al. (2013)

(46) estuary and Bakkhali estuary (45). Rahman (2005) assembled a list of 265 species of freshwater fishes belonging to 154 genera and 55 families from Bangladesh. Bhuiyan (1964) gave an account of 71 species of freshwater fishes belonging to 45 genera and 25 families which were collected from the Buriganga River, Dhaka. Considering the variable species richness in different rivers in Bangladesh, the Andharmanik River may be considered as moderately enriched with fish species diversity. The high percentage of fish species revealed by the order Perciformes may be due to the presence of a suitable environment and river bottom that the members of this family prefer. Among those fish species, Hilsa was recorded as the most dominant fish species from the study areas.

Variation in species composition was observed at different locations in the study area due to the different environmental characteristics of the aquatic ecosystem. Loss of fish biodiversity is considered as an alarming threat and its conservation is the only solution to this problem. Hossain (2010), Ali et al. (2014c), Ali et al. (2015a) and Hossain et al. (2015) reported the same causes of decreasing biodiversity from the Padma, Chitra, Lohalia and Tetulia Rivers, respectively. Although the rivers are gradually losing their biodiversity, they still support a large number (30) of threatened fish species of Bangladesh. Rahman et al. (2012) also reported similar results on the case of threatened fish from the Padma River.

Different anthropogenic activities are synergistically affecting and reducing the water flow and water depth of the study area. Human activities along with increased fishing pressure are gradually reducing fisheries diversity in the Andharmanik River. The S3 area represented the highest number of individuals that are subject to relatively low human interference and thus is under-fished and retains an optimum environmental condition. A biodiversity index refers to the characterisation of the species diversity of a sample or community by a single number (Magurran, 1988). Diversity is high when all species that make up a population community are equally abundant. Biodiversity index assessment was conducted for the analysis of fish diversity by comparing the estimated values within three areas of the Andharmanik River.

The concept of "species diversity" consists of two components: the number of species (or richness) and the distribution. The Shannon-Wiener diversity index represented the richness and proportion of each species, whereas the evenness and dominance indices showed the relative number of individuals in the sample and the fraction of common species, respectively (Hossain et al., 2014). The highest Shannon-Wiener index was observed from the S2 site and the lowest value was observed in the S3 area. Chowdhury et al. (2011) found the Shannon-Wiener values (H) ranging from 1.63 to 3.41 in the Naaf River estuary. The present study shows significantly lower H values due to less number of species. The H value usually ranges from 1.5 to 3.5 for ecological data and hardly exceeds 4.0, which is related with our calculated data. When the body of water maintains sustainable condition, then H values could be higher than 3.5. Alam et al. (2013) found H values to be from 3.29 to 3.49 in the Halda River; which was higher than that of the present study because the influence of the environmental factors on the Andharmanik River is higher than that of the Halda River. Simpson's dominance index (D) value usually ranges from 0 to 1, and the higher the range of values, the smaller the biodiversity represented.

Simpson's dominance index was higher in the S1 area and lower values were observed in stations S2 and S3. Considering the D value, the S2 area was found to be the most enriched with species diversity and the S1 site was found to be the least enriched with species diversity. The Simpson index of diversity ($1-D$) value also ranges between 0 and 1; the greater value indicates the greater sample diversity. The dominant Simpson's index of diversity value was observed in the S2 area and represented the highest species diversity. Evenness value ranges from 1 and 0; lowest Evenness value indicates a higher species diversity. Peak Evenness value was observed in the S3 area, whereas the least value was observed in the S2 area. Based on the Evenness value, S2 was considered a rich diversity zone. For breeding purposes, a number of fish species migrate to this river, and sampling station S2 was considered as the breeding zone of these species, which may be the reason behind the highest and lowest Evenness value in S3 and S2 areas, respectively.

The Margalef index value is used as an indicator to compare the sites; generally, and depending on the species number, it shows deviation (Vyas et al., 2012). The Margalef index (*d*) value ranged from 7.84-8.19, which is similar to Hanif et al. (2015) who recorded a high Margalef's index (*d*) of 8.67 and a low of 7.48. The maximum Margalef index value represents the maximum number of individuals in the studied area. Site S3 represented the highest Margalef's index value, which indicated the presence of significantly higher individuals than that of the S1 and S2 areas. Positive correlation between the Evenness index and Simpson's dominance index, and a negative relation between the Shannon–Weiner and Evenness indices were observed in this study, which was similar to the values reported by Vyas et al. (2012) and Alam et al. (2013).

The present study showed the species abundance in different parts of the studied area. From the analysis of the different biodiversity index, it can be concluded that sampling station S2 is comparatively rich in fish biodiversity. This might be due to the fishing prohibition in this zone. This river acts as a home to a large number of globally threatened species. Compared with other rivers on the basis of species abundance, the Andharmanik River can be considered an ecological hub of southern Bangladesh, and therefore its biodiversity needs to be conserved with due diligence.

Considering the rich fish biodiversity and threats to the biodiversity of the Andharmanik River, a sustainable biodiversity conservation action plan needs to be formulated and implemented. Improved hydrological and ecological connectivity and habitat protection, as well as elimination of all destructive fishing gears, are urgently needed to conserve biodiversity (Hossain, 2014; Rahman, 2015; Galib et al., 2018). Some destructive gears have been extremely harmful for juvenile fish, which include set-bag-nets (Behundi jal, Pona jal and Badha jal), beach seine nets (Ber jal, Moshari jal and Char Ghera jal) and small-meshed monofilament net (Current jal). Proper administrative initiatives would be essential to implement measures to control harmful gears, especially gears that target threatened species.

Recent Government initiatives target the incentive-based Hilsa fishery management, and some of these measures have already been effectively put into practice in Bangladesh (Islam et al., 2016; Islam et al., 2017). Some recent studies assessing the effectiveness of this incentive-based fishery management suggest improvements for reducing the capture of small-sized fish, as well as protecting the brood Hilsa during the peak spawning season (Mohammed and Wahab, 2013; Haldar and Ali, 2014; Dewhurst-Richman et al., 2016). An effective sanctuary-based co-management body should be introduced in the sanctuary to conserve resources in a sustainable manner. It is also essential to take immediate action for habitat enhancement of the Andharmanik River to conserve and improve fish biodiversity. Proper management strategies must be applied with an integrated approach among government, researchers, NGOs and donors that can conserve and improve the fisheries diversity of the Andharmanik River.

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RAZNOLIKOST RIBA U RIJECI ANDHARMANIK, BANGLADESH

SAŽETAK

Gubitak biološke raznolikosti riba, posebno u kopnenim i obalnim područjima, jedan je od glavnih interesa održive proizvodnje riba. Neselektivni ulov ribe, klimatske promjene i mnoge druge antropogene aktivnosti sinergijski utječu na biološku raznolikost riba. U svrhu formuliranja održivog plan očuvanja biološke raznolikosti riba u rijeci Andharmanik, procijenjena je biološka raznolikost riba u 40 km dugačkom svetištu Hilsa, u južnom dijelu Bangladeša. Studija je provedena kako bi se utvrdio status raznolikosti ribljih vrsta i to uzorkovanjem na tri lokacije od prosinca 2014. do studenog 2015. Ukupno je pronađeno 93 vrste riba koje pripadaju 66 rodova, 45 porodica i 14 redova. Grgečke (27,65%) su utvrđene kao dominantni red, a slijede ih šaranke (20,21%), somovi (21,28%), sleđevke (7,45%), bodljikave jegulje (4,26%) i zmijoglave ribe (4,26%). Od 93 vrste ribe u rijeci, utvrđeno je udio osjetljivih riba 14%,, ugroženih 11%, kritično ugroženih 6% te neugroženih riba 59%. Četiri indeksa populacije, Shannon-Wiener-ov indeks raznolikosti (H), Simpsonov indeks dominacije (D), Simpsonov indeks raznolikosti (1-D) i Margalef-ov indeks (d), primijenjeni su kako bi se prikazala raznolikost, bogatstvo i ujednačenost ribljih vrsta na uzorkovanim područjima. Ukupne vrijednosti navedenih indeksa bile su 2,70-3,51, 0,10-0,12, 0,88-0,90 tj. 7,84-8,19. Procijenjene su glavne prijetnje biološkoj raznolikosti riba i preporučene mjere za očuvanje biološke raznolikosti ribe. Kao glavne prijetnje biološkoj raznolikosti u rijeci Andharmanik identificiran je neselektivni ribolov, koji koristi štetne mehanizme po biološku raznolikost, kao i gubitak hidrološke i ekološke povezanosti s okolnim staništima. Preporučuju se efikasno zajedničko upravljanje te neposredne akcije za jačanje staništa radi očuvanja i poboljšanja biološke raznolikosti ribe na istraživanoj lokaciji. Predloženi su i potrebni koraci za poboljšanje hidrološke i ekološke povezanosti radi zaštite staništa i uklanjanja svih štetnih ribolovnih alata radi očuvanja biološke raznolikosti u rijeci Andharmanik.

Ključne riječi: Rijeka Andharmanik, utočište, raznolikost riba, indeks biološke raznolikosti.

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