

PHYSICOCHEMICAL VARIABLES AND FISH DIVERSITY IN HIZLA-MEHENDIGANJ HILSA SANCTUARY IN BANGLADESH

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Abstract

Out of six hilsa sanctuaries in Bangladesh, the newly established Hizla-Mehendiganj sanctuary is significantly lacking in data in terms of fish diversity and physicochemical properties. Therefore, the present study aims to assess water quality variables and fish biodiversity of the Hizla-Mehendiganj hilsa sanctuary. Water and fish samples were collected from different sites within and outside the sanctuary. Physicochemical variables such as dissolved oxygen (DO), temperature, pH, electrical conductivity (EC), total dissolved solids (TDS) and transparency were measured and fish biodiversity was estimated using different richness and evenness indices. The mean DO, temperature, pH and transparency inside the sanctuary were 5.6 ± 0.1 mg/l, $29.1 \pm 0.7^\circ\text{C}$, 8.3 ± 0.05 and 20.5 ± 2.3 cm, respectively which were nearly similar to the estimated values of those variables of the outside sanctuary. This study found a total of 374 individuals of 21 fish species under 6 orders and 14 families. According to the IUCN report 2015, this study found that 76.19, 9.52 and 4.76% of these species are listed in the Least Concern, Endangered and Vulnerable category, respectively. Within the sanctuary, 76 individuals of 13 fish species under 4 orders were recorded which was lower than the recorded number of total individuals and number of species outside the sanctuary sites. Within the sanctuary, estimated Shannon's, Simpson's, Margalef's and Buzas and Gibson's indices were 1.881, 0.214, 1.881 and 1.156, respectively which indicated comparatively moderate diversity. The highest biodiversity was found in the Ilisha river near Rukundi, outside the sampling site of the sanctuary. The findings of this study can be used for future biodiversity assessments, conservation and impact assessments of the Hizla-Mehendiganj hilsa sanctuary.

Introduction

The fisheries sector of Bangladesh has experienced the fastest growth in recent decades, resulting in self-sufficiency in fish production. The fisheries sector contributes about 3.52% in total gross domestic product (GDP), 1.39% in foreign exchange earnings and provides employment opportunities for more than 12% (170 million) of the country's entire population both directly and indirectly⁽¹⁾. In spite of huge fish production, the biodiversity of fish has decreased during the same period and more fish species are now

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threatened⁽²⁾. Overexploitation and degradation of habitats are alarming threats to fish biodiversity management in Bangladesh⁽³⁾. Faced with widespread over-fishing, many types of management actions have been undertaken in attempts to halt or reverse the trend of declining biodiversity⁽⁴⁾. Different types of spatial (e.g., sanctuary, marine protected area), temporal (e.g., marine fishing ban in May - July), input (e.g., fishing gear ban and net mesh size limit) and output (e.g. fish size and species ban) controls have been implemented to conserve biodiversity and ensure sustainable fish production.

Fish sanctuaries are especially important for decreasing targeted fishing effort on spawning aggregations and protecting critical habitats^(5,6). In Bangladesh, five hilsa sanctuaries have already been established to protect anadromous hilsa (*Tenualosa* sp.) from over-exploitation during its spawning season⁽⁷⁾. Recently, the Bangladesh government has declared an 83-kilometer stretch of the Meghna river from Hizla to Mehendiganj in Barisal district as its 6th Hilsa sanctuary, in order to protect the national fish stock⁽⁷⁾. However, in order to create sustainable management or conservation actions, as well as to assess their effectiveness, a thorough understanding of fish biodiversity and water quality is required⁽⁸⁾. Fish diversity and water quality assessment of previously established five hilsa sanctuaries have been well documented⁽⁹⁻¹³⁾. Flura *et al.*⁽⁹⁾ studied the physicochemical properties in sanctuary areas of the Meghna river, Bangladesh. Hossain *et al.*⁽¹⁰⁾ conducted a study to assess the physicochemical variables from the Shatnol to Chor Alexander. Kundu *et al.*⁽¹¹⁾ studied the community composition and biodiversity of previously established five hilsa sanctuaries; Hossain *et al.*⁽¹²⁾ studied fish biodiversity and habitat relationships in the estuarine area of the Meghna river as well as Mohsin *et al.*⁽¹³⁾ studied species composition in the Andharmanik river. But, the 6th hilsa sanctuary in Bangladesh is highly data-deficient in terms of fish biodiversity assessment and water quality monitoring. Besides, the lack of baseline data (except for landings data) before the establishment of 6th sanctuary restricts the comparative assessment of the sanctuary's impact on fish biodiversity and communities. Therefore, the objectives of this present study were to assess the physicochemical variables of water and fish biodiversity in the newly established Hizla-Mehendiganj hilsa sanctuary in Bangladesh. The findings of this study will help to establish proper management of this sanctuary. The findings can also serve as a baseline for assessing the impacts of anthropogenic processes such as pollution, fisheries management and climate change.

Materials and Methods

Study area: In this study, primary data like water quality variables and fish samples were collected from within and outside sampling sites of the newly established Hizla-Mehendiganj hilsa sanctuary in Bangladesh. Samples were collected from three sites within the sanctuary (site 1: Gazariya river near Lalkharabad, site 2 and 3: Meghna river near Moulovirhat and near Char Killa, respectively) and three sites outside the sanctuary

(site 4: Meghna river near Ulania, site 5: Ilisha river near Rukundi and site 6: Meghna river near Thandarbar) (Fig. 1).

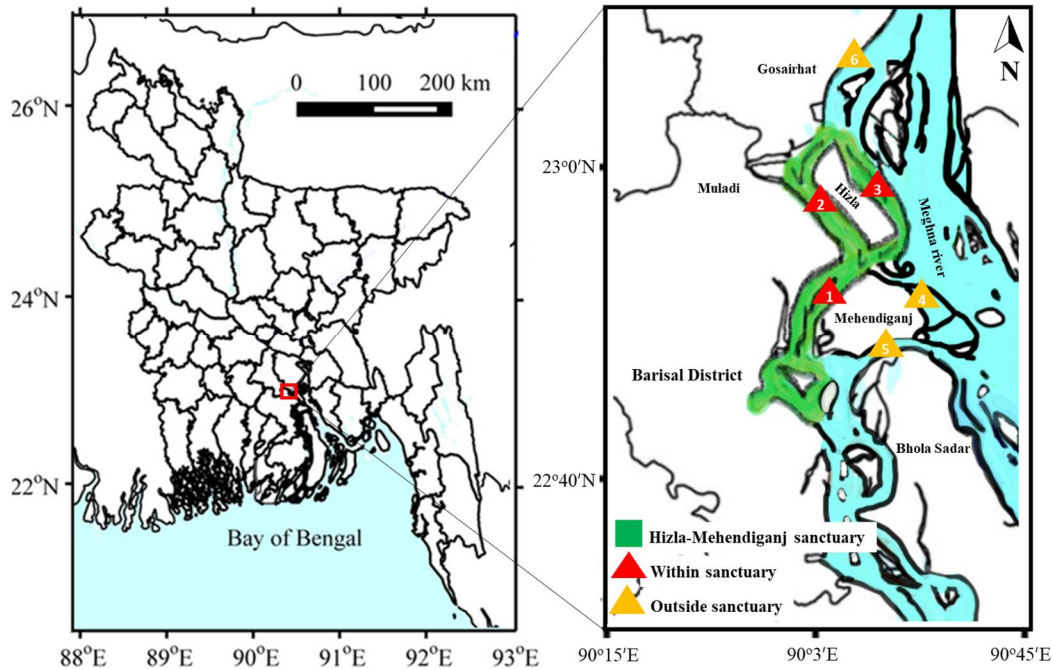


Fig.1. Sampling sites of the Hizla-Mehendiganj Hilsa sanctuary in Mehendiganj and Hizla Upazila, Barisal district and Gosairhat Upazila, Shariatpur district. The red triangle 1 (Lalkharabad), 2 (Moulvirhat) and 3 (Char Killa) represent the sampling sites within the Hizla-Mehendiganj hilsa sanctuary; orange triangle 4 (Ulania), 5 (Rukundi) and 6 (Thandarbar) represent sampling sites outside Hizla-Mehendiganj hilsa sanctuary.

Sample collection and identification: Physicochemical variables of waters such as DO, pH, EC, TDS, temperature and transparency were measured in this study. DO was measured on spot by Hanna DO-5510 instrument and pH, EC, TDS and temperature were measured by HI9811-5 instrument. A Secchi disk was used to measure the transparency of the water in each site. Fish samples were collected from the sampling sites using different fishing gear such as current jal, bata jal, sutar jal and ber jal which are most abundant and very commonly used for fishing in the areas. Though all gear was not found in each sampling site. Fish species were identified at the species level on spot based on both morphometric and meristic characteristics using the standard methods followed by Shafi and Quddus⁽¹⁴⁾, and Rahman⁽¹⁵⁾. If it is not possible to identify on spot, then the fish samples were preserved for later identification at 'Fish population dynamics, ecology and climate change laboratory' of the Department of Fisheries, University of Dhaka. To keep record of each species, photographs were taken. All

individuals were assessed carefully and recorded for biodiversity analysis. The fish threatened status was evaluated following the IUCN's procedure 2015⁽¹⁶⁾.

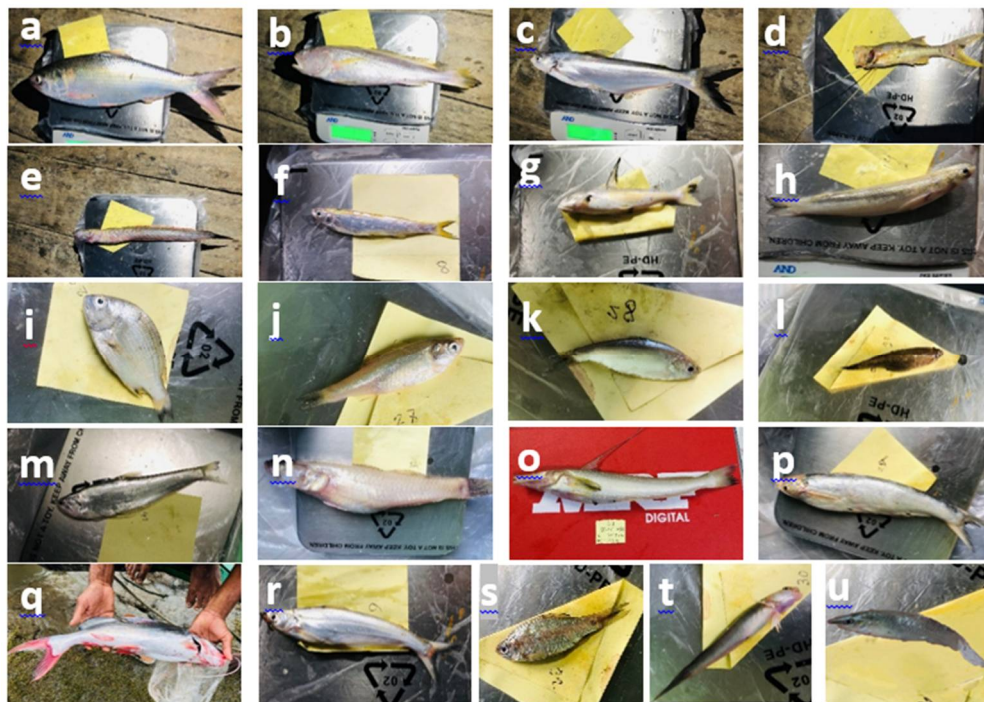


Fig. 2. List of fish species within and outside the Hizla-Mehendiganj hilsa sanctuary. a = *Tenuulosa ilisha*, b = *Otolithoides pama*, c = *Silonia silondia*, d = *Polynemus paradiseus*, e = *Pseudapocryptes elongates*, f = *Salmostoma phulo*, g = *Gagata gagata*, h = *Rhinomugil corsula*, i = *Acanthopagrus latus*, j = *Amblypharyngodon mola*, k = *Gudusia chapra*, l = *Butis butis*, m = *Setipinna taty*, n = *Glossogobius giuri*, o = *Sillaginopsis panijus*, p = *Clupisoma garua*, q = *Pangasius pangasius*, r = *Eutropiichthys vacha*, s = *Puntius chola*, t = *Apocryptes bato* and u = *Apocheilus panchax*.

Data analysis: Descriptive statistics like mean and standard deviation were calculated for physicochemical variables of water using MS Excel (version 2010). Species heterogeneity or species diversity of fish community was assessed using different species diversity indices such as Shannon-Weiner's index [$H = \sum_{i=1}^S P_i * \log P_i$]⁽¹⁷⁾ where S is the total number of species and P_i is the relative cover of i^{th} species; Simpson's index [$D = \sum n(n-1)/N(N-1)$]⁽¹⁸⁾, where n is the total number of fish of a particular species and N is the total number of fish of all species; Margalef's index [$d = (S/1) = \log(N)$]⁽¹⁹⁾, where S is the total species number and N is the total number of individuals in the sample; and Buzas and Gibson's index [$E = eH/S$]⁽²⁰⁾, where H is the Shannon diversity value and S is the total species number. Combined indices were also calculated for inside and outside the sanctuary.

Results and Discussion

This study assessed physicochemical variables of water and fish biodiversity of the newly formed Hizla-Mehendiganj hilsa sanctuary.

Physicochemical variables: This study found that mean DO, temperature, pH, EC, TDS, and transparency were 5.6 ± 0.1 mg/l, $29.1 \pm 0.7^\circ\text{C}$, 8.3 ± 0.05 , 126.7 ± 4.7 $\mu\text{S/cm}$, 50 mg/l and 20.5 ± 2.3 cm, respectively within different sampling sites of the sanctuary (Table 1). In contrast, mean DO, temperature, pH, and transparency were 5.4 ± 0.08 mg/l, $29.2 \pm 0.5^\circ\text{C}$, 8.2 ± 0.3 and 16.8 ± 2.7 cm, respectively in different sampling sites outside the sanctuary. However, the reported values of all physicochemical variables in this study remained within the DOE standard limit⁽²¹⁾. This study found nearly similar values of physicochemical variables of water in different sampling sites within and outside the sanctuary except for the EC and TDS. The EC and TDS values were higher in the Meghna river near Ulania than in other sites which might have occurred because of both anthropogenic and natural activities like fishing, navigations, water currents, tidal influences, etc. Moreover, this study found a strong positive correlation (correlation coefficient, $r = 0.99$) between TDS and EC (i.e. EC values increased with increasing TDS values) in all the sampling sites which is in line with the findings of Essien-Ibok *et al.*⁽²²⁾ and Alam *et al.*⁽²³⁾. In contrast, a negative correlation ($r = -0.10$) was found between TDS and transparency. The recorded DO values of this study were more or less similar to the reported value of other studies in the Meghna river^(9,10). These recorded values of this study also coincided with the results of the study by Sharif⁽²⁴⁾.

Table 1. Physicochemical variables of water within and outside sampling sites of the Hizla-Mehendiganj hilsa sanctuary.

Site name	Waterbody	Value of water variables					
		DO (mg/l)	Temp ($^\circ\text{C}$)	pH	EC ($\mu\text{S/cm}$)	TDS (mg/l)	Transparency (cm)
Hizla- Mehendiganj: Inside sanctuary	Gazariya river, near Lalkharabad	5.6	29	8.2	120	50	17.5
	Meghna river, near Moulovirhat	5.8	28.4	8.3	130	50	23
	Meghna river, near Char Killa	5.5	30	8.3	130	50	21
Mean		5.6\pm0.1	29.1\pm0.7	8.3\pm0.05	126.7\pm4.7	50	20.5\pm2.3
Hizla- Mehendiganj: Outside sanctuary	Meghna river, near Ulania	5.5	28.8	7.8	220	100	18
	Ilisha river, near Rukundi	5.4	28.9	8.3	110	40	19.3
	Meghna river, near Thandarbazar	5.3	29.9	8.4	120	50	13
Mean		5.4\pm0.08	29.2\pm0.5	8.2\pm0.3	150\pm49.6	63.3\pm26.2	16.8\pm2.7

Table 2. List of recorded fish species including order, family and IUCN status.

Sampling sites	Waterbody	Gear name	Order	Family	Scientific name	Common name	Total number of individuals	IUCN status (2015)
Hizla-Mehendiganj: Inside sanctuary	Gozariya river, near Lalkharabad	Current jal	Clupeiformes	Clupeidae	<i>Temalosa ilisha</i>	Hilsa shad	2	LC
			Siluriformes	Schilbeidae	<i>Silonia silondia</i>	Silond catfish	1	LC
	Bata jal		Perciformes	Sciaenidae	<i>Otolithoides pama</i>	Pama croaker	2	LC
				Polynemidae	<i>Polynemus paradiscus</i>	Paradise threadfin	1	LC
				Gobiidae	<i>Pseudapocryptes elongates</i>	Lanceolate goby	4	LC
				Mugilidae	<i>Rhinomugil corsula</i>	Corsula	23	LC
	Sutar jal		Clupeiformes	Clupeidae	<i>Gudusia chapra</i>	Indian river shad	4	VU
			No fish was caught	Engraulidae	<i>Scipinna taty</i>	Scaly hairfin anchovy	2	LC
			Ber jal	Absent				
	Subtotal			4	7	8		39
Meghna river, near Moulvirhat	Current jal		Clupeiformes	Clupeidae	<i>Temalosa ilisha</i>	Hilsa shad	7	LC
			Perciformes	Sciaenidae	<i>Otolithoides pama</i>	Pama croaker	2	LC
	Ber jal		Siluriformes	Schilbeidae	<i>Clupisoma garua</i>	Garua bacha	1	EN
				Pangasidae	<i>Pangasius pangasius</i>	Yellowtail catfish	1	EN
	Sutar jal		Absent	Sisoridae	<i>Gagata gagata</i>	Gangetic gagata	1	LC
			Absent					
		Bata jal	Absent					
Subtotal			3	5	5		12	

(Table contd.,)

Sampling sites	Waterbody	Gear name	Order	Family	Scientific name	Common name	Total number of individuals	IUCN status (2015)
	Meghna river, near Char Killa	Current jal	Clupeiformes	Clupeidae	<i>Tenualosa ilisha</i>	Hilsa shad	17	LC
			Perciformes	Sciaenidae	<i>Otolithoides pama</i>	Pama croaker	2	LC
				Sillaginidae	<i>Sillaginopsis panijus</i>	Flathead sillago and gangetic sillag	1	LC
			Siluriformes	Sisoridae	<i>Gagata gagata</i>	Gangetic gagata	1	LC
				Schilbeidae	<i>Silonia silondia</i>	Silond catfish	2	LC
					<i>Clupisoma garua</i>	Garua bacha	1	EN
					<i>Eutropiichthys vacha</i>	Bacha	1	LC
		Ber jal	Absent					
		Sutar jal	Absent					
		Bata jal	Absent					
	Subtotal		3	5	7		25	
Total							76	
Hizla-Mehendiga nj: Outside sanctuary	Meghna river, near Uliania	Ber jal	Cypriniformes	Cyprinidae	<i>Salmostoma phulo</i>	Finescale razorbelly minnow	3	NT
							1	LC
		Sutar jal	Mugiliformes	Mugilidae	<i>Rhinomugil corsula</i>	Corsula	7	LC
		Current jal	Clupeiformes	Clupeidae	<i>Tenualosa ilisha</i>	Hilsa shad	8	LC
		Bata jal	Clupeiformes	Clupeidae	<i>Tenualosa ilisha</i>	Hilsa shad		
			Absent					
	Subtotal		3	3	3		19	

(Table contd.)

Sampling sites	Waterbody	Gear name	Order	Family	Scientific name	Common name	Total number of individuals	IUCN status (2015)	
Ilisha river, near Rukundi		Ber jal	Clupeiformes	Clupeidae	<i>Gudusia chapra</i>	Indian river shad	4	VU	
			Cypriniformes	Cyprinidae	<i>Amblypharyngodon mola</i>	Mola carplet	4	LC	
					<i>Salmostoma phulo</i>	Finescale razorbelly minnow	25	NT	
					<i>Puntius chola</i>	Chola barb	6	LC	
					<i>Aplocheilichthys panchax</i>	Blue panchax	4	LC	
Bata jal					<i>Rhinomugil corsula</i>	Corsula	52	LC	
					<i>Acanthopogonius latius</i>	Yellowfin seabream	1	-	
					<i>Apocryptes bato</i>	Goby	16	LC	
					<i>Glossogobius giuris</i>	Fresh water goby	101	LC	
					<i>Butis butis</i>	Crimson-tipped gudgeon	1	LC	
Bata jal			Siluriformes	Schilbeidae	<i>Silonia silonia</i>	Silond catfish	4	LC	
			Clupeiformes	Clupeidae	<i>Tenulosa ilisha</i>	Hilsa shad	1	LC	
			Cypriniformes	Cyprinidae	<i>Salmostoma phulo</i>	Finescale razorbelly minnow	4	NT	
			Mugiliformes	Mugilidae	<i>Rhinomugil corsula</i>	Corsula	26	LC	
			Perciformes	Sciaenidae	<i>Otolithoides pama</i>	Pama croaker	5	LC	
				Polynemidae	<i>Polynemus paradiseus</i>	Paradise threadfin	6	LC	
			Siluriformes	Schilbeidae	<i>Silonia silonia</i>	Silond catfish	1	LC	
				Sisoridae	<i>Gagata gagata</i>	Gangetic gagata	1	LC	

(Table contd.)

Sampling sites	Waterbody	Gear name	Order	Family	Scientific name	Common name	Total number of individuals	IUCN status (2015)
		Sutar jal	Clupeiformes	Clupeidae	<i>Tenualosa ilisha</i>	Hilsa shad	1	LC
		Current jal	Clupeiformes	Clupeidae	<i>Tenualosa ilisha</i>	Hilsa shad	1	LC
			Mugiliformes	Mugilidae	<i>Rhinomugil corsula</i>	Corsula	1	LC
			Perciformes	Sciaenidae	<i>Otolithoides pama</i>	Pama croaker	2	LC
				Polynemidae	<i>Polynemus paradiseus</i>	Paradise threadfin	1	LC
			Siluriformes	Schilbeidae	<i>Silonia silonia</i>	Silond catfish	1	LC
					<i>Clupisoma garua</i>	Garua bacha	1	EN
				Sisoridae	<i>Gagata gagata</i>	Gangetic gagata	2	LC
			6	11	16		272	
	Meghan river, near Thandar bazar	Current jal	Clupeiformes	Clupeidae	<i>Tenualosa ilisha</i>	Hilsa shad	7	LC
		Ber jal	Absent					
		Sutar jal	Absent					
		Bata jal	Absent					
		Subtotal	1	1	1		7	
Total							298	
Grand total			6	14	21		374	

Fish biodiversity: This study found a total of 374 individuals of 21 fish species under 6 orders and 14 families. Within the sanctuary, 76 individuals of 13 fish species under 4 orders were recorded which was lower than the recorded values outside the sanctuary sites (Table 2). In this study, a maximum of 212 individuals of 16 different fish species under 6 orders were reported in outside sanctuary sites at Ilisha river near Rukundi. The availability of more fishing gear in Rukundi might be the reason for having more fish individuals there. The recorded fish species in this study were lower than the 53 species documented by Hossain *et al.*⁽¹⁰⁾ in the Meghna river estuary. Another study reported a total of 107 species under 13 orders and 36 families in the 16 sampling stations of the Meghna river⁽²⁵⁾ which is almost three times higher than the recorded number of species in the present study due to the lower number of sampling sites than the reported study. Only 16 species were documented by Mondal *et al.*⁽²⁶⁾ in the Meghna river at Ramgoti Upazila, which is lower than the present study. Mia *et al.*⁽²⁷⁾ recorded 20 species from the Meghna river at Ashugonj Upazila which is closer to the present findings.

This study found that 76.19% of all recorded species were in the Least Concern category as per IUCN (2015) (Table 3). Two endangered fish species of *Clupisoma garua* and *Pangasius pangasius*, and one vulnerable species *Gudusia chapra* were found inside the sampling sites of the Hizla-Mehendiganj sanctuary which indicated that the sanctuary might provide shelters for those endangered or vulnerable species.

Table 3. Local conservation category of fish species found inside and outside the Hizla-Mehendiganj sanctuary.

Conservation categories	Number of species found	Percentage (%)
Endangered (EN)	2	9.52
Vulnerable (VU)	1	4.76
Near Threatened (NT)	1	4.76
Least Concern (LC)	16	76.19
Data Deficient (DD)	1	4.76

Some studies have also found threatened species in the southern coastal district of Bangladesh^(25,28,29). Pramanik *et al.*⁽²⁵⁾ documented twenty-one threatened fish species (20%) from the Meghna river in which 11 species (10.28%) were found as VU, 8 species (7.48%) as EN and 2 species (2%) as CR. Ullah *et al.*⁽²⁸⁾ reported that the highest percentage was found as NT (46%), followed by VU (14%), EN (13%) and CR (8%) in the coastal areas of Noakhali and Lakshmipur region.

Biodiversity index: The higher the site-specific Shannon-Weiner index (H), the greater the diversity. In this study, the biodiversity within the sanctuary was moderate (H= 1.881) and it was lower than the biodiversity outside of the sanctuary (H= 1.935) (Table 4). The highest biodiversity was found in Rukundi (H=1.836). However, the H values

(biodiversity) of this study were lower than the reported value of H (3.198) in the Meghna river estuary by Hossain *et al.* (2012) and in the old- Brahmaputra river (H= 3.659)⁽³⁰⁾. Simpson index value (D) generally varies in between 0-1 where the lower the value, the more evenly distributed the species. This study found that fish species were more evenly distributed in outside sites of the sanctuary. The reported D values within and outside of the hilsa sanctuary of this study were higher than the D value reported in the Old-Brahmaputra river (0.031)⁽³⁰⁾. Simpson's index of diversity (1-D) and Margalef's index (d) showed that the higher fish diversity was found in the Ilisha river near Rukundi, outside the site of the hilsa sanctuary. The d values of the present study were lower than the reported value of d (6.75) in the Meghna river estuary⁽¹¹⁾.

Table 4. Fish biodiversity index across different sites of Hizla-Mehendiganj hilsa sanctuary.

Site name	Study area	Shannon-Weiner diversity index value (H)	Simpson index value(D)	Simpson's index of diversity, D' = 1 - D	Margalef richness index (d)	Buzas and Gibson's evenness index, E= e ^H /S
Hizla-Mehendiganj: Inside sanctuary	Gozariya river, near Lalkharabad	1.423	0.362	0.638	1.591	1.195
	Meghna river, near Moulovirhat	1.234	0.333	0.667	1.079	1.280
	Meghna river, near Char Killa	1.181	0.46	0.54	1.398	1.184
Combined		1.881	0.214	0.785614	1.881	1.156
Hizla-Mehendiganj: Outside sanctuary	Ilisha river, near Ulania	0.633	0.632	0.368	1.279	1.235
	Meghna river, near Rukundi	1.836	0.237	0.763	2.435	1.189
	Meghna river, near Thandarbazar	-	1	-	0.845	1
Combined		1.935	0.208	0.792	2.474	1.156

The values of Buzas and Gibson's index in this study were more or less similar to the other index values. However, from the findings, it is said that fish biodiversity was highest in outside sampling sites of the Hizla-Mehendiganj hilsa sanctuary at Rukundi than in the sampling sites within the sanctuary area. This could be happened due to the availability of more fishes and more fishing gear in this area. Ecological conditions also have an effect on the distribution of the fish species⁽¹¹⁾. However, the findings of this study can be used as a baseline for future biodiversity assessments, conservation efforts, and impact assessments of the Hizla-Mehendiganj hilsa sanctuary. The findings of this study will help to establish proper management of this sanctuary. Further studies are

required to assess the effect of the Hizla-Mehendiganj sanctuary on fish biodiversity and physicochemical properties of water in the sanctuary areas.

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