

IMPACTS OF WATER QUALITY ON FINFISH AND SHELLFISH BIODIVERSITY IN THE RIVER MEGHNA

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Abstract

Fish biodiversity largely depends on different environmental factors including water quality parameters. The current study was conducted to investigate the impacts of water quality variables on fish biodiversity at upstream and downstream of the river Meghna in dry and rainy season in 2011. Twelve water samples and 66 fish samples were collected from 2 different sampling stations of the river Meghna during the study period where 61 were finfish species and 5 were shellfish species. The number of finfish and shellfish catch at upstream in both dry and rainy seasons were significantly higher than that of downstream ($p < 0.01$). Shannon-Weiner index and species richness were determined where significantly higher Shannon-Weiner index was observed at upstream in dry season than that of downstream ($p < 0.01$) and similar species richness was observed at upstream and downstream in both of the seasons. Significant correlation was observed between physicochemical parameters and the fish biodiversity indices. The obtained results suggested that the changes in environmental parameters of water including conductivity, pH, DO, BOD had significant impacts on Shannon-Wiener indices at downstream which indicate the water quality deterioration. This findings have the implications in designing policies to sustain the finfish and shellfish biodiversity and to mitigate the environmental changes in the river Meghna.

Introduction

Bangladesh is blessed with extensive water resources including ponds, lakes, rivers, canals, estuaries and sea which together account water area of 4.73 million hectares⁽¹⁾. These enormous areas have enriched fisheries sector of the country. The economy and socio-cultural life largely depend on fisheries sector. Open water capture fisheries specially riverine and estuarine systems conjointly have contributed 7.5% of total fish production in 2017-2018 to the fisheries sector of Bangladesh. The landmass comprises mainly the delta of the three major rivers: the Ganges, the Brahmaputra and the Meghna. There are also thousands of tributaries with a total length of about 24,140 km. The Meghna is one of the biggest rivers of the country which has its great estuary that discharges the flows of the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna itself. The current deltaic Meghna together with Padma and Meghna, forms the the largest river of Bangladesh.

These rivers are the sources of many aquatic resources where fishes are the principal output. According to the Red List of Bangladesh, 64 freshwater fish species are threatened in Bangladesh

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where 9 species are listed as critically endangered; 30 as endangered and 25 as vulnerable⁽²⁾. Considering the habitat structure of Meghna, it's downstream encounters huge industrial and urbanizing infestation along with mechanical fishing effort and fuel transportation which trigger the water quality degradation. A larger number of anthropogenic activities such as human settlements, towns, ports and industries (thermal power plant, fertilizer factories) have sprung up on both the banks of the Meghna. All of these stressors have made the downstream prone to water pollution that severely affect the aquatic diversity. These stressors directly or indirectly influence on the water chemistry thus changing the values of different physicochemical parameters.

Physicochemical parameters reflect the abundance of freshwater fisheries biodiversity. Water temperature, pH, DO, BOD, conductivity, depth and water velocity influence the water chemistry. Several studies have been conducted on the fish biodiversity and physicochemical parameters in the river Meghna⁽³⁻⁴⁾. However no comprehensive study was carried out addressing the impact of water quality degradation on finfish and shellfish richness and diversity indices at upstream and downstream. Current study was thus conducted to estimate the present status of finfish and shellfish diversity of the river Meghna and to assess the impact of some physicochemical parameters of water on the biodiversity indices.

Materials and methods

The present study was carried out at upstream (Ajmiriganj and Habiganj) and at downstream (Bhairab Bazar and Kishoreganj) of the river Meghna during dry and rainy season in 2011. The downstream of Surma river from Ajmiriganj is often referred to as the Meghna and this region was considered as the upstream in the study. The channel from Ajmiriganj down to the confluence with the Dhanu river is referred to as the Surma. The Meghna receives the old Brahmaputra on its right at Bhairab Bazar. The width of the river is three quarters of a kilometer. Several small channels branching off from the Meghna and meandering through the low land bordering the Tippera surface received the flow of a number of hilly streams and rejoin the main river downstream. Two different stations were selected each for upstream sampling and downstream sampling. In each station, 2 samplings were done where in each sampling 3 nettings were performed using cast net and seine net.

Different water quality variables were determined in samples taken from upstream and downstream of the river Meghna. pH was determined using Orion field pH meter (model 210A, Orion Laboratories) with a glass combination electrode and automatic temperature compensation probe calibrating with buffers at pH 4.7 and 10.0 at 25°C. Electrical conductivity was determined using conductivity meter (HACH, Model CO150). Dissolved oxygen was measured using a portable DO meter (HACH, Model DO175). Biochemical oxygen demand (BOD), total dissolved solids (TDS), turbidity, total nitrogen (TN) and free ammonia (NH₃) (FA) content of water were determined according to APHA⁽⁵⁾. Water samples were analyzed in the Department of Soil, Water and Environment, University of Dhaka and Department of Fisheries, University of Dhaka. Eight major water quality parameters which have influence on fish biodiversity (BOD, DO, pH, TDS,

turbidity, electrical conductivity, total nitrogen and free ammonia were taken under consideration to determine the Water Quality Index (WQI) as explained in Water Research Center by Oram⁽⁶⁾.

For the determination of diversity indices total samples of fish in each sampling were recorded from 12 nettings using cast net and seine net from the sampling stations (one at upstream and one at downstream) during the study period. Fishes and shellfishes were identified up to species level by following Shafi and Quddus⁽⁷⁾. Species richness, total individual counts in a sample and also, total number of individuals under each species were estimated. Shannon-Wiener index (SWI) values were calculated by Maryland computer online calculation for biodiversity⁽⁸⁾. Both number of species and their abundance/density are considered in Shannon-Weiner diversity index⁽⁹⁻¹⁰⁾. Shannon-Wiener indices (SWI) obtained from the fish samples were considered as the dependent variables where as the values of 8 parameters of water were considered as the independent variables. Data were analysed using SPSS (Statistical Package for Social Science) version 20 and Microsoft Excel 2016. Pearson correlation test was performed to determine the correlations between the variables with the level of significance at $p < 0.05$. Regression analysis between diversity index and water quality variables was also performed. Principal component analysis (PCA) was done to determine the key factors correlated with SWI and species richness. Data were transformed to natural logarithm before conducting PCA.

Results and Discussion

Variation in water quality parameters: Total Nitrogen (TN) concentration determined in water sampled from downstream of the river Meghna was higher than that of upstream during the dry season (Table 1). Lowest TN value (around 0.66 mg/l) was recorded from upstream during rainy season. Dissolved oxygen (DO) at upstream was lower than downstream in both dry and rainy seasons. Average DO concentration at upstream was higher than downstream. Overall DO values recorded during the study period ranged between 6 and 7.5 mg/l which were favourable for fishes⁽¹¹⁾. Significantly higher BOD was observed at downstream ($p < 0.0001$). Individually, both dry and rainy season at downstream showed significantly higher BOD than that of upstream ($p < 0.01$). Similarly, significantly higher concentration of TDS and EC were found at downstream in both seasons than that of upstream ($p < 0.01$). Higher but not significant turbidity was observed during rainy season at both upstream and downstream. Average free ammonia (FA) concentration was similar in both upstream and downstream (Table 1).

Species diversity: A total number of 61 finfish and 5 shellfish species were recorded from upstream and downstream of the river Meghna. In the present study, 42 species of finfish and 5 species of shellfish were observed in the upstream while in the downstream 34 species of finfish and 5 species of shellfish were found (Table 2a and 2b). Among the finfish, 27 species were found only in the upstream and 19 only in the downstream (Table 2a). All 5 species of shellfish were found in both upstream and downstream (Table 2b).

Table 1. Water quality variables (Mean \pm Standard Error of Mean) of water samples (n=3).

Water quality variables	Upstream		Downstream	
	Dry season	Rainy season	Dry season	Rainy season
pH	6.87 \pm 0.32	6.25 \pm 0.27	7.01 \pm 0.25	7.06 \pm 0.49
DO (mg/l)*	6.33 \pm 0.54	6.66 \pm 0.71	5.45 \pm 0.33	5.00 \pm 0.50
BOD (mg/l)***	2.96 \pm 0.19	3.09 \pm 0.34	4.37 \pm 0.33*	4.55 \pm 0.26*
TDS (mg/l)**	28.63 \pm 1.68	28.43 \pm 3.04	36.00 \pm 1.30*	38.63 \pm 0.67*
EC (μ S/cm)**	70.23 \pm 5.43	72.47 \pm 3.71	89.87 \pm 4.81*	93.27 \pm 1.65*
Turbidity (FTU)	36.78 \pm 19.63	64.35 \pm 24.58	54.69 \pm 22.62	64.35 \pm 19.09
Total Nitrogen (mg/l)*	0.71 \pm 0.10	0.66 \pm 0.06	1.04 \pm 0.03*	0.89 \pm 0.08
Free ammonia (mg/l)	3.57 \pm 1.60 $\times 10^{-4}$	4.90 \pm 1.57 $\times 10^{-4}$	5.47 \pm 1.36 $\times 10^{-4}$	4.00 \pm 0.62 $\times 10^{-4}$

Asterisk at the variable name indicates significantly different between overall values of upstream and downstream. Asterisk at other values are significantly different within season between upstream and downstream (*, ** and *** denote significantly different at $p < 0.01$, $p < 0.001$ and $p < 0.0001$, respectively).

Table 2a. Finfish species found at upstream and downstream of the river Meghna.

Sl. No.	Order	Family	Scientific Name	Location of availability
1	Anguilliformes	Anguillidae	<i>Anguilla bengalensis</i>	Upstream
2	Beloniformes	Belonidae	<i>Xenentodon cancila</i>	Downstream
3	Clupeiformes	Clupeidae	<i>Corica soborna</i>	Both
4			<i>Gudusia chapra</i>	Upstream
5			<i>Tenuialosa ilisha</i>	Upstream
6			<i>Ilisha megaloptera</i>	Downstream
7	Cypriniformes	Cyprinidae	<i>Amblypharyngodon mola</i>	Both
8			<i>Amblypharyngodon microlepis</i>	Downstream
9			<i>Barilius barila</i>	Downstream
10			<i>Cirrhinus mrigala</i>	Downstream
11			<i>Crossocheilus latius</i>	Downstream
12			<i>Devario devario</i>	Downstream
13			<i>Cirrhinus reba</i>	Upstream
14			<i>Labeo calbasu</i>	Upstream
15			<i>Labeo gonius</i>	Upstream
16			<i>Labeo rohita</i>	Downstream
17			<i>Lepidocephalus guntea</i>	Both
18			<i>Puntius chola</i>	Upstream
19			<i>Puntius chonchonius</i>	Downstream
20			<i>Puntius sophore</i>	Downstream
21			<i>Puntius ticto</i>	Both
22			<i>Salmostoma bacaila</i>	Both
23		Cobitidae	<i>Botia dario</i>	Upstream
24			<i>Lepidocephalichthys irrorata</i>	Downstream
25			<i>Lepidocephalichthy guntea</i>	Downstream
26	Osteoglossiformes	Notopteridae	<i>Chitala chitala</i>	Both
27			<i>Notopterus notopterus</i>	Both
28	Channiformes	Channidae	<i>Channa marulius</i>	Upstream

Contd.

Sl. No.	Order	Family	Scientific Name	Location of availability
29			<i>Channa punctatus</i>	Upstream
30			<i>Channa striatus</i>	Both
31	Perciformes	Anabantidae	<i>Anabas testudineus</i>	Upstream
32			<i>Nandus nandus</i>	Upstream
33		Ambassidae	<i>Chanda nama</i>	Upstream
34			<i>Parambassis ranga</i>	Downstream
35		Badidae	<i>Badis badis</i>	Downstream
36		Gobiidae	<i>Glossogobius giuris</i>	Both
37		Nandidae	<i>Nandus nandus</i>	Downstream
38		Sciaenidae	<i>Pama pama</i>	Both
39		Osphronemidae	<i>Trichogaster fasciata</i>	Both
40	Siluriformes	Schilbeidae	<i>Ailia coila</i>	Both
41			<i>Ailia punctata</i>	Downstream
42		Clariidae	<i>Clarias batrachus</i>	Upstream
43		Schilbeidae	<i>Clupisoma garua</i>	Upstream
44			<i>Eutropiichthys vacha</i>	Upstream
45			<i>Neotropius atherinoides</i>	Upstream
46		Sisoridae	<i>Gagata gagata</i>	Upstream
47			<i>Bagarius bagarius</i>	Downstream
48		Heteropneustidae	<i>Heteropneustes fossilis</i>	Upstream
49		Bagridae	<i>Mystus aor</i>	Both
50			<i>Mystus tengara</i>	Upstream
51			<i>Mystus cavasius</i>	Downstream
52			<i>Mystus bleekeri</i>	Downstream
53			<i>Mystus vittatus</i>	Both
54		Siluridae	<i>Ompok bimaculatus</i>	Upstream
55			<i>Ompok pabda</i>	Both
56			<i>Wallago attu</i>	Upstream
57	Synbranchiformes	Mastacembelidae	<i>Macragnathus aculeatus</i>	Upstream
58			<i>Macragnathus aral</i>	Upstream
59			<i>Mastacembelus armatus</i>	Upstream
60			<i>Mastacembelus pancalus</i>	Upstream
61		Synbranchidae	<i>Monopterusuchia</i>	Upstream

Table 2b. Shellfish species found in both upstream and downstream of the river Meghna.

Sl. No.	Phylum	Class	Order	Family	Scientific name
1	Arthropoda	Malacostraca	Decapoda	Palaemonidae	<i>Leander styliifera</i>
2					<i>Macrobrachium malcolmsonii</i>
3					<i>Macrobrachium rosenbergii</i>
4					<i>Macrobrachium rudis</i>
5				Portunidae	<i>Scylla serrata</i>

Species diversity index and water quality variables: Finfish and shellfish diversity at upstream and downstream of the river Meghna was determined by the catch of nettings where the total number of catch in dry season at upstream was significantly higher than that of downstream ($p < 0.01$, Table 3). Number of species were at upstream was higher than downstream but not significant. SWI and richness were determined where SWI in dry season at upstream was

significantly higher than that of downstream ($p < 0.01$). Similar species richness was observed in both seasons at both sampling stations (Table 3).

Shannon-Wiener index (SWI) was negatively correlated with at both study areas. Similar results were observed by Bashir *et al.*, 2010⁽¹²⁾. Negative correlations were found with BOD and turbidity at upstream levels whereas with DO and FA at the downstream levels. Positive correlations were observed with BOD, EC, TDS and turbidity at the downstream level while it observed with EC, DO, TDS and FA at upstream areas (Table 4). Regression coefficient (B) of Shannon-Wiener index (SWI) were less on pH and TN at both sampling areas whereas the coefficient (B = -0.6678) of SWI on BOD at upstream and the coefficient (B = -0.561) on FA at downstream were the least in values. On the other hand, the coefficient (B = 0.143) of SWI on FA at upstream was positive. The other coefficients of SWI on BOD at downstream; on DO at upstream; on TDS, EC and turbidity at the both sampling areas were positive in values (regression graphs not shown).

Table 3. Finfish and shellfish species diversity during the study period at upstream and downstream during dry and rainy season.

Indicators	Upstream		Downstream	
	Dry season	Rainy season	Dry season	Rainy season
SWI	2.35±0.13*	2.04±0.22	1.72±0.05	2.06±0.14
Species richness	14.67 ±1.20	12.00±3.61	8.00±0.58	10.00±1.00
Number of fish and shellfish species caught	36	32	21	27
Total catch (number)	158*	115	83	98

Three nettings were performed for each season at both upstream and downstream to catch the fish and shellfish. Asterisk (*) indicates significantly different at $p < 0.01$.

Table 4. Correlation matrix between Shannon-Wiener Index and independent variables (Water quality parameters). Values are Pearson correlation coefficients, $p < 0.01$.

	Water quality parameters							
	pH	BOD	EC	TN	DO	TDS	Turbidity	FA
Up stream	-0.219	-0.678	0.373	-0.910	0.050	0.491	-.019	0.143
Down stream	-0.808	0.416	0.190	-0.524	-0.689	0.528	0.370	-0.561

Principal component analysis (PCA): A PCA was performed to establish relationship between the variables. Varimax rotation was performed to reduce the variable and simplify the interpretation of different variables. Varimax grouped the variable into fewer factors, thus simplified the interpretation. The rotation mode reduced all variables into two factors, which represented 68.3 and 70.1% of the cumulative variances respectively for Shannon-Wiener Index (SWI) and water quality variables; and species richness and water quality variables. In case of diversity index, SWI was negatively correlated with TDS, EC and BOD (PC1); and BOD, pH, TDS, EC, BOD and TN were positively correlated (PC2) while no correlation was found with

turbidity and FA (Fig. 1A). Similar trend was found for species richness and other variables (Fig. 1B).

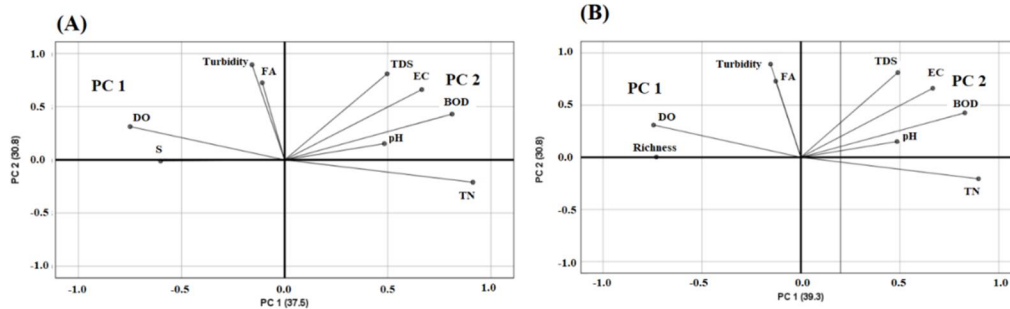


Fig. 1. Principal component analysis (PCA) between SWI and water quality variables (A); and richness and water quality variables (B).

Different fish species composition has been reported by several authors for a different section of Bangladesh⁽¹³⁾. Very limited research works have been conducted on the fish biodiversity of Meghna River. An account of 293 freshwater fish species including 13 orders and 61 families was reported in different water bodies including river, haor, baors, streams, floodplains, beels and lakes in Bangladesh⁽¹⁴⁾. In another study a list of 265 species of freshwater fishes belonging to 154 genera and 55 families from Bangladesh have been reported⁽¹⁵⁾. Fish species recorded in the study comprehensively suggests that the river Meghna is an incredible resource of inland fishes at the upstream level whereas at the downstream level fish species diversity was comparatively prominent. Sixty six species of finfish (61) and shellfish (5) were found at upstream and downstream with sufficient number of individuals. Significant correlation between various physicochemical variables in the Meghna river system was observed in the current study which means physicochemical parameters are interdependent where change in one parameter might change others. Shannon-Wiener index was positively correlated with turbidity at downstream which may be due to the effects of rainy season where the turbidity is due to nutrients and primary producers. SWI was positively correlated with TDS at downstream which may be because of the higher extent of sedimentation and higher content of nutrients. Electrical conductivity (EC) is an important parameter which indirectly analyzes the rivers' quality⁽¹⁶⁻¹⁷⁾. Previously, the highest value (220 $\mu\text{S}/\text{cm}$) of conductivity was recorded at downstream level of Meghna. Southern Regional Aquaculture Centre (SRAC)⁽¹⁸⁾ demonstrated that the optimum EC for fish culture should be between 60 and 2000 $\mu\text{S}/\text{cm}$. The EC observed in the present study was within this range. The higher level of TDS allowed the EC level to be higher as well.

Turbidity is another indicator of water quality. The recommended range of turbidity for fish culture is 30-80 $\text{cm}^{(19)}$ and turbidity observed in the present study is within the range. In the upstream, turbidity was negatively correlated with fish diversity index. Seasonal variation especially the rainy season has prominent effects on turbidity. Rainy season generally affects the turbidity level of flowing water body. Besides this effect, the other effects would be the geographical and habitat structure of the Meghna where the area of floodplains were large at the

upstream level than downstream what becomes inundated and associated with the river flow due to the uprising water level of rainy season. Chances of alluvial deposition and siltation from the floodplains probably made upstream level much siltation prone where the siltation proved to be the major source of turbidity.

DO is one of the most important water quality parameters and limiting factors. For better growth of fish, DO should be above 5 mg/l⁽¹⁹⁾. DO in both upstream and downstream of the river Meghna was within the optimum range. Shannon-Wiener index was also positively correlated with DO at upstream because of the increment of DO levels during rainy season. Proper extent of seasonal water mixing made the DO level much higher in that period. DO content was found to gradually decrease from the upper to lower stretches of the Meghna river system as expected for many major rivers⁽²⁰⁾. Fish growth and survival depend on pH to some extent⁽²¹⁾. Northeastern Regional Aquaculture Centre (NRAC) recommended that for fish to survive and grow best in waters with a pH between 6 and 9⁽²¹⁾. The pH observed in the upstream was within the range, however, at downstream recorded pH was slightly lower than the lower recommended value. Correlation between SWI and total NH₃ at downstream level demonstrate the higher content of nitrogen sources from the numerous industrial and mechanical effluents like Ashuganj power plant, Fenchuganj urea fertilizer factory etc.

Hossain *et al.*⁽³⁾ found 53 fish species at estuarine Meghna where in the present study similar number of fish species was observed. Water quality parameters including conductivity, depth and salinity have been shown to significantly influence the fish biodiversity in Indian floodplains and lakes⁽²²⁾. The richness and abundance of fishes have also been shown to be correlated with turbidity and pH in coastal rivers of India⁽²³⁾ which supports the findings of the current study. The findings suggest that there is deliberate effects of water quality on fish diversity at downstream but in some cases index was low although the water quality was pretty good. The findings might be used in future research for predictions over temporal scales.

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