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FULL LENGTH ARTICLE

Fish diversity and habitat relationship with environmental variables at Meghna river estuary, Bangladesh

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Abstract Meghna river estuary is the largest estuarine ecosystem of Bangladesh and support diverse fisheries communities compared to others. Present study was carried out to assess the fish diversity status with relation to major hydrological and meteorological parameters in both spatio-temporal scales. Fish samples were collected together with water quality parameters from eight sampling stations of the Meghna river estuary from November 2011 to April 2012. Fifty years meteorological data were collected from meteorological department. Diversity status were analyzed from all fisheries data by using PAST (version 2.15) software. Findings showed that Meghna river estuary is the habitat of 53 fish species and *Oxyurichthys microlepis*, *Hemiarius sona Arius thalassinus*, *Batrachocephalus mino* and *Arius caelatus* are the major contributory species ($>6\%$) for both spatio-temporal scales. Water temperature and rainfall was found as major influential factors for species distribution.

Introduction

Estuaries are the meeting place of freshwater from rivers and saltwater from the sea and, as such, are dynamic environments characterized by large fluctuations in environmental conditions (James et al., 2007). Importance of estuaries is well understood in many parts of the world as breeding and nursery grounds for a wide variety of fishes. Although estuaries provide a father harsh environment because of changes in salinity, many species of fish have found them to be highly advantageous areas in which to spawn, develop, and grow during early life; productivity tends to be high. Estuarine environments are among the most productive on earth, creating more organic matter each year than comparably-sized areas of forest, grassland, or agricultural land and have important commercial value with providing economic benefits for tourism, fisheries, and recreational activities. The protected coastal waters of estuaries also support important public infrastructure, serving as harbors and ports vital for shipping and transportation.

Fisheries population in the estuary is very much dynamic in both temporal and spatial spectrum. Besides intra-annual environmental differences, short-term changes, such as those of the day/night cycle, can also affect the interactions between

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the distribution and abundance of these communities, such as behavioral changes in the period of activity to that of rest (and vice versa), competition for prey etc (Noakes, 1992; Helfman, 1993; Axenrot et al., 2004). The diversity of natural populations is partially dependent on the environmental variables which always affect the competing populations. Estuaries are areas of physical and biological transition between the land, freshwaters, and the sea (Chowdhury et al., 2009). There are about 20 estuaries throughout the coastal zone of Bangladesh as well as some complex estuarine ecosystems in natural and planted mangrove forest dominated areas, but relatively little is known (Shafi and Quddus, 1982; Islam, 1987, 2005; Islam et al., 1993; Kamal, 2000; Ahammad, 2004) about the fisheries diversity and factors controlling their distribution and abundance.

Fish and shrimp assemblage structure in the estuaries of Bangladesh has not been well studied; although there are some scattered works on different biological aspects of the coastal estuarine system of Bangladesh (Hossain et al., 2007), none of them examined the species assemblage structure (Nabi et al., 2011). Meghna river estuary is the largest estuarine ecosystem of Bangladesh which is still unknown, unmanaged and unmonitored. The main reason behind this is the complexity and high variability at different temporal and spatial scales with lack of reference on previous conditions of ecosystem. Meghna estuary possesses an extensive system of aquatic ecosystem which supports multitudes of species of plants, fish and other organisms. Of all these living organisms, fish are the most important element and is the major source of dietary protein for the national sector. This sector also generates employment opportunity which forms the lifeline for rural economy.

However, considering the reason motioned above present study aimed to describe fin fish assemblages structure at Meghna river estuary in relation to major hydrological and meteorological parameters.

Study area

Meghna Estuary (Fig. 1) is the easternmost sector of the Ganges delta. The geographical location is between latitude 20°30′ and 22° N and longitude 91°45′ and 92°15′ E. The Hatiya Island to the east, Bhola to the west, greater Noakhali to the north and Bay of Bengal to the South surround the study area. The main economically important resources related to river and sea, are fisheries, aquaculture, mangrove forest, land and water. Cage culture of tilapia in Meghna river is presently a dominant water use pattern in this area.

The Meghna river estuary features a sunny and tropical weather along with monsoon climate. The area has been greatly influenced by the seasonal monsoon winds like other parts of the country. Mean annual rainfall in the study area is 3207 mm, and mean annual temperature is 26.24 °C. The monsoon or rainy season (June–October) is characterized by southeast monsoon wind with high rainfall, humidity and cloud cover. Occasional thunderstorms, cyclones and storm surges occur during monsoon season. The post-monsoon or winter season (November–February) with northeast monsoon wind is characterized by dry cool and sunny weather with occasional raining. Extreme lowest temperature (8–10 °C) occasionally occurs for a couple of hours in few days of December–January having dry and sunny days with heavy dewfall at night and morning that greatly disturb the navigational activities. The summer or pre-monsoon (March–May) with southwest monsoon wind is characterized by the southerly winds, high temperature and evaporation rates with occasional heavy thunderstorms (locally called *Kalbaishakhi*) and hail. Sunshine hours are minimum during rainy and winter seasons and maximize in summer. Annual mean sunshine is about 5–6 h per day and annual mean wind speed varies 1.6–2.0 knots.

The estuary is formed inside Bangladesh by the joining of the Surma and Kushiyara rivers originating from the hilly regions of eastern India. Down to Chandpur, this area is hydrographically referred to as the Upper Meghna. After the Padma joins, it is referred to as the Lower Meghna which falls to the Bay of Bengal. Major tributaries in the Meghna river region included the Dhaleshwari river, Gumti river, and Feni river. The Meghna empties into the Bay of Bengal via four principal mouths, named Tetulia, Shahbazpur, Hatiya, and Bamni.

In the estuary, fresh water from the rivers meets with saline ocean water from the Bay of Bengal. Due to strong currents and shallow depths, density stratification is not very characteristic. Rather, there are fronts (or transition zones) between the water masses. The location of these transition zones depends on the river discharge and the tide.

The entire area is tidal-influenced all year. Tides are semidiurnal with two high and two low waters during a lunar day. Tidal behavior varies along the coast in terms of magnitude but not of pattern. The tide ranges from 0.07 m during neap tide to 4.42 m during spring tide. The tidal range increases in the direction from South–West (around 4 m range at South Bhola) towards North–East (around 7 m range at Sandwip). There is a pronounced seasonal sea level variation. The sea level is highest during the South–West monsoon and lowest in the winter. The range of the seasonal variation is about 0.8 m in the southern part of the study area and about 2.7 m at Chandpur (at the northern boundary of the area). Extreme set-ups occur during cyclones, where the storm surge can reach 5–7 m (on a 20–100 years basis, in the Chittagong–Bhola sector). The main, large scale circulation in the marine water of Bangladesh is of clockwise and anti-clockwise rotation, both created by the wind waves running up the coast often throw large numbers of organisms on to the beach, where they die. Wave height varies from 0 to 4 meters. The dominant soil characteristics include muddy and sandy-clay loam texture (Hossain et al., 2009).

Materials and methods

Data collection

The study area is divided into eight sampling stations, i.e. Ramgati North (St 1), Bhola Sadar (St 2), Ramgati Middle (St 3), Daulatkhan (St 4), Burhanuddin (St 5), Noakhali Sadar (St 6), Hatiya (St 7) and Tazumudin (St 8) for hydrological parameters and finfish species collection. Data were collected from November 2011 to April 2012 following lunar periodicity (full moon and New moon) as during these periods higher abundance of fishes were reported by the fishermen. Thus by conducting two samplings per month total 96 samples were collected during this study period form 8 stations. Though estuarine set bag net (ESBN) are destructive, it is widely used

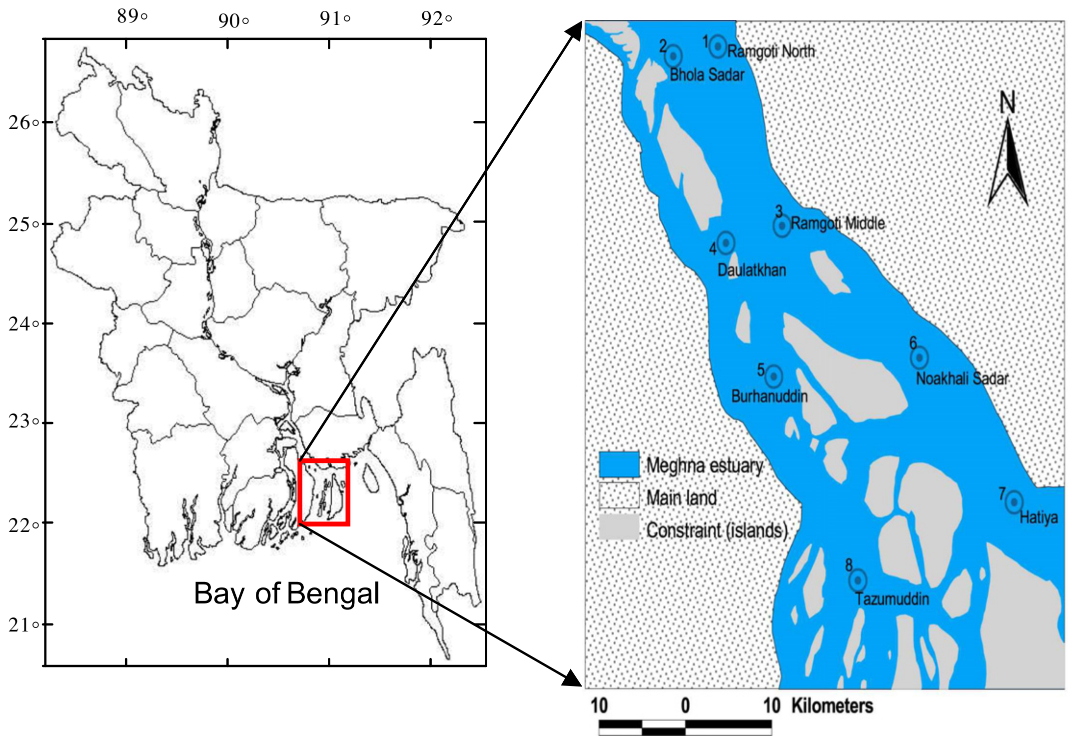

Figure 1 Geographical location of the study area.

by fishermen for fishing at Meghna river estuary. Besides ESBN, Set Gill Net, drift gill net and Moshari bar jal (Fig. 2) are also used for fishing purpose in this estuary.

Fish samples are collected from the local landing centers from previously contacted fishermen. Generally fishermen sort non target fishes after catching at river. Local fishermen are requested not to throw the non target species and convinced them to understand the importance of both target and non target species in research. For laboratory study 10% of the total catch are collected from each station during study period and frozen them in ice box. In the laboratory, samples were sorted and identified to species level (Fischer and Whitehead, 1974; Shafi and Quddus, 1982; Talwar and Jhingran, 1991; DeBruin et al., 1995 and Hossain et al., 2007). Total numbers of each species were recorded for each month and stations. During sampling, in situ water quality parameters were measured at each sampling site. The salinity, pH, temperature and dissolved oxygen were determined by using a refractometer (NewS-100, TANAKA, Japan), a pen pH meter (s327535, HANNA Instruments), a thermometer in centigrade and a DO meter (HI 9142, HANNA Instruments), respectively. A Secchi disc (20 cm diameter) was used to measure the water

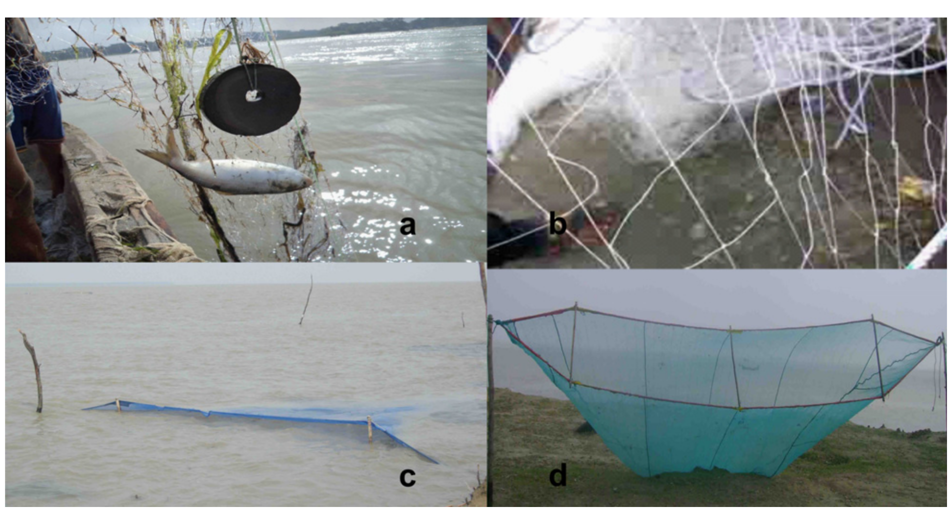

Figure 2 Different types of net used in Meghna Estuary. a)drift gill net b) set gill net c)ESBN d) moshari bar jal.

transparency. Meteorological data were collected from meteorological department and due to absent of meteorological department at Lakshmipur data of Chandpur district is considered for this stations as Chandpur is nearer to Lakshmipur compared to other stations.

Data analysis

In the first stage of data analysis diversity of fish assemblage was quantified and then statistical comparison was performed. PAleontological Statistics (PAST) version 2.15, a software package for paleontological data analysis written by P.D. Ryan, D.A.T. Harper and J.S. Whalley, was used to run the analysis. PAST has grown into a comprehensive statistical package that is used not only by paleontologists, but in many fields of life science, earth science, and even engineering and economics. Species diversity was assessed using four different indices viz., species richness, Shannon–Wiener diversity, Evenness and Dominance Indices in spatial and temporal spectrum.

Shannon Weiner diversity index (Shannon, 1949; Shannon and Weaver, 1963; Ramos et al., 2006) considers both the number of species and the distribution of individuals among species. The Shannon Weiner diversity was calculated by following formula:

$$H = \sum_{i=1}^{S} P_i * logP_i$$

where S is the total number of species and P_i is the relative cover of i_{th} species.

Margalef index (d) (Margalef, 1968) was used to measure species richness by using following formula:$d = (S/1) = \log (N)$; where S is total species and N is total individuals.

Buzas and Gibson's evenness (Harper, 1999) was measured by using $E = e^H/S$ to measure the evenness.

The dominance index (Harper, 1999) was measured to determine whether or not particular fisheries species dominate in a particular aquatic system and can be useful index of resource monopolization by a superior competitor, particularly in communities that have been invaded by exotic species. This index was determined by using following formula:

$$D = \sum_i \left(\frac{n_i}{n}\right)^2$$

where n_i is number of individuals of species i.

One-way analysis of variance (ANOVA) was used for hydrological (temperature, pH, transparency, salinity and Dissolve Oxygen) and meteorological parameters (air temperature, humidity, sunshine hour and rainfall) to calculate any existence of difference among the stations and months. In the event of significance, a post hoc Tukey HSD test was used to determine which means were significantly different at a 0.05 level of probability (Spjotvoll and Stoline, 1973). One way Analysis of Similarities (ANOSIM) (Clarke, 1993; Clarke and Warwick, 1994) was performed to test the significant difference among the stations and months. ANOSIM is normally used for taxa-in-samples data, where groups of samples are to be compared. Similarity percentages analysis (SIMPER) (Clarke, 1993) was performed to observe the percentage of similarity among months and stations. In addition percentage of major contributing species both for month and stations were also estimated through this analysis. The hierarchical clustering (Clarke and Warwick, 1994) was calculated to produce a dendrogram for investigating similarities among months and stations. Canonical Correspondence Analysis (CCA) (Legendre and Legendre, 1998) was calculated to find out the association between species and environmental variables (hydrological and meteorological parameters). CCA of a site/specie matrix where each site has given values for one or more environmental variables. The ordination axes are linear combinations of the environmental variables. CCA is thus an example of direct gradient analysis, where the gradient in environmental variables is known a priori and the species abundances (or presence/absences) are considered to be a response to this gradient. The implementation in PAST follows the Eigen analysis algorithm given in Legendre and Legendre (1998). The ordinations are given as site scores – fitted site scores are presently not available. Environmental variables are plotted as correlations with site scores. Both scaling (type 1 and 2) of Legendre and Legendre (1998) are available. Scaling 2 emphasizes relationships between species.

Result

Water parameters

Distinct hydrographic conditions of different stations at different months are shown in Fig. 3. Maximum water temperature was recorded 30 °C at St8 during April 2012 where minimum water temperature was found 20 °C at St4 during February 2012. Maximum average water temperature occurred 24 °C at St3, St5, St6, St7 and St8 and minimum average water temperature was recorded 22 °C at St1. No significance difference was found in temperature among the stations. Transparency was recorded at highest values (40 cm) during April at St8 where minimum value observed at St3 (26 cm) during December. Mean water transparency occurred at highest value in St1 (33 cm) where lowest value recorded at St3 (29 cm). Significant difference was found in transparency among the stations ($F = 2.84$, $P < 0.05$). Water pH values varies between 7.7 (March 2012, St1) to 6.9 (April 2012, St8). Mean water pH found in highest value 7.5 at St1 where lowest value 7.15 at St4. pH values also showed significant difference among the stations ($F = 4.14$, $P < 0.05$). Dissolve Oxygen (DO) ranges from 5.8 mg/l (recorded during April 2012 at St8) to 4.6 mg/l (recorded during January 2012 at St 3) with a maximum mean 5.6 mg/l at St6 and minimum mean 4.83 at St3. No significant difference was found in Dissolve Oxygen concentration among the stations. Salinity data was found 0 for all the stations for whole study period due to huge fresh water discharge from surrounding land and fresh water supply from upstream river of Chandpur and very long distance from downstream coastal water.

Meteorological parameters

Fifty years trend of meteorological data is shown in Fig. 4. Rainfall occurred at maximum level 759 mm during July at Hatiya Island where minimum found 6 mm during December and January at Chandpur and at Hatiya during January. Air temperature varied between 29 °C during May at Bhola, Hatiya and Chandpur and during June, July and August at Chandpur to 18 °C during January at Bhola, Noakhali and

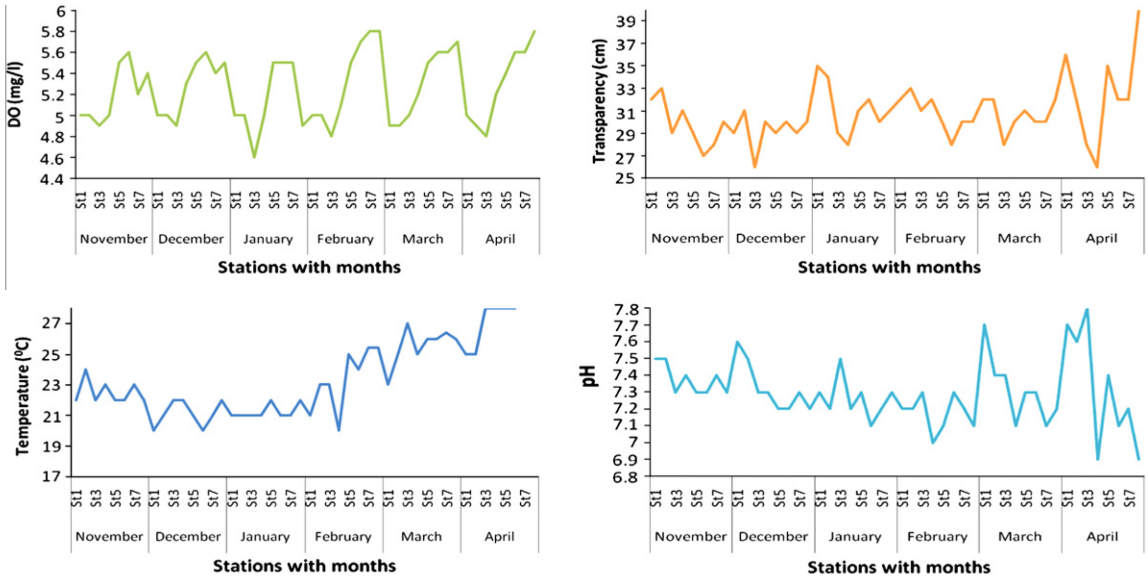

Figure 3 Hydrological conditions of different stations at different months.

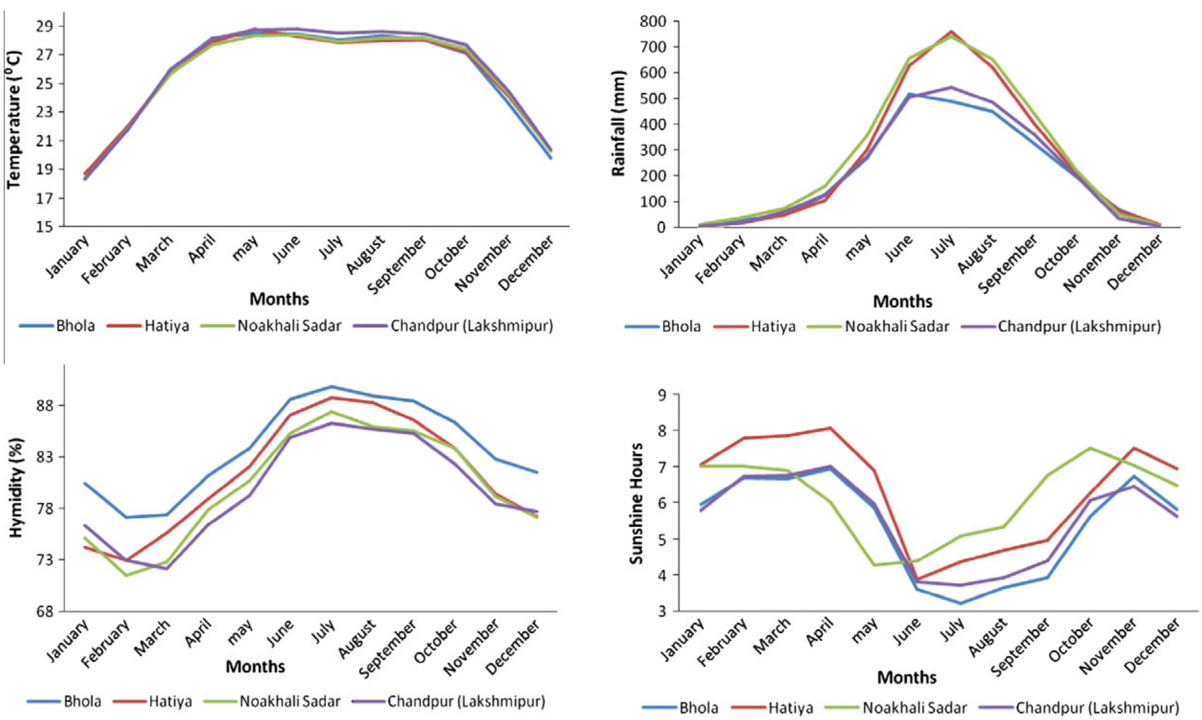

Figure 4 Fifty years trend of meteorological data.

Chandpur. Maximum sun shine hour was recorded 8 h at Hatiya Island during February to April and during October at Noakhali Sadar. Minimum sun shine hour recorded 4 h during May at Noakhali Sadar, during June for all study areas, During July at Hatiya and Chandpur, during August and September at Bhola and Chandpur. In case of Humidity, maximum occurred 90% during July at Bhola and minimum observed 72% during February at Noakhali Sadar and during March at Chandpur. No significant difference was found among the stations.

Fisheries bio-diversity

Species abundance and distribution

A total of 21,650 individuals were enumerated which comprises of 53 species of finfish's (Table 1). Maximum number was counted for *Hemiarius sona* (2524 individuals) and minimum for *Platycephalus indicus* (16 individuals) which are 11.7% and 0.1% of total individuals respectively. Highest number of 4168 individuals was counted in Station 3 throughout the study period where lowest number of individuals

Table 1 Temporal and spatial species abundance and distribution.

Species	Code	Total	%	St1	St2	St3	St4	St5	St6	St7	St8	Nov	Dec	Jam	Feb	Mar	Apr
Butis butis	C1	150	0.7	4	32	6	28	20	12	24	24	17	22	36	17	22	36
Cynoglossus spp.	C2	201	0.9	6	34	11	28	38	20	40	24	37	34	32	36	30	32
Devario devario	C3	146	0.7	4	24	8	30	20	16	18	26	19	31	24	18	31	23
Eleutheronema tetradactylum	C4	538	2.5	40	92	11	90	88	71	86	60	77	94	103	74	88	102
Gadusia chapra	C5	356	1.6	56	52	60	46	48	12	44	38	57	61	60	57	61	60
Glossogobius giuris	C6	771	3.6	2	234	0	230	122	20	86	77	115	134	142	115	134	131
Harpodon nehereus	C7	1047	4.8	12	144	18	248	186	175	214	50	168	155	211	167	142	204
Tenualosa ilisha	C8	244	1.1	12	30	40	80	22	26	18	16	30	44	48	30	44	48
Johnius argentatus	C9	200	0.9	4	10	2	12	42	60	62	8	31	27	42	31	27	42
Lates calcarifer	C10	108	0.5	2	4	4	12	32	10	38	6	17	18	19	17	18	19
Liza subviridis	C11	486	2.2	60	40	78	48	52	88	94	26	77	78	92	69	78	92
Mystus aur	C12	88	0.4	4	12	10	16	8	4	4	30	14	18	12	14	18	12
Mystus vittatus	C13	222	1.0	28	20	16	20	28	50	40	20	55	26	30	55	26	30
Mugil cephalus	C14	312	1.4	6	70	20	64	48	38	38	28	41	56	59	41	56	59
Mugil corsula	C15	341	1.6	2	62	4	74	50	71	48	30	51	55	67	51	55	62
Odontamblyop rybicundus	C16	493	2.3	4	44	62	54	65	60	148	56	79	71	80	78	90	95
Pangasius pangasius	C17	211	1.0	12	20	37	38	26	36	24	18	25	42	24	31	51	38
Pomadasys spp.	C18	68	0.3	4	12	0	22	6	4	6	14	13	10	11	13	10	11
Polynemus paradesius	C19	925	4.3	60	82	550	84	49	20	42	38	66	77	82	149	239	312
Rita rita	C20	254	1.2	38	12	92	26	24	28	22	12	26	39	57	46	52	34
Silago domina	C21	200	0.9	22	20	18	26	28	36	32	18	35	27	38	36	25	39
Trichiurus lepturus	C22	76	0.4	8	8	10	12	12	8	10	8	11	12	18	10	10	15
Tetradon potaka	C23	82	0.4	16	2	32	6	4	2	4	16	13	16	13	11	16	13
Trypauchan vagina	C24	224	1.0	2	30	0	32	36	36	60	16	36	27	49	36	27	49
Wallago atu	C25	26	0.1	6	2	6	4	0	2	0	6	0	7	6	0	7	6
Escualosa thoracata	C26	92	0.4	2	18	0	16	20	8	18	10	11	17	18	11	17	18
Sardinella melanura	C27	216	1.0	2	6	172	10	6	2	8	10	5	12	7	20	50	122
Sardinella spp.	C28	50	0.2	6	6	6	8	4	6	6	8	2	11	12	2	11	12
Coilia dussumieri	C29	24	0.1	2	2	0	2	2	6	2	8	3	6	3	3	6	3
Coilia ramcarati	C30	77	0.4	2	14	4	12	10	8	12	15	9	14	16	9	13	16
Sillago spp.	C31	83	0.4	2	6	25	10	14	6	16	4	12	10	9	16	17	19
Platycephalus indicus	C32	124	0.6	10	16	18	18	10	30	8	14	21	27	14	21	27	14
Apocryptes bato	C33	50	0.2	0	6	2	8	10	2	12	10	13	3	9	13	3	9
Taenioides buchanani	C34	64	0.3	6	4	8	8	8	8	12	10	8	12	12	8	12	12
Scatophagus argus	C35	12	0.1	0	0	0	0	2	0	2	8	3	3	0	3	3	0
Arius sp.	C36	70	0.3	26	8	12	12	4	0	2	6	11	13	11	11	13	11
Arius bilineatus	C37	422	1.9	48	36	174	40	32	38	36	18	37	51	56	67	65	146
Osteogeneiosus sp.	C38	324	1.5	100	18	96	10	20	52	18	10	40	39	83	40	39	83
Satepinna phasa	C39	122	0.6	34	4	38	6	6	14	8	12	15	32	14	15	32	14
Johnius argentatus	C40	542	2.5	72	70	132	72	36	70	58	32	78	102	91	78	102	91
Johnius sp.	C41	42	0.2	6	4	6	8	4	2	6	6	6	6	9	6	6	9
Setipinna taty	C42	298	1.4	35	37	39	37	37	39	37	37	8	0	0	60	99	131
Stolephorus tri	C43	174	0.8	20	22	22	22	22	22	22	22	0	8	0	46	40	80
Coilia neglecta	C44	204	0.9	25	26	25	26	26	25	25	26	0	4	0	64	48	88
Stolephorus commersonii	C45	40	0.2	5	5	5	5	5	5	5	5	0	0	0	0	16	24

Johnius carutta	C46	869	4.0	127	134	3.1	76	76	131	118	76	20	0	8	76	168	597
Johnius diacanthus	C47	236	1.1	29	30	0.7	30	30	29	29	30	0	4	0	0	48	184
Oxyurichthys microlepis	C48	2371	11.0	419	165	16.2	165	165	196	422	165	4	0	0	126	1110	1131
Arius caelatus	C49	1377	6.4	152	152	5.1	162	162	194	182	162	0	0	42	397	280	658
Arius thalassinus	C50	1706	7.9	203	203	5.7	198	198	238	230	198	0	0	0	200	760	746
Batrachocephalus mino	C51	1752	8.1	270	270	6.5	134	134	270	270	134	0	0	0	0	312	1440
Hemiarius sona	C52	2524	11.7	364	249	18	249	249	215	215	249	0	8	0	740	719	1057
Platycephalus indicus	C53	16	0.1	2	2	0.0	2	2	2	2	2	0	0	0	0	0	16
Total		2160	100	2383	2605	4168	2676	2348	2523	2983	1952	1416	1563	1769	3234	5373	8295

(1952) was found in Station 8. Monthly abundance (individuals) variation was significant in all sampling zones. Highest number of individuals was recorded in April. The monthly abundance for each sampling zone sharply reduced from November to January and gradually increased February to April.

Diversity status

The value of Shannon Wiener diversity index (H') and Margaleaf richness (M) were calculated according to month and stations (Fig. 5). After polling whole samples (48), total H' value was found 3.197625. Highest Shannon diversity index (3.69) was found at station 5 and lowest (2.83) was found at station 3. Higher Shannon diversity index values were found in December (3.144875) where low during April (2.788875). No significant difference was found in the mean Shannon diversity index among the stations and months. Margaleaf richness value for pooled 48 samples was 6.38575. The maximum margalef richness value was observed 6.863 at station 6 where minimum value was observed 5.519 at station 3. Higher margalef richness value was found 6.750125 during March where lower value 6.107875 observed during November. Similar to Shannon diversity index no significant difference was observed in mean margalef richness value among the stations and months. Evenness index value for pooled 48 samples was 0.4842625, where the highest (0.5584) and the lowest (0.3558) poled Evenness recorded in station 5 and station 1, respectively. Highest evenness value was found 0.686413 in November and lowest value observed 0.350938 in April. No significant difference was found in mean value of evenness value among the months but significant difference was observed among the stations. Dominance diversity index value for pooled 48 samples was 0.0626425. After pooling all the samples of each sampling station, highest dominance index value (0.09252) observed in station 3 and lowest value (0.04883) observed in station 5. Highest monthly dominance diversity index value was 0.102963 during March and lowest value was 0.062065 during December. Significant difference was found in the mean value of dominance diversity index both for month and stations.

Spatial and temporal relation of fisheries bio-diversity

The analysis of similarity (ANOSIM) showed significant dissimilarity in assemblage structure among stations and months (Table 2). Station 1 showed significant difference in fish assemblage with all the stations except station 3, 6 and 8. Station 2 showed significant difference with station 1 and 3. Except station 1 and 8, station 3 showed significant difference with all other stations. Station 4 and 5 showed significant similarity with all stations except 1 and 3 where Station 6 showed significant difference with station 3 and no significant difference was observed for station 8 with other stations. In case of months, November, December and January showed significant dissimilarity with February, March and April. Similarly February, March and April showed significant dissimilarity with the month November, December and January.

According to Similarity percentage (SHRIMPER) analysis (Table 3), 56.3% similarity were found among the stations and major contributing speceis are *Oxyurichthys microlepis* (12.24%), *H. sona* (11.95%), *Arius thalassinus* (8.18%),

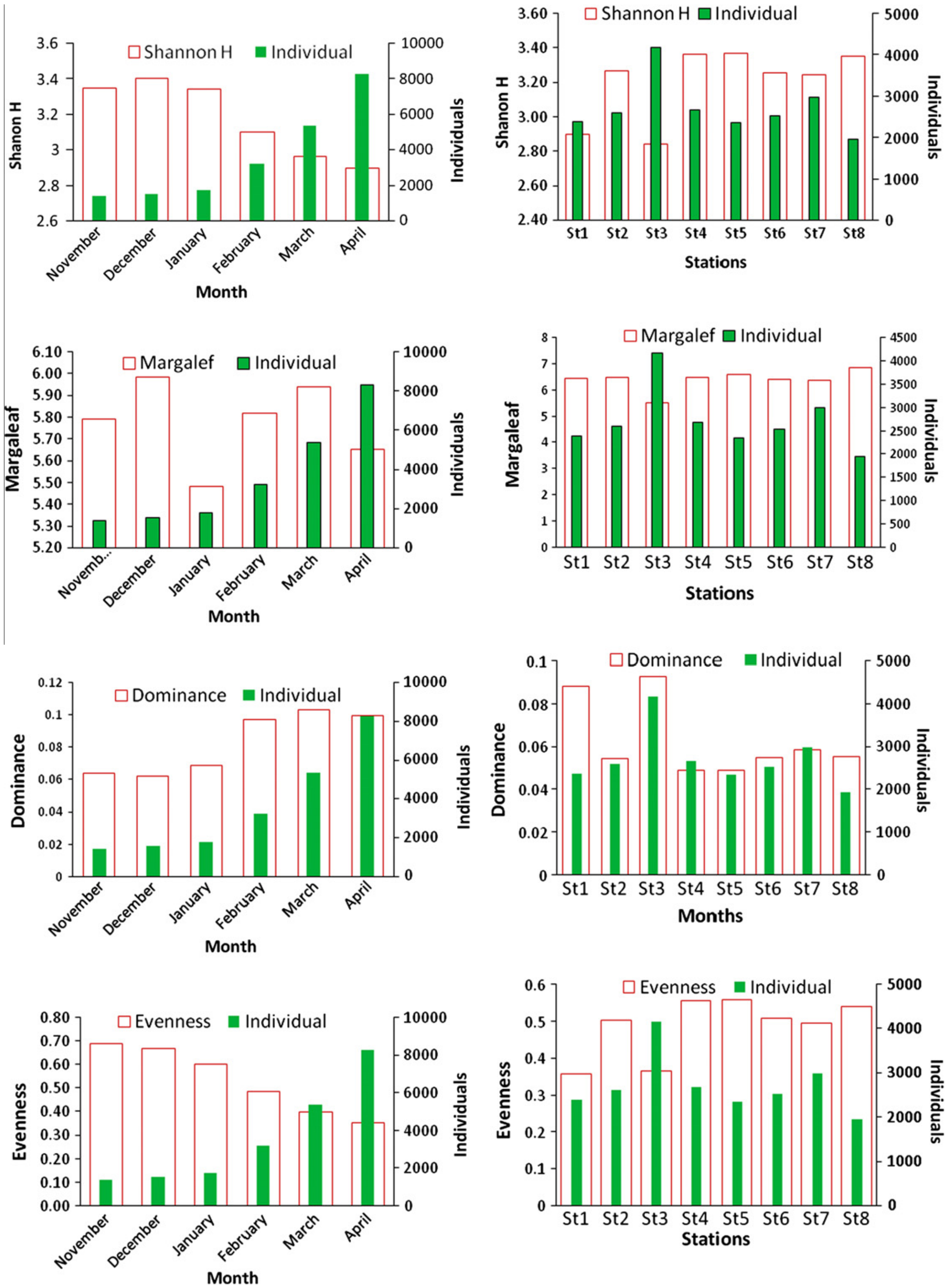

Figure 5 Different fisheries diversity status at Meghna estuary.

Batrachocephalus mino (8.11%), *Arius caelatus* (6.58%), *Glossogobius giuris* (5%), *Harpodon nehereus* (4.91%), *Johnius carutta* (4.01%), *Polynemus paradesius* (3.55%), *Odontamblyop rybicundus* (2.2%) *and Osteogeneiosus* sp. (2.03%). On the other hand 59.36% similarity were observed among the months and major contributing species are *O. microlepis* (13.21%), *H. sona* (13.1%), *A. thalassinus* (9.24%), *B. mino* (9.03%), *A. caelatus* (7.30%), *J. carutta* (4.40%), *G. giuris* (4.17%), *H. nehereus* (4.08%), *P. paradesius* (3.24%), *O. rybicundus* (1.86%) and *Osteogeneiosus* sp. (1.75%).

At the similarity level 32% separation, either for month or station, was identified by cluster analysis (Fig. 6). Two major clusters were observed-first cluster consists station 3 with January, April, February, station 2 with February, March and April, station 4 with February, March, station 5 with February, March, station 6 with February, March, April,

Table 2 Result of one-way ANOSIM (significant levels) among different stations and months.

Stations	St1	St2	St3	St4	St5	St6	St7	St8
St1	–	0.0229	–	0.004	0.0241	–	0.0282	–
St2	0.0229	–	0.0222	–	–	–	–	
St3	–	0.0222	–	0.0088	0.0189	0.0497	0.025	–
St4	0.004	–	0.0088	–	–	–	–	–
St5	0.0241	–	0.0189	–	–	–	–	–
St6	–	–	0.0497	–	–	–	–	–
St7	0.0282	–	0.025	–	–	–	–	–
St8	–	–	–	–	–	–	–	–

Months	November	December	January	February	March	April
November	–	–	–	0.0003	0.0003	0.0002
December	–	–	–	0.0006	0.0004	0.0002
January	–	–	–	0.0002	0.0001	0.0001
February	0.0003	0.0006	0.0002	–	–	–
March	0.0003	0.0004	0.0001	–	–	–
April	0.0002	0.0002	0.0001	–	–	–

Table 3 Average similarity and discriminating fish in each station using SIMPER analysis.

SIMPER			
Average similarity			
Station (56.3%)		Month (59.36%)	
Contributory species		Contributory species	
Species	%	Species	%
Oxyurichthys microlepis	12.24	*Oxyurichthys microlepis*	13.21
Hemiarius sona	11.95	*Hemiarius sona*	13.1
Arius thalassinus	8.183	*Arius thalassinus*	9.235
Batrachocephalus mino	8.107	*Batrachocephalus mino*	9.032
Arius caelatus	6.576	*Arius caelatus*	7.304
Glossogobius giuris	4.99	*Johnius carutta*	4.404
Harpodon nehereus	4.913	*Glossogobius giuris*	4.169
Johnius carutta	4.014	*Harpodon nehereus*	4.077
Polynemus paradesius	3.547	*Polynemus paradesius*	3.241
Odontamblyop rybicundus	2.199	*Odontamblyop rybicundus*	1.862
Osteogeneiosus sp.	2.027	*Osteogeneiosus* sp.	1.751

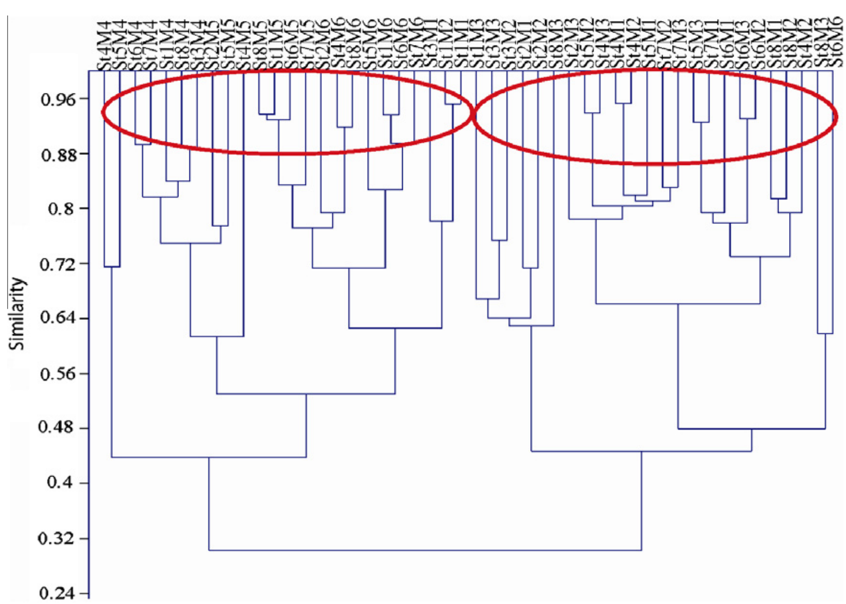

Figure 6 Spatial and temporal cluster of fish assemblage based on Bray–Curtis similarity matrix.

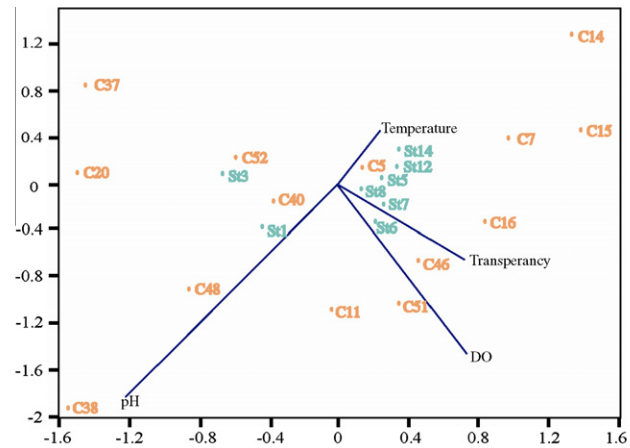

Figure 7 CCA analysis of species abundance and water parameters.

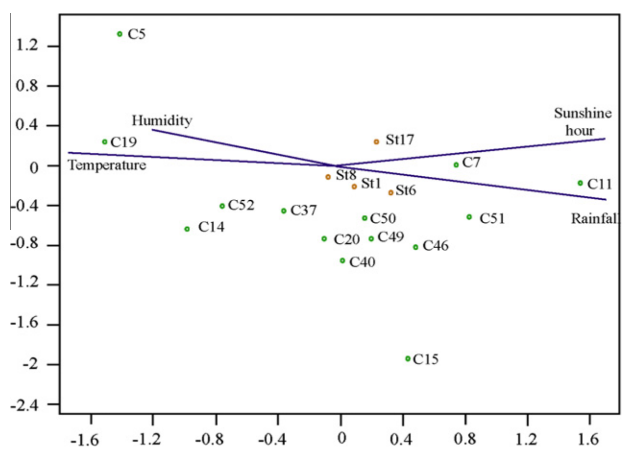

Figure 8 CCA analysis of species abundance and meteorological parameters.

station 7 with February, March and April, station 1 with April, February and March and station 8 with February, March and April and second cluster consists of station 3 with November, December and January, station 1 with December, November, January, station 2 with November, December and January, station 8 with January, November and December, station 5 with December, January and February, station 5 with December, November and February, station 4 with January, February and November, station 7 with December, January and November, station 6 with November, December and January.

Driving force of fisheries distribution at Meghna estuary

Eigen values of CCA (hydrological parameters) for the first four axes (CCA1, CCA2, CCA3 and CCA4) were found 0.46, 0.42, 0.14, and 0.13, respectively. For the first four axes species hydrological Pearson correlation coefficients were calculated 0.88, 0.87, 0.78, and 0.77, respectively. For the first four axes cumulative percentage variance of species was 51.21. The first and second axes modeled 17.21% and 19.14% of species data, respectively and the results obtained from the first two axes were plotted in Fig. 7. The vector length of a given variable indicates the importance of that variable in CCA analysis and the longest vector of pH at fourth axis showed significant correlation with station 1. Vector length of dissolve oxygen showed significant relation with station 6 where transparency showed significant relation with station 7 and 8 and temperature showed significant relation with station 2, 4 and 5. High values of pH are associated with *Liza subviridis*, *Osteogeneiosus* sp., and *O. microlepis*. High values of dissolve Oxygen are associated with the occurrence of *J. carutta and B. mino*. High transparency value is associated with the occurrence of *O. rybicundus, A. caelatus and A. thalassinus and* high temperature is associated with the occurrence of *Eleutheronema tetradactylum*, *Gadusia chapra*, *H. nehereus*, *Mugil cephalus and Mugil corsula*.

Eigen values of CCA (meteorological parameters) for the first four axes (CCA1, CCA2, CCA3 and CCA4) were found 0.29, 0.27, 0.08, and 0.07, respectively. For the first four axes species meteorological Pearson correlation coefficients were calculated 0.89, 0.90, 0.81, and 0.80, respectively. For the first four axes cumulative percentage variance of species was 48.25. The first and second axes modeled 16.32% and 17.21% of species data, respectively and the results obtained from the first two axes were plotted in Fig. 8. Sunshine hour is significantly related with station 7, humidity is significantly related with station 8, air temperature is related with station 2 and rainfall is associated with station 1 and 6. Occurrence of *H. nehereus* is associated with high value of sunshine hour. High value of air temperature is associated with the occurrence of *P. paradesius* and occurrence of *G. chapra* is associated with high humidity value. High value of rainfall is associated with occurrence of *L. subviridis, M. corsula, Osteogeneiosus* sp., *J. carutta, A. caelatus, A. thalassinus* and *B. mino*.

Discussion

Salinity of the present work found 0 at all stations throughout the study period. Though McErlean et al. (1973) stated that salinity of an estuary ranged between 0.50 and 35 ppt and Ahammad (2004) showed the salinity ranged between 14.43 and 25.92 ppt. This is due to heavy fresh water discharge from surrounding land area and also a function of annual rainfall pattern. Historical rainfall pattern showed a sharp increase in rainfall pattern. Moreover downstream area is far from the present study area which is another reason for no saline water. Inflow of fresh water from Ganga–Brammaputra river system makes the area no saline zone. Dissolve oxygen concentration was found in this study ranges between 4.6 and 5.8 mg/L and almost same value is also reported by Ahammad (2004) in the same estuary. Though variation in DO concentration in Meghna river estuary is not so high, but Kamal (1992) also observed variation in DO content of Moheskhali channel water. Ahammad (2004) showed DO concentration of Moheskhali channel was 3.63–6.83 mg/l. pH value of the present study shows the similarity with Dutta et al. (1954) Martin (1970), Ahmed (1989), Noori (1999) Belaluzzaman (1995) and Rshid (1999). High pH value at station 1 is due to presence of harbor and extreme human interference with domestic waste disposal. Minimum water temperature was recorded at station 4 and maximum at station 8 due to seasonal variation. Alam (1993) also reported variation of water temperature for seasonal change. Kamal (1992) observed seasonal variation of water temperature ranged between 7.54 and 10 °C. Belaluzzaman (1995) also found 10 °C water temperature variations at Bangladesh coast. Water transparency is a function of rainfall pattern and found maximum during April where minimum observed during December. Highest rainfall found in April where minimum recorded at December. Air temperature varies between 18 °C (January) and 29 °C (May). Maximum sunshine hour recorded 8 h during February to April and humidity 90% during July. Estuaries are highly dynamic area and continuously changing. The Meghna river estuary is also same. No significance difference was found in temperature and DO concentration among the stations where significant difference was found in transparency and pH value. Though temporal variation in meteorological parameters was observed due to seasonal variation but no spatial difference was found in this study.

A total of 53 fin fish species were recorded during the study period. Among them are *E. tetradactylum*, *G. giuris*, *H. nehereus*, *L. subviridis*, *O. rybicundus*, *P. paradesius*, *Arius bilineatus*, *Osteogeneiosus* sp., *Setipinna taty*, *J. carutta*, *O. microlepis*, *A. caelatus A. thalassinus*, *B. mino* and *H. sona* each contributing more than 1% of the composition. Hossain et al. (2007) reported about 161 species collected by different types of net from Naaf river estuary where Islam (1987) observed 97 species from the same study area. Islam et al. (1992) reported about 185 species from the coastal waters of Bangladesh collected from the estuarine set bag net. Islam (2005), Ahammad (2004), Kamal (2000) and Nabi et al. (2011) identified 48, 76, 46 and 45 finfish species from Chittagong coast, Moheskhali Channel, Karnaphulli river estuary and Bakkhali estuary. Though present study area is the largest estuarine system in Bangladesh, but this findings showed a small number of species composition compared to Naaf river estuary study of 2007 and 1987 although more or less similarities was found with Chittagong, Moheskhali, Karnafulli and Bakkhali estuary. The reasons for reduction in species diversity are long term change in hydrological and meteorological parameters. Use of ESBN net by fishermen for a long time is another reason for low species diversity as these types of net catch tinny aquatic organisms to large fish. Heavy fresh water discharge from adjacent land mark brings sediment and causes siltation and makes water turbid which ultimately effects on species number. Increased fishing pressure is the main triggering factors for fisheries diversity loss. Highest number of individuals was observed at station 3 and this is due to relatively low human interference and optimum environmental condition and on the other hand lowest number of individuals observed at station 8 due to extreme human interference. Three major dominant species was observed in the Meghna river estuary which is similar to several studies which reported the dominance of the resident species in the estuaries (Thomson, 1966; Hotos and Vlahos, 1998), although in the case of the Bakkhali estuary no species was found to be dominant (Nabi et al., 2011). Present study also differs with Blaber (2000) as that findings stated that the estuarine resident species are a relatively insignificant proportion of the fish fauna available in an estuary and are generally all relatively small-sized fish. *H. sona* and *O. microlepis* are the most abundant species in the Meghna estuary and contributed 11.7% and 11% of the total catch composition respectively. *H. sona* occurred in maximum number in station 1 and minimum at station 3. During November and January no species were recorded though only few species were observed during December. A sharp increase in the number observed during February to April and in last month this species occurred in maximum number, this is may be due to their breeding season. Another dominant species *O. microlepis* observed in maximum number at station 7 which is in Hatiya island and known as the heaven ground for this fishery due to favorable environmental condition. In terms of dominant species this study differs with the findings of Nabi et al. (2011) and Chowdhury et al. (2010). The species abundance found in the Meghna river estuary is composed of small numbers of species with high contribution and a large number of species whose contributions are very negligible, a common feature of estuarine faunal populations (Gaughan et al., 1990; Harrison and Whitfield, 1990; Drake and Arias, 1991; Harris and Cyrus, 1995; Whitfield, 1999). Moreover, each estuarine system may have a different abiotic environment (Blaber, 2000), resulting from the tidal range, freshwater input, geomorphology and human pressure (Dyer, 1997; McLusky and Elliott, 2004) which also affects the species abundance. So a difference in species abundance with other study area is not likely to be the exception.

A biodiversity index seeks to characterize the diversity of a sample or community by a single number (Magurran, 1988). The concept of the ‘‘species diversity’’ involves two components: the number of species or richness and the distribution of individuals among species. However, the formal treatment of the concept and its measurement is complex (Williamson, 1973). Shannon–Wiener diversity index considers the richness and proportion of each species while Evenness and Dominance indices represent the relative number of individuals in the sample and the fraction of common species respectively. The biodiversity index values (H') obtained from present study is not so very high according to Shannon-Weaver biodiversity index values and they do not exactly show the differences occurring among the stations either. According to Keskin and Ünsal (1998), the reason for showing lower species biodiversity is that fishing gears used have high selectivity effect. The equipment effect of the fishing gear used in this study was ignored. In spite of this, the fact that the fishing gear had lower selectivity during sampling both gives an idea about the fish species biodiversity in the region and shows the presence of a medium sized biodiversity in the region. Highest Shannon diversity index was found in station 5 and December month where lowest was observed at station 3 and during April. In each case high Shannon diversity index is involved with low individuals and low diversity involved with high number of individuals. The main causes of the differences occurring in the biodiversity indexes are seasonal variations of nutrients at the sea grass beds affecting the coexistence of many fish species (Huh and Kitting, 1985), atmospheric air currents and environmental conditions (Keskin and Ünsal, 1998), and seasonal fish migrations (Ryer and Orth, 1987). Dominance diversity index value was highest in station 3 and lowest value observed in station 5. Highest monthly dominance diversity index value was in March and lowest value was in during December. If we compare the temporal variation of dominance status among the all sampling zones and months, it did not fluctuate for a greater magnitude. According to months, the evenness index had the lowest value in April and the highest value in November. Where the highest and lowest poled Evenness recorded in station 5 and station 1, respectively. A number

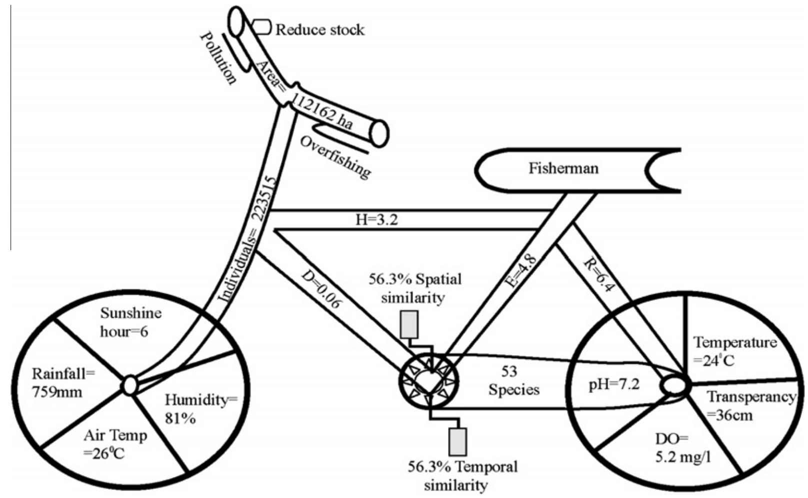

Figure 9 Driving forces of fisheries distribution at Meghna estuary.

of fish species reproduce in April in the coastal water of Bangladesh which may be the reason behind the highest and lowest evenness value during November and April. Therefore, the main reason why the number of individuals increased towards the April months in our study is that new individuals joined the fish stocks. In addition to this, ecological conditions also have an effect on the distribution of the fish species. The maximum margalef richness value was observed at station 6 where minimum value was observed at station 3 and in case of month higher richness value was found during March where lower value observed during November. Shannon diversity index was found in station 5 and December and dominance diversity index value has dropped at this station and month. The evenness index rose during November at station 5 which is almost similar to Shannon diversity index. On the other hand richness value observed at highest level at station 6 and during March which is similar to dominance diversity index. There is positive correlation found between Shannon–Weiner and Evenness index similar to Nair et al. (1989) as their study has shown same relationship of fish species diversity in the Nair river of the Western Ghats of India. On the other hand a negative relation was observed between Shannon–Weiner and Dominance index in this study which is similar to the study of Naaf river estuary by Chowdhury et al. (2010). In Shannon (*H*), Evenness (*e*), Dominance index (*D*) and Mergalef (*d*) diversity there was no significant difference observed. Therefore, it may be concluded that the seasonal difference in species diversity is a common phenomenon in the studied area.

In terms of spatial and temporal assemblage structure of fin fish, two major groups were indicated by cluster analysis in the Meghna river estuary. Group 1 comprises the sample of the February, March and April with all the stations. On the other hand Group 2 is formed by November, December and January with all sampling stations and showed 32% similarity with Group 1. In general samples from first three months (November–January) maintained a similarity which is also same for last three months (February–April). Station 1 and 3 showed more or less dissimilarity with all other stations as these two stations are situated far from other stations where station 4–7 has high similarity with other stations. These stations are located in middle position of the present stations which is the reason behind this similarity. In case of months November to January and February to April showed dissimilarity with each other which is also clear from the catch composition of this study. Present study found almost same similarity in case of occurrence of finfish assemblage among the stations and months. Major contributing species for both stations and months are also similar although their percentage of contribution differs from each other. This similarity and dissimilarity is mainly affected by seasonality which is responsible for fluctuation of hydrological and meteorological parameters and thus affecting the fish assemblage in estuaries (Whitfield, 1989; Loneragan and Potter, 1990; Young and Potter, 2003). Seasonality also affects the spawning activity of fish and which ultimately influence in catch composition (McErlean et al., 1973). In his research similarity was found in more among the months rather than stations.

Many interacting physical and biological factors influence the occurrence, distribution, abundance and diversity of estuarine tropical fishes. Among the environmental variables, water salinity, temperature, turbidity, dissolved oxygen, and their regular or irregular fluctuations at different time scales, have been identified as determinants in estuarine fish ecology (Whitefield, 1999; Blaber, 2000). Effects of environmental variable on species distributions were tested by CCA analysis. Species located near the origin either do not show a strong relationship to any of the variables or are found at average values of environmental variables (Marshall and Elliott, 1998). Water temperature variation showed less impact on species distribution as value of this parameter was more or less similar throughout the whole station during the study period. Though difference occurs between the water temperature degrees throughout the year varies according to seasonal variations of the sunlight and the effect of winds and water currents. Fish communities are highly affected by temperature within estuaries (Cyrus and McLean, 1996). A sudden increase or decrease in water temperature may cause fish mortality (Blaber, 2000). Transparency is one of the hydrological impact factors playing role in species distribution. Turbidity affects the estuarine fishes in three main ways: it may afford greater protection for juvenile fish from predators; it is generally associated with areas where there is an abundance of food; and it may provide an orientation mechanism for migration to and from the estuary (Blaber, 2000). Excessive high water turbidity showed negative effect on fish egg survival, hatching success, feeding efficiency (mainly on filter feeders), and growth rate and population size (Whitefield, 1999). Dissolve oxygen concentration is another major factor triggering the species distribution at Meghna river estuary. DO generally effect the survival of fishes especially juvenile and fry. Maes et al. (2004) mentioned dissolved oxygen is one of the most important factors for fish abundance and distribution. pH is the most important hydrological factors for species distribution though Nabi et al. (2011) found very little impact of this parameter on fish distribution at Bakkhali river estuary. In case of meteorological parameter, rainfall and air temperature is main triggering factors. Rainfall influences salinity distribution though salinity was found throughout the stations. This factor also influences the transparency and carries out sediment from surrounding land area. Humidity and sunshine hour has less impact on species distribution. Present study used 8 environmental variable (four hydrological and four meteorological) and found 19.2% of the total species variation, where Marshall and Elliott (1998) found that five environmental variables accounted for 18.4% of the total species variation even though they included bottom, mid and surface values of each variable in CCA. On the other hand Rakocinski et al. (1996) used 11 environmental variables that together explained only 21.9% of the total species variations in CCA. Martino and Able (2003) explained 29.9% of the total species variation in Mullica river estuary, New Jersey, using five environmental variables that included salinity and geographic distance.

The Meghna river estuary is the largest estuarine system with an extensive water body providing favorable condition for fisheries abundance. The environmental aspects i.e. water and meteorological parameters are act as a driving force (Fig. 9) for fisheries distribution at Meghna estuary. The vast water body provides a spacious area for distribution of different species of different characteristics.

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