Freshwater Fish Diversity at Greater Noakhali, Bangladesh

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ABSTRACT

This study assessed the spatial-temporal diversity of fish at greater Noakhali, an aquatic ecosystem that supports the most diverse fish communities in Bangladesh. Fish samples were collected from eight locations from July 2010 to June 2011 and diversity analyzed using PAST software. Findings showed that greater Noakhali is the habitat for 128 fish species. For the whole sampling area, the Shannon diversity index, evenness, Margalef richness and dominance index values were 4.501, 0.889, 15.763 and 0.012, respectively. Oreochromis mossambicus, Mastacembelus armatus and Tenualosa toli were the major contributory species in temporal terms and Tenualosa ilisha, Somileptes gongota and Mystus vittatus in spatial terms.

Keywords: Freshwater, Fish biodiversity, Noakhali, Bangladesh

INTRODUCTION

The extensive freshwater resources in Bangladesh (5,433,900 ha, covering 37% of the country) are the third most bio-diverse aquatic fishery in Asia, after China and India, with about 800 species in fresh, brackish and marine waters (Hussain and Mazid, 2001). This species diversity has been attributed to the diverse aquatic ecosystems that are scattered across the country in the form of rivers, ponds, ditches, lakes, beels/haors/baors (saucer shaped water bodies with monsoon expansion and winter contraction), floodplains and canals. Total fish production from the inland/freshwater area in 2003-04 was 914,752 MT, representing 78.3% of total fisheries production, accounting for 4.92% of GDP, 23% of the gross value added to agricultural products, more than 11% of export earnings, and employment for over 2 million people (DoF, 2005). Although fish provide 63% of Bangladesh's animal protein intake, fisheries production is not keeping pace with population growth (Hussain, 2010). To address this issue, the fisheries sector needs to maximize fish production in parallel with conserving its biological diversity.

Fisheries populations are very dynamic, both temporally and spatially (Chowdhury et al., 2010). Greater Noakhali possesses an extensive aquatic ecosystem, which supports multitudes of species of plants, fish, prawn and other organisms. Of these, fish are the most important element and the major source of dietary protein for the rural poor. This sector also generates employment opportunities that form the lifeline for the rural economy. Only a few years back, greater Noakhali contained a huge number of fish. However, over-exploitation, habitat alteration and indiscriminate use of agro-chemicals has led to drastic declines in their numbers, threatening people's livelihood. Considering the lack of baseline information on the fish species of greater Noakhali, this study explores the existing fish faunal composition, including their temporal and spatial diversity, of greater Noakhali.

Study area

This study was conducted at greater Noakhali (Figure 1), located at the central coastal zone of Bangladesh between latitude 22°30′ and 23°15′ N and longitude 89°45′ and 91°30′ E. The Noakhali River and small Feni River join many canals, tributaries, creeks and stream corridors. The tidal range at the Noakhali coast is large, ranging from 0.48 m at neap tide to 3.79 m at spring tide (Das and Hossain, 2005). Average temperatures vary between 12°C during December-February to 34°C during April-June. The monsoon or rainy season (June-October) is characterized by southeast monsoon winds with high rainfall, humidity and cloud cover. The greater Noakhali possesses different types of aquatic ecosystems, supporting a multitude of aquatic flora and fauna (Hossain, 2009).

Fisheries in this area support livelihood options for a significant proportion of the rural population, who primarily grow rice and fish, and to a lesser extent are engaged in fisheries aquaculture (Hossain and Das, 2010). The fishermen of the Noakhali coast fish for goby from early November to late March and for Bombay duck with estuarine set bag net and small-engine boats at the Meghna estuary from mid November to late March (Hossain, 2011). From late May to early November, they fish Hilsha. Besides fishing in rivers and estuaries, fishermen also use seine nets in local ponds along with hand nets, push nets, lift nets and traps in ponds, canals, rivers, creeks and flood plains.

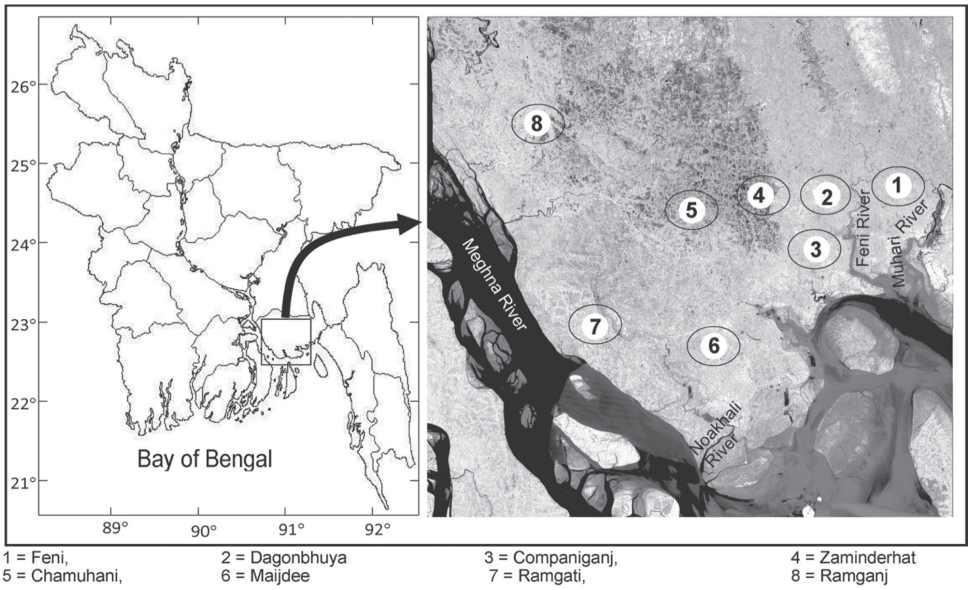

Figure 1. Geographical location of greater Noakhali, Bangladesh.

MATERIALS AND METHODS

Data collection

To collect fish species specimens, the study area is divided into eight sampling stations: Feni (sampling station #1, hereafter St 1), Dagonbhuya (St 2), Companiganj (St 3), Zaminderhat (St 4), Chamuhani (St 5), Maijdee (St 6), Ramgati (St 7) and Ramjanj (St 8). Fish samples were collected from July-October 2011 through extensive field visits. The fish were collected with seine nets, hand nets, push nets, lift nets, traps and hooks. Generally, fishermen throw away non-target fish, whether alive or dead, that they catch as a byproduct. Local fishermen were requested to keep all fish, target and non-target, for our research purposes. Samples were collected through personal visits to fishing and landing centers as well as fish markets in the area. Fishermen, fish traders and fish farmers were consulted for sampling purposes. Samples were collected, photographed and refrigerated. Chemicals were not added to preserve the fish. The samples were then transferred to the lab for taxonomic identification. The specimens were identified using the keys of Hamilton, 1822; Bhuiyan, 1964; Fischer & Whitehead, 1974; Shafi & Quddus, 1982; Rahman, 1989; Talwar & Jhingran, 1991; Bhuiyan et al., 1992; DeBruin et al., 1995; Siddiqui et al., 2007 and Hossain et al., 2007.

Data analysis

In the first stage of data analysis, the diversity of the fish assemblage was quantified and compared statistically. 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 statistics package that is used not only by paleontologists, but also in many fields of life science, earth science, and even engineering and economics. Species diversity was assessed using four different indices: Shannon–Wiener, richness, evenness and dominance indices in both the spatial and temporal spectrum. The pre-monsoon, monsoon and post-monsoon diversity indices were calculated from the spatial raw data by combining the fish communities of all study sites. All indices –Shannon-Weiner, Margalef, evenness and dominance – were calculated from the raw data for each temporal assemblage of fish.

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

$$H' = \sum_{i-1}^{S} P_i * \log P_i$$

Where, S is the total number of species and P_i is the relative cover of i^{th} species.

Margalef index (d) (Margalef, 1968) measured species richness according to the 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 the following formula:

$$E = e^H/S$$

The dominance index (Harper, 1999) determines whether particular fisheries species dominate in a particular aquatic system. It is a useful index of resource monopolization by a superior competitor, particularly in communities that have been invaded by exotic species. This index was determined by the 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 diversity indices to calculate any difference among the months and stations. In the event of significance, a post-hoc Tukey HSD test determined which means were significantly different at a 0.05 level of probability (Spjotvoll & Stoline, 1973). Similarity percentages analysis (SIMPER) (Clarke, 1993) determined the percentage of similarity among

months and stations. In addition, SIMPER also estimated the percentage of major contributing species, for both months and stations. Hierarchical clustering (Clarke & Warwick, 1994) produced a dendrogram for investigating similarities among months and stations.

RESULTS

Species abundance and distribution

A total of 5,146 individual specimens were enumerated, comprising 128 species of finfish (Table 1). *Oreichthys cosuatis* represented the most individuals counted (82, or 1.6% of total individuals) and *Puntius mahmoodi* the least (9, or 0.17%). St 2 had the most individuals (799, 15.5%) counted throughout the study period and St 1 the least (491, 9.5%). Seasonal variation in abundance was significant in all sampling zones. The monsoon season recorded the highest number of individuals (2,069, 40.2%) and post-monsoon the least (1,403, 27.3%).

Table 1. Temporal and spatial fish species abundance and distribution in Noakhali, Bangladesh.

Species	Total	%	St 1	St 2	St 3	St 4	St 5	St 6	St 7	St 8	Pre-monsoon	monsoon	Post-monsoon
Chitala chitala	43	0.84	5	6	7	3	5	7	5	5	16	18	9
Chitala latifi	49	0.95	3	3	6	3	6	8	11	9	16	19	14
Notopterus notopterus	41	0.80	4	6	3	7	5	6	3	7	14	17	10
Pisodonophis boro	33	0.64	1	1	4	6	3	8	6	4	8	14	11
Corica soborna	51	0.99	6	4	6	4	5	13	7	6	10	19	22
Gonialosa manmina	29	0.56	4	4	3	3	6	6	1	2	11	9	9
Anodontostoma chacunda	18	0.35	4	4	9	0	1	0	0	0	9	6	3
Tenualosa ilisha	54	1.05	14	13	14	6	6	0	1	0	19	21	14
Tenualosa toli	31	0.60	11	10	6	0	4	0	0	0	11	14	6
Ilisha megaloptera	51	0.99	5	7	9	4	5	8	7	6	15	23	13
Gudusia chapra	41	0.80	3	3	14	0	12	0	9	0	14	16	11
Channa marulius	66	1.29	6	6	7	10	11	9	7	10	18	29	19
Channa orientalis	41	0.79	4	5	4	4	3	8	5	8	15	14	12
Channa punctatus	56	1.09	6	5	5	14	6	9	6	5	17	25	14
Channa striatus	41	0.79	4	4	4	7	5	5	6	6	13	17	11
Amblypharyngodon microlepis	48	0.93	6	4	4	10	4	5	10	5	18	19	11
Amblypharyngodon mola	45	0.88	4	1	6	9	4	6	10	5	17	16	12
Aristichthys nobilis	46	0.90	7	8	4	0	4	8	7	8	15	19	12
Barbonymus gonionotus	49	0.95	7	5	5	9	1	10	7	5	18	18	13
Catla catla	48	0.93	9	4	5	7	6	8	3	6	15	20	13
Chela cachius	49	0.95	5	14	4	8	4	7	0	7	18	21	10
Chela laubuca	25	0.49	5	6	4	0	5	0	5	0	8	10	7
Cirrhinus cirrhosus	61	1.19	6	5	7	3	14	14	8	4	18	28	15

Table 1. Temporal and spatial fish species abundance and distribution in Noakhali, Bangladesh (Cont.).

Cirrhinus reba	51	0.98	8	3	3	10	11	11	5	0	15	21	15
Ctenopharyngodon idella	52	1.01	10	6	10	8	3	3	4	8	18	17	17
Cyprinus carpio	57	1.11	8	5	8	5	6	6	11	8	18	22	17
Danio dangila	47	0.91	7	4	5	6	6	7	5	7	15	18	14
Esomus danricus	42	0.81	6	4	5	7	4	4	5	7	16	15	11
Esomus lineatus	39	0.75	8	4	7	5	4	4	3	4	16	12	11
Hypophthalmichthys molitrix	40	0.78	8	1	5	4	4	4	6	8	13	15	12
Labeo calbasu	37	0.72	7	6	4	8	1	2	4	5	10	14	13
Labeo gonius	41	0.80	8	4	8	5	6	6	4	0	13	16	12
Labeo rohita	53	1.02	9	5	5	9	4	8	4	9	24	17	12
Oreichthys cosuatis	82	1.59	10	14	9	15	5	10	4	15	35	29	18
Osteobrama cotio	38	0.74	6	11	15	6	0	0	0	0	13	17	8
Osteochilus hasseltii	50	0.98	7	5	6	4	11	4	4	9	17	20	13
Puntius chola	53	1.02	8	4	4	8	7	4	3	15	18	17	18
Puntius conchonius	37	0.71	7	6	8	8	4	0	4	0	9	15	13
Puntius guganio	59	1.15	6	4	5	12	14	9	5	4	24	21	14
Puntius phutunio	45	0.88	8	14	9	3	11	0	0	0	16	20	9
Puntius sarana	59	1.14	8	9	15	5	5	4	4	9	21	22	16
Puntius sophore	44	0.86	3	5	6	4	3	4	0	19	14	17	13
Puntius terio	30	0.58	3	7	11	3	6	0	0	0	9	15	6
Puntius ticto	51	0.98	5	7	9	4	5	7	5	9	20	17	14
Puntius yusufi	48	0.94	4	6	5	5	4	4	5	15	18	16	14
Puntius mahmoodi	9	0.17	5	0	0	0	0	0	4	0	5	2	2
Puntius kaderi	14	0.27	0	0	0	0	3	0	11	0	5	6	3
Puntius matini	67	1.30	4	4	11	8	11	10	7	12	19	29	19
Rasbora daniconius	44	0.86	3	6	9	4	9	5	4	4	13	18	13

Table 1. Temporal and spatial fish species abundance and distribution in Noakhali, Bangladesh (Cont.).

Salmostoma bacaila	30	0.59	1	4	5	5	5	4	3	3	12	9	9
Acanthocobitis botia	63	1.22	5	14	4	6	4	14	6	10	22	24	17
Schistura beavani	40	0.78	3	9	5	5	5	4	5	4	14	16	10
Botia dario	11	0.21	2	4	5	0	0	0	0	0	3	4	4
Botia lohachata	19	0.37	2	6	11	0	0	0	0	0	4	10	5
Lepidocephalus berdmorei	37	0.71	2	4	9	8	6	3	5	0	12	15	10
Lepidocephalichthys annandalei	62	1.21	2	14	5	7	10	5	5	14	17	25	20
Lepidocephalichthys guntea	33	0.64	2	9	7	11	0	4	0	0	17	10	6
Somileptes gongota	67	1.30	2	11	8	11	11	14	5	5	19	29	19
Pygocentrus nattereri	67	1.30	6	10	5	11	9	11	7	8	21	27	19
Batasio batasio	64	1.24	6	7	10	10	5	5	11	10	20	26	18
Batasio tengana	57	1.11	2	12	13	8	4	3	7	8	13	25	19
Hemibagrus menoda	17	0.33	2	0	0	0	5	0	9	1	4	10	3
Mystus bleekeri	59	1.15	2	11	1	11	8	5	11	10	17	22	20
Mystus cavasius	52	1.02	2	10	5	9	5	4	11	6	12	22	18
Mystus gulio	52	1.01	2	4	0	5	11	11	7	12	17	20	15
Mystus tengara	40	0.78	2	14	9	4	7	0	4	0	12	13	15
Mystus vittatus	66	1.28	6	7	13	5	11	2	10	12	19	25	22
Sperata aor	51	0.98	4	10	6	8	10	2	4	7	18	15	18
Sperata oblongata	52	1.01	3	9	3	5	10	7	7	8	18	16	18
Ompok bimaculatus	16	0.31	0	0	3	0	5	6	2	0	5	6	5
Ompok pabda	34	0.66	6	9	7	8	4	0	0	0	9	15	10
Ompok pabo	21	0.41	0	7	9	5	0	0	0	0	5	8	8
Wallago attu	49	0.95	4	8	11	4	5	1	8	8	18	22	9
Wallago sudharami	29	0.56	0	0	6	14	5	0	4	0	11	10	8

Table 1. Temporal and spatial fish species abundance and distribution in Noakhali, Bangladesh (Cont.).

Silonia silondia	38	0.74	4	7	2	11	5	0	4	5	13	20	5
Pseudeutropius atherinoides	26	0.51	0	10	1	5	10	0	0	0	6	14	6
Pangasius pangasius	53	1.03	2	9	3	3	13	2	9	12	12	26	15
Clarias batrachus	39	0.75	2	7	3	6	6	2	4	9	10	19	10
Clarias gariepinus	52	1.02	2	10	9	5	5	12	5	4	16	23	13
Heteropneustes noakhaliensis	45	0.87	2	9	4	4	9	6	7	4	15	16	14
Aplocheilus panchax	42	0.82	2	7	1	8	5	7	7	5	11	25	6
Monopterus cuchia	36	0.70	2	10	2	5	10	7	0	0	9	19	8
Platycephalus indicus	29	0.56	2	9	1	4	13	0	0	0	7	12	10
Lates calcarifer	34	0.66	2	9	3	14	6	0	0	0	11	16	7
Chanda nama	57	1.11	2	5	9	11	5	10	4	11	16	26	15
Pseudambasis baculis	46	0.89	2	7	3	5	4	8	5	12	16	20	10
Pseudambasis lala	50	0.98	2	7	9	3	14	5	9	1	21	16	13
Pseudambasis ranga	50	0.97	2	6	7	6	11	5	13	0	15	22	13
Parambasis thomassi	58	1.13	2	9	10	5	5	7	12	8	22	24	12
Nandus nandus	40	0.78	2	5	9	4	3	5	5	7	13	17	10
Nandus meni	43	0.84	2	7	7	6	6	5	5	5	12	21	10
Badis badis	23	0.45	0	7	10	1	5	0	0	0	10	7	6
Oreochromis mossambicus	37	0.72	9	6	9	3	4	1	3	2	12	14	11
Oreochromis niloticus	46	0.89	2	9	9	7	10	5	3	1	15	16	15
Liza parsia	24	0.47	2	5	5	4	8	0	0	0	5	12	7
Mugil cephalus	34	0.66	2	7	2	8	5	10	0	0	8	17	9
Rhinomugil corsula	29	0.57	2	7	2	5	5	8	0	0	11	10	8
Polynemus paradiseus	21	0.41	2	6	2	4	7	0	0	0	10	6	5
Acentrogobius caninus	38	0.74	2	9	2	15	5	1	2	2	14	17	7

Table 1. Temporal and spatial fish species abundance and distribution in Noakhali, Bangladesh (Cont.).

Acentrogobius viridipunctatus	30	0.58	2	5	2	11	1	5	3	1	8	15	7
Apocryptes bato	19	0.37	2	7	2	5	3	0	0	0	5	12	2
Pseudapocryptes elongatus	21	0.41	2	7	2	3	7	0	0	0	11	5	5
Awaous guamensis	20	0.39	2	6	2	6	4	0	0	0	5	8	7
Glossogobius giuris	26	0.51	2	9	2	5	8	0	0	0	7	13	6
Oxyurichthys microlepis	23	0.45	2	5	7	4	5	0	0	0	10	8	5
Parapocryptes batoides	23	0.45	2	7	6	4	4	0	0	0	8	10	5
Stigmatogobius sadanundio	33	0.64	2	7	9	1	14	0	0	0	13	13	7
Odontamblyopus rubicundus	31	0.60	6	6	5	3	11	0	0	0	9	12	10
Taenioides buchanani	30	0.58	4	7	7	7	5	0	0	0	8	15	7
Eleotris fusca	24	0.47	3	7	7	4	3	0	0	0	13	5	6
Eleotris lutea	32	0.62	4	6	6	10	6	0	0	0	8	11	13
Anabas testudineus	49	0.96	6	7	9	3	5	5	9	5	15	20	14
Anabas oligolepis	42	0.82	0	7	5	7	4	4	11	4	15	15	12
Pseudosphromenus cupanus	29	0.56	4	6	9	4	6	0	0	0	9	11	9
Malpulutta kretseri	11	0.21	0	0	0	0	0	0	6	5	3	5	3
Colisa fasciatus	50	0.96	4	2	2	11	4	11	7	9	15	19	16
Colisa lalia	38	0.74	0	6	2	8	2	9	8	3	12	13	13
Ctenops nobilis	35	0.68	2	2	2	5	4	5	11	4	15	12	8
Macrognathus aculeatus	49	0.95	6	2	7	5	9	4	11	5	17	17	15
Macrognathus pancalus	52	1.00	2	7	6	7	9	5	10	6	20	19	13
Mastacembelus armatus	55	1.06	4	2	9	5	11	5	10	9	15	25	15
Xenentodon cancila	27	0.52	3	8	3	3	5	0	5	0	6	13	8
Oryzias dancena	63	1.23	6	12	7	9	9	11	4	5	18	32	13
Tetraodon cutcutia	51	0.98	3	5	9	5	11	9	4	5	13	22	16
Total	5146	100	491	799	733	720	746	545	562	550	1674	2069	1403

Diversity status

After polling whole samples (48), total H′ value was 4.5005 (Table 2). The maximum H′ value by station was 4.675 at St 2 and the minimum was 4.226 at St 8. In terms of temporal distribution, the maximum H′ value by season was 4.62 during monsoon at St 1 and the minimum was 4.009 during pre-monsoon at St 8. The average H′ value was 4.368 for pre-monsoon, 4.437 for monsoon and 4.365 for post-monsoon. Significant difference (Table 6) was observed between samples and within samples (F=17.58 and P=0.001).

Table 2. Shannon-Weiner (H′) diversity value in eight sampling stations.

Sampling station	Sampling season			Pooled (H′) value	
	Pre-monsoon	Monsoon	Post-monsoon	Each station	Whole sampling area
St1	4.353	4.620	4.083	4.581	4.5005
St2	4.599	4.575	4.542	4.675	
St3	4.491	4.608	4.424	4.640	
St4	4.490	4.497	4.581	4.610	
St5	4.536	4.515	4.570	4.625	
St6	4.202	4.254	4.229	4.309	
St7	4.264	4.222	4.356	4.338	
St8	4.009	4.207	4.138	4.226	
Each season	4.368	4.437	4.365		

Total evenness value for the whole sampling area was 0.888 (Table 3). The maximum evenness value by station was 0.911 at St 7 and the minimum was 0.849 at St 1. In terms of temporal distribution, the maximum evenness value was 0.928 during post monsoon at St 7 and the minimum was 0.811 during pre monsoon at St 8. The average evenness value was 0.848 for pre-monsoon, 0.841 for monsoon and 0.902 for post-monsoon. Similar to H′ value, significant difference was also observed (Table 6) between and within the samples for evenness value (F=16.63 and P=0.0004).

Table 3. Evenness index (E) value in eight sampling stations.

Sampling station	Sampling season			Pooled evenness	
	Pre-monsoon	Monsoon	Post-monsoon	Each station	Whole sampling area
St1	0.863	0.882	0.927	0.849	0.8885
St2	0.864	0.822	0.912	0.909	
St3	0.850	0.850	0.878	0.870	
St4	0.841	0.816	0.895	0.897	
St5	0.840	0.809	0.894	0.887	
St6	0.868	0.838	0.915	0.885	
St7	0.847	0.832	0.928	0.911	
St8	0.811	0.883	0.871	0.901	
Each season	0.848	0.841	0.902		

Total dominance index value for the whole sampling area was 0.0124 (Table 4). The maximum dominance index value by station was 0.016 at St 8 and the minimum was 0.010 at St 2. In terms of temporal distribution, the maximum dominance index value was 0.018 during post-monsoon at St 1 and the minimum was 0.011 during monsoon at St 1. The average dominance index value was 0.015 for pre-monsoon, 0.014 for monsoon and 0.014 for post-monsoon. No significant difference (Table 6) was found between and within samples for dominance index value (F=1.03 and P=0.3825).

Table 4. Dominance index (D) value in eight sampling stations.

Sampling station	Sampling season			Pooled dominance	
	Pre-monsoon	Monsoon	Post-monsoon	Each station	Whole sampling area
St1	0.015	0.011	0.018	0.012	0.0124
St2	0.011	0.012	0.012	0.010	
St3	0.013	0.011	0.014	0.011	
St4	0.013	0.013	0.011	0.011	
St5	0.013	0.013	0.012	0.011	
St6	0.017	0.016	0.016	0.015	
St7	0.016	0.017	0.014	0.015	
St8	0.021	0.017	0.018	0.016	
Each season	0.015	0.014	0.014		

Total Margalef richness value for the whole sampling area was 15.763 (Table 5). The maximum Margalef richness value by station was 18.40 at St 1 and the minimum was 11.96 at St 8. In terms of temporal distribution, the maximum Margalef richness value was 20.96 during monsoon at St 1 and the minimum was 13.09 during pre-monsoon at St 8. The average Margalef richness value was 17.464 for pre-monsoon, 18.139 for monsoon and 16.904 for post- monsoon.

No significant difference (Table 6) was found between and within samples for Margalef richness value (F=1.431 and P=0.2719).

Table 5. Margalef richness (d) value in eight sampling stations.

Sampling station	Sampling season			Pooled richness	
	Pre-monsoon	Monsoon	Post-monsoon	Each station	Whole sampling area
St1	17.67	20.96	13.40	18.40	15.763
St2	20.39	19.96	19.56	17.49	
St3	18.78	20.65	17.76	17.89	
St4	19.29	19.57	19.94	16.91	
St5	20.20	19.68	19.91	17.26	
St6	14.80	15.49	14.62	13.25	
St7	15.49	14.67	16.31	12.95	
St8	13.09	14.13	13.73	11.96	
Each season	17.464	18.139	16.904		

Table 6. Factorial analysis of variance for fisheries diversity indices.

Indices	Source of Variation	Sum of Squares	df	Mean squares	F-ratio	P
Shannon-Wiener index	Between samples	0.026583	2	0.013291	17.58	0.0001
	Within samples	0.776267	21	0.036965		
	Total	0.80285	23			
Evenness diversity index	Between samples	0.01793	2	0.008965	16.63	0.0004
	Within samples	0.011318	21	0.000539		
	Total	0.029248	23			
Dominance diversity index	Between samples	0.0006	2	0.00003	1.03	0.3825
	Within samples	0.00017	21	0.0036		
	Total	0.000176	23			
Margalef richness index	Between samples	6.11853	2	3.05927	1.431	0.2719
	Within samples	162.368	21	7.73182		
	Total	168.487	23			

Spatial and temporal relation of fisheries bio-diversity

According to SIMPER (Table 7), 60.9% similarity was found among the seasons and the major contributing species were *Oreochromis mossambicus* (2.5%), *Mastacembelus armatus* (2.5%), *Tenualosa toil* (2.5%), *Oryzias dancena* (2.0%), *Chanda nama* (2.0%) and *Ctenopharyngodon idella* (2.0%). Among the stations, 56.01% similarity was observed and the major contributing species were *Tenu-*

alosa ilisha (1.4%), *Somileptes gongota* (1.2%), *Mystus vittatus* (1.2%), *Puntius phutunio* (1.2%), *Pangasius pangasius* (1.2%) and *Gudusia chapra* (1.2%). At the similarity level, 45% separation, either for month or station, was identified by cluster analysis (Figure 2).

The cluster analysis represents two groups of fish that divided the fish community structure into two major groups between 0.48 and 0.54 similarity levels. The first cluster consists of: St 1 with monsoon; St 2 with pre-monsoon, monsoon and post-monsoon; St 3 with pre- monsoon, monsoon and post-monsoon; St 4 with pre-monsoon, monsoon and post-monsoon; St 5 with pre-monsoon, monsoon and post-monsoon; St 6 with pre-monsoon, monsoon and post-monsoon; St 7 with pre-monsoon, monsoon and post-monsoon; and St 8 with pre-monsoon, monsoon and post-monsoon seasons. The second cluster consists of St 1 with pre-monsoon and post-monsoon seasons.

Table 7. Average similarity and discriminating fish species in all stations and seasons.

Average Similarity			
Temporal (60.9%)		Spatial (56.0%)	
Species	Contribution %	Species	Contribution %
Oreochromis mossambicus	2.5	*Tenualosa ilisha*	1.4
Mastacembelus armatus	2.5	*Somileptes gongota*	1.2
Tenualosa toli	2.5	*Mystus vittatus*	1.2
Oryzias dancena	2.0	*Puntius phutunio*	1.2
Chanda nama	2.0	*Pangasius pangasius*	1.2
Ctenopharyngodon idella	2.0	*Gudusia chapra*	1.2

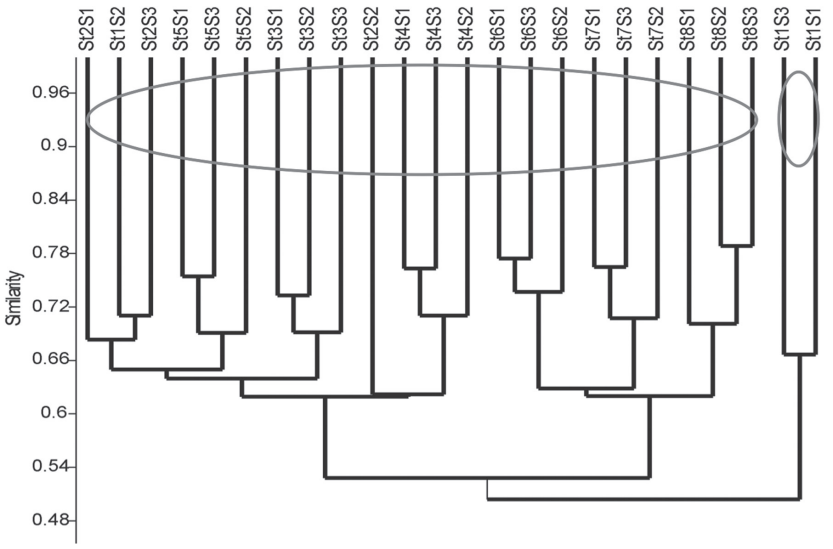

Figure 2. Spatial and temporal cluster of fish assemblage based on Bray-Curtis similarity matrix.

DISCUSSION

This study recorded 128 species of freshwater fishes from the greater Noakhali District. The following species contributed more than 1% of the total composition: *Tenualosa ilisha, Channa marulius, Channa punctatus, Cirrhinus cirrhosus, Ctenopharyngodon idella, Cyprinus carpio, Labeo rohita, Oreichthys cosuatis, Puntius chola, Puntius guganio, Puntius sarana, Puntius matini, Acanthocobitis botia, Lepidocephalichthys annandalei, Somileptes gongota, Pygocentrus nattereri, Batasio batasio, Batasio tengana, Mystus bleekeri, Mystus cavasius, Mystus gulio, Mystus vittatus, Sperata oblongata, Pangasius pangasius, Clarias gariepinus, Chanda nama, Parambasis thomassi, Macrognathus pancalus, Mastacembelus armatus* and *Oryzias dancena.*

Rahman (2005) identified 265 freshwater fish species in Bangladesh. From our survey, Noakhali represents 48% of the country's total fish species (Table 8). Mymensingh and Rajshai, regions with similar environmental characteristics as Noakhali, also have a similar number of species, 139 and 133, respectively, and share considerable species overlap with Noakhali.

Table 8. Studies on freshwater fish species of Bangladesh in the past 50 years.

Number of species	Number of family	Study area	References
128	34	Noakhali	Present study (2013)
139	34	Mymensingh	Chandra (2009)
251	61	Bangladesh	Siddiqui et al. (2007)
265	55	Bangladesh	Rahman (2005)
133	32	Rajshahi	Bhuiyan et al. (1992)
106	34	Mymensingh and Tangail	Doha (1973)
71	25	Dhaka	Bhuiyan (1964)

Variation in species composition was observed at different locations in the Noakhali study area due to the different environmental characteristics of the aquatic ecosystem. The number of order, families and species of fish represented in greater Noakhali is a rich and diverse resource, providing a significant contribution to both the national economy and protein demand for Bangladesh.

However, human interaction is continuously reducing the water body of the area. This, coupled with increased fishing pressure, is reducing fisheries diversity in greater Noakhali. St 2 has the highest number of individuals (803). This is an area that is subject to relatively low human interference and thus is under-fished and retains an optimum environmental condition. In contrast, St 1, which is subject to extreme human interference, had the lowest number of individuals (491).

Major dominant species were observed in the present study area, similar to several studies that reported the dominance of the resident species (Doha, 1973; Bhuiyan et al., 1992; Rahman, 2005 and Chandra, 2009).

A biodiversity index seeks to characterize the diversity of a sample or community by a single number (Magurran, 1988). The concept of "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). The Shannon-Wiener diversity index considers the richness and proportion of each species, while the 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 the present study are not high according to the Shannon-Weaver biodiversity index values and they do not show differences among the stations, either. According to Keskin and Ünsal (1998), lower species biodiversity can reflect the high selectivity effect of fishing gear. This study ignored the fishing gear effect. The maximum Shannon diversity index was during the monsoon at St 1 and the minimum during the pre-monsoon at St 8. In each case, the high Shannon diversity index value indicates low individuals and low diversity involved with a high number of individuals. The main causes of the differences occurring in the biodiversity indexes are seasonal variations in nutrients of the sea grass beds, affecting the coexistence of many fish species (Huh and Kitting, 1985); atmospheric air currents and environmental conditions (Keskin and Unsal, 1998); and seasonal fish migrations (Ryer and Orth, 1987). The maximum evenness value was at St 7 and the minimum at St 1. In terms of temporal distribution, maximum evenness value was during the post-monsoon at St 7 and the minimum during pre-monsoon at St 8. A number of fish species reproduce in the monsoon water bodies of Bangladesh, which may be the reason why the number of individuals increased during and after the monsoon period, as 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 dominance index value was at St 8 and the minimum at St 2. In terms of temporal distribution, the maximum dominance index value was during the post-monsoon and the minimum during the monsoon. If we compare the temporal variation of dominance status among the all sampling zones and months, it did not fluctuate much. The maximum Margalef richness value was at St 1 and the minimum at St 8. In terms of temporal distribution, maximum Margalef richness value was during the monsoon and the minimum during the pre-monsoon.

In terms of the spatial and temporal assemblage structure of fish, this study found two major groups using cluster analysis. Group 1 and 2 showed 45% similarity with each other. This study also found virtually the same similarity of the fish assemblage among the stations and months. The major contributing species for both stations and months are also similar, although their percentage contribution differs from each other. The fluctuating hydrological and meteorological parameters of seasonality are the primary factor affecting this similarity and dissimilarity (Whitfield, 1989; Loneragan & Potter, 1990; Young & Potter, 2003). Seasonality also affects the spawning activity of fish, which ultimately influences the catch composition (McErlean et al., 1973).

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none