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Fish assemblage and structure as well as hydrological parameters at Karatoya Fish Sanctuary, Panchagarh, Bangladesh

Md. Rashidul I.[1]*; Md. Jewel M.[1]; Shirin S[2].

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Abstract

Spatiotemporal variations in fish assemblage structure was studied from January to December 2015 in order to understand the impacts of the sanctuary on ichthyo-faunal diversity and to determine the indices and major hydrological factors in six sampling stations of Karatoya Fish Sanctuary sectioned in the River Karatoya. A total of 69 fish species were obtained from this sanctuary including 21 threatened species where *Aspidoparia jaya*, *Pethia ticto*, *Puntius sophore*, *Canthophrys gongota* and *Barilius barna* were the major contributory species (>4.17%) both in space and time. The uppermost species richness and abundance were viewed in January and lowest in May. Based on analysis of similarities (ANOSIM), fish assemblages were significantly different in all stations (p<0.001, R=0.15) and months (p<0.001, R=0.62). Through two-dimensional nonmetric multidimensional scaling (nMDS) and cluster analysis based on Bray-Curtis similarity index, assemblages were alienated into two groups at a value of 42% and 28% partition for station and month, respectively. Canonical Correspondence Analysis (CCA) recognized considerable relations between the number of fishes and hydrological parameters where dissolved oxygen (mg L^{-1}) and water temperature (ºC) were the main leading factors in shaping the fish assemblage structure.

Keywords: Fish assemblage, Spatial and temporal variation, Stream biodiversity

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1-Department of Fisheries Biology and Genetics, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh

2-National Institute of Biotechnology, Ganakbari, Ashulia, Savar, Dhaka-1349, Bangladesh

*Corresponding author's Email: mrislalm_fbg@hstu.ac.bd

Introduction

Aquatic biodiversity, an important element and measure of the fitness of biological and ecological sustainability (Vačkář *et al.,* 2012), especially of stream or riverine biodiversity is endlessly threatened because of over fishing, pollution and development activities eventually affecting the structure and function of aquatic biota (Stoddard *et al.*, 2006; Holcomb *et al.*, 2016). However, most of the inland fisheries in the developing world are heavily exploited and have declined faster than both terrestrial and marine biodiversity in the last 30 years (Jenkins, 2003) due to the lack of successful management plans (De Mitcheson *et al.,* 2013). So, effective management and conservation strategies would be necessary especially for small indigenous species (Baishya *et al.,* 2016). Fish sanctuary is the most thriving category of protected areas for shelter and conservation of aquatic biodiversity either yearly or seasonally that was geographically demarcated by communities and governments at various levels (Baird, 2006). But, very little information including their effectiveness was recorded about fish sanctuaries in tropical rivers, streams and other types of inland wetlands (Poulsen *et al.,* 2002; Cucherousset *et al.,* 2007). According to Rahman (2003), there is no accessible scientific information regarding the establishment of freshwater protected areas in Bangladesh. Biodiversity indices act as the key indicators applied to depict diversity status of a community (Magurran, 1988; Van Strien *et al.,* 2012) where Shannon-Weiner diversity, evenness and dominance species indexes consider the number of species, proportion or relative abundance of each species (Hossain *et al.,* 2012) while Margalef richness value is used to contrast the stocks of an ecosystem (Vyas *et al.,* 2012). Additionally, knowledge on aquatic environments and their surroundings, in order to evaluate, manage and conserve the habitat and fish population, shape the assemblage and structure of fishes (Pease *et al*., 2011). The concentrations of ecological parameters are highly able to associate with fish assemblage (Daga *et al*., 2012) distressing the survival of fin fishes (Anjos *et al*., 2008).

Bangladesh has globally important wetland ecosystems, and with its diversified aquatic habitats ranked third in Asia (Jahan *et al.,* 2014) where inland fisheries comprise a large share of total fish production. The river Karatoya, changing its name to Atrai near Khansam upazila of Dinajpur district, is said to be a lifeline in the northwestern part of Bangladesh with an approximate total length of 380 km (Ahmed *et al.,* 2013). During the dry season, this river is like a narrow rivulet with virtually low water flow in many places because of colossal siltation and water abstraction (Rahman *et al.,* 2003). Along with the view of conservation of fishes and other riverine animals, the Karatoya Fish Sanctuary was first established in January 2008 in the section of Karatoya River and with the enlistment of the livelihood of local fishers, the additional aim of this sanctuary was to introduce the concept of *in-situ* conservation to students, scientists and fishers. While this fish sanctuary contains a number of native and threatened fish species, fisheries research is unsatisfactory, fisheries data sets are required and no available information is known about it. The points of this study were to identify spatial and temporal turnover in fish assemblage structure along with major water quality parameters at the Karatoya Fish Sanctuary of this river.

Materials and methods

Study area and site selection

An investigation was carried out in Karatoya Fish Sanctuary, a section of the River Karatoya established on 1 January 2008, from January to December 2015. The location of fish sanctuary is between 26.1303º N 88.7450º E, 26.1311º N 88.7516º E and 26.1119º N 88.7486º E, 26.1127º N 88.7510º E with an area of about 2000 × 600 m^2 and a water depth of 2.50 to 8.00 m in the monsoon, and an area of 2000× 300 m^2 and depth of 0.50 to 2.5 m in the dry season.

Design and setting up the sanctuary

The study area was mainly divided into three sites i.e. upstream (1 km upward from sanctuary), inside the fish sanctuary, and downstream (1 km downward from sanctuary) with two sampling stations at 500 m distance from each other (Fig. 1). Bamboo poles, branches of bamboo and tree were collected and placed properly by experienced and skilled laborers in the bottom of the sanctuary to create a habitat, shelter and breeding ground for aquatic organisms. Before the monsoon, sanctuary materials can only be kept inside fish sanctuary from November to April due to less currents and turbulence. At the onset of monsoon in early month May, all materials e.g. bamboo poles, ropes and tree branches were collected from the sanctuary in order to pile on the river bank, and set up again within it in early November.

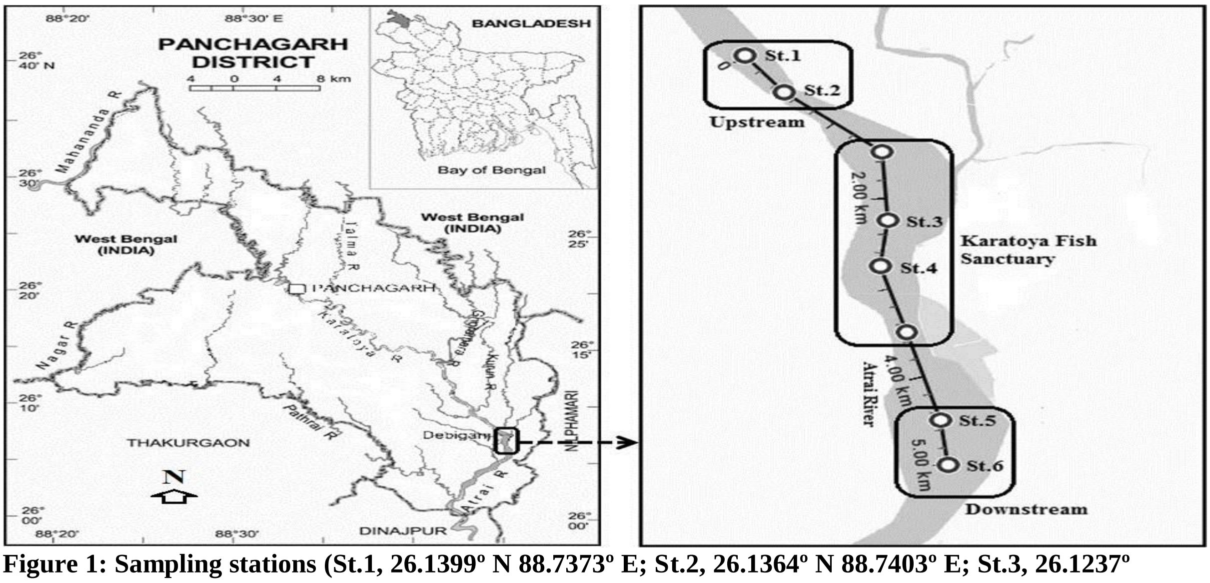

Figure 1: Sampling stations (St.1, 26.1399º N 88.7373º E; St.2, 26.1364º N 88.7403º E; St.3, 26.1237º N 88.7485º E; St.4, 26.1191º N 88.7480º E; St.5, 26.1041º N 88.7523º E; St.6, 26.0994º N 88.7531º E) at Karatoya Fish Sanctuary of the Atrai River in Bangladesh.

Sampling and data collection

Experimental data were collected at monthly intervals for hydrological factors and finfish species. Based on *in-situ* standard method (APHA, 2012), a digital thermometer, DO meter (Model: DO5509, Lutron), pH meter (Model: RI-02895, HANNA instruments) and Secchi disk were used to determine the water temperature (°C), dissolved oxygen (mgL^{-1}), water pH and transparency (cm), respectively. Fish samplings were done with the help of traditional fishing gear specifically seine net (15×3.5 m^2, 4 mm), cast net (4×6.5 m^2, 8 mm), gill net (12×1 m^2, 15 mm) and fishing trap locally known as Ucha (2×1.5 m^2, 3.5 mm) (Bengali name). All these fishing gear were operated at the same sampling spot within a 0.5 km area to ensure maximum harvesting of fishes. At each site, both gill nets and fishing traps were laid down in the late afternoon (8.00 pm) and checked in the morning (6.00 am) where five throws were made for cast net and one haul for seine net per sampling station (8.00 am). Six fishing traps named Ucha made from bamboo were placed at the bottom of each sampling site for fishing. On every sampling day (6.00 am), three persons took the Uchas out of the water one by one and brought them to the river bank. The tree branches from Uchas were removed carefully. Immediately after harvesting, a total of 7,501 fish specimens were caught, sorted and counted on spot anchored in their external morphology. Then, all live individuals were carefully released into the respective areas of the fish sanctuary where they were collected from.

Identification of the fishes

Fish species that seemed difficult to identify in field were preserved in 7 to 10% buffered formalin solution and conveyed to the laboratory of the Department of Fisheries Biology and Genetics under Hajee Mohammad Danesh Science and Technology University (HSTU) (Bangladesh) to facilitate identification and further study. The ichthyo-fauna were systematically identified and classified based on their external morphological characters following Talwar and Jhingran (1991), Rahman (2005) and Nelson (2006).

Biodiversity parameters and data analysis

A community may be considered to have high species diversity when it has more equally abundant species but thought as low species diversity if it has few species or few species are more abundant. A variety of diversity measures such as Shannon-Weiner, richness, evenness, Simpson's and dominance diversity indices can be used to know the similarity or dissimilarity of biological communities. However, in order to realize the natural index of community and fish assemblage structure, month-wise data were collected and recorded where diversity indices were calculated using the formulae:

Buzas-Gibson's evenness, $E = e^H/S$ (Pielou, 1966)

Dominance index, $D = \sum_i \left(\frac{n_i}{n}\right)^2$ (Harper, 1999)

Margalef's richness index, $d = (S-1)/\ln(n)$ (Margalef, 1968)

Shannon-Weiner diversity index, $H = -\sum_i \frac{n_i}{n} \ln \frac{n_i}{n}$ (Shannon and Weiner, 1949)

Simpson's index, SI = 1-D (Harper, 1999)

Where, n_i is the number of individuals of taxon i; n is the total number of individuals; *ln* is the

For hydrological parameters (temperature, dissolved oxygen, pH and transparency), one-way analysis of variance (ANOVA) followed by Tukey's post hoc test were used to resolve the dissimilarities among stations and months. Canonical Correspondence Analysis (CCA) is an appropriate ordination technique designed to explore the correlation between physical factors and species composition, and has recently been applied to fish communities (Toham and Teugels, 1998). To assess the relative importance of each hydrological variable on both spatial and temporal patterns of fish assemblage and structure, we used CCA derived from abundance and hydrological matrices in each station and month. CCA was applied to overall fish data matrix and environmental data matrix in order to obtain a direct environmental interpretation of extracted ordination axes. Both spatial and temporal differentiation in fish assemblage structure were reviewed with two-dimensional nonmetric multidimensional scaling (nMDS), distance based process ordinates research items by rank contrasts, founded on the relative abundance of fishes. Fishes responsible for similarity in assemblage structure were determined with the similarity percentages (SIMPER) even as one-way analysis of similarities (ANOSIM) was performed to test the significant variations among months and stations, respectively. The composition of fish species among stations and months was compared through cluster analysis by Unweighted Pair Group Method with Arithmetic mean (UPGMA) by Clarke and Warwick (1994). All statistical analyses were done using PAST (Paleontological Statistics) software (version 2.17 and 3.10) based on Bray-Curtis similarity index to assemble the similarity matrices for spatiotemporal scale.

Results

Hydrological parameters

The major water quality parameters in six stations of Karatoya Fish Sanctuary during twelve months (January-December) are shown in Figs. 2 and 3. Both minimum and maximum water temperatures were recorded as 17.50 ºC at the sanctuary (St.3) in January and 34.50 ºC upstream (St.1) in August. The highest level of dissolved oxygen (DO) was noted to be 6.50 mg L^{-1} at the sanctuary (St.3) in June and July while the lowest value was 4.40 mg L^{-1} recorded downstream (St.6) in December. Values of water pH ranged from 6.80 to 8.60 upstream (St.1) and at the sanctuary (St.4) in November and

April, respectively. Transparency reached its maximum value of 35.60 cm downstream (St.5) in May, whereas the minimum value (23.70 cm) was recorded upstream (St.2) in January. No considerable differences ($p<0.05$) were observed in hydrological parameters i.e. water temperature (F=0.02, $p>0.05$), dissolved oxygen (F=0.19, $p>0.05$), pH (F=1.19, $p>0.05$) and transparency (F=0.19, $p>0.05$) among stations. In contrast, significant differences were found in water temperature (F=209.00, $p<0.01$), dissolved oxygen (F=24.87, $p<0.01$), pH (F=3.28, $p<0.01$) and transparency (F=30.88, $p<0.01$) among months.

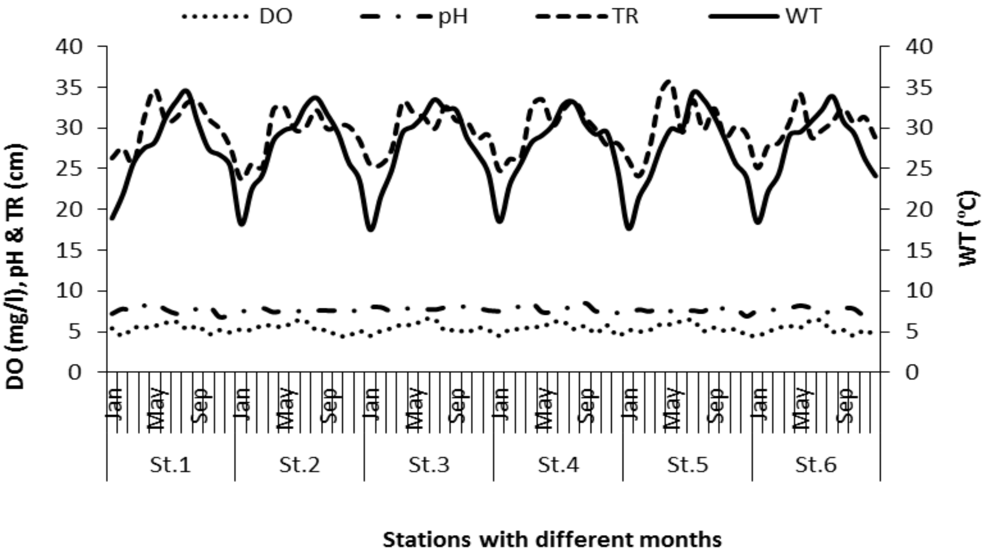

Figure 2: Hydrological parameter at stations with months of the Karatoya Fish Sanctuary.

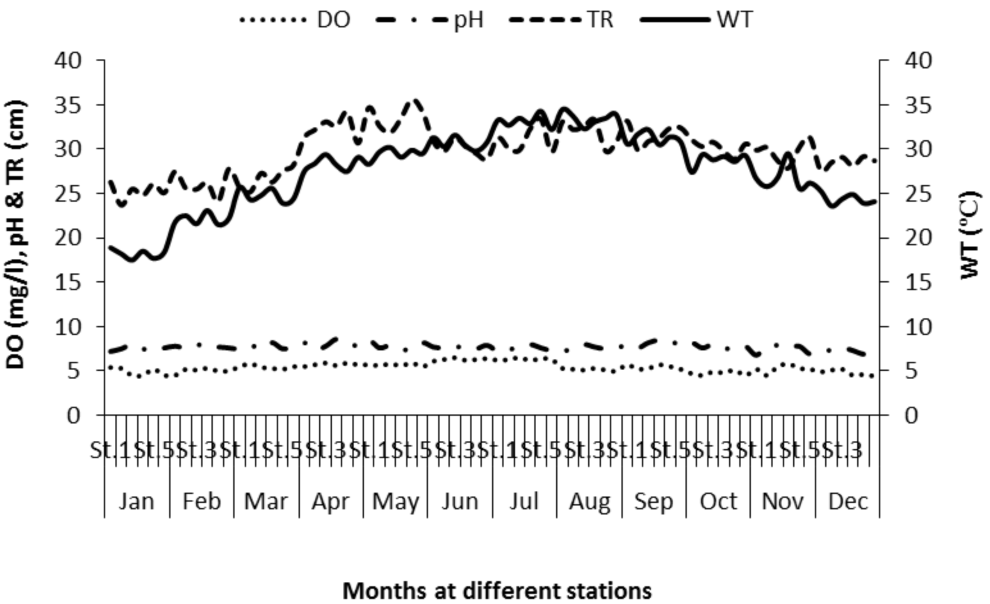

Figure 3: Hydrological parameter with months at stations in the Karatoya Fish Sanctuary.

Relative abundance, allocation and seasonal profusion of fishes

A total of 7501 individuals, comprising 8.01% in St.1, 6.32% in St.2, 33.41% in

St.3, 29.84% in St.4, 10.93% in St.5 and 11.49% in St.6, were trapped in December (Maximum, 14.00% of total catch) and June (Minimum, 3.80%) belonging to 49 genera, 23 families, 10 orders and 69 fish species (Table 1). Besides, highest number of fishes were recorded in January (38 species) at the sanctuary (67 species, St.3) and the lowest number of species were found both in June and September (23 species) upstream (27 species, St.2). According to the red list of International Union for Conservation of Nature (IUCN) in Bangladesh (IUCN Bangladesh, 2016), 21 threatened fish species (1814 individuals, 24.18% of total catch) were caught inside the study area. Based on number of species, maximum threatened fishes were recorded at the sanctuary (21 species, St.3) equally in January and February (11 species) and minimum fishes were wedged upstream (9 species, St.1 and St.2) jointly in April and May (7 species). The total catch of threatened fishes was maximized at the sanctuary (St.3, 7.71%) in December (3.31%) and were minimized upstream (St.2, 1.73%) in April (1.00%). However, month-wise abundance of fishes in each station gradually decreased from January to April and increased from September to December except from April to September with some fluctuations.

Table 1: Abundance and allocation of fishes in Karatoya Fish Sanctuary both space and time.

Scientific names	Fish code	Stations						Total	Months												IUCN status
		St.1	St.2	St.3	St.4	St.5	St.6		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Acanthocobitis botia	S1	15	0	88	85	2	2	192	45	15	0	6	0	15	0	100	0	11	0	0	LC
Amblypharyngodon mola	S2	0	0	23	42	10	10	85	25	0	0	0	60	0	0	0	0	0	0	0	LC
Anabas testudineus	S3	0	0	73	79	0	0	152	56	0	0	0	20	0	0	20	0	0	50	6	LC
Aspidoparia jaya	S4	105	98	179	141	107	110	740	142	10	54	14	128	0	0	160	20	45	75	92	LC
Aspidoparia morar	S5	15	5	17	10	15	15	77	0	10	0	0	0	5	2	0	0	60	0	0	VU
Barilius barna	S6	39	25	154	128	46	36	428	37	26	40	27	0	48	21	98	11	49	71	0	EN
Barilius bendelisis	S7	0	2	8	8	0	0	18	0	0	0	3	0	4	0	0	0	11	0	0	EN
Batasio tengana	S8	0	0	5	6	0	0	11	0	0	0	0	0	0	5	0	0	0	0	6	EN
Botia dario	S9	0	0	7	9	0	0	16	0	0	0	0	0	9	0	0	7	0	0	0	EN
Botia lohachata	S10	14	11	77	55	14	14	185	0	7	0	13	80	0	20	10	0	5	25	25	EN
Canthophrys gongota	S11	47	38	127	116	54	46	428	40	38	21	41	0	25	17	27	0	48	72	99	NT
Catla catla	S12	0	0	11	0	0	2	13	0	0	4	0	0	2	7	0	0	0	0	0	LC
Chagunius chagunio	S13	10	7	12	12	10	10	61	0	0	0	0	0	4	0	0	0	57	0	0	VU
Chanda nama	S14	20	15	77	92	20	20	244	25	40	0	55	67	0	0	0	25	0	0	32	LC
Channa orientalis	S15	0	0	41	45	0	0	86	21	0	0	0	25	0	0	0	0	0	15	25	LC
Channa punctatus	S16	6	9	65	68	6	6	160	34	7	5	17	17	0	0	10	0	10	31	29	LC
Channa striatus	S17	0	0	14	9	0	0	23	10	0	0	0	0	0	0	2	0	7	1	3	LC
Cirrhinus cirrhosus	S18	0	0	9	5	0	0	14	0	0	5	0	0	0	9	0	0	0	0	0	NT
Cirrhinus reba	S19	13	12	93	73	13	22	226	44	6	15	7	18	27	3	45	3	3	20	35	NT
Clarias batrachus	S20	0	0	11	18	0	0	29	2	0	0	0	0	0	0	20	0	0	5	2	LC
Crossocheilus latius	S21	2	1	28	19	2	2	54	10	7	0	0	0	0	0	10	7	0	20	0	EN
Ctenonpharyngodon idella	S22	5	0	0	3	5	5	18	0	3	0	0	0	0	0	0	0	0	0	15	NE
Cyprinus carpio	S23	0	0	7	7	0	0	14	0	4	0	0	0	0	3	0	0	4	0	3	NE
Devario devario	S24	3	2	29	31	3	3	71	0	0	0	0	0	0	0	0	61	10	0	0	LC
Erethistes pussilus	S25	0	0	5	9	0	0	14	0	0	9	0	0	0	5	0	0	0	0	0	LC

Esomus danricus	S26	0	0	54	47	0	0	101	0	0	0	0	0	0	0	48	0	0	10	43	LC
Eutropiichthys vacha	S27	1	1	4	2	1	1	10	5	0	0	0	0	0	0	0	4	1	0	0	LC
Gagata cenia	S28	7	5	13	9	7	7	48	0	0	0	0	0	0	20	0	17	11	0	0	LC
Gagata youssoufi	S29	0	0	6	6	0	0	12	0	4	0	2	3	0	0	0	0	3	0	0	NT
Glossogobius giuris	S30	80	71	107	99	80	80	517	22	63	37	46	65	10	5	32	12	81	86	58	LC
Hemibagrus menoda	S31	0	0	5	6	0	0	11	1	0	0	0	0	6	0	0	4	0	0	0	NT
Heteropneustes fossilis	S32	0	0	52	37	0	0	89	5	0	0	0	25	0	0	20	24	0	10	5	LC
Labeo angra	S33	0	0	64	51	0	0	115	3	0	0	0	50	0	0	5	0	0	27	30	LC
Labeo bata	S34	4	4	41	31	4	17	101	16	0	10	0	6	0	0	31	3	0	2	33	LC
Labeo boga	S35	0	0	10	30	0	1	41	1	0	0	0	0	0	0	0	0	0	0	40	CR
Labeo calbasu	S36	1	0	9	5	1	1	17	5	0	2	5	3	0	0	0	0	1	1	0	LC
Labeo gonius	S37	0	0	11	2	0	0	13	5	0	0	0	0	0	8	0	0	0	0	0	NT
Labeo rohita	S38	1	0	2	4	5	0	12	0	3	0	0	0	4	0	0	0	5	0	0	LC
Lepidocephalichthys guntea	S39	9	6	100	76	9	9	209	48	15	18	0	45	0	0	0	45	3	0	35	LC
Macrognathus aculeatus	S40	5	6	83	87	5	5	191	0	61	0	19	0	0	5	50	0	2	4	50	NT
Macrognathus pancalus	S41	34	26	78	61	34	27	260	44	0	5	0	66	0	0	38	31	18	44	14	LC
Mastacembalus armatus	S42	10	10	48	22	10	11	111	5	3	10	3	5	4	8	8	3	32	0	30	EN
Monopterus cuchia	S43	0	0	4	7	0	0	11	0	0	0	11	0	0	0	0	0	0	0	0	VU
Mystus bleekeri	S44	0	0	20	25	0	0	45	10	0	0	0	21	0	0	1	0	0	3	10	LC
Mystus cavasius	S45	0	3	2	3	4	0	12	0	0	3	0	0	0	0	0	0	0	2	7	NT
Mystus tengara	S46	4	3	60	57	4	7	135	24	12	15	8	26	0	0	10	4	10	3	23	LC
Nandus nandus	S47	0	0	4	5	0	1	10	0	0	0	5	0	4	0	0	0	0	1	0	NT
Neotropius atherinoides	S48	0	0	37	42	0	0	79	0	0	0	0	28	0	0	0	0	0	10	41	LC
Notopterus notopterus	S49	0	0	3	9	0	0	12	0	0	0	2	0	4	6	0	0	0	0	0	VU
Ompok bimaculatus	S50	0	0	6	3	0	2	11	2	0	0	0	0	3	6	0	0	0	0	0	EN
Ompok pabda	S51	0	0	4	6	0	3	13	3	0	3	0	0	0	0	7	0	0	0	0	EN
Osteobrama cotio	S52	0	0	7	3	0	0	10	0	0	0	0	3	0	0	0	0	0	0	7	NT
Pethia conchonius	S53	0	0	13	20	0	0	33	0	0	0	0	0	0	0	0	0	0	33	0	LC
Pethia ticto	S54	76	66	135	102	95	97	571	23	74	22	16	68	0	0	77	63	0	90	138	VU
Pseudambassis lala	S55	3	0	12	18	3	3	39	0	9	0	0	0	0	5	3	0	0	13	9	LC
Psilorhynchus balitora	S56	0	0	6	10	0	0	16	0	4	0	0	0	6	6	0	0	0	0	0	LC
Puntius sophore	S57	44	31	87	80	44	46	332	0	75	0	34	0	78	82	0	0	63	0	0	LC
Raiamas bola	S58	4	3	17	13	4	0	41	18	1	0	0	10	0	0	5	0	0	3	4	EN
Rita rita	S59	0	0	13	7	0	17	37	7	1	5	0	2	0	0	10	7	0	2	3	EN
Salmophasia bacaila	S60	13	13	67	60	102	110	365	57	26	48	13	22	10	26	46	29	19	12	57	LC
Salmostoma phulo	S61	0	0	0	0	30	52	82	0	0	0	0	0	0	82	0	0	0	0	0	NT
Schistura scaturigina	S62	0	0	5	0	13	13	31	0	2	17	0	0	0	0	0	0	12	0	0	EN
Sisor rabdophorus	S63	0	0	8	0	2	2	12	0	0	0	0	0	0	12	0	0	0	0	0	CR
Sperata aor	S64	1	0	9	1	19	20	50	4	1	9	0	1	0	0	1	17	13	2	2	VU
Systomus sarana	S65	5	0	33	20	5	3	66	4	6	1	5	0	5	0	5	0	3	0	37	NT
Tetraodon cutcutia	S66	0	0	4	7	1	0	12	0	0	0	7	0	4	1	0	0	0	0	0	LC
Trichogaster fasciata	S67	0	0	62	55	0	0	117	5	0	0	0	0	0	0	100	0	0	10	2	LC
Wallago attu	S68	0	0	8	3	5	7	23	2	1	7	0	3	2	1	0	3	3	1	0	VU
Xenentodon cancila	S69	5	1	33	37	26	17	119	19	7	2	5	26	6	5	27	1	1	20	0	LC
Total		601	474	2506	2238	820	862	7501	829	541	367	364	893	285	370	1026	401	601	774	1050	
Number to fish taxa		32	27	67	65	39	41		38	31	25	24	28	23	26	31	23	31	34	36	

CR: Critically endangered; EN: Endangered; VU: vulnerable; NT: Near threatened; LC: Least concern; NE: Not evaluated; IUCN: International Union for Conservation of Nature

Diversity status of finfishes

After polling all samples (72), values of diversity indices were calculated on the basis of month and station (Figs 4 and 5) where average value of dominance diversity index (*D*) value was 0.17±0.01 (Mean±SE). Above and beyond the fish sanctuary (St.3 and St.4) showed considerable differences ($F=8.95$, $p<0.01$) measured up to upstream (St.1 and St.2) and downstream (St.5 and St.6) respectively (except St.4 with St.5 and St.6) while no variations were noted among the months ($F=2.04$, $p>0.05$) expect between June and October ($p<0.01$). Maximum dominance index value (0.63) was observed in June at the station located upstream (St.2) and minimum value (0.05) was found in December at the sanctuary (St.4). Evenness index value (*E*) was noted to be 0.74±0.01. The highest (0.97) and lowest (0.48) values of evenness were recorded in May and July at the upstream (St.1) and downstream (St.6) stations, respectively. Significant differences were found in the values of evenness between January-March and March-August (F=2.41, *p*<0.05) but no significant differences were observed among stations (F=1.20, *p*>0.05). Average Margaleaf richness value (*d*) was 2.70±0.14. The maximum richness value observed was 5.51 at the sanctuary (St.3) in January, whereas the minimum value observed was 0.72 at the station upstream (St.1) in May. Moreover, richness values of the sanctuary were significantly different from stations upstream and downstream (F=16.73, *p*<0.01) but not among the various months (F=1.38, *p*>0.05). Mean value of Shannon-Weiner diversity index (*H*) was found to be 2.14±0.06. Highest Shannon diversity index (3.18) was found at the sanctuary (St.4) in December and the lowest (0.68) was observed downstream (St.2) in June. Significant differences were also found in mean diversity values of the sanctuary than outside its boundary (F=19.67, *p*<0.01) but not among months (F=1.40, *p*>0.05). Simpson diversity index (*SI*) value was 0.83±0.01 where the highest value (0.95) was observed in December at the sanctuary (St.4) and the lowest value (0.37) was observed in June at the station upstream (St.2). Moreover, momentous differentiations (F=8.61, *p*<0.01) originated in the values of dominance diversity index for sanctuary compared to upstream and downstream whereas no differences were found among months (F=2.04, *p*<0.05) expect between June and October.

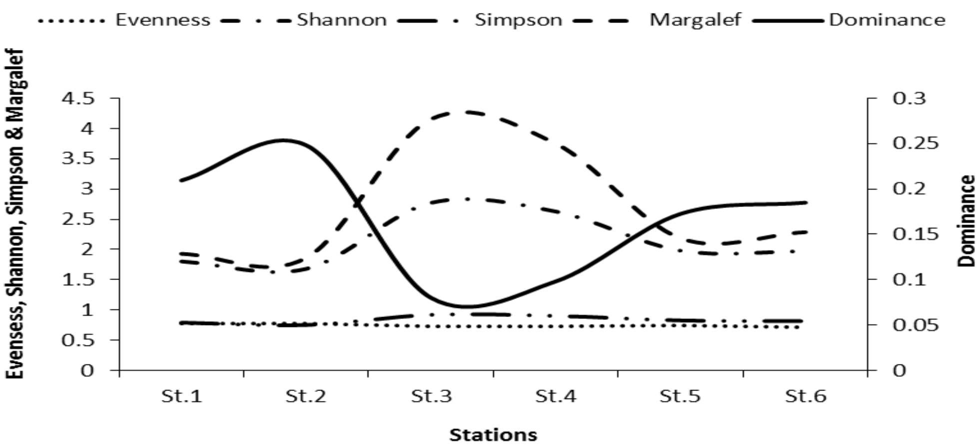

Figure 4: Mean values of Ichthyo-faunal diversity indices at different stations of Karatoya Fish Sanctuary.

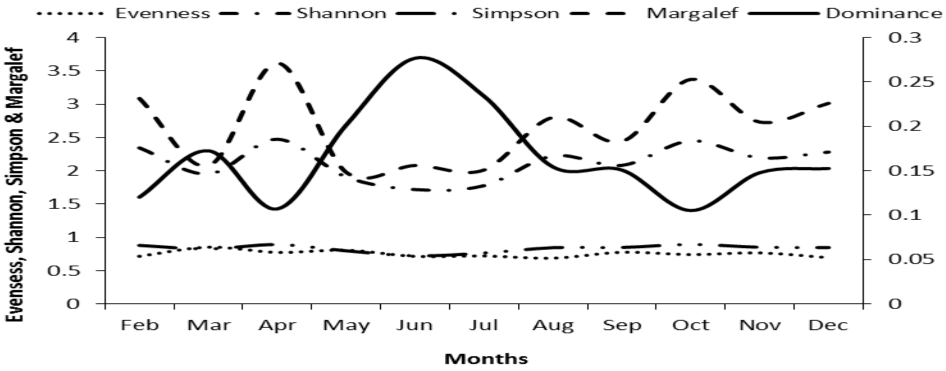

Figure 5: Mean values of Ichthyo-faunal diversity indices at different months of Karatoya Fish Sanctuary.

Fish assemblage and structure

A two-dimensional nMDS based on Bray-Curtis's similarity index suggests that fish assemblages at sanctuary (St.3 and St.4) were varied from that upstream (St.1 and St.2) and downstream (St.5 and St.6) having stress as 0.18 (Fig. 6) while similar assemblages were connected with the months i.e. January and August; February and October; March and September; April, June and July; and May, November and December stressing as 0.18 (Fig. 7). The analysis of similarity (ANOSIM) showed considerable dissimilarity in assemblage structure (Table 2 and 3) among stations (p<0.001, R=0.15) and months (p<0.001, R=0.62). Fish sanctuary (St.3 and St.4) showed significant differences in fish assemblage with that upstream (St.1 and St.2) and downstream (St.5 and St.6) where no significant difference was observed between upstream and downstream. In the case of months, there were significant dissimilarities among months wherever similarities were recorded in fish assemblage between January and May, January and August, February and April, May and August, May and November, May and December, June and July as well as November and December.

Table 2: One-way ANOSIM (uncorrected significant) among the stations of Karatoya Fish Sanctuary.

Stations	Overall p-value = 0.0001 (R-value = 0.1468)					
	St.1	**St.2**	**St.3**	**St.4**	**St.5**	**St.6**
St.1		-	0.0012	0.0109	-	-
St.2	-		0.0001	0.0010	-	-
St.3	0.0012	0.0001			0.0003	0.0001
St.4	0.0109	0.0010			0.0026	0.0050
St.5	-	-	0.0003	0.0026		-
St.6	-	-	0.0001	0.0050	-	

Table 3: One-way ANOSIM (uncorrected significant) among the months of Karatoya Fish Sanctuary.

Months	Overall *p*-value = 0.0001 (*R*-value = 0.6217)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Jan		0.0015	0.0175	0.0017	-	0.0033	0.0029	-	0.0019	0.0019	0.0027	0.0123
Feb	0.0015		0.002		0.0025	0.0028	0.002	0.0018	0.0026	0.0017	0.0055	0.024
Mar	0.0175	0.002		0.0016	0.0107	0.0024	0.0026	0.0077	0.0405	0.0017	0.0152	0.0471
Apr	0.0017	-	0.0016		0.0023	0.0024	0.0014	0.0024	0.0019	0.0017	0.002	0.0019
May	-	0.0025	0.0107	0.0023		0.0017	0.0022	-	0.0236	0.0018	-	-
Jun	0.0033	0.0028	0.0024	0.0024	0.0017		-	0.0016	0.0023	0.0022	0.0022	0.0016
Jul	0.0029	0.002	0.0026	0.0014	0.0022	-		0.0025	0.0026	0.0026	0.0025	0.0027
Aug	-	0.0018	0.0077	0.0024	-	0.0016	0.0025		0.0029	0.0021	0.0282	0.0074
Sep	0.0019	0.0026	0.0405	0.0019	0.0236	0.0023	0.0026	0.0029		0.0022	0.0012	0.0026
Oct	0.0019	0.0017	0.0017	0.0017	0.0018	0.0022	0.0026	0.0021	0.0022		0.0019	0.0017
Nov	0.0027	0.0055	0.0152	0.002	-	0.0022	0.0025	0.0282	0.0012	0.0019		-
Dec	0.0123	0.024	0.0471	0.0019	-	0.0016	0.0027	0.0074	0.0026	0.0017	-	

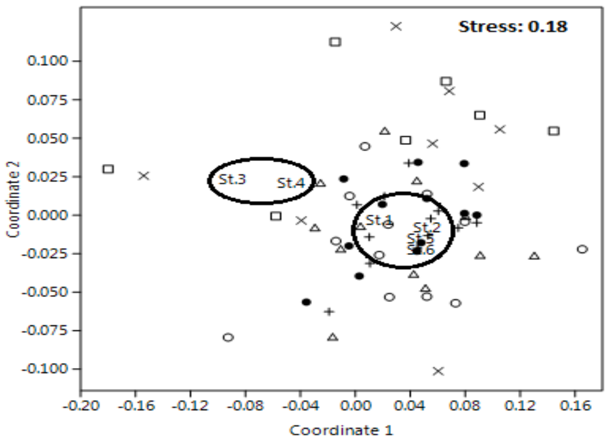

Figure 6: Two dimensional nMDS scaling of comparative fish assemblage data based on Bray-Cruits similarity index among stations of Karatoya Fish Sanctuary.

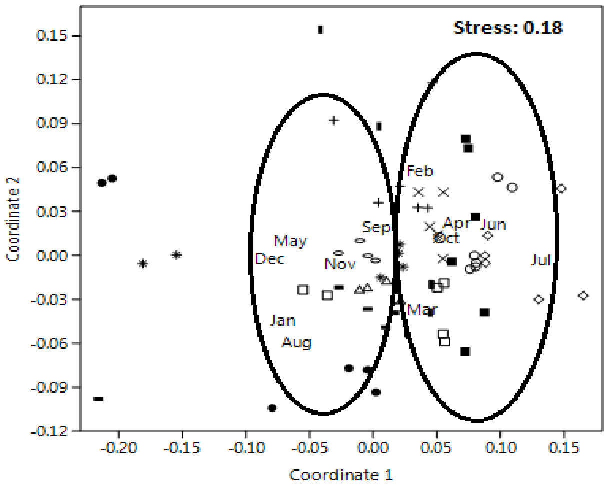

Figure 7: Two dimensional nMDS scaling of comparative fish assemblage data based on Bray-Cruits similarity index among months of Karatoya Fish Sanctuary.

Based on SHIMPER analysis (all pooling), about 74.81% and 76.14% average dissimilarity were found among stations and months, respectively (Fig 8). The highest contributing species was *A. jaya* (8.59% and 9.15%) while the lowest was *Osteobrama cotio* (0.08% and 0.08%) both for spatial and temporal scale, respectively.

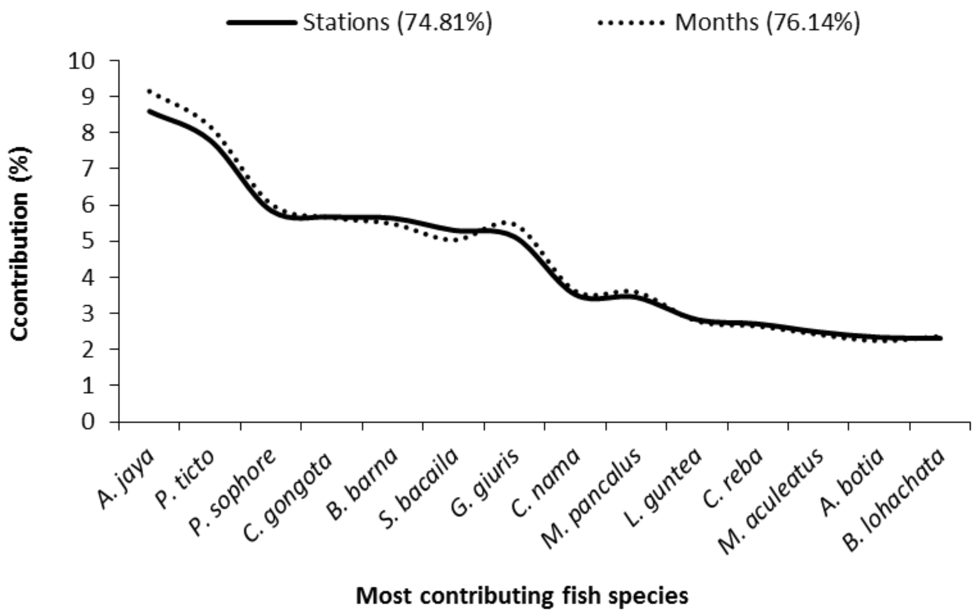

Figure 8: Most discriminating fishes both in stations and months (average dissimilarity) using SIMPER analysis by Bray-Curtis similarity index.

Two major clusters were viewed based on Bray-Curtis similarity index where severance was perceived at about 42.00% and 28.00% for station and month, respectively (Figs. 9 and 10). Spatially, one cluster twisted at St.3 and St.4 (fish sanctuary) while another cluster united upstream (St.1 and St.2) and downstream (St.5 and St.6) indicating very close relationship between them but alienated from fish at the sanctuary. Conversely, two main clusters were also viewed temporally i.e. September with January, May, August, November and December for the 1st cluster where January with August, May with November and December, and November with December showed close resemblance. Then, March with February, April, June, July and October were unified for the 2nd cluster and the sub-clusters consist of month June with July, October with February and April, and February with April.

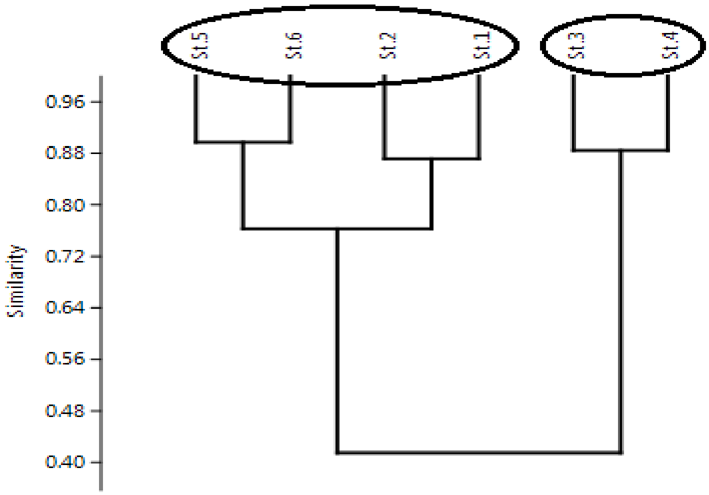

Figure 9: Classical UPGMA clustering (spatial) of fish assembly unglued as two groups based on Bray-Curtis similarity index of Karatoya Fish Sanctuary.

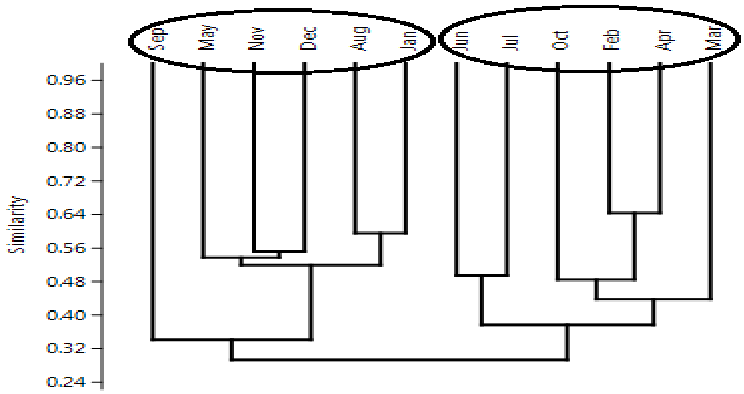

Figure 10: Classical UPGMA clustering (temporal) of fish assembly separated as two groups based on Bray-Curtis similarity index of Karatoya Fish Sanctuary.

In case of water quality parameters, eigen values of canonical correspondence analysis (CCA) of the first four axes were found to be 0.2093 (CCA_1), 0.1158 (CCA_2), 0.0690 (CCA_3) and 1.890E-05 (CCA_4) both for spatial and temporal scale where the first (CCA_1) and second (CCA_2) axes were polled and modeled as 53.10% and 29.38% of species data, respectively (Fig. 11). Vector length of any specific parameters is a sign of magnitude of that variable in CCA analysis. The highest vector length of water temperature at the fourth axis showed significant correlation with the sanctuary (St.3 and St.4) in March and November where high values of it allied with the occurrence of *Canthophrys gongota*. Besides, vector length of dissolved oxygen showed significant relations with upstream (St.2) and downstream (St.5) in August connected with the incidence of *Cirrhinus reba*, pH showed significant relations with the sanctuary (St.3) and outside the sanctuary (St.1 and St.6) in March and August linked with the abundance of *Anabas testudineus* where transparency showed insignificant relation without any associations with the occurrence of fishes.

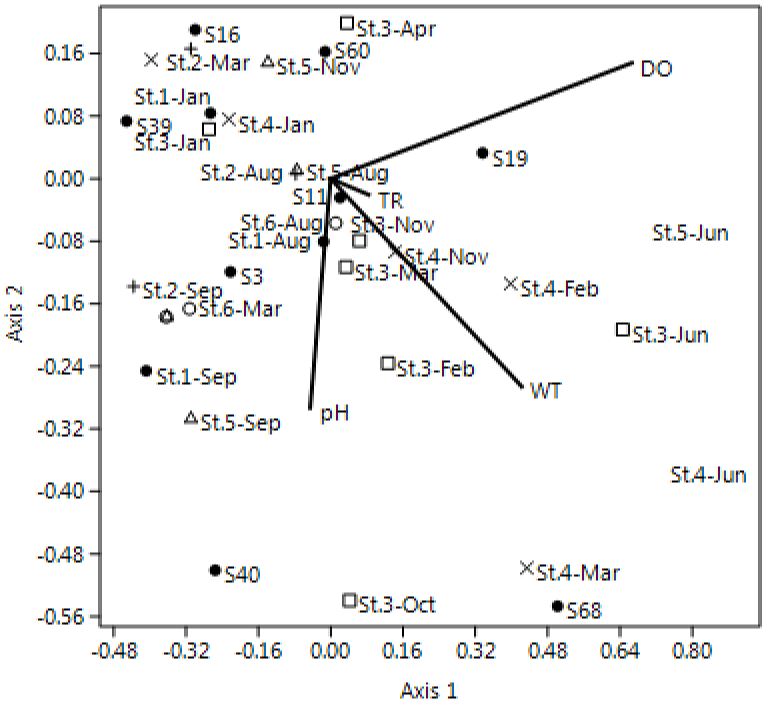

Figure 11: Canonical correspondence analysis (CCA) of fish abundance and hydrological parameters of Karatoya Fish Sanctuary.

Discussion

The Karatoya River, an arm of the Jamuna River, had no previous scientific information on fish assemblage inside the sanctuary or in this river and it was not possible to compare the present findings with previous ones. However, there were significant differences (p<0.05) observed in the hydrological parameters among months similar to Grimaldo *et al.* (2012) but insignificant variations among stations of this vicinity. Besides, values of water quality parameters from both inside and outside the sanctuary lie within the limits of Dhepa River in Dinajpur district of Bangladesh where water temperature was noted to be 17.00-33.50 °C, DO was 3.80 to 11.60 mg L^{-1}, pH was from 6.50-7.90 and transparency was 8.10-48.70 cm (Rakiba and Ferdoushi, 2013) due to the same geographical area.

Fishes especially indigenous and threatened species were found more inside the sanctuary compared with its outside area correspondingly over the successive months mainly in winter representing positive impacts of the sanctuary. Moreover, the presence of minnows, eels, loaches and other small fishes within the sanctuary indicates a friendly ecosystem where materials were also helpful to congregate the bottom dwelling fishes. Both the number of fishes and individuals maximized inside the sanctuary might be due to the greater periphyton community and other food stuff grown on tree branches and bamboos making the habitat more suitable for charitable shelters, natural food particles and breeding places than its outside zones. A trend of fluctuation in the number of species and specimens might be due to dispersion of fishes from the sanctuary in early April for breeding purposes after entering of new water, and to increase water level and flow in the Karatoya River. Fishes were registered at 57, 60 and 62 in 2003, 2004 and 2005, respectively at the sanctuary of Dopi beel in Joanshahi haor where threatened species were found to have reappeared during three years (Azher *et al.,* 2007); 30, 25 and 24 species out of 32 small indigenous fishes were recorded inside the sanctuary, upstream and downstream, respectively from Matshaya Rani Fish Sanctuary (Hasan *et al.,* 2012); and 78 species in the Atrai River (Joadder, 2012). Sarker *et al.* (1999) reported five Kuas (Catch-ponds) protected as fish sanctuaries in the Goakhola-Hatiara beel allowing wild fishes to breed obtaining 33% higher fish catch in 1998 than in 1997. Fish diversity, abundance and catch were augmented after the establishment of a fish sanctuary in the deeper part of a beel (Ahmed and Ahmed, 2002) and more than 500 waterbodies considered under co-management in Bangladesh (Mustafa *el al.,* 2014). On the other hand, among the threatened fishes *Pethia ticto*, *Barilius barna* and *Botia lohachata* were most prominent in Karatoya Fish Sanctuary being a sign of the forthcoming habitat for that species. This is not analogous to Hasan *et al.* (2012) because of its territorial and hydrological deviations where notable threatened fishes *P. conchonius*, *Acanthocobitis botia*, *Amblyceps mangois* and *Chaca chaca* were found in Matshaya Rani Fish Sanctuary of the Old Brahmaputra River. Additionally, threatened fishes were also documented from other aquatic haunts such as 28 species from the Chalan beel (Galib *et al.,* 2009) and 26 species from the River Choto Jamuna (Galib *et al.,* 2013). The findings differ from the present results, and this may be owing to its geographical and environmental discrepancies. However, occurrence of the mentioned threatened fishes in the study area corroborated the fact that they found suitable feeding and breeding grounds inside the sanctuary compared with its outside.

Increasing fishing pressure is one of the main triggering factors to decline aquatic biodiversity. The higher number of individuals observed at the fish sanctuary may be as a result of low human hindrance and most favorable environmental conditions, whereas the lower number of individuals observed outside the sanctuary may be due to extreme human interference. In the study area, the highest number of species and specimens were caught in January and December, the winter months of the study area, may be due to the reduced volume of water. The minimum number of species and individuals were recorded in June, the monsoon month and this would be due to heavy rainfall resulting in flooded area, whereas the lowest number of fishes also observed in September would be by reason of seasonal or climate changes. The results were divergent with the highest fishes found in October and lowest in February (Jahan *et al.*, 2014) from rivers and nearby beels of Karimganj would be down toward geographical and climate changes. The highest number of fishes were recorded in November but the lowest were in June and August from Padma River (Chaki *et al.*, 2014) more or less similar to the present findings.

Because of low species variety and high selectivity effect of fishing gear, low values were obtained for biodiversity indices from the investigated area (Keskin and Unsal, 1998) which was ignored during this study period. Besides, there was a positive relationship between Shannon-Weiner with Margalef richness, Evenness and Simpson index supported by Galib *et al.* (2013) who reported a similar relationship for fish diversity in the river Choto Jamuna. Conversely, a negative relation was observed between dominance with Shannon-Weiner, Margalef richness, evenness and Simpson index in the present study which was supported by the study of Chowdhury *et al.* (2010) of Naaf River estuary. Based on the spatiotemporal scale, values of all diversity indices were assorted for stations but not for months (except June-October for dominance and Simpson diversity index) in the Karatoya Fish Sanctuary where discrepancies may have occurred due to dissimilarities in nutrients (Huh and Kitting, 1985), water currents and environmental incidents (Keskin and Unsal, 1998) and fish migrations (Ryer and Orth, 1987) as well as seasonal differences in species diversity. In Bangladesh, a number of small indigenous fish species reproduce in freshwater habitats from April to May that would be the subsequent reason for the diversity indices to fluctuate and join as new fish stocks, and where ecological circumstances also have an effect on the distribution of fishes.

The non-metric multidimensional scaling (nMDS) composes associations among assemblages in particular coordination rooted in their similarity or dissimilarity. Both spatial and temporal scales (stress as 0.18) of the fish sanctuary just above the minimum value (<0.15) of nMDS model that close to the finding (0.16) of Li *et al.* (2012), but below the spatial stress as 0.20 in relative abundance for the Brazilian reservoir (Sanches *et al.*, 2016). The fish sanctuary showed dissimilarity in fish assemblage with upstream and downstream where more similarity was observed between upstream and downstream through analysis of similarity may be due to less human interference in the sanctuary than its outside region. In case of months, equally good fish assemblages scrutinized between January and May, January and August, February and April, May and August, May and November, May and December, June and July and November and December would be attributable to particular ecological variables for breeding, feeding, rearing and sheltering fluctuating seasonally with water quality parameters (Agostinho *et al.*, 2008). However, the present study found almost the same similarity in case of occurrence of finfish assemblage among sampling zones and months. For both spatial and temporal points, the main donating species are also similar but their percentage of contribution varied from each other. At this point, resemblance was found more among months rather than stations where major causal fishes are related to the Chalan beel for *Puntius sophore* and *P. ticto* (Kostori *et al.*, 2011) and to the Halti beel for *P. sophore* (Imteazzaman and Galib, 2013) while it was different from Meghna River estuary (Hossain *et al.*, 2012). In addition, the alienation of the fish sanctuary from upstream and downstream may be as a result of secured sheltering, feeding and breeding grounds, and the estrangement of the months November and December from June and July could be due to seasonal variations. This similarity and dissimilarity of fish assemblage and structure are mainly affected by seasonal alterations among hydrological and meteorological parameters in estuaries (Loneragan and Potter, 1990; Whitfield, 1999; Young and Potter, 2003). Seasonality also affects the spawning activity of fin fishes accelerating to alter the catch composition (McErlean *et al.*, 1973).

In a lotic ecosystem, especially rivers, the biological condition is strongly influenced by water chemistry and habitat quality (Bio *et al.*, 2011). Water temperature variations among months showing more impacts on species distribution upstream and downstream may be due to water depth and water currents compared to the fish sanctuary. In this study area, minimum level of fish diversity was detected at low water temperature and small flowing discharge in the winter months but maximum fish diversity was viewed with comparatively high temperature and water discharge in summer similar to Yan *et al.* (2010). Alteration in water temperature influences the physical, chemical and biological uniqueness of aquatic environments and fish reproduction ultimately altering their abundance and diversity (Kathiresan and Bingham, 2001; Rashleigh, 2004). Dissolved oxygen, an indicator of water excellence, primary production and contamination, also plays a vital role for fish profusion and allotment (Maes *et al.*, 2004) generally influenced by temperature (Vijayakumar *et al.*, 2000). Water pH also the most important abiotic factor for fish migration and distribution (Vega-Cendejas *et al.*, 2013) would be the upshots of pollution from municipal sewage and small industries contiguous to this river. Transparency, attributes of turbidity, is also regarded as another hydrological factor in fish assemblage and distribution where poor transparency has been considered as a driving factor in order to support the survival of fishes (Whitfield, 1999).

However, for the existence of any aquatic inhabitants, they need to have a suitable feeding and breeding ground in order to stay, grow and reproduce without any commotions. During lean season, both threatened and non-threatened fishes with other aquatic animals can feed, breed and attain sexual maturity in the next spawning season in the Karatoya Fish Sanctuary which will ultimately increase and conserve them. Besides, strong management by the local community and administration through either temporally or permanently natural courses of a fish sanctuary may nourish and preserve the targeted species within this sheltered area. Finally, upcoming well supervised and advanced plans should be geared for this sanctuary in order to enrich and conserve the aquatic biodiversity of Atrai River in the northwestern quarter of Bangladesh.

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