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Physicochemical parameters influence the temporal and spatial distribution of catfish assemblages in Kushiyara River, Bangladesh

MD. ARIFUR RAHMAN[1,2], MOHAMMED MAHBUB IQBAL[1*], MD. ARIFUL ISLAM[3], SHYAML KANTI BARMAN[4], SOHEL MIAN[1], SIMON KUMAR DAS[5] AND MOHAMMAD MOSAROF HOSSAIN[6]

[1]Department of Fish Biology & Genetics, Sylhet Agricultural University, Sylhet, Bangladesh
[2]Dept. of Fisheries Biology & Genetics, Patuakhali Science & Technology University, Patuakhali
[3]Bangladesh Fisheries Research Institute, Shrimp Research Station, Bagerhat, Bangladesh
[4] Sustainable Development Associates (SDA), Banani, Dhaka, Bangladesh
[5]Department of Marine Science, University Kebangsaan Malaysia, Malaysia
[6]Department of Coastal & Marine Fisheries, Sylhet Agricultural University, Sylhet
*Email: mmiqbal5@yahoo.com

Abstract. A yearlong study was carried out to assess the influences of physico-chemical parameters on the temporal and spatial dispersal and biodiversity status of catfishes in the *Kushiyara* River, Bangladesh. Five fishing boats equipped with various fishing gears namely seine net, gill net, lift net, and cast net were used fortnightly to harvest fish. Water quality parameters were assessed on spot. Twenty catfish species belonging to 8 families were identified from *Kushiyara* River. Shannon-Weaver diversity index, Margalef species richness, and Simpson dominance index significantly varied between seasons ($p < 0.05$), where in the summer season the indices values were low. Total dissolve solids (TDS) and transparency were identified as two most striking factors shaping the catfish assemblage structure. Canonical correspondence analysis ordination plot revealed that *Clupisoma garua, Ompok bimaculatus* and *Ailia coila* had the highest level of TDS preference than the other parameters. In similarity percentage at 85.65%, three groups were attained while summer season showed separate clustering from other groups. The Non-metric Multidimensional Scaling showed similarity at 60% in all seasons based on Bray-Curtis similarity matrix, and summer was found to form a distinct group. Findings of the present study are expected to be helpful for the respective researchers, policy makers and conservationist as baseline information for the sustainable management of this water body.

Keywords: Catfish, Diversity index, Fish assemblage, Kushiyara River

Introduction

The *Kushiyara* is one of the longest and ecologically important rivers in Bangladesh, providing multidimensional economic benefits and considered as mother fishery and source of income for millions of dependent communities. The *Manu* is an international river, rises from the mountains of Tripura (India), enters Bangladesh and conjoins with the *Kushiyara* River (KR) at *Manumukh* and makes the jumble area highly suitable for nursing, breeding and feeding grounds of many of the threatened fish species. Besides, *Manu* River brings lots of nutrients and sediments from its upstream resulting in changes in the physico-chemical parameters of *Kushiyara* River water along with seasonality. On the other hand, a bulk amount of industrial effluents discharge from the Shahjalal Fertilizer Factory Ltd., Fenchuganj, Sylhet, to this KR basin, mainly recognizable during the month of January, could have an impact on the life, water quality and environmental settings of the river.

Catfish (Siluriformes), commonly available in diverse natural aquatic habitats perform a significant role by providing nutrition to the people (Winemiller and Kelso-Winemiller 1996). Because of their worldwide distribution and diversity, catfishes are of great interest to ecologists and evolutionary biologists (Lundberg and Friel 2003). Approximately 197 catfish species comprising 52 genera were recorded from the Indian subcontinent (Rajagopal and Davidar 2013), where 55 species under 35 genera have been recorded so far from the natural waters of Bangladesh (Rahman 2005). Due to lucrative size and delicious taste, they comprise high market demand and esteemed as food for convalescence and invalids. Among the 289 freshwater fish species in Bangladesh, 56 species are threatened, majority of which are catfishes (IUCN 2000). Suitable physico-chemical factors are prerequisites for the distribution and abundance of aquatic organisms including fishes (Balcombe *et al.* 2006), for instance fluctuation in temperature (Blaber 2000), dissolved oxygen (Maes *et al.* 2004), transparency and water pH. Low and poor water quality can results impair development, growth, reproduction, or even cause mortality to fishes (Stone and Thomforde 2004) and hence affect the species assemblage. It is also reported that the abundance and composition of fish species is highly variable in space and time and closely related to environmental variables (Vilar *et al.* 2011). Despite majority of literature focusing on systematics, feeding, breeding ecology and morphometric characteristics of catfishes around the world, there are still scarcity of information on their distribution, species richness, abundance and composition (Ajithkumar *et al.* 1999). Therefore, the present study was carried out to assess the influences of the water quality parameters on the temporal (seasonal) and spatial dispersal and biodiversity status of catfishes in the *Kushiyara* River.

Materials and Methods

Study area

The research was accomplished in the *Kushiyara* River, meeting point of *Manu* River, Maulvibazar, Sylhet, Bangladesh lying between the latitude of 24.5833° E, Longitude of 91.7333° N. Samplings were done within 1km in both East and West direction of *Kushiyara* River.

Sampling

On spot assessment of water quality parameters were executed (8.00 AM to 12.00 PM of the day) fortnightly in a depth of 0.5 meter (m) (Fig.1). Monitoring of environmental and water quality parameters were observed and recorded following standard procedures and methods (Rice *et al.* 2012). The water temperature (°C) were measured by using a standard mercury thermometer, water pH by digital Pen pH meter (s327535, HANNA, USA), transparency (cm) by Secchi disc, TDS (mg/L) by TDS meter (HI96302, HANNA, USA), while DO (mg/L), CO_2 (mg/L), NH_3 (mg/L), NH_4^+

(mg/L), NO_2 (mg/L), NO_3 (mg/L), total hardness and chloride were measured by titration methods using HACH Test Kit (Model FF-2, USA). The data of air temperature and rainfall (mm) were collected from the Bangladesh Meteorological Department, Sylhet. In the meantime the catfishes were harvested covering four different seasons i.e. winter (December-February), summer (March-June), monsoon (July-September) and post-monsoon (October-November). Fishes were caught with the direct help from local fishermen. Five fishing boats equipped with various fishing gears namely seine net, gill net, lift net, and cast net were used to catch fish from five specific points in junction of the *Kushiyara* and *Manu* River. Samples were preserved in different iced plastic bags and jars carefully. Each individual fish species of all life stages were counted except those having a length below 5 cm. Photographs were taken immediately and the identifications were done by secondary document consultation and according to Rahman (Rahman 2005).

Statistical analysis

For the environmental variables and water quality parameters, one-way ANOVA followed by Duncan multiple range test and Tukey test were carried out by PAST to detect significant difference among the different seasons at 5% level of significance. In the present study, diversity of catfish species was evaluated by dint of Shannon-Weaver index (H') (Shannon and Weaver 1949), species richness by Margalef index (d) (Margalef 1968), Evenness by Pielou's index (J') (Pielou 1966), and dominance by Simpson index (c) (Simpson 1949). One-way ANOVA test was performed to analyze the diversity index values among seasons. Canonical correspondence analysis was used to investigate the relationship between species assemblage composition and environmental variables. PAST version 2.16 was used to perform ANOVA and CCA. Multivariate analyses were performed through the software PRIMER V6 (Clarke and Warwick 2001). Similarity percentages analyses (Clarke and Warwick 1994) were used to observe the percentage contribution of each taxon to the average dissimilarity among the various seasons.

Results and Discussion

Environmental and physico-chemical parameters of water

The recorded physico-chemical parameters in *Kushiyara* River illustrating distinct seasonal variations are listed in Table I. Concentration of total dissolved solids (TDS) varied between 93.67 mg/L (winter) and 131.30 mg/L (monsoon) along with a relatively high concentration of chloride (54.13 mg/L) in winter and low (23.13 mg/L) in the monsoon. Lowest nitrite and nitrate concentrations were recorded in monsoon, whereas the highest was in winter (Table I).

Table I. Environmental and water quality parameters measured from the study area over the different seasons of the year

Parameters	Monsoon	Post-monsoon	Winter	Summer
Rainfall (mm)	479.6 ± 124.51^a	222.1 ± 314.03^b	24.93 ± 3.15^c	466.23 ± 318.53^a
Air Temperature (°C)	30.2 ± 1.80^a	26.1 ± 1.17^b	23.25 ± 1.212^c	30.75 ± 1.21^a
Water Temperature (°C)	29.7 ± 1.61^a	26 ± 1.12^b	22.81 ± 1.87^c	30.75 ± 1.34^a
Transparency (cm)	11.33 ± 3.05^c	30.51 ± 7.81^b	44.50 ± 5.34^a	30.56 ± 1.18^b
pH	7.2 ± 0.32	7.47 ± 0.51	7.76 ± 0.36	7.97 ± 0.63
DO (mg/L)	6.9 ± 0.36^a	8.06 ± 0.63^a	8.74 ± 0.71^a	5.7 ± 0.56^b
Ammonia (NH_3) (mg/L)	0.07 ± 0.001	0.04 ± 0.001	0.08 ± 0.01	0.07 ± 0.001
Ammonium (NH_4^+) (mg/L)	0.46 ± 0.18	0.55 ± 0.02	0.52 ± 0.14	0.61 ± 0.19
TDS (mg/L)	131.30 ± 10.41^a	93.75 ± 5.30^b	93.67 ± 3.84^b	95.5 ± 6.17^b
Nitrite (NO_2) (mg/L)	0.55 ± 0.15	0.73 ± 0.16	0.95 ± 0.23	0.61 ± 0.12
Nitrate (NO_3) (mg/L)	0.03 ± 0.01	0.04 ± 0.01	0.06 ± 0.01	0.05 ± 0.02
Total Hardness (mg/L)	92.84 ± 13.97	88.59 ± 11.37	96.25 ± 15.53	92.83 ± 14.71
Chloride (mg/L)	23.13 ± 2.83^c	31.5 ± 5.87^b	54.13 ± 7.24^a	35.7 ± 7.56^b

All physico-chemical parameters were measured at same depth (1m) in study area; TDS= Total dissolved solids. Values are (mean±SD) of fortnightly determinations. Values in the same row with same superscripts are not significantly different ($p > 0.05$). Absence of superscripts indicate no significant differences between different seasons. Coverage of months in various seasons e.g. monsoon (July-September) and post-monsoon (October-November)winter (December-February),summer (March-June).

Among all the parameters determined, rainfall, air and water temperature, transparency, chloride, DO and TDS attributed significant ($p < 0.05$) seasonal variations. Being a maiden study, this paper lacks the discussion on available literature from the same area. However, values were found to be within the permissible limits that coincide with the findings of Kamal *et al.* (2007) in case of *Mouri* River, Khulna, Bangladesh. Fish survive and grow best in waters with a pH between 6 and 9 (Iwama *et al.* 2000). The pH can affect fish health while the range goes beyond 7.5-8.5 (Boyd and Tucker 2012). The value of pH throughout the annual cycles was in conformity with the present findings. Seasonal fluctuations of turbidity in *Kushiyara* River showed higher values during the monsoon season, whereas lower values were recorded during winter and pre monsoon. This is due to the flow from the upstream which brings clay, sand, and organic matter from adjoining areas of the river during the monsoon. Primary productivity is largely influenced by fluctuations in water transparency which ultimately affects the fish distribution (Arthington *et al.* 2004). The most important environmental variables for the assemblage of the catfishes in *Kushiyara* River were TDS and transparency, which is supported by the findings of Gupta *et al.* (2012). It was evident that in running waters, the fish assemblages were predominately structured by hydro morphological factors (Sarkar and Bain 2007). Water temperature showed a negative correlation with dissolved oxygen, indicating that an increase in water temperature drastically decreases dissolved oxygen in the river water. Total hardness showed a negative correlation with pH and TDS. A similar negative correlation between total hardness and pH was also observed in *Kosi* River (Bhandari and Nayal 2008). Nonetheless, physico-chemical parameters of *Kushiyara* River were found mostly optimal for existing fish community.

Catfish biodiversity and assemblage

Twenty species of catfishes belonging to eight families were identified, while 11 were documented as threatened (Table II). The leading family was Bagridae (6 species) encompassing 35.48% of the whole biomass followed by Schilbeidae 32.06%, Siluridae 21.11%, Ariidae 3.16%, Pangasiidae 2.05%, Heteropneustidae 2%, Clariidae 2%, Chacidae 1% and Sisoridae 0.93% (Table II).

Total individuals under each species were used to find out the dominancy of each species in the study area where *M. bleekeri* covers the highest (13.42%) followed by *Aili apunctata* comprising (11.73%) and *C. chaca* covers the lowest (0.90%) of the total biomass (Table II). One of the revolutionary findings is that the abundance of the *Arius gagora*, a species considered to be near threatened (Rashed-Un-Nabi *et al.* 2011) found to comprise only 3.16% of the total biomass that indicated its severe declination from the study area. Another striking finding was the relatively higher abundance of some critically endangered catfish species i.e. *C. garua* (6.19%), *R. rita* (4.21%), *P. pangasius* (2.05%), *E. vacha* (2.01%) and *B. bagarius*(0.93%) comprised 3.16% of the total biomass, compared to the others revealing the uniqueness of the study area as a suitable habitat for the catfishes (Table II).

A total of 11 threatened catfish species were documented out of 20 identified catfish species from the study area. Bashar *et al.* (2009) observed 18 species under six families, among which three were critically endangered, nine endangered, five available and one near threatened species reported by IUCN from *Barnai* River, Rajshahi which corroborates the present findings. Rahman (2005) described 55 species of freshwater catfishes from 11 families however, IUCN reported 54 catfish species under the order Siluriformes. Haroon *et al.* (2002) recorded a total of 21 species of catfish from the Sylhet-Mymensingh basin. Similarly, Ali *et al.* (2004) reported only 12 catfish species. On the other hand, Sarker *et al.* (2008) recorded 38 species of catfishes under 11 families from the greater Sylhet-Mymensingh basin. This study recorded 20 species from the known 55 species of freshwater catfishes available in Bangladesh that is congruent with the other findings. Rajagopal and Davidar (2013) recorded 12 catfish species of five families from the wetlands of two floodplains districts of Tamil Nadu, India coincide with the present findings. Nevertheless, these sorts of judgments about species abundance must be found on distinctness in sampling gear, sampling period and most importantly habitat attributes. Additionally, each meeting point of rivers or estuarine system may have an alternate abiotic environmental characteristics, resulting from the tidal range, freshwater input, geomorphology and anthropogenic pressure (McLusky and Elliott 2007) which also impacts the species abundance.

Table II. List of identified catfish species with their abundance

Family	Scientific name	Common name	Local name	Percent of harvested fish	Family abundance (%)	IUCN Status[1]
Bagridae	*Sperata aor*	Long-whiskered catfish	Ayer	5.39		VU
Bagridae	*Sperata seenghala*	Giant River catfish	NuillaAyre	3.83		EN
Bagridae	*Rita rita*	Rita	Rita	4.21		CR
Bagridae	*Mystus bleekeri*	Gantaticmystus	Gulsha	13.42	35.48	NO
Bagridae	*Mystus tengara*	Stripped dwarf catfish	Ghuitta tengra	3.48		NO
Bagridae	*Mystus vittatus*	Striped dwarf catfish	Tengra	5.15		NO
Schilbeidae	*Eutropiichthy svacha*	Batchwa bacha	Bacha	2.04		CR
Schilbeidae	*Ailia punctata*	JamunaAilia	Baspata	11.73		VU
Schilbeidae	*Ailia coila*	Gangeticailia	Kajuli	3.83		NO
Schilbeidae	*Clupisoma garua*	Garua bacha	Ghaura	6.19	32.03	CR
Schilbeidae	*Neotropius atherinoides*	Indian potasi	Batashi	8.24		NO
Siluridae	*Wallago attu*	Freshwater shark	Boal	12.10		NO
Siluridae	*Ompok pabda*	Pabda catfish	Modhupabda	3.68	21.05	EN
Siluridae	*Ompok bimaculatus*	Indian butter catfish	Boalipabda	5.27		EN
Ariidae	*Arius gagora*	Gagora catfish	Gagla	3.16	3.16	NT
Pangasidae	*Pangasius pangasius*	Pangas	Pangas	2.05	2.05	CR
Chacidae	*Chaca chaca*	Indian chaca	Cheka	0.90	0.90	EN
Sisoridae	*Bagarius bagarius*	Gangetic goonch	Baghair	0.93	0.93	CR
Clariidae	*Clarias batrachus*	Walking catfish	Magur	1.88	1.88	NO
Heteropneustidae	*Heteropneustes fossilis*	Stinging catfish	Shing	2.95	2.95	NO

[1]IUCN Status in Bangladesh (BD) according to the Red Book of Threatened Fish of Bangladesh. Categories of IUCN status: Not Threatened (NO), Least Concerned (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR).

Diversity indices

There was significant seasonal variation ($p = 0.011$) for the Shannon-Weaver diversity index (H'), where the H' was significantly lower in summer than the other three seasons (Fig. 1a). Besides, significant difference was also observed in the Margalef richness index *(d)* between the seasons ($p = 0.044$), and d was lower in summer than the monsoon (Fig. 1b). No significant difference was found for Pielou's evenness index *(J')* between seasons (Fig. 1c). Moreover, Simpson dominance index *(c)* attributed significant difference between summer and winter ($p = 0.013$) (Fig. 1d). Seasonal variation in species diversity is very common in rivers and estuaries in tropical areas. Patra (2011) documented seven catfish species from Karalla River where the species diversity index of different sampling sites ranged from 1.04 to 1.218. The evenness index at three sampling stations (SI=0.947, SII=0.707 and SIII=0.879) indicated uneven distribution of catfishes in that tributary. The present finding showed higher species diversity along with maximum species richness compared to Karalla River. The evenness index derived from *Kushiyara* River indicated even distribution of catfishes in the River. Significant difference was observed among different seasons in case of dominance. The uppermost mean dominance value 0.862 was observed in post-monsoon and lowest 0.784 in winter. The species dominancy was higher in the post-monsoon season than the others in the study area. The catfish diversity, richness, evenness and dominance of the River found satisfactory may be due to the presence of a large number of small indigenous species, which are fed by these carnivorous fish species.

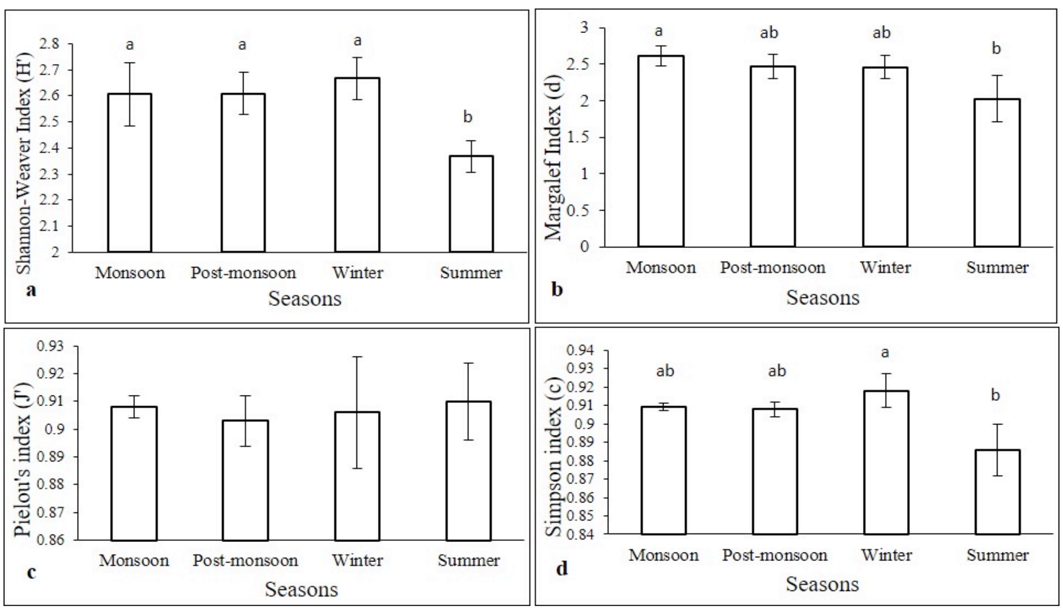

Fig. 1. Diversity indices of catfish assembles in the juncture of *Kushiyara* River, Sylhet, Bangladesh, over the study period: (**a**) Shannon-Weaver diversity index; (**b**) Margalef richness index; (**c**) Pielou's evenness index; and (**d**) Simpson dominance index. Bar with different superscripts are significantly different ($p < 0.05$), whereas absence or same superscripts are not significantly different ($p > 0.05$).

Canonical correspondence analysis (CCA)

CCA provided insight into the relationship between the fish assemblage and environmental variables (Peralta-Meixueiro and Vega-Cendejas 2011). CCA of the top most 50% fish species in the present study were considered in which the length of vector of a given variable on the CCA plots reveals the significance of that variable

(Fig. 2). CCA ordination indicated TDS and transparency were the two most important environmental parameters shaping species assemblage structure in *Kushiyara* River compared to the other variables unlike estuarine habitat where salinity perhaps strongly is allied with the dissemination of species assembles (Selleslagh and Amara 2008). Species plotted closer to the vector have stronger relationship with them. CCA ordination plot revealed that *C. garua*, *O. bimaculatus*and *A. coila*have the highest level of TDS preference than the other parameters (Fig. 2).

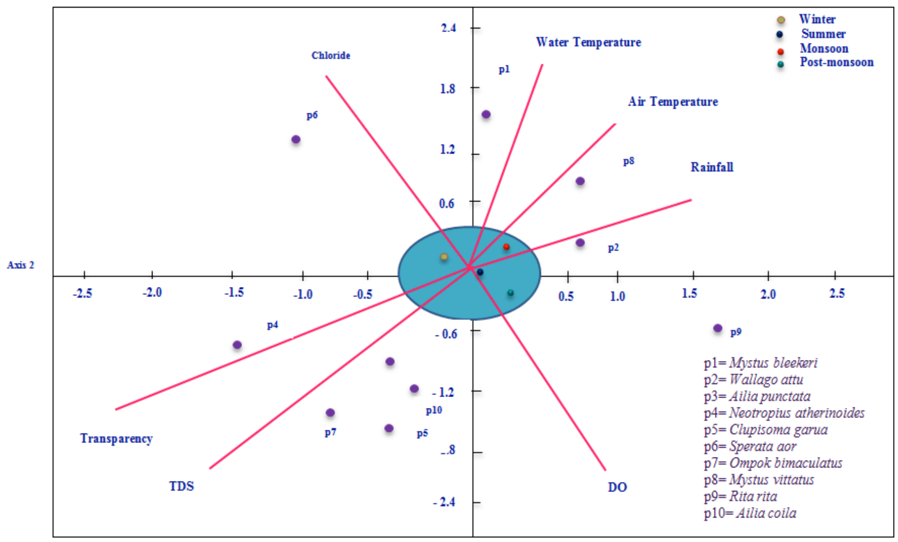

Fig. 3. Canonical correspondence analysis represents the relationship between environmental variables and catfish assemblage. TDS = Total dissolve solids; DO= Dissolved oxygen.

Similarity percentage between seasons

In the present study, highest dissimilarity (20.12%) was observed between winter and summer whereas lowest (10.07%) between post-monsoon and winter (Table III). About 11.76% dissimilarity was observed between monsoon and post-monsoon followed by 15.63% between monsoon and summer, 16.89% between monsoon and winter and 18.78% between post-monsoon and summer (Table III). SIMPER analysis revealed significant spatial, temporal and seasonal variation in the abundance and distribution of fish assembles. It may be clear that highest number of similar species was found between monsoon and post-monsoon and lowest between winter and summer. Seasonality is one the most crucial aspect among different studied parameters changing the fish assemblage in estuaries or meeting point of rivers (Askeye *et al.* 2015).

The CCA reveals that water quality parameters have impact on the disappearance, dispersal or migration of catfishes in the study area. In conclusion, seeking an urgent attention of the relevant authority to declare perennial and seasonal (e.g. during breeding seasons) fish sanctuaries along with initiatives to developing fisher's awareness and prevention of water pollution are essential to sustainably conserve the threatened catfishes as well as protect the River for future generation.

Table III. SIMPER analysis showing (%) dissimilarity among different seasons

Monsoon and Post-monsoon AD = 11.76		Monsoon and Winter AD = 16.89		Monsoon and Summer AD = 15.63		Post-monsoon and Winter AD = 10.07		Post-monsoon and Summer AD = 18.78		Winter and Summer AD = 20.12	
Species	Cont. (%)	Species	Cont. (%)	Species	Cont. (%)	Species	Cont. (%)	Species	Cont. (%)	Species	Cont. (%)
S. seenghala	15.31	*C. chaca*	15.01	*R. rita*	22.59	*C. chaca*	23.49	*R. rita*	17.65	*R. rita*	13.05
C. batrachus	8.69	*S. seenghala*	13.17	*S. seenghala*	11.88	*S. aor*	7.99	*E. vacha*	9.61	*C. chaca*	9.95
O. bimaculatus	8.17	*S. aor*	10.06	*S. aor*	10.52	*E. vacha*	7.71	*M. vittatus*	8.23	*A. coila*	9.17
S. aor	7.47	*O. bimaculatus*	8.96	*E. vacha*	8.16	*O. pabda*	6.04	*C. garua*	7.2	*C. garua*	8.33
N. atherinoides	7.01	*N. atherinoides*	6.96	*H. fossilis*	7.52	*A. coila*	6	*A. coila*	6.55	*O. pabda*	8.25
A. punctata	6.7	*O. pabda*	6.91	*M. vittatus*	5.97	*P. pangasius*	5.91	*A. punctata*	6.31	*O. bimaculatus*	8.12
M. vittatus	5.58	*A. coila*	5.97	*A. coila*	5.81	*O. bimaculatus*	5.54	*C. batrachus*	5.74	*M. vittatus*	7.46
E. vacha	5.13	*C. garua*	5.33	*C. garua*	5.39	*C. batrachus*	4.84	*O. bimaculatus*	5.65	*A. punctata*	6.02
H. fossilis	5.08	*A. punctata*	4.92	*C. chaca*	4.67	*S. seenghala*	4.72	*O. pabda*	5.49	*P. pangasius*	4.3
C. garua	4.69	*M. vittatus*	3.88	*N. atherinoides*	3.9	*R. rita*	4.69	*W. attu*	4.33	*E. vacha*	4.22
O. pabda	4.59	*P. pangasius*	3.87	*O. pabda*	3.25	*B. bagarius*	4.17	*A. gagora*	3.65	*S. seenghala*	3.44
W. attu	4.04	*H. fossilis*	2.74	*A. punctata*	2.52	*A. gagora*	3.8	*C. chaca*	3.58	*N. atherinoides*	3.43
A. gagora	3.92	*C. batrachus*	2.68			*N. atherinoides*	3.61	*M. vittatus*	3.57	*H. fossilis*	2.72
M. bleekeri	3.78					*C. garua*	3.47	*S. aor*	3.18	*C. batrachus*	2.39

AD= Average dissimilarity

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Literature Cited

Ajithkumar, C.R., K. Remadevi, K.R. Thomas and C.R. Biju, 1999. Fish fauna, abundance and distribution in Chalakudy river system, Kerala. *J. Bombay Nat Hist Soc.,* 96: 244-254.

Ali, M.Y., G.M. Sahm, M.A. Manna, M.M. Rahman, W. Sabbi, A. Murshida, 2004. Fish species availability observed in the fish landing centers of Khulna district in Bangladesh. *J. Biol Sci.*, 4: 575-580.

Arthington, A.H., K.L.B. Pusey, R.A.A.H.K. Winemiller and D.A.E Baran, 2004. Session 3 Review River Fisheries: Ecological Basis for Management and Conservation. Symposium on 'The Management of Large Rivers for Fisheries Volume.

Askeye, O., I. Askeyev and A. Askeyev, 2015. River fish assemblages in relation to environmental factors in the eastern extremity of Europe. *Environ. Biol. Fish.,* 98: 1277.

Balcombe, S.R., A.H. Arthington, N.D. Foster, M.C. Thoms, G.G. Wilson and S.E. Bunn, 2006. Fish assemblages of an Australian dry land river: abundance, assemblage structure and recruitment patterns in the Warrego River, Murray–Darling Basin. *Mar. Freshw. Res.,* 57: 619-633.

Bashar, M.A., M.A. Salam, M.M. Kamal, M.A.B. Siddique and M.S. Mofasshalin, 2009. Present biodiversity status of freshwater catfishes at the Barnai river of Rajshahi district. *J. Agrofor. Environ.* 3: 137-142.

Bhandari, N.S. and K. Nayal, 2008. Correlation study on physico-chemical parameters and quality assessment of Kosi River water, Uttarakh and. *E-J. Chem.,* 5: 342-346.

Blaber, S.J.M., 2000. Tropical Estuarine Fishes: Ecology, Exploitation and Conservation. Blackwell Science, Oxford.

Boyd, C.E. and C.S. Tucker, 2012. Pond aquaculture water quality management. Springer, USA.

Clarke, K.R. and R.M. Warwick, 1994. Change in Marine Communities: An approach to statistical analysis and interpretation. Plymouth Marine Laboratory, UK.

Clarke, K.R. and R.M. Warwick, 2001. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation (PRIMER-E). Plymouth Marine Laboratory, Plymouth.

Gupta, B.K., U.K. Sarkar and S.K. Bhardwaj, 2012. Assessment of habitat quality with relation to fish assemblages in an impacted river of the Ganges basin, northern India. *Environmentalists*, 32(1): 35-47.

Haroon, A.K.Y., G.C. Halder, S.L. Rahman, M.A. Razzaque, M. Alam and S.N. Amin, 2002. Sylhet-Mymensingh basin fish stock assessment. Final Report. BFRI, Riverine Station, Chandpur.

IUCN, 2000. Red book of threatened fish of Bangladesh. The world Conservation Union. Appendix, 1, p.xii+116.

Iwama, G.K., M.M. Vijayan and J.D. Morgan, 2000. The stress response in fish. Ichthyology, recent research advances. Oxford and IBH Publishing Co Pvt Ltd, New Delhi.

Kamal, D., A.N. Khan, M.A. Rahman and F. Ahamed, 2007. Study on the physico chemical properties of water of Mouri River, Khulna, Bangladesh. *Pak. J. Biol. Sci.*10: 710-717.

Lundberg, J.G. and J.P. Friel, 2003. Siluriformes. Catfishes. Version 20 January 2003.

Maes, J., S. Van Damme, P. Meire and F. Olivier, 2004. Statistical modeling of seasonal and environmental influences on the population dynamics of an estuarine fish community. *Mar. Biol.* 145: 1033-1042.

Margalef, R., 1968. Perspectives in ecological theory. Chicago University Press, USA.

Patra, A.K., 2011. Catfish (Teleostei: Siluriformes) diversity in Karala River of Jalpaiguri District, West Bengal,India. *J. Threatened Taxa,* 3: 1610-1614.

Peralta-Meixueiro, M.A. and M.E. Vega-Cendejas, 2011. Spatial and temporal structure of fish assemblages in a hyperhaline coastal system: *Neotrop. Ichthyol.,* 9: 673-682.

Pielou, E.C., 1966. The measurement of diversity in different types of biological collections. *J. Theor Biol.* 13: 131-144.

Rahman, A.K.A., 2005. Freshwater fishes of Bangladesh. Zoological Society of Bangladesh,

Rajagopal. B. and P. Davidar, 2013. Distribution of catfishes in wetlands of two flood plain districts in Tamil Nadu, India. *J. Threatened Taxa*.5: 5277-5282.

Rashed-Un-Nabi, M., M.A. Al-Mamun M.H. Ullah and M.G. Mustafa, 2011. Temporal and spatial distribution of fish and shrimp assemblage in the Bakkhali river estuary of Bangladesh in relation to some water quality parameters. *Mar. Biol. Res.* 7: 436-452.

Rice, E.W., R.B. Baird, A.D. Eaton and L.S. Clesceri, 2012. Standard methods for the examination of water and wastewater. American Public Health Association, USA.

Sarkar, U.K. and M.B. Bain, 2007. Priority habitats for the conservation of large river fish in the Ganges river basin. *Aquat Conserv: Mar. Freshw.Ecosyst.* 17: 349-359.

Sarker, M.Y., F. Ayub, S. Mia, N.S. Lucky and and M.A.R. Hossain, 2008. Biodiversity status of freshwater catfishes in some selected water bodies of Bangladesh. *J. Taxon. Biodivers. Res.*, 2: 17-26.

Selleslagh, J. and R. Amara, 2008. Environmental factors structuring fish composition and assemblages in a small macrotidal estuary. *Estuar. Coast. Shelf Sci.* 79: 507-517.

Shannon, C.E. and W. Weaver,m 1949. The mathematical theory of communication. University of Illinois Press, Urbana, USA.

Simpson, E.H., 1949. Measurement of diversity. *Nat.,* 163: 688 p.

Stone, N.M. and H.K. Thomforde, 2004. Understanding your fish pond water analysis report. Aquaculture/Fisheries, Co-operative Extension Program, University of Arkansas, USA.

Vilar, C.C., H.L. Spach and J.M. Souza-Conceicao, 2011. Fish assemblage in shallow areas of Baia da Babitonga, southern Brazil: structure, spatial and temporal patterns. *Panama J. Aquat. Sci*. 6: 303-319.

Winemiller, K.O. and L.C. Kelso-Winemiller, 1996. Comparative ecology of catfishes of the Upper Zambezi River floodplain. *J. Fish Biol.,* 49: 1043-1061.

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