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Spatial and temporal variations of fish assembly with environmental parameters from two major rivers in Dinajpur district of Bangladesh

M. M. Rahman[1], M. Al-Amin[2], M. I. A. Lima[2], N. Mostari[2], H. Ahmmed[2] and M. R. Islam[1]*

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

[2]*Faculty of Fisheries, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh*

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Abstract

The study examined habitat and seasonal variations of finfish structures and ecological parameters in the Atrai and Dhepa Rivers, Dinajpur, Bangladesh. The researchers collected data from four sampling stations, revealing 15532 individuals from 44 genera and 59 species. *Pethia ticto*, *Chanda nama*, *Cirrhinus reba*, *Puntius sophore*, and *Salmophasia bacaila* were recorded as dominat fishes (>4.95%). The fish population was highest in autumn at Mohonpur (MP), while lowest in the monsoon at Karnai Bazar (KB). There were no significant variations across stations for rainfall, dissolved oxygen, pH, transparency, air and water temperatures, and pH. However, significant differences were observed among seasons based on all factors. The study also revealed differences in dominance, Margalef, Shannon, and evenness diversity indices spatiotemporally, except for evenness diversity indices among seasons. Thus, the findings could be useful for conservation studies in the future, especially after establishing and managing restricted areas like fish sanctuaries in both rivers.

Keywords: Rivers; Fish assemblage; Ecological factors; Spatiotemporal variations

Introduction

Bangladesh is a country with a rich aquatic diversity, including 265 freshwater fishes, 475 marine fishes, and 36 shrimps (Rahman, 2005). The fisheries sector contributes to 3.6% of Bangladesh's GDP and 1.2% of total export earnings (DoF, 2022). The major rivers in the Dinajpur district are the Atrai and Dhepa, with an annual catch of 296 MT (DoF, 2022). The Atrai River, originating from Siliguri, flows through Bangladesh's northwestern parts and passes through the Dinajpur district. The Dhepa River rises in the Atrai River close to Mohonpur in the Dinajpur district and is a 40-kilometer section of the Karatoya-Atrai River. These rivers serve as natural habitats, breeding grounds, and spawning grounds for indigenous fishes (Islam and Mia, 2016; Islam et al. 2017a; Islam et al. 2017b; Islam et al. 2018). However, downstream of these river systems are silted, reducing water flow and habitat degradation. The Atrai and Dhepa Rivers have been severely impacted by destructive fishing practices, soil erosion, agrochemicals, and concrete embankments, necessitating urgent measures to safeguard the indigenous fish.

Biodiversity parameters are crucial for understanding the impact of management strategies on diversity. Diversity indices provide more than just species count; they offer insights into the rarity and ordinariness of species in a habitat, enhancing their understanding. The Shannon-Wiener diversity index assesses the proportion and richness of species (Gamito, 2010), while the Evenness and Dominance indices show the percentage of common species and the number of individuals in a sample (Harper, 1999; Vijaylaxmi *et al.* 2010). The assemblage of fish populations is changed by the availability of riparian vegetation, which aids small fish species by allowing branches and leaves to fall into the water of rivers (Casatti *et al.* 2003).

*Corresponding author's e-mail: mrislam_fbg@hstu.ac.bd

However, dams, barrages, and embankments reduce freshwater inflow, affecting the allocation and affluence of algae in rivers. Moreover, low freshwater inflow negatively impacts the fish assemblage structure (Willis *et al.* 2005). However, human activity has continually changed and harmed freshwater ecosystems (Saunders et al. 2002; Ferreira et al. 2007). Fish assemblage structure is a complicated thing and an integrated measure of the water source's ecological health. It exhibits traits and changes in response to biotic processes, especially predatory behavior, and contest (Ziliukas and Ziliukiene, 2009; Siqueira-Souza and Freitas, 2004). On the other hand, hydrological characteristics of an aquatic habitat play an important role in the determination of the fish assemblage structure. Geo-morphological variables such as the width of the stream (Gerhard et al. 2004), depth and distance to the source (Kadye et al. 2008), altitude (Ferreira et al. 2007; Kadye et al. 2008; Suárez et al. 2007), physicochemical characteristics of water, such as pH and dissolved oxygen (Araújo *et al.* 2009; Jackson *et al.* 2001; Silva *et al.* 2007), as well as temperature (Cetra and Petrere, 2006), habitat availability, conductivity and heterogeneity (Willis et al. 2005) reported influencing the fish assemblages.

Although there are some scattered research works on fish biodiversity in freshwater habitats, fish assemblage structure at freshwater rivers has not been well studied in Bangladesh except in our previous studies (Islam *et al.* 2017b; Islam *et al.* 2019; Mia *et al.* 2019). It is essential to understand the current situation of fish assemblage structure in the Atrai and Dhepa Rivers for efficient and rational management. Considering the above reasons, the Atrai and Dhepa Rivers were chosen as a reference study to describe the aquatic surroundings and the variations in the primary hydrological parameters. Therefore, a plan was designed to know the biodiversity indices and their variations both in space and time in the Atrai and Dhepa Rivers of Dinajpur district in Bangladesh, compare the stock assembles between the Atrai and Dhepa Rivers, and determine the major ecological indicators that affect the availability of fin fishes in these two rivers.

Materials and methods

Site selection and sample collection

The spatiotemporal variations of fish assemblage with ecological parameters were studied for one year in the Atrai and Depha Rivers of Dinajpur district, Bangladesh. For these purposes, two sampling stations namely Khansama (KS), and Mohonpur (MP) in the Atrai River, and another two stations Birganj (BG) and Kornai Bazar (KB) in the Dhepa River were selected (Supplementary Fig. 1). The samples were collected at a monthly interval from 08:00 am to 12:00 and total duration of the research work was one year. According to Mia *et al.* (2019), based on similarity, January, December, and February are considered winter (WN) seasons; May, June, and July are considered monsoon (MS); August, September, and October are considered autumn (AU); and February, March, and April are considered summer (SM).

Data were collected at monthly intervals for hydrological factors and fish species during the study period. Air- (AT) and water-temperature (WT), transparency (TR), water depth (WD), water pH, dissolved oxygen (DO), and water flow (WF) were considered as hydrological factors in the study area described in Section 2.4.

Collection of fish samples

Fishes were monthly collected by using traditional fishing gears, the cast- (4×6.5 m^2, 8 mm) and seine-net (15×3.5 m^2, 4 mm) followed by Mia *et al.* (2019). Every hour, nine throws of the cast net and three hauls of the seine net were made. Within a 0.5 km radius, all of these fishing devices were used at the same location to maximize the number of study site species in the haul. As soon as the fish were harvested, a quick count was done.

Identification of the collected fishes

The fish species collected and identified primarily in the field as many as possible. Some fish which appeared difficult to identify, were marked properly. Fishes caught alive or in fresh condition were stored in a 10% formalin mixture and taken to the Department of Fisheries Biology and Genetics Laboratory at Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh, for identification and additional study. After studying their morphometric and meristic characteristics in the laboratory, the ichthyo-faunas were identified using the methods described by Talwar and Jhingran (1991) and Rahman (2005). Fishes were identified and then methodically categorized by Nelson (2006) and Rahman (2005).

Measurement of physical parameters

In this study, air temperature, AT (°C); water temperature, WT (°C); water depth, WD (m); dissolved oxygen, DO (mg/L); pH; and transparency, TR (cm) were considered as major physical factors. However, a digital thermometer (Digi-thermo), a dissolved oxygen meter (Model: DO5509, Lutron), a depth meter (wooden scale), a pH meter (Model: HI-8014, HANNA instruments), and a Secchi disk were monthly used to measure these physical parameters *in-situ* using a standard approach (APHA, 2012). The meteorological department at Dinajpur of Bangladesh provided the recorded data of rainfall (RF, mm).

Biodiversity parameters

Using the following equations, the diversity, evenness, and richness indices were computed to assess the state of diversity followed by Mia *et al.* (2019). Data was collected and analyzed every month to determine the seasonal variety of fishes in this study area:

Shannon-Wiener diversity index, $H = -\sum P_i \ln P_i$ (Shannon and Weaver, 1949)

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

Evenness index, $E = H/\ln S$ (Pielou, 1966)

Simpson's dominance index, $D = \sum n_i(n_i -1)/N (N-1)$ (Harper, 1999)

Where H is the diversity index, P_i is the relative abundance (s/N), *ln* is the natural logarithm, d is the richness index, s is the number of individuals for a species, S is the total number of species, N is the total number of individuals, e is the similarity or evenness index, D is the dominance index and n_i is the total number of individuals for a species.

Data analysis

For the Dhepa River, the dry season months of March, April, and May were not included in the research because of extremely low water levels (less than 5.0 feet) or dry periods. To identify the variations within stations and seasons, the study analyzed hydrological variables such as temperature, dissolved oxygen, pH, and transparency using ANOVA and Tukey's test. Canonical Correspondence Analysis (CCA) was used to investigate how physical characteristics affect the structure of fish communities (Toham and Teugels 1998). This study utilized Convolutional Calculation (CCA) to evaluate the significance of hydrological variables, based on hydrological patterns and fish availability. Four major biodiversity indices were used to identify aquatic community discrepancies. However, data was obtained and tracked monthly to determine the state of the fish community assembly and its structure. Diversity indices, such as the Shannon-Weiner diversity index (Shannon and Weiner, 1949), Margalef's richness index (Margalef, 1968), Dominance index (Harper, 1999), and Buzas-Gibson's evenness (Pielou, 1966), were determined. This study utilized two-dimensional nonmetric multidimensional scaling (nMDS) to transform data on fish availability into In (x+1) and reviewed fish assemblages on habitat and seasonal scales. The similarity approach of Bray-Curtis was used to identify major contributory fishes responsible for parallel grouping. The study used ANOSIM to compare variations among seasons and stations, and cluster analysis using UPGMA (Clarke and Warwick, 2001) to graphically compare affiliations among fish assemblages from each station and season. PAST software (versions 2.17 and 3.10) was used for all statistical analysis.

Results and discussion

Fish availability

An accumulation of 15532 individuals belonging to 59 types of fishes under 45 genera, 18 families, and 6 orders was captured from two rivers namely Atrai (KS and MP stations) and Dhepa Rivers (BG and KB stations) of Dinajpur district in Bangladesh. Fish composition, spatiotemporal contribution, and Supplementary Table I list the current condition of these fishes. The highest number of fish individuals were found at MP station approximately 33.22% of the total catch in autumn (29.67%) but the lowest was at KB as 10.98% in monsoon (22.76%), respectively (Fig. 1).

Table I. One way ANOVA of biodiversity indices (mean±SE) at different stations and seasons at the Atrai and Dhepa Rivers

Factors		Arai River		Dhepa River		Seasons			
		KS (○)	MP (●)	BG (□)	KB (■)	WN (✸)	SM (+)	MN (×)	AU (△)
Indices	λ	0.059±0.004[a]	0.050±0.002[a]	0.058±0.003[a]	0.092±0.009[b]	0.069±0.004[a]	0.081±0.010	0.057±0.004[b]	0.052±0.003
	J'	0.707±0.015	0.731±0.013	0.691±0.012[a]	0.755±0.022[b]	0.717±0.019	0.716±0.020	0.742±0.016	0.708±0.013
	d	5.273±0.193[a]	5.648±0.302[a]	5.343±0.251[a]	3.751±0.232[b]	4.689±0.183[a]	4.259±0.261[a]	5.248±0.383	5.819±0.263[b]
	H	3.099±0. 0.052[a]	3.232±0.054[a]	3.106±0.049[a]	2.645±0.079[b]	2.955±0.065	2.834±0.101[a]	3.088±0.081	3.205±0.065[b]

SE, standard error; λ, Simpson dominance, J', Plieus evenness; d, Margalef richness; H, Shannon-Weiner diversity index; KS, Khansama; MP, Mohonpur; BG, Birganj; KB, Karnai Bazar; WN, Winter seasons; MS, Monsoon; AU, Autumn; SM, Summer.

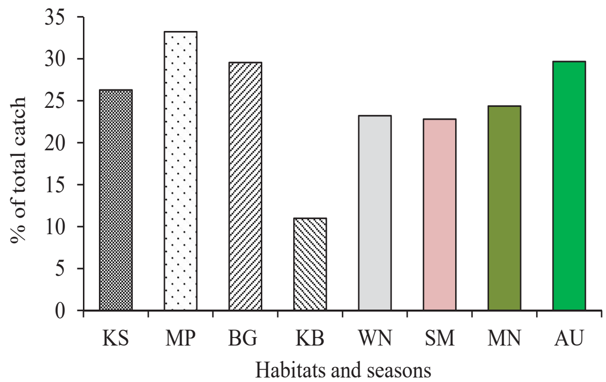

Fig. 1. Availability of fishes found in the different stations and seasons from the Atrai and Dhepa Rivers of Dinajpur district, Bangladesh. KS, Khansama; MP, Mohonpur; BG, Birganj; KB, Karnai Bazar; WN, Winter seasons; MS, Monsoon; AU, Autumn; SM, Summer

According to the Red List of IUCN Bangladesh (2015), approximately 15.87% of the fish caught, or 15 threatened species, were observed consisting of 5.16% at KS, 6.89% at MP, 5.02% at BG, and 1.80% at KB during winter (5.27%), summer (5.20%), monsoon (4.33%) and autumn (4.06%), respectively. Besides, the highest numbers of threatened fish species (14 species) were found in Mohanpur (Atrai River), and the lowest (six species) were captured from KB station (Dhepa River), respectively. Again, minimum fishes (12 species) were found in monsoon, but the maximum (13 species) were in the other three seasons (winter, summer, and autumn). Based on the number of species and specimens, fishes including threatened species from all sampling stations were commonly increased from monsoon to winter season and vice-versa with some fluctuations. The rarest species occurrence was spatiotemporally recorded for *N. notopterus* followed by *A. morar*, *Barilius bendelisis*, *B. barna, B. lohachata*, *C. chagunio*, *C. latius*, *Notopterus notopterus*, *N. nandus*, *O. pabda*, *P. ticto*, *R. bola*, *R. rita*, *S. scaturigina*, *S. aor*, and *W. attu*, respectively (Supplementary Fig. 2).

Environmental variables and fish accumulation

At four sites along the Atrai and Dhepa Rivers, the primary water quality indicators were monitored every month throughout the summer, monsoon, autumn, and winter. Both maximum and minimum values of WT were recorded as 33.4ºC in monsoon (MP) and 19.0ºC in winter (KS) season. The highest values of DO were noted to be 8.30 mg/l at BG in autumn but the lowest value was found as 4.00 mg/l at KS in winter season. The pH values varied from 6.23 in winter (MP) to 9.10 (BG) in monsoon. The greatest and lowest values of TP were attained as 71.12 and 22.86 cm in summer at MP and autumn at BG, respectively. Additionally, the maximum value of RF was recorded as 552.40 mm in monsoon, but no rainfall (0.0) was recorded during the winter season from all stations. The highest value of AT was noted to be 34.9 ºC in monsoon (BG) and the lowest was recorded as 20.2ºC in winter (BG), respectively. The maximum and

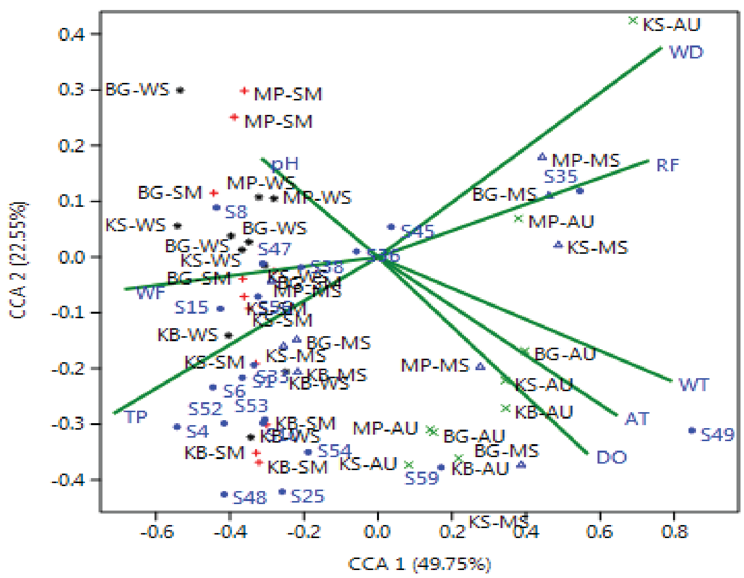

Fig. 2. Canonical correspondence analysis (CCA) of fish abundance and hydrological parameters at stations and months in the Atrai and Dhepa Rivers

minimum values of water depth (m) were recorded as 2.74 (MP) and 0.91 m (KB) whereas water flow (s/10 m) was 47.00 (KB) in winter and 21.00 s (KS) in monsoon seasons, respectively. No significant variations on WT ($F = 0.03$, $P > 0.05$), DO ($F = 0.09$, $P > 0.05$), pH ($F = 1.26$, $P > 0.05$), TR ($F = 0.65$, $P > 0.05$), AT ($F = 0.03$, $P > 0.05$) and RF ($F = 0.01$, $P > 0.05$) were observed within stations (Supplementary Table II) while significant changes were recorded in WD monsoon (MP) and autumn (KS and KB) where association was also found with *R. bola*. Vector length of RF showed a significant relation with the monsoon (MP and BG) and autumn (MP) seasons relating to the occurrence of *Mastacembelus aculatus*. The vector lengths of TR (*Somileptes gongota*), WF (*Mystus tengara* and *P. sophore*), and pH (*M. pancalus*) showed a correlation with fishes during the seasons in all stations from these rivers (Fig. 2).

Table II. Assemblage and structure of riverine fishes, Dinajpur, Bangladesh

Rivers		ANOSIM ($P = 0.001/R = 0.40$)				PREMANOVA ($P = 0.001/F = 8.85$)			
	Stations	KS (○)	MP (●)	BG (□)	KB (■)	KS (○)	MP (●)	BG (□)	KB (■)
Atrai	KS (○)	-	0.0056	ns	0.0001	-	0.0042	ns	0.0001
	MP (●)	0.22	-	0.0422	0.0001	3.48	-	0.0476	0.0001
Dhepa	BG (□)	ns	0.12	-	0.0001	ns	2.23	-	0.0001
	KB (■)	0.63	0.77	0.66	-	11.40	16.29	13.76	-

Tests		ANOSIM ($P = 0.001/R = 0.27$)				PREMANOVA ($P = 0.001/F = 4.40$)			
	Seasons	WN (✸)	SM (+)	MN (×)	AU (△)	WN (✸)	SM (+)	MN (×)	AU (△)
Seasons	WN (✸)	-	ns	0.0001	0.0001	-	ns	0.0004	0.0001
	SM (+)	ns	-	0.0017	0.0001	ns	-	0.0055	0.0001
	MN (×)	0.33	0.22	-	0.0068	4.81	3.99	-	
	AU (△)	0.51	0.45	0.17	-	8.40	7.40	ns	-

KS, Khansama; MP, Mohonpur; BG, Birganj; KB, Karnai Bazar; WN, Winter seasons; MS, Monsoon; AU, Autumn; SM, Summer; ns, Not significant.

($F = 3.76$, $P < 0.05$) and WF ($F = 3.92$, $P < 0.05$), respectively. Conversely, highly significant variations were observed among season based on all factors such as WT ($F = 48.80$, $P > 0.01$), DO ($F = 17.19$, $P > 0.01$), WD ($F = 10.33$, $P > 0.01$), pH ($F = 4.88$, $P > 0.05$), TR ($F = 19.61$, $P > 0.01$), AT ($F = 20.65$, $P > 0.01$), RF ($F = 9.43$, $P > 0.01$) and WF ($F = 19.85$, $P > 0.01$).

The first four axis' eigenvalues from the canonical correspondence analysis (CCA) of water quality variables were determined to be 0.15 (CCA_1), 0.07 (CCA_2), 0.03 (CCA_3), and 0.02 (CCA_4) based on habitat and seasonal scales where the polling and modeling of the first (CCA1) and second (CCA2) axis represented 49.75% and 22.55% of the species data, respectively. Given the availability of *P. conchonius*, the longest vector of water depth in the CCA analysis demonstrated a strong correlation with autumn. Temperature (air and water) showed a significant correlation with autumn (BG) associated with the occurrence of *Raiamas bola*. Similarly, the vector length of DO was correlated with the

Spatiotemporal variations in biodiversity indices

Average biodiversity index values (mean±SE) based on habitat and time (all polls) are presented in Table I. The mean value of the dominance diversity index was (0.07±0.004) which peaked as 0.17 at KB in summer and lowest as 0.03 at MP in autumn, respectively. The mean evenness value was (0.72±0.009) which peaked as 0.88 at KB in monsoon and lowest as 0.61 at BG in winter. Margalef values (5.00±0.16) varied from 2.61 (KB, summer) to 7.88 (MP, monsoon). Shannon indexes (3.02±0.06) were determined to their greatest and lowest values approximately 3.58 at MP in autumn and 2.22 at KB in summer, respectively. The significant differences were spatially observed in dominance ($F = 11.82$, $P < 0.01$), Margalef ($F = 11.75$, $P < 0.01$), Shannon ($F = 18.48$, $P < 0.01$), and evenness ($F = 2.88$, $P < 0.05$) diversity indices. Similarly, significant differences were observed in the values of dominance (F = 3.91, P < 0.01), Margalef (F = 5.77, P < 0.01), and Shannon (F = 4.07, P < 0.05) except for evenness (F = 0.70, P > 0.05) diversity indices among seasons.

Based on biodiversity indices, one-way PERMANOVA showed that the Dhepa River (KB) was different (F = 14.30, P < 0.01) from the Atrai River (KS and MP) whereas autumn was statistically different (F = 4.40, P < 0.01) from other seasons. These findings on biodiversity indices suggested that the availability of fish was more dominant in autumn from the Atrai River than in other seasons.

Assemblage and structure of riverine fishes

The fish assemblage and structure of these two rivers were compared using both non-parametric PERMANOVA and one-way analysis of similarity (ANOSIM) tests spatiotemporally (Table II). Analysis of similarity (ANOSIM) also showed considerable variations in fish grouping among stations (R = 0.40, P < 0.01) and seasons (R = 0.27, P < 0.01). The one-way PERMANOVA test also revealed significant variations in fish assemblage between stations (F = 8.85, P < 0.01) and times (F = 4.40, P < 0.01), respectively. Both tests suggested that the fish assemblage of station KB was significantly (P < 0.01) different from BG (R = 0.66, F = 13.76), KS (R = 0.63, F = 11.40) and MP (R = 0.77, F = 16.29). Whereas BG from MP (R = 0.12, F = 2.23) and KS from MP (R = 0.22, F = 3.48) were significantly (P < 0.01) different and no variations (P > 0.05) were found between KS and BG stations. On the contrary, fish assemblage during winter was statistically (P < 0.01) isolated from monsoon (R = 0.33, F = 4.81) and autumn (R = 0.51, F = 8.40); summer from monsoon (R = 0.22, F =3.99) and autumn (R = 0.45, F =7.40) and monsoon from autumn (R = 0.17). Both tests showed no statistical deviations (P > 0.05) were observed between winter and summer (R = 0.02, F = 1.02), and autumn from monsoon (F = 2.15).

This study used Bray-Curtis's similarity index to analyze a two-dimensional nMDS with a stress of 0.13 (Fig. 3) suggesting that fish assemblage at KB (Dhepa River) were spatio-temporally speckled from BG (Dhepa River), KS and MP (Atrai River). In the case of seasons, winter and summer seasons were alienated from summer and monsoon due to the alteration of fish availability captured from the two rivers Depha and Atrai in the Dinajpur district of Bangladesh.

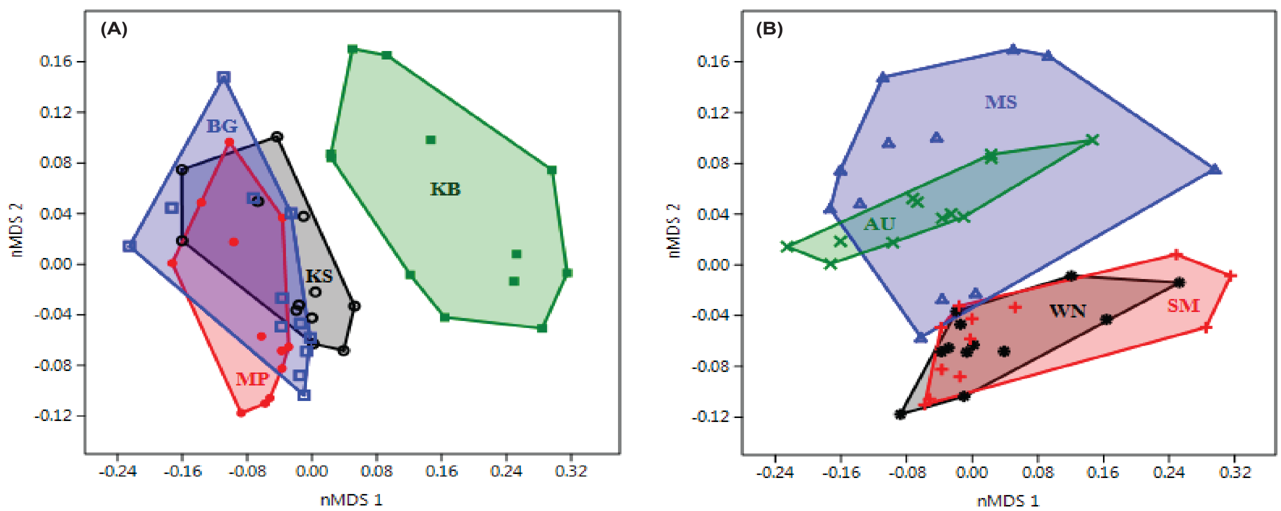

Fig. 3. Two dimensional nMDS scaling of comparative fish assemblage data among stations (A) and seasons (B) of the Atrai and Dhepa Rivers stressing as 0.13. KS, Khansama; MP, Mohonpur; BG, Birganj; KB, Karnai Bazar; WN, Winter seasons; MS, Monsoon; AU, Autumn; SM, Summer

The average dissimilarity within stations and seasons was determined to be approximately 53.51% and 52.49%, respectively, using SHIMPER testing (all pooling, Table III). The major dominating (>4.13%) fishes were *P. ticto*, *C. nama*, *P. sophore*, *S. bacaila*, and *S. gongota* to stations and seasons. The major contributory fishes were *P. ticto* (5.47% and 5.64%) while the minor was *C. cirrhosis* for habitat (0.05%) and (0.06%) for season, respectively.

Table III. SIMPER analysis of fin fishes between the Atrai and Dhepa Rivers, Bangladesh

Stations (53.51%)			Seasons (52.49%)	
Average Dissimilarity	Contribution (%)	Taxon	Average Dissimilarity	Contribution (%)
2.92	5.47	*Pethia ticto*	2.96	5.64
2.85	5.32	*Chanda nama*	2.68	5.10
2.64	4.93	*Puntius sophore*	2.40	4.57
2.48	4.64	*Salmophasia bacaila*	2.58	4.91
2.33	4.35	*Somileptes gongota*	2.17	4.13
2.30	4.29	*Pseudeutropius atherinoides*	2.04	3.88
2.07	3.86	*Cirrhinus reba*	1.99	3.80
2.00	3.74	*Esomus danricus*	2.41	4.60
1.97	3.68	*Lepidocephalus guntea*	1.93	3.68
1.96	3.66	*Aspidoparia jaya*	1.83	3.48
1.91	3.56	*Barilius barna*	1.81	3.44

The first two axes namely PCA_1 and PCA_2, principal component analysis (PCA) for finfish assemblage in the Atrai and Depha Rivers, explained as 23.50% and 21.20% of the total variation for stations (KS, MP, BG, and KB) while 23.50% and 21.20% for seasons (SM, MS, AU, and WN) resulting in a clear spatiotemporal separation of fish samples (Fig. 4). Separations along PCA plots in the samples among four stations were highly influenced by increasing number of most fishes during summer and winter seasons. In contrast, a declining trend for fish abundance at KB station (Dhepa River) during the monsoon and autumn seasons (Fig. 4).

Lastly, two major clusters were perceived as 82.53% amalgamation using Bray-Curtis's similarity index where summer and winter seasons also united to one cluster at KB station of the Dhepa River that isolated from the

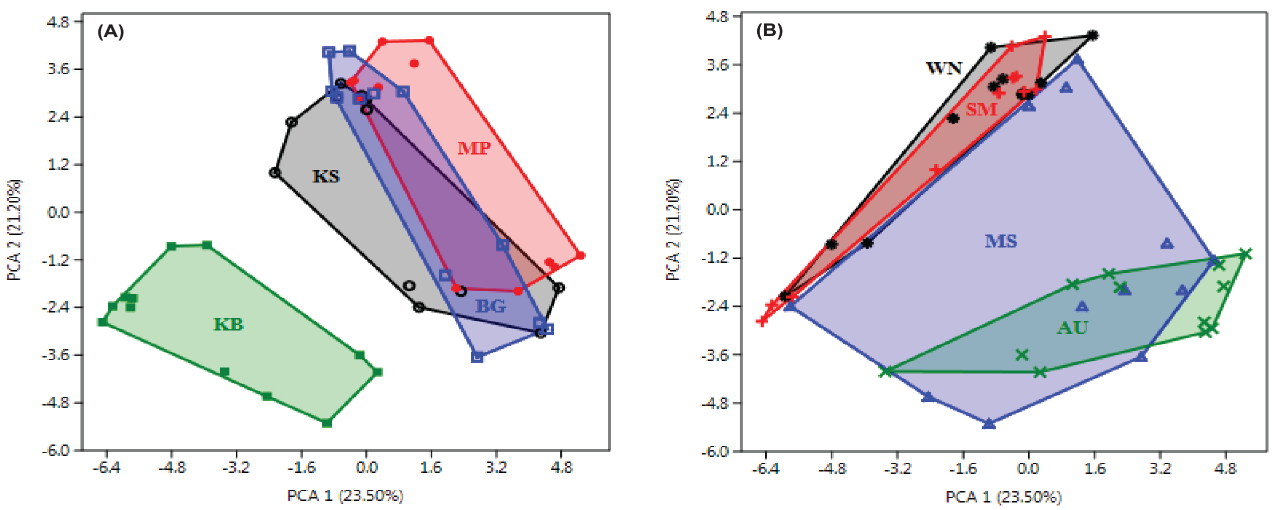

Fig. 4. Principal component analysis (PCA) in the finfish assemblage data among stations (A) and seasons (B) of the Atrai and Dhepa Rivers. KS, Khansama; MP, Mohonpur; BG, Birganj; KB, Karnai Bazar; WN, Winter seasons; MS, Monsoon; AU, Autumn; SM, Summer

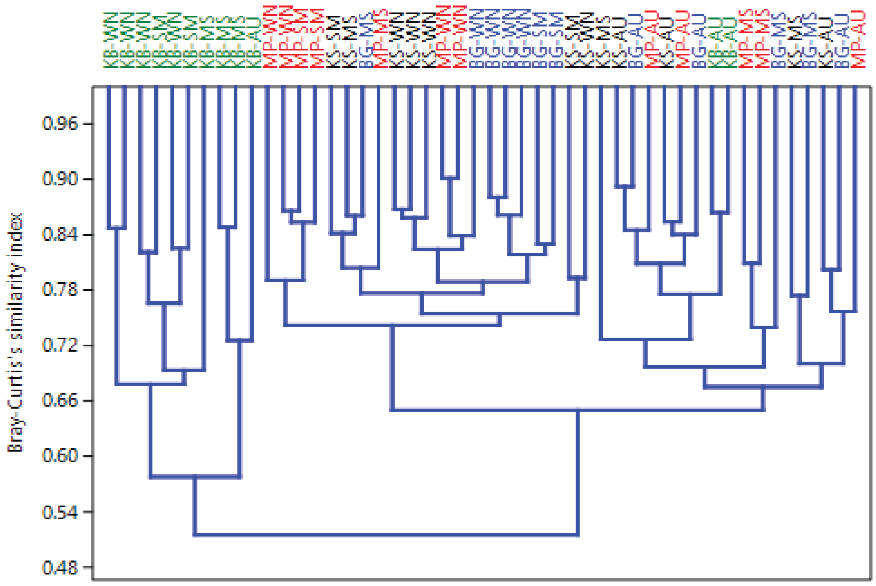

Fig. 5. Classical UPGMA clustering based on Bray-Curtis's similarly index of fish assemblage both in stations and seasons from the Atrai and Dhepa Rivers. KS, Khansama; MP, Mohonpur; BG, Birganj; KB, Karnai Bazar; WN, Winter seasons; MS, Monsoon; AU, Autumn; SM, Summer

stations of the Atrai River (another cluster) during monsoon and autumn seasons (Fig. 5).

Biological diversity changes through the construction of dams and pools that alter hydrological factors changing and sectioning the dynamics of rivers (Dynesius and Nilsson, 1994) and fish communities (Hänfling *et al.* 2004). The biological state of a river ecosystem is heavily impacted by aquatic biochemistry and habitat conditions (Bio *et al.* 2011). The distribution of species was highly affected by variations in water temperature over the months in the Atrai and Dhepa Rivers. This might be because of decreased river currents and depth. Yan *et al.* (2010) found that fish abundance in rivers is highest during winter months when the water temperature is low and discharge is small, while minimum diversity is lowest during summer due to geographical variations. Changes in hydrological parameters, such as water temperature, dissolved oxygen, pH, transparency, and depth, have an impact on the individuality of the aquatic environment and fish breeding (Kathiresan and Bingham, 2001; Rashleigh, 2004). Additionally, profusion and allocation, migration and distribution, and fish survival, (Vega-Cendejas *et al.* 2013; Whitfield, 1999), all change the assemblage and structure of fish. Moreover, minor changes were found among stations in this study area, although substantial differences ($P < 0.05$) were noted in hydrological parameters among months comparable to Grimaldo *et al.* (2012). Furthermore, Atrai River water quality parameter values were within the limits reported by Mia *et al.* (2019) and Islam *et al.* (2019) due to the close ecological area. Accordingly, seasonal variations in hydrological and climatic elements in estuaries primarily influence the similarity and dissimilarity of fish assemblage and structure (Loneragan and Potter, 1990; Young and Potter, 2003).

The MP station showed a higher number of fish including threatened species over time, possibly due to increased periphyton community, charitable shelters, natural food particles, and breeding sites in Atrai River. The number of fish species and specimens may vary due to their early April dispersal from the MP station for spawning. The MP station recorded the highest number of fish, possibly due to better environmental conditions, especially in terms of water depth, compared to the KS station. The BG station of the Dhepa River had a higher number of native and susceptible species of fish and individuals over time compared to the KB station, which might be due to a more favorable aquatic environment. In the study area, the highest number of fish individuals were found at MP station (38.19% of total catch) in autumn but the lowest was at KB (10.98%) in monsoon (22.76%), due to scarcity of minimum water flow, depth and seasonal or climate changes. The Padma River recorded the highest fish abundance in November, but lowest in June and August, possibly due to geographical and environmental variations (Chaki *et al.* 2014; Jahan *et al.* 2014).

All diversity indexes have comparable values among the stations from both rivers while significant variations were found among months. Differences can develop owing to nutritional dissimilarity (Huh and Kitting, 1985), water currents and climatic conditions (Keskin and Unsal, 1998), fish movements (Ryer and Orth, 1987), and temporal variability in the species diversity. From April to May, some small indigenous fish species in Bangladesh spawn and join as new populations in aquatic habitats, which would be another reason to change the diversity indexes.

Furthermore, the current study finds very close similarities in the presence of finfish assemblages among sample sites and periods. For spatiotemporal scales, the primary contributory species are also comparable, although their level of contribution varies. At this time, the similarity was identified more within periods than within areas, including significant contributory fishes associated with the Chalan beel for *P. sophore* and *P. ticto* (Kostori *et al.* 2011), but not with the Meghna River estuary (Hossain *et al.* 2012). The non-metric multidimensional scaling (nMDS) constructs linkages among assemblages in particular coordination based on similarities or differences. The fish assemblage in the present rivers, with a stress level of 0.13, is better fitting with petite suspects due to reduced stress (<0.10) of nMDS in the study area, as supported by Kruskal and Wish (1984) and Sanches *et al.* (2016). Remarkable differences in fish grouping within stations and seasons were found using ANOSIM analysis. Additionally, major variations in fish assembly within stations and seasons were found using the one-way PERMANOVA test. Both tests suggested that the fish assemblage of station KB showed a considerable change ($P < 0.01$) from BG, KS, and MP. Whereas BG from MP and KS from MP were considerably ($P < 0.01$) distinct, and no variations ($P > 0.05$) were found between KS and BG stations. On the contrary, fish assemblage during winter was statistically ($P < 0.01$) isolated from monsoon and autumn, summer from monsoon, and autumn and monsoon from autumn. Both tests showed that no statistical deviations ($P > 0.05$) were observed between winter and summer and autumn from monsoon. Fish assemblage changes over months because of water quality characteristics and seasonal ecological factors for mating, feeding, growing, and sheltering which impact spawning activity and catch composition (Agostinho *et al.* 2008; McErlean *et al.* 1973).

Conclusion

In summary, major contributory fishes such as *P. ticto*, *C. nama*, *C. reba*, *P. sophore*, and *S. bacaila* including endangered species, depend on the spatiotemporal relationship between hydrological factors to complete their life cycle. The temperature and depth in the present rivers significantly influence fish assemblage and structure. Bangladesh's government, scientists, and authorities should focus on saving threatened, endemic, and commercial fish from low water levels during dry or winter seasons. Fish sanctuaries should be declared around known spawning and nursery grounds, and year-round fishing should be restricted to conserve biodiversity. During the breeding season, fishermen should be discouraged from catching fish, and alternative livelihood support should be provided. Further research, governmental rule enforcement, and awareness raising can help regenerate rare fishes and sustain dominant species in the Atrai and Dhepa Rivers in Dinajpur district, Bangladesh.

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Author contributions

M. M. Rahman: Conceptualization, Methodology, Data curation, Data analysis, Writing - original draft, preparation; M. Al-Amin: Data curation, Writing - original draft, preparation; N. Mostari: Data curation, Writing - original draft, preparation; M. I. A. Lima: Data curation, Writing - original draft, preparation; H. Ahmmed: Data curation, Writing - original draft, preparation; M. R. Islam: Conceptualization, Software, Data analysis, Writing - review and editing, Funding acquisition, Supervision. All authors have read and agreed to the published version of the manuscript.

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