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# Diversity and Seasonal Variation of Fish Assemblages of Dingapota Haor an Eutrophic Wetland of Northeastern Bangladesh

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**Abstract**

Wetlands are considered as the heart of natural feeding and breeding grounds of many indigenous fishes of Bangladesh. These are also the most diversified habitat in the world. However, the wetlands of Bangladesh are in danger of extinction due to various manmade and natural causes. Therefore, wetlands need special attention to conserve this unique ecosystem of Bangladesh. As a part of the conservation measures needed for wetland ecosystem, the present study was undertaken to describe the abundance and diversity status of fish in Dingapota wetland of Bangladesh and to identify the key environmental factors influencing the fish community assemblage. A total of 52 fish species were recorded from 7 orders during the study period. Cypriniformes comprises the most abundant order (47.91%) followed by Perciformes (20.71%) and Clupeformes (20.22%). Higher number of species was recorded in post-monsoon season. Fish community assemblage was significantly differentiated among the three seasons (ANOSIM, Global $R = 0.803$, $P < 0.05$), while the overall average differences in the period of three seasons was estimated as 39.92% and similarity percentage analysis (SIMPER) revealed the greater contribution of *Osteobrama cotio*, *Esomus danricus*, *Nandus nandus*, *Gudusia chapra* and *Chanda nama* to ascertain this dissimilarity. Multivariate analysis based on non-metric multidimensional scaling (nMDS) generated three separate groups of each seasonal samplings and cluster analysis to find out natural grouping of samples according to their abundance. Diversity indices (Shannon-Weiner diversity (*H*), Margalef's richness (*D*) and Pielou's evenness (*e*)) were found to vary significantly among the seasons. Canonical correspondence analysis (CCA) revealed the significant roles of temperature, depth, transparency, pH, dissolved oxygen and alkalinity for structuring the community assemblage of fish in Dingapota wetland. Essential baseline information generated by this study will help the respective authority to formulate sustainable conservation measures for Dingapota wetland.

**Keywords:** diversity indices, environmental parameters, fish community, Canonical correspondence analysis, similarity percentage analysis

## 1. Introduction

Haor (bowl-shaped massive geological depression in wetland) is the most diverse habitat in Bangladesh. These special ecosystems are considered as the sixth hotspot in the Delta Plan 2100 of Bangladesh. Haors are typically submerged during the rainy season and merge with riverine flood waters. Therefore, seasonal flooding in these haors mostly controls the variety and number of fish species. Owing to the increase in water areas, fish are not typically present in large numbers during the monsoon. There are about 373 haors, or roughly 43% of the entire area of the haor region, spread across the districts of Netrokona,Kishoreganj,Sunamganj, Habiganj, Sylhet, Maulvibazar and Brahmanbaria, (Ahmed, 2013; Islam *et al.*, 2010; Master Plan of Haor Areas, 2012).They encompass an area of about 858,000 ha. Numerous freshwater fin fish species as well as several prawn species, including 143 indigenous and 12 exotic species, are found in these haors (Mustafa *et al.*, 2019; Islam *et al.*, 2012; MoW, 2005; Muzaffar, 2004).

Since the turn of the century, there has been significant human meddling in the natural world, leading to overexploitation, loss of natural habitats, and terrible conditions for aquatic ecosystems. For this reason, many fish species are currently in danger of going extinct. Bangladesh is now facing a serious problem with the ongoing aquatic biodiversity declining from natural water bodies (Galib *et al*., 2009 and 2013; Mohsin *et al.,* 2013 and 2014). The decline in fish biodiversity in inland water bodies serves as an example of the need for an extensive study, which is necessary for evaluating the present situation and ensure the effective management approach of a water body (Imteazzaman and Galib, 2013).

Dingaputa Haor is One of the significant inland freshwater wetland ecosystems, which is situated at Mohonganj Upazila of Netrakona District at 24°52′00″N 90°58′00″E / 24.8667°N 90.9667°E (Fig. 1) covering the surface area of 8000 ha. To the authors' knowledge, several research projects on the fish faunal biodiversity of

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various water of diverse water bodies in Bangladesh have been carried out; however, there has only been one study on the aquatic fish faunal biodiversity of the Dingapota Haor, Netrokona. In this case, study is necessary to comprehend the wetland's overall state and maintain the appropriate management practices. The diversity of fish in the water must be known before implementing any fisheries management technique, but no report on the fish diversity and ecological status of the water has been released (Huda *et al.* 2009). Therefore, the current study examines seasonal variation in environmental variables as well as changes in various freshwater fish species diversity indices at Dingapota Haor (Mohangonj Upazilla) Netrokona, Bangladesh.

## 2. Materials and methods

### 2.1. Study area and duration

From July 2020 to June 2021, the study was carried out over a 12-month period at three sampling sites (Karchapur, 24°77’72” N, 91°05’10”E; Mollikpur, 24°80’23” N, 91°03’57”E: Khurshimul, 24°88’66” N, 91°01’99”E) in the Dingapota haor, a wetland at Mohangonj Upazila (Sub-district) in Netrokona District, Bangladesh (Fig. 1). It is an important ecosystem that supports many different fish species and is regarded as an essential breeding and feeding habitat for inland freshwater fish species. Additionally, this region provides small-scale fishermen and nearby residents with a means of subsistence. Fish and environmental factors were sampled throughout each month, which was further divided into three distinct seasons; a) From July to October is monsoon season; b) from November to February is post-monsoon; and c) from March to June is pre-monsoon

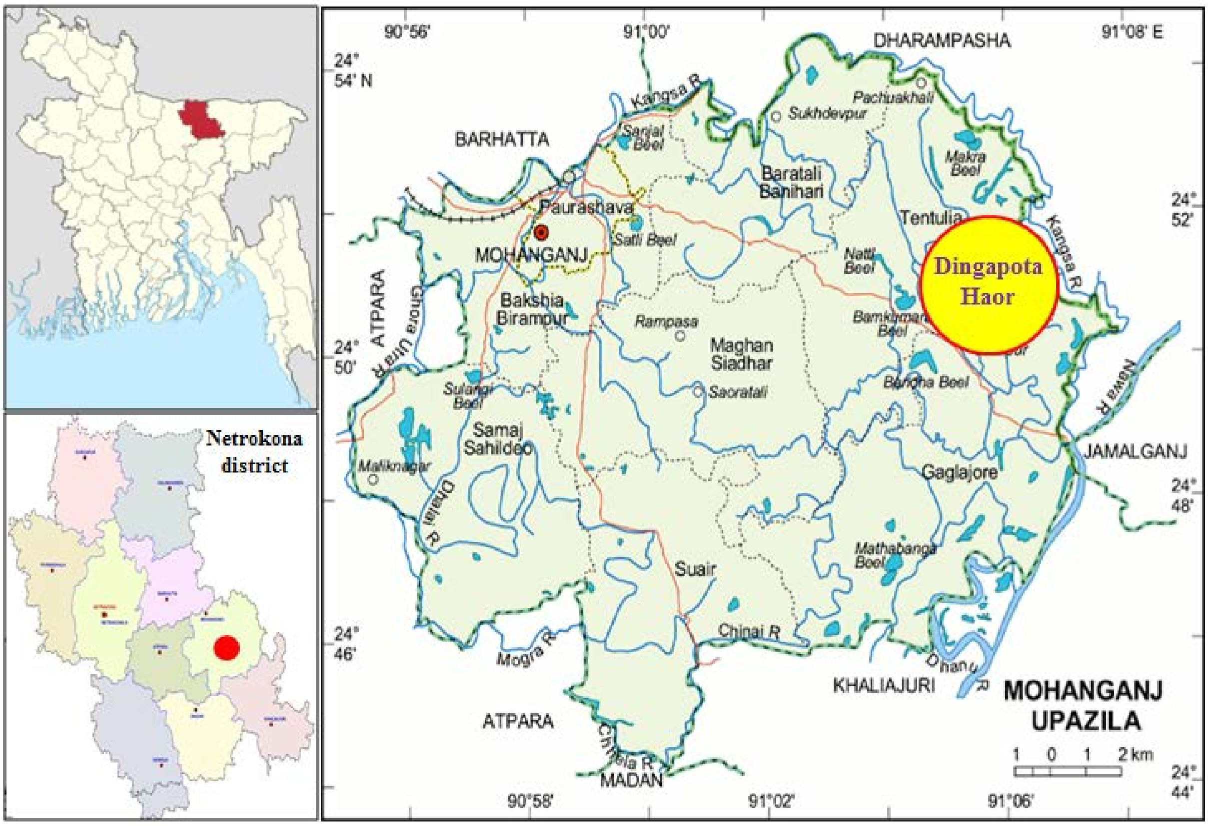


**Figure 1**. Map of the Dingapota haor at Mohanganj Upazila of Netrokona district, Bangladesh.

### 2.2. Measurement of water quality parameters

Temperature, transparency, depth, dissolved oxygen, pH, $NO_3$-N, $PO_4$-P, alkalinity, and TDS were the water quality parameters measured each month and documented. Water quality parameters were measured between 9:00 am and 12:00 pm throughout every sampling month. On the sampling date, 500ml of surface water from each study locations were collected in black colored coded bottles. A highly advanced Multi-Parameter Water Quality Meter (HANNA, HI 98194, pH/EC/DO multi-parameter) was used to measure the water's temperature (°C), pH, DO, and TDS. Water depth was measured with a measuring tape. A Secchi disk was used to measure the water's transparency (in cm). A spectrophotometer (DR-1900) was used to measure alkalinity (mg/l), $NO_3$-N, and $PO_4$-P.

### 2.3. Species collection and identification

Fish samples were collected from the specified sampling site with the assistance of experienced fishermen on each sampling date. A seine net with a length, width and mesh size of 100 m, 5 m and 1-2 mm, respectively, was used for sampling of fishes. After collecting, the fishes were identified and enumerated. Fishes which were difficult to identify were kept in 10% buffered formalin solution and transported to the laboratory of the Bangladesh Fisheries Research Institute, Mymensingh. Subsequently, morphometric and meristic data were used to identify the fishes up to species level followed by the keys of (Rahman *et al.* 2009). Identified fishes were categorized into taxonomic groups following Nelson *et al.* (2006).

*2.4. Diversity indices*

Shannon-Weiner diversity, Margalef's richness and Pielou's evenness were calculated by using the following formula-

Shannon-Weiner diversity, $H = -\sum i \frac{n_i}{N} \ln \frac{n_i}{N}$ (Shannon and Weiner, 1949)

Where, S is the number of individuals for each species, N is the *total* number of individuals, $n_i$ is the relative abundance (S/N) H represents the diversity index,

Margalef's richness, $D = \frac{S-1}{\ln N}$ (Margalef 1968)

Where, N is the total number of distinct species in the sample, S is the different species in the sample; D is Margarlef's richness index.

Pielou's evenness, $Je = \frac{H}{L_n S}$ [$L_n$ = the natural logarithm] (Poule's, 1966)

Where, S indicates the number of distinct species in the sample and H is the Shannon- Weiner index.

*2.5. Statistical analyses*

One-way analysis of variance (ANOVA) was used to assess seasonal fluctuation in water quality parameters using Statistical Package for Social Sciences (version 20.0) software. Seasonal distribution of water quality parameters was analyzed by principal component analysis (PCA). Species abundance and diversity indices were also analyzed by ANOVA. Mean differences among the seasons were determined by Duncan's multiple range test (DMRT) at 5% level of significance. Community assemblage pattern of fish species among the seasons was tested by multivariate analysis. Before analyzing the data, water quality parameters were square root transformed, and the fish abundance data was $\log_{10}$ (x+1) transformed for the normalization. Analysis of similarity (ANOSIM) was conducted to assess the differences in fish community assemblage among the seasons. Similarity percentage analysis (SIMPER) was also used to determine the most contributory species causing differences among the seasons (Clarke and Warwick 1994). The distribution pattern of the fishes among the season was visualized using non-metric multi-dimensional scaling (nMDS), and the species was categorized using a cluster analysis based on Bray-Curtis similarity matrix. The potential correlations between fish species and water quality parameters were determined by canonical corresponding analysis (CCA) using PAST (Paleontological Statistics, Version 4.10) program.

## 3. Results

*3.1. Seasonal variation of water quality parameters*

Table 1 provides an overview of the water quality metrics that were noticed and noted during the investigation. All the water quality measures showed a significant variation across the seasons (P < 0.05). Pre-monsoon had the greatest water temperature (29.89 ± 0.65°C), while post-monsoon had the lowest (22.36 ± 3.98°C). Observed transparency was ranged between 39.59±4.41cm (Post-monsoon) to 24.66±0.81 cm (Monsoon). The highest water depth was observed during the Monsoon (5.96±1.61 m) and the lowest during pre-monsoon (1.66±0.82 m) whereas pH was ranged between 7.00±0.78 (post-monsoon) to 6.38±0.60 (pre-monsoon). In addition, DO was between 6.63±0.74 mg/l (post-monsoon) to 4.56±0.53 mg/l (pre-monsoon). In case of $NO_3$-N and $PO_4$-P, pre-monsoon showed the greatest levels of (0.33 0.04 and 1.34 0.11 mg/l), while monsoon had the lowest levels (0.13 0.01 mg/l and 1.16 0.02 mg/l). The total alkalinity was 126.89±7.47 mg/l during pre-monsoon and 103.38±4.44 mg/l during monsoon while TDS was also the highest during pre-monsoon (135.73±5.50 mg/l) and the lowest during monsoon (100.97±5.16 mg/l). PCA was also used to explain the seasonal variation of water quality measures, with its first two axes accounting for 85.94% of the variability in the data (Fig. 2). PCA demonstrated a distinct seasonal separation of the samples, whereas the monsoon samples are related with water depth and the post-monsoon samples are associated with transparency, DO, $NO_3$-N and $PO_4$-P. Furthermore, pre-monsoon samples are correlated with alkalinity and TDS.

**Table 1.** Water quality parameters (Mean ± SD) in different seasons

| Variables | Monsoon | Post-monsoon | Pre-monsoon |
|---|---|---|---|
| Temperature ($^0$C) | 28.70±0.62$^a$ | 22.36±3.98$^b$ | 29.89±0.65$^a$ |
| Transparency (cm) | 24.66±0.81$^c$ | 38.02±3.29$^b$ | 39.59±4.41$^a$ |
| Depth (m) | 5.96±1.61$^a$ | 1.93±0.41$^b$ | 1.66±0.82$^c$ |
| pH | 6.99±0.85$^a$ | 7.00±0.78$^a$ | 6.38±0.60$^b$ |
| DO (mg/l) | 5.72±0.52$^b$ | 6.63±0.74$^a$ | 4.56±0.53$^c$ |
| $NO_3$-N (mg/l) | 0.13±0.01$^c$ | 0.21±0.11$^b$ | 0.33±0.04$^a$ |
| $PO_4$-P (mg/l) | 1.16±0.02$^c$ | 1.28±0.09$^b$ | 1.34±0.11$^a$ |
| Total alkalinity (mg/l) | 103.38±4.44$^c$ | 112.79±2.00$^b$ | 126.89±7.47$^a$ |
| TDS (mg/l) | 100.97±5.16$^c$ | 116.92±7.38$^b$ | 135.73±5.50$^a$ |

Mean values in the same row having difference superscript letters indicate significant (P< 0.05) differences.

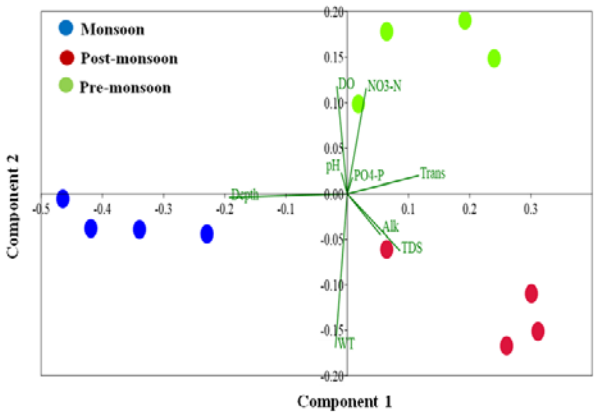


**Figure 2**. Water quality parameters during the monsoon, post-monsoon, and pre-monsoon seasons were analyzed using the principle component method (Wt = water temperature, Trans = transparency, Depth, DO = dissolved oxygen, pH, NO3-N = nitrate-nitrite, PO4-P = phosphate-phosphorus, Alka = total alkalinity, TDS = total dissolved solids).

 

### 3.2. Catch composition

During the study period, 52 fish species from 17 families and 7 orders were recorded. Figure 3 demonstrates that the most abundant order was the cypriniformes followed by the perciformes (20.71%) and the clupeformes (20.22%). A total of 1242 individual of fishes was collected during the study period (Table 2) which consists of 52 species. The total abundance was significantly higher during post-monsoon season (725) and the lowest in pre-monsoon season (107). Similarly, total number of species was significantly higher during post-monsoon season (47) and the lowest in pre-monsoon season (34). *Amblypharyngodon mola* (11.03%) was the most dominant species followed by *Gudusia chapra* (10.03%) and *Osteobrama cotio* (8.01%).

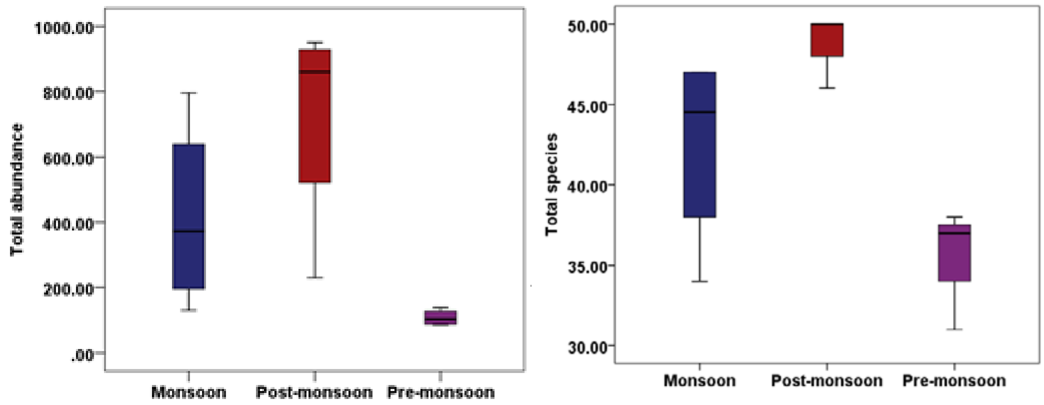


**Figure**  ıdance (a) and species count (b) during the study period

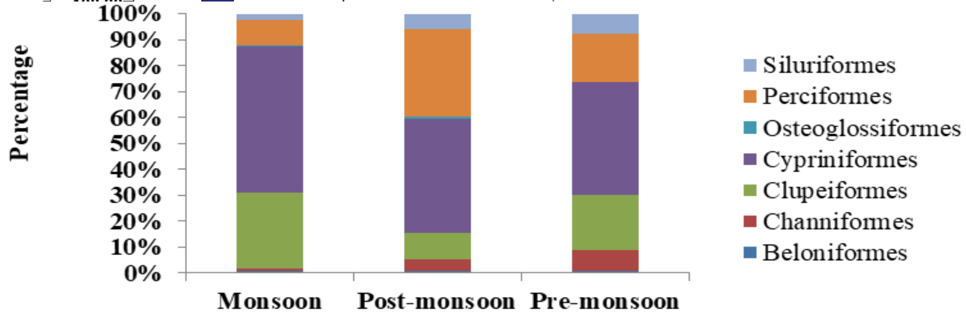


**Figure. 4**. Percentage composition of different fish taxonomic orders in the studied wetland

**Table 2**. List of species with number of individuals and their contribution (%) in each season

| Sl. No. | Species Name | Code | Total | Overall contribution (%) | Seasonal contribution (%) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Monsoon | Post-monsoon | Pre-monsoon |
| 1 | *Xenentodon cancila* | Xc | 9 | 0.73 | 0.54 | 0.82 | 0.89 |
| 2 | *Hyporhamphus limbatus* | Hl | 1 | 0.07 | 0.21 | 0.00 | 0.00 |
| 3 | *Channa punctatus* | Cp | 21 | 1.65 | 0.61 | 1.85 | 4.35 |
| 4 | *Channa striatus* | Cs | 19 | 1.56 | 0.28 | 2.23 | 1.94 |
| 5 | *Channa orientalis* | Co | 6 | 0.52 | 0.32 | 0.50 | 1.36 |
| 6 | *Channa marulius* | Cm | 5 | 0.42 | 0.13 | 0.50 | 1.02 |
| 7 | *Corica soborna* | Cso | 114 | 9.20 | 18.49 | 3.15 | 14.24 |
| 8 | *Gudusia chapra* | Gc | 131 | 10.52 | 15.60 | 7.79 | 9.39 |
| 9 | *Gibelion catla* | Gca | 2 | 0.16 | 0.16 | 0.18 | 0.00 |
| 10 | *Labeo rohita* | Lr | 1 | 0.05 | 0.16 | 0.00 | 0.00 |
| 11 | *Labeo bata* | Lb | 11 | 0.90 | 0.33 | 0.66 | 4.69 |
| 12 | *Labeo calbasu* | Lc | 6 | 0.47 | 0.18 | 0.30 | 2.70 |
| 13 | *Labeo gonius* | Lg | 10 | 0.81 | 0.38 | 0.87 | 2.05 |
| 14 | *Cirrhinus cirrhosus* | Cci | 5 | 0.39 | 0.27 | 0.39 | 0.84 |
| 15 | *Amblypharyngodon Mola* | Am | 137 | 11.03 | 21.14 | 4.98 | 13.03 |
| 16 | *Chela Laubuca* | Cl | 64 | 5.19 | 5.06 | 5.10 | 6.35 |
| 17 | *Osteobrama cotio* | Oc | 99 | 8.01 | 11.11 | 7.24 | 1.26 |

**Table 2. cont**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 18 | *Pontius sarana* | Ps | 10 | 0.77 | 0.77 | 0.57 | 2.18 |
| 19 | *Puntius sophore* | Pso | 65 | 5.21 | 1.09 | 8.02 | 2.05 |
| 20 | *Pethia ticto* | Pt | 18 | 1.43 | 0.67 | 1.74 | 2.28 |
| 21 | *Salmostoma Bacaila* | Sb | 2 | 0.13 | 0.11 | 0.17 | 0.00 |
| 22 | *Esomus danricus* | Ed | 85 | 6.84 | 7.12 | 7.51 | 1.15 |
| 23 | *Botia dario* | Bd | 2 | 0.18 | 0.31 | 0.13 | 0.00 |
| 24 | *Lepidocephalichthys Guntea* | Leg | 17 | 1.38 | 1.15 | 1.71 | 0.00 |
| 25 | *Notopterus chitala* | Nc | 4 | 0.35 | 0.09 | 0.55 | 0.00 |
| 26 | *Notopterus notopterus* | Nn | 0 | 0.04 | 0.06 | 0.03 | 0.00 |
| 27 | *Anabas testudineus* | At | 16 | 1.30 | 0.08 | 1.82 | 2.49 |
| 28 | *Chanda nama* | Cn | 47 | 3.79 | 1.44 | 5.53 | 1.02 |
| 29 | *Pseudambassis ranga* | Pr | 13 | 1.04 | 0.40 | 1.56 | 0.00 |
| 30 | *Glossogobius giuris* | Gg | 12 | 0.95 | 0.39 | 1.40 | 0.00 |
| 31 | *Glossogobius chuno* | Goc | 49 | 3.91 | 1.32 | 5.68 | 1.91 |
| 32 | *Macrognathus aculeatus* | Ma | 30 | 2.45 | 1.43 | 3.05 | 2.28 |
| 33 | *Macrognathus pancalus* | Mp | 37 | 2.96 | 1.31 | 4.05 | 1.97 |
| 34 | *Mastacembelus armatus* | Maa | 11 | 0.89 | 0.30 | 1.13 | 1.57 |
| 35 | *Nandus nandus* | Nan | 28 | 2.22 | 0.17 | 3.38 | 2.25 |
| 36 | *Colisa fasciata* | Cf | 21 | 1.65 | 0.37 | 2.33 | 2.05 |
| 37 | *Badis badis* | Bad | 0 | 0.04 | 0.00 | 0.07 | 0.00 |
| 38 | *Mystus aor* | Mao | 10 | 0.83 | 0.11 | 1.21 | 1.02 |
| 39 | *Mystus cavassius* | Mc | 37 | 2.96 | 2.49 | 3.40 | 1.76 |
| 40 | *Mystus vittatus* | Mv | 18 | 1.43 | 0.83 | 1.74 | 1.57 |
| 41 | *Rita rita* | Rr | 1 | 0.09 | 0.08 | 0.10 | 0.00 |
| 42 | *Ompok bimaculata* | Ob | 6 | 0.45 | 0.18 | 0.49 | 1.21 |
| 43 | *Ompok pabda* | Opa | 8 | 0.62 | 0.42 | 0.63 | 1.36 |
| 44 | *Wallago attu* | Wa | 8 | 0.68 | 0.32 | 0.83 | 1.08 |
| 45 | *Ailia coila* | Ac | 8 | 0.63 | 0.54 | 0.78 | 0.00 |
| 46 | *Clupisoma garua* | Clug | 9 | 0.73 | 0.61 | 0.91 | 0.00 |
| 47 | *Eutropiichthys vacha* | Eucv | 1 | 0.05 | 0.16 | 0.00 | 0.00 |
| 48 | *Bagarius bagarius* | Bb | 2 | 0.16 | 0.11 | 0.22 | 0.00 |
| 49 | *Clarias batrachus* | Cb | 4 | 0.33 | 0.14 | 0.28 | 1.39 |
| 50 | *Heteropneustes fossilis* | Hfo | 5 | 0.41 | 0.12 | 0.39 | 1.65 |
| 51 | *Chaca chaca* | Cch | 3 | 0.26 | 0.00 | 0.21 | 1.65 |
| 52 | *Neotropius atherinoides* | NA | 14 | 1.16 | 0.32 | 1.80 | 0.00 |

### *3.3. Species diversity*

The seasonal values of the Pielou's evenness, Margalef's richness, and Shannon-Wiener diversity indices are presented in Fig. 6. The studied haor is more diverse in post-monsoon season with the Shannon–Wiener diversity value of 3.27 ± 0.17. Furthermore, fish species of the studied haor were more evenly distributed for the period of post-monsoon season (Pielou's evenness value 0.89 ± 0.08). Species richness was also higher in post-monsoon season with the Margalef's richness value 7.97 ± 0.24.

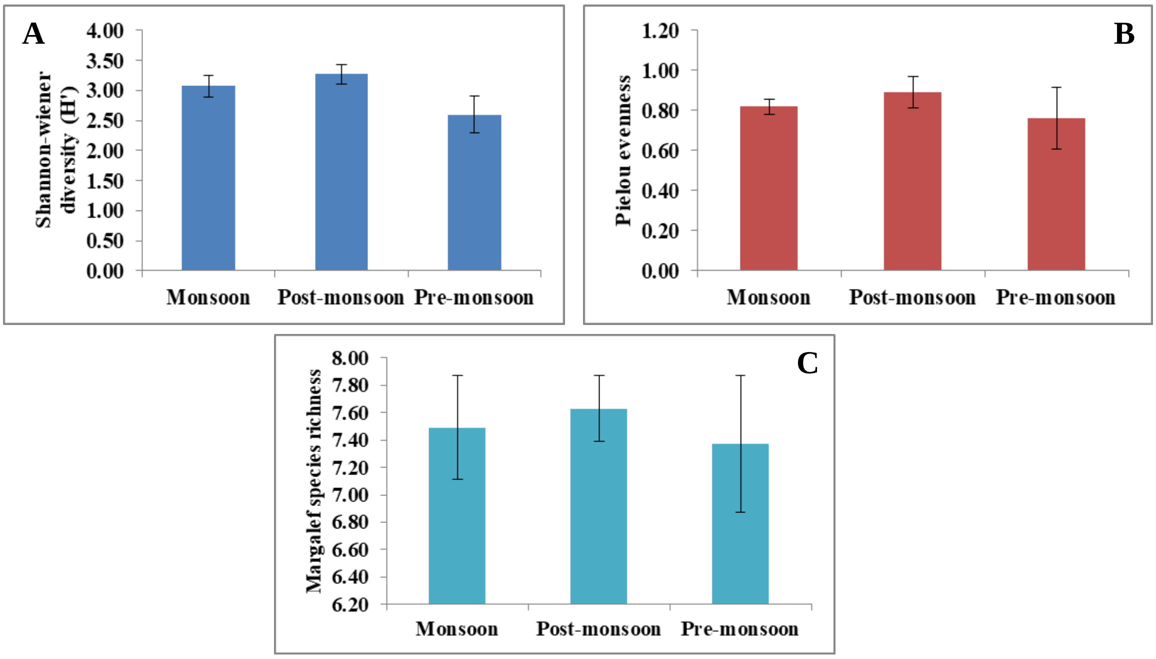


**Figure 5**. Seasonal variation of species diversity indices. (A) Shnnon-wiener, (B) Pielou evenness, (C) Magalef richness.

*3.4. Species assemblage*

According to analysis of similarity (ANOSIM), the species assemblage varied significantly among each of the seasonal groups (Table 3), with global R values of 0.5313, 0.0.8646, and 0.9063 and P values of 0.0477, 0.0293, and 0.0323. According to SIMPER analysis, there is an average dissimilarity of 36.61, 39.89, and 43.25 % between monsoon and post-monsoon, monsoon and pre-monsoon, and post-monsoon and pre-monsoon, respectively, whereas the most contributory species from each group were *Nandus nandus* (5.55%), *Esomus danricus* (5.53%) and *Gudusia chapra* (4.34%). ANOSIM (P < 0.0007, R = 0.8032) has revealed significant variation in species assemblage among the seasons with an overall average dissimilarity of 39.92% determined by SIMPER analysis. Five most contributory fish species responsible for these seasonal variations are *Osteobrama cotio* (4.04%), *Esomus danricus* (3.96%), *Nandus nandus* (3.90%), *Gudusia chapra* (3.36%) *and Chanda nama* (3.30%).

**Table 3.** ANOSIM and SIMPER analysis of fish species assemblage

| Groups | ANOSIM | | Dissimilarity index from SIMPER | | % contribution |
|---|---|---|---|---|---|
| | R | P | Ave. Diss. (%) | Typical species | |
| Monsoon vs. Post-monsoon | 0.5313 | 0.0477 | 36.61 | *Nandus nandus* | 5.55 |
| | | | | *Gudusia chapra* | 4.17 |
| | | | | *Channa striatus* | 3.83 |
| | | | | *Chanda nama* | 3.57 |
| | | | | *Puntius sophore* | 3.36 |
| Monsoon vs. pre-monsoon | 0.0.8646 | 0.0293 | 39.89 | *Esomus danricus* | 5.53 |
| | | | | *Osteobrama cotio* | 5.35 |
| | | | | *Gudusia chapra* | 4.18 |
| | | | | *Lepidocephalichthys guntea* | 3.80 |
| | | | | *Amblypharyngodon mola* | 3.65 |
| Post-monsoon vs. Pre-monsoon | 0.9063 | 0.0323 | 43.25 | *Gudusia chapra* | 4.34 |
| | | | | *Chanda nama* | 4.15 |
| | | | | *Osteobrama cotio* | 4.07 |
| | | | | *Neotropius atherinoides* | 3.76 |
| | | | | *Glossogobius giuris* | 3.59 |
| overall or pool all groups | 0.8032 | 0.0007 | 39.92 | *Osteobrama cotio* | 4.04 |
| | | | | *Esomus danricus* | 3.96 |
| | | | | *Nandus nandus* | 3.90 |
| | | | | *Gudusia chapra* | 3.36 |
| | | | | *Chanda nama* | 3.30 |

According to the Bray-Curtis similarity index (stress 0.043), three distinct seasonal groupings of fish assemblage were found by nMDS. (Fig. 6) which is indicating dissimilarity of fish samples among the three seasons. The fish samples collected from different sites of Dingapota haor are grouped separately indicating their similarity. Samples within a group are more similar compared to the other groups.

Cluster analysis also separated the collected fish species into three distinct groups at 50.00% similarity (Fig. 7), whereas the first cluster (from the left side of the Fig. 7) consists of the species which had lower abundance during the study period. However, fish species with a moderate abundance are classified into the second cluster, and the fish species with the greatest abundance are represented by the third cluster.

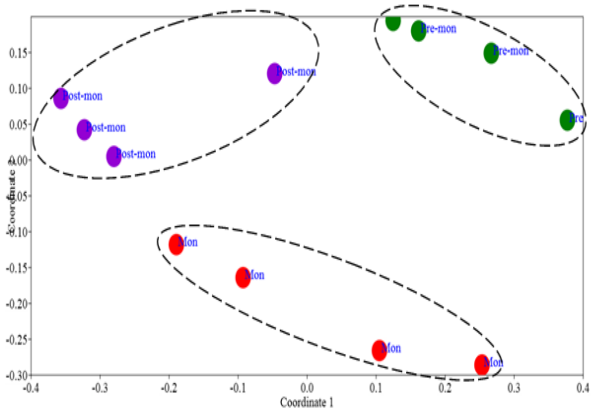


**Figure 6.** Non-metric multidimensional scaling (NMDS) of fish species

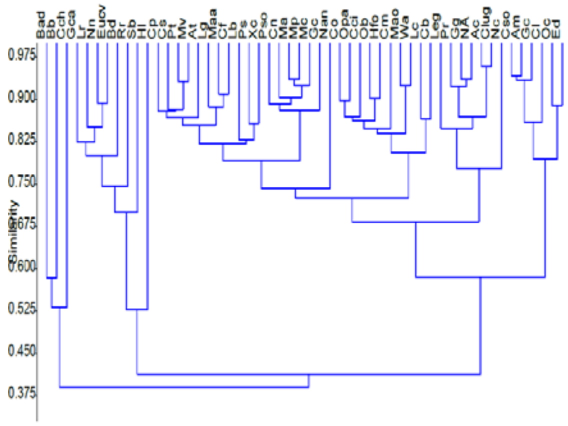


**Figure 7.** Dendrogram demonstrating 2D ordination of a cluster analysis of fish species using the Bray-Curtis similarity matrix.

### *3.5. Canonical correspondence analysis (CCA)*

Results obtained from CCA were plotted in Fig. 8 whereas the species placed nearer the vector were more closely related to them. The length and direction of the arrows show the relative significance of the water quality parameters. The CCA ordination directs that transparency, depth, DO and TDS are the most influential water quality parameters shaping fish species accumulation in the studied wetland. Water temperature and depth have close affinity with *Esomus danricus, Gudusia chapra* and *Amblypharyngodon mola* which are describing the monsoonal abundance of these species. *Osteobrama cotio, Chanda nama* and *Macrognathus pancalus* are found to be influenced mainly by DO, pH, $NO_3$-N and $PO_4$-P, and this interaction is highlighting the post monsoonal species abundance. Transparency, alkalinity and TDS showed their highest value during pre-monsoon season and the fish species *Glossogobius chuno*. *Channa striatus, Chela laubuca* and *Puntius sophore* are found to be influenced mostly by these parameters

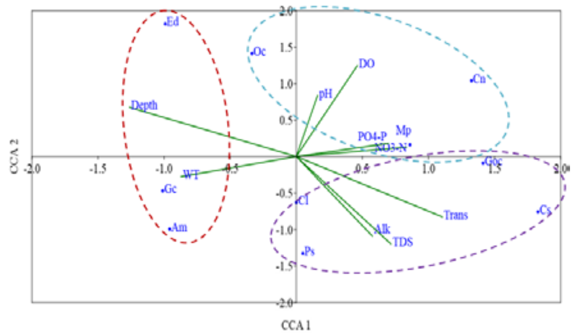


**Figure 8.** Biplot for canonical correspondence analysis. Wt = Water temperature, Trans = Transparency, Depth, DO = Dissolved oxygen, pH, $NO_3$-N = Nitrate-nitrite, $PO_4$-P = Phosphate-phosphorus, Alk = Total alkalinity, TDS = Total dissolved solids. Species codes are shown in Table 2.

## 4. Discussion

The maximum average temperature was 29.89±0.65 °C in pre-monsoon, and the minimum temperature was 22.36±3.98°C in post-monsoon. The temperature in Ashulia beel ranged between 28.7 to 31.7ºC and 22.4 to 25.6ºC during wet and dry season, respectively (Islam *et al.*2010). During the study period, transparency was fluctuated from 39.59±4.41 cm (Post-monsoon) to 24.66±0.81 cm (Monsoon). Chowdhury and Mazumder (1981) reported the instances of excessive turbidity during the monsoon season. Productive water body should contain transparency of less than 40 cm (Salauddin and Islam 2011). The Water depth was found to range between 5.96±1.61 m in Monsoon to 1.66±0.82 m during pre-monsoon. The water level in the haor area becomes lowest during February, reaching its peak during July and declining again from August onward (Salauddin and Islam 2011). The maximum pH was noted 7.00±0.78 in post-monsoon and the lowermost was 6.38±0.60 in pre-monsoon. pH ranged between 7.15 and 7.45 was recorded by (Islam *et al. 2017)* at Karimganj haor in Kishoreganj, which is more or less similar to the present study. The DO contents ranged from 6.63±0.74 mg/L in post-monsoon to 4.56±0.53 mg/L in pre-monsoon. DO in Hakaluki haor and Karimganj haor (Akter *et al.*2017) ranged between 3.1 to 7.0 and 6.4 to 6.8 mg/L, respectively, which are mostly similar to the current investigation. $NO_3$-N was the highest during pre-monsoon (0.33±0.04 mg/L), and the lowest during monsoon (0.13±0.01 mg/L). Nitrate-N ($NO_3$-N) concentrations ranged from 0.01 to 0.33 mg/L at different locations in Chalan Beel, and in Kaptai Lake (Halder *et al.* 1992) of Bangladesh. The $PO_4$-P was 1.34±0.11 mg/L in pre-monsoon to 1.16±0.02mg/L in monsoon. The $PO_4$-P in the Kaptai Lake ranged from 0.32 to 0.41 mg/L with an average of 0.367 mg/L. Khan *et al.* (1996) also revealed a higher level of $PO_4$-P in dry season compared to rainy season in their study location. Total alkalinity was 126.89±7.47 mg/L in pre-monsoon to 103.38±4.44 mg/L during monsoon season which is more or less similar to the findings of Ahatun *et al*. (2020) in Korotoa River (122.05 mg/L). The peak TDS content of the haor was 135.73±5.50 mg/L throughout pre-monsoon mg/L, and the lowermost was 100.97±5.16 mg/L in monsoon season. The TDS at various sampling locations of Hakaluki haor ranged between 80.75 to 184.0 mg/L with the mean value of 132.38 mg/L (Akter *et al*., 2017), which was comparable to the present study.

Fifty-two fish species were incurred during the study period which was abundantly belonging to 17 families, and the Cypriniformes was the most dominant (47.91%) group. Previous study conducted by Hasan *et al*. (2017) reported 17 families from Kishorgonj haor in Bangladesh, while slightly higher number of families was recorded by Islam *et al*. (2021) and Pandit *et al*. (2015) from Dekhar haor, Bangladesh. Freshwater bodies of Bangladesh are mainly dominated by Cypriniformes as was stated by Maria *et al*. (2016), Chowdhury *et al*. (2019), Akhi *et al*. (2020), Mazumder *et al*. (2016), Sunny *et al*. (2020), and Jannatul *et al*. (2015). Therefore, the current results supported the previous investigations. A total of 52 fish species obtained during the present work, which was supported by the findings of Islam *et al*. (2021) who described 57 species of fishes in their study. Seasonal fluctuation in the total species abundance was significant, whereas the maximum abundance was found in post-monsoon and the lowest in pre-monsoon season. *Amblypharyngodon mola* (11.03%) was the most dominant species followed by *G. chapra* (10.03%) and *O. cotio* (8.01%) which were mainly influenced by water temperature and depth. Small indigenous fishes are the main and inexpensive form of indispensable vitamin and mineral in the diet of people in Bangladesh (Bogard *et al*., 2015). Therefore, market value of these fish species is increasing day by day. As a result, fishermen are currently enhancing their fishing effort in the haor to catch them.

Seasonal changes in diversity of the present study were depicted by several diversity indices such as the number of species in an assemblage (Gotelli and Chao, 2013), evenness (Jost, 2010) and richness (Delang and Li, 2013). Diversity indices in the present study were found to increase significantly in post-monsoon season and decrease for the period of monsoon season. Higher diversity index during post-monsoon indicates the increase in fish species by reproducing, feeding and sheltering themselves successfully (Aziz *et al*., 2021). Similar findings were also made by Nath and Deka (2012) and Iqbal *et al*. (2015), who observed the highest diversity of fish during the post-monsoon season. However, lower species diversity during monsoon can be described by the higher water depth which reduced the effectiveness of fishing gear to catch fish. On the other hand, comparatively lower diversity indices during pre-monsoon season are possibly because of the stress caused by overfishing and scarcity of water (Aziz *et al*., 2021). Increased water temperature is also causing higher evaporation rate and decreased surface water area. As a result, intensive rice production and irrigation activities are affecting the ecological process of haor. Reduced transparency caused by silt particle inhibits the light penetration into the water. As a result reduced the primary and secondary productivity of water, which might be responsible for declining fish diversity in the present study. However, the diversity index recorded during the present study (2.60-3.27) was within the range (2.90-3.12) reported by Iqbal *et al*. (2015), higher (1.22-1.36) than the findings of Hossain and Rabby (2020) and lower (3.76-3.81) than the findings of Aziz *et al*. (2021). According to Biligrami (1988) improved status of an aquatic habitat for fish diversity is indicated by Shannon-Wiener index of 3.0-4.5. That means studied haor is light to slightly polluted during monsoon season and this might be due to the domestic discharge, poor water quality and the uses of different insecticides and pesticides. Evenness and richness of fish species was also peak in post-monsoon season. Evenness is the degree of relative diversity which can be higher when the entire habitat supports similar density and richness is the range of relative abundance of fish species. In an even population, all species are assumed to be distributed identically into the habitat. As observed in the present study, decreased water level during post-monsoon season leads to more fish species caught by fishing activities causing a homogenous catches of the fishes. On the contrary, higher water depth during monsoon season causes irregular distribution of fish species, and the majority of fishes were caught using selective fishing gears which have low evenness and richness indices. Similar patterns of seasonal variation of fishes are also observed in various aquatic habitat of Bangladesh (Jewel *et al*., 2018; Joadder *et al*., 2015; Akhi *et al*., 2020).

## 5. Conclusion

Along with 52 species, Dingapota haor is the most species-rich haor in Bangladesh. However, water depth and heavy post-monsoonal fishing pressure were the main causes of the seasonal variation in species diversity in this area. To protect the remaining fish species, control over the perennial water regions during post-monsoon season needs to be maintained. The present study recommends designation of the perennial water areas as a sanctuary for the survival of matured fish in the post-monsoon season.

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