Assemblage, Abundance and Diversity of Fish Species in River Dhaleshwari, Bangladesh

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Authors’ contributions

This work was carried out in collaboration between both authors. Author MI designed the study, managed the literature searches, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author RY helped in data acquisition and managed the analyses of the study. Both authors read and approved the final manuscript.

ABSTRACT

Biodiversity in realism is a measure of the adherents of species that characterize a biological community and thought to be one of the extremely imperative aspects of community establishment and structure. The study regarding the fish biodiversity is very much needed as it is directly related to the fisheries resource structure and also contributes significantly towards resource richness. Therefore the present study was performed to evaluate the concurrent fish species composition, abundance and some major fish biodiversity indices of the River Dhaleshwari of Bangladesh. The study area was about 564.20 ha and 20 kilometers long along the main stream of the river Dhaleshwari. The starting point was the Tulshikhali bridge, Keranigonj and the end point was Balu char, Munshigonj. The geographical locations of the sampling stations were between 90° 17’ E to 90° 25’ E and 23° 40’ N to 23° 37’ N. The study was conducted between August’2015 and October’2016. The fish species diversity showed spatial variation among the sampling stations. The biodiversity appraisal validates Shannon index (0.122-0.634) with highest value in Balur char and...
The country abounds in large varieties of fish species that is 260 of fresh water fish species, 24 species that of prawns in inland water bodies and 475 species of marine fish, 36 species of marine shrimps and 12 species of exotic fishes [8]. The World Wildlife Fund (WWF) has ranked Bangladesh amongst the topmost 20 fishing countries those contribute about 80% of the world’s marine fish catch [9]. Bangladesh mostly lying in the Bengal basin and is an immense lowland embracing the greatest delta in the Globe made by the Brahmaputra and Ganges river system. The rivers and streams, shallow fresh water lakes, fish ponds, seasonally flooded farmed plains, and marsh areas known as haors, baors, beels or jheels are the foremost wetlands. As mentioned earlier Bangladesh’s rivers and other inland water bodies embodies 260 indigenous fish species (in 55 families). Currently the inland water bodies are also act as habitat for 63 species of prawns. Around 20 fresh water mollusk species have been recognized. Marine waters are habitat to 200 fish species and at least 16 species of marine shrimps. Nearly 301 species of mollusks under 151 genera have been acknowledged from the Bay of Bengal. Furthermore, several species of crabs and 31 species of turtles and tortoises, of which 24 live in freshwater, are acquired. Thirteen alien invasive species of fish have been introduced [10]. The furthermore imperative commercial fishery for the large-sized fishes is for the hilsa or ilish (Hilsa ilisha), a marine fish that penetrates the rivers to spawn [10] and composes nearby 30% of total fish production. Three distinct species are found in the Bay of Bengal, of which two are circumscribed to seawater [9].

The continuing forfeiture of numerous of the perennial water bodies has stemmed in severe tribulations in freshwater fisheries and biodiversity [9]. The third of the three species of Hilsa ilisha found in the Bay of Bengal,
*Tenualosa ilisha*, migrates up the rivers. A large number of its newly hatched larvae and juveniles those are locally known as “Jatka” are caught while drifting downstream. Throughout the peak catch interlude, the scarcity of adequate stowage and ice obtainability and wretched conveyance services mean much of the catch is wasted. Added to the undiscerning abuse of the jatka, interruption of their migration courses and increased fishing, low water acquittal from the Farakka barrage and the allied substantial siltation depresses riverine catches of the Hilsha. Though the entire production of the Hilsha has lingered steady thru the past few years, the mass of the catch appears from marine or estuarine regions [9].

While encompassing fewer than 1% of the Earth’s superficial freshwater ecosystems afford humans with a affluence of commodities and amenities, and offer a home for about 10% of the worlds described species, incorporating a quarter of all vertebrates [11]. Their value to human civilization is effortlessly perceived throughout the straight facilities they afford, such as fish for food or water refinement for drinking; however they additionally deliver many indirect facilities which provide almost universal benefits for instance nutrient cycling, flood control and water filtration. Putting a dollar value on these services is extremely problematic as many have no market value. Conversely, efforts have been made to quote the yearly worth of the direct and indirect conveniences of the world’s wetlands, including contradictory outcomes. For instance, the Millennium Ecosystem Assessment [12] prices the total goods and services subsequent from inland waters worldwide at equal to USD 15 trillion, whereas additional investigation appraises an assessment of USD 70 billion [13]. Independently tropical inland fisheries have been appraised at USD 5.58 billion per year [14]. Asia partakes as the outsized fisheries producer of a appraised at USD 5.58 billion per year [14]. Asia Independently tropical inland fisheries have been appraised at USD 70 billion [13].

Therefore the present study was performed to evaluate the concurrent fish species composition, abundance and some major fish biodiversity indices (e.g. Shannon index, Simpson’s index, Species richness and evenness index etc. are most prominent) of the River Dhaleshwari of Bangladesh.

2. MATERIALS AND METHODS

2.1 The Study Site and Period

The study area was about 564.20 ha and 20 kilometers long along the main stream of the river Dhaleshwari. The starting point was the Tulshikhali bridge, Keranigonj and the end point was Balur char, Munshigonj. The geographical locations of the sampling stations were between 90°17’ E to 90°25’ E and 23°40´ N to 23°37´ N. The study was conducted between August’2015 and October’2016.

2.2 Biodiversity Analysis

2.2.1 Fish sample collection and identification

The fish were sampled using seine nets of 40 metres and 5 mm mesh size and the sampling was performed up to 100 m reach of all the stations and collected samples were counted

| Sampling stations | Geographic locations | Name of the locations | Districts (On both sides of the River) |
|-------------------|----------------------|----------------------|--------------------------------------|
| 1                 | 90.287° E 23.669° N  | Tulshikali            | Keranigonj(Dhaka)-Munshigonj         |
| 2                 | 90.307° E 23.662° N  | Syedpur               | Keranigonj(Dhaka)-Munshigonj         |
| 3                 | 90.331° E 23.654° N  | Gaberpara             | Munshigonj                           |
| 4                 | 90.358° E 23.637° N  | Kuchiamora            | Munshigonj                           |
| 5                 | 90.351° E 23.636° N  | Dhaleshwari bridge 2  | Munshigonj                           |
| 6                 | 90.391° E 23.624° N  | Pathor ghata          | Munshigonj                           |
| 7                 | 90.431° E 23.614° N  | Balur Char            | Narayangonj-Munshigonj               |
then according to method stated by Vyas et al. [16]. Species identification and confirmation were carried out using the standard keys of Shafi and Quddus [17], Rahman [18] and Siddiqui et al. [19].

2.2.2 Determination of various biodiversity indices and other analysis

2.2.2.1 Biological indices

All the Biological indices were calculated by using MVSP, R, Biodiversity pro and Primer 6 software package.

2.3 Statistical Analysis

All the statistical analysis was done by using SPSS, Minitab and MS Excel.

3. RESULTS AND DISCUSSION

3.1 Fish Biodiversity

Provided the considerable amount of indices, it is often abstruse to resolve which the best approach of assessing diversity. One decent manner is to acquire an ambiance for diversity consequences is to analyze their implementation with one’s own data. A relatively added scientific approach of picking a diversity index is on the footing of whether it accomplishes specified purposes conditions-aptitude to differentiate between locations, reliance on sample magnitude, what constituent of diversity is taken under consideration, and whether the index is extensively exercised and comprehended. Quantifying biodiversity is one of the most intricate aspects of biodiversity [20]. Numerous indices of biodiversity have been conceived in an endeavor to apprehend the diversity of an ecosystem. These indices attempt to outline biodiversity in several approaches although utmost indices manipulate an array of number of species and the extent of disparity between those species [20]. Huston [21] contended that it is irrational to presume one index to symbolize the diversity of a whole ecosystem and alleged that the preeminent approach to describe biodiversity is throughout the usage of abundant biodiversity indices. It is implausible to ever discern the “true” biodiversity of an ecosystem [20]. The purpose of exercising multiple indices is to try to explain the diversity of an ecosystem as precisely as feasible.

The study resulted as identification of twenty fish species belonging to twenty Genus from thirteen
families and seven orders (Table 4). All the fish species, except one belong to the class Actinopterygii and phylum Chordate. The only one decapod was recorded under the family Caridae (Fig 2 (i) and 2 (ii)). The study regarding the fish biodiversity was key criteria for the evaluation of the resource richness of the river Dhaleshwari of Bangladesh.

3.1.1 Alpha diversity

Alpha diversity denotes the species diversity in a given community, habitat or local area. Thus, it is the measurement of the species diversity of a unit area. The alpha index value shows a resembling to S-shaped curve. The value was 1.32 (least) for the Station 2 (Syedpur) and 2.83 (highest) for the Station 7 (Balur char) of the study area (Fig. 3). Thus the Station 7 (Balur char) is the most diverse among all the sampling stations and Station 2 (Syedpur) is least diverse in terms of species diversity.

3.1.1.1 Shannon index

The Shannon index ($H'$) has probably been the most widely used index in community ecology. It is based on information theory and is a measure of the average degree of "uncertainty" in predicting to what species an individual chosen at random from a collection of S species and N individuals will belong. This average uncertainty increases as the number of species increases and as the distribution of individuals among the species becomes even [22]. The higher value of the index indicates higher species diversity. All the values of Shannon index including Shannon $H'$ Log base 10 values showed highest value for the Station 7 (Balur char) and least for the Station 6 (Pathor gha) (Fig. 4). The rest of the sampling stations show the value as there order of presence. The Shannon index value shows the highest fish species diversity for the Station 7 (Balur char) and least for the Station 6 (Pathor ghata) (Table 7). Shannon diversity is the very widely used index for comparing diversity between various habitats [23]. It is regarded as species diversity index. This indeed assumes that individuals are randomly sampled from an independently large population. The index also assumes that all the species are represented in the sample.

Corresponding to Wilhm and Dorris [24] Shannon index value ranged from $>3$ indicates clean water, 1.00 to 3.00 indicates moderate water and <1.00 indicates polluted water (Table 5). As the Shannon index value for all the sampling station were less than 1 (Table 7) that could be concluded that the river water is much polluted or, the most possible reason for lower fish biodiversity might be due to over exploitation and impact of climate change. Thus the governing body should give consent to conserve river from over exploitation and consequently conserve the fish biodiversity of the river Dhaleshwari of Bangladesh.

Table 2. Abundance of fish species in river Dhaleshwari of Bangladesh (Individual species/kg)

| Species  | Station 1 | Station 2 | Station 3 | Station 4 | Station 5 | Station 6 | Station 7 |
|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Kanchki  | 3251      | 2407      | 2601      | 2013      | 2053      | 2011      | 100       |
| Chingri  | 1         | 1         | 1         | 2         | 2         | 1         | 1         |
| Kajuli   | 1         | 0         | 0         | 2         | 3         | 1         | 1         |
| Beti     | 1         | 0         | 1         | 2         | 1         | 1         | 1         |
| Ghaura   | 1         | 0         | 0         | 0         | 0         | 0         | 0         |
| Chapila  | 20        | 0         | 10        | 22        | 19        | 8         | 5         |
| Mola     | 244       | 0         | 36        | 62        | 72        | 60        | 30        |
| Baim     | 0         | 4         | 0         | 0         | 0         | 0         | 0         |
| Bailla   | 1         | 1         | 1         | 4         | 3         | 1         | 1         |
| Tenga    | 1         | 7         | 2         | 7         | 6         | 2         | 1         |
| Shing    | 0         | 1         | 0         | 0         | 0         | 0         | 0         |
| Punti    | 0         | 247       | 167       | 279       | 243       | 42        | 20        |
| Meni     | 0         | 5         | 0         | 0         | 0         | 1         | 2         |
| Catla    | 0         | 0         | 1         | 1         | 1         | 0         | 0         |
| Bacha    | 0         | 0         | 0         | 0         | 0         | 0         | 30        |
| Kakkle   | 0         | 0         | 1         | 0         | 0         | 0         | 0         |
| kholisha | 1         | 1         | 1         | 2         | 2         | 1         | 1         |
| Poa      | 1         | 1         | 1         | 2         | 1         | 0         | 0         |
| Bata     | 0         | 2         | 0         | 0         | 0         | 0         | 0         |
Table 3. List of fish species enlisted throughout the present study regarding fish biodiversity of the river Dhaleshwari (EN-English Name)

| Order          | Family    | Genus       | Species | Local name | Fish Base name            |
|----------------|-----------|-------------|---------|------------|---------------------------|
| Beloniformes   | Belonidae | Xenentodon  | X. cancila | Kakila | Freshwater-garfish(EN)    |
| Clupeiformes   | Clupeidae | Corica      | C. soborna | Kachki | Ganges river sprat       |
| Clupeiformes   | Clupeidae | Gudusia     | G. chapra | Chapila | Indian river shad        |
| Cypriniformes  | Cobitidae | Botia       | B. dario | Rani, Beti | Bengal Loach             |
| Cypriniformes  | Cyprinidae| Amblyphtyngodon | A. mola | Mola | Indian carpet             |
| Cypriniformes  | Cyprinidae| Puntius     | Puntius sp. | Punti | Barb                     |
| Cypriniformes  | Cyprinidae| Catla       | C. catla | Catla, Katal | Catla                  |
| Cypriniformes  | Cyprinidae| Labeo       | L. bata | Bata | Bata labeo (EN)           |
| Decapoda       | Caridae   | Macrobrachium | Macrobrachium sp. | Icha | Prawns (EN)               |
| Perciformes    | Gobiidae  | Glossogobius | G. giuris | Baila | Tank goby                |
| Perciformes    | Nandidae  | Nandus      | N. nandus | Meni | Mud perch (EN)            |
| Perciformes    | Anabantidae | Colisha  | C. fasciatus | Khalisha | Banded gourami          |
| Perciformes    | Sciaenidae| Johnius     | J. coitor | Koitor, Koitor-poa | Coitor Crocker (EN) |
| Siluriformes   | Bagridae  | Mystus      | M. tengra | Bajari-tenga | Stripped Dwarf Catfish (EN) |
| Siluriformes   | Schilbeidae | Silonia | S. silondia | Shillong | Silond catfish            |
| Siluriformes   | Schilbeidae | Ailia     | A. coila | Kajuli, Baspata | Gangetic ailia        |
| Siluriformes   | Schilbeidae | Clupisoma | C. garua | Ghaura | Garua Bachacha           |
| Siluriformes   | Heteropneustidae | Heteropneustes | H. fossilis | Shing | Stinging catfish          |
| Siluriformes   | Schilbeidae | Eutropichthys | E. vacha | Bacha | Bacha (EN)               |
| Synbranchiformes | Mastacembelidae | Mastacembelus | Mastacembelus Sp. | Baim | Eel                        |
3.1.1.2 Simpson’s index

The sampling Station 6 (Pathar ghata) showed the value of 0.89 (Largest) regarding the Simpson’s index whereas the Station 7 (Balur char) represents the value 0.33 (Lowest) and the rest of the stations showed the values as their order of occurrence (Fig. 5). In the case of Simpson’s index the lower the value the more richer the commune and the higher the value the lower the richness, thus the Station 7 (Balur char) has the most fish species richness.

Fig. 2. (i). Identified fish species of the river Dhaleshwari; (A) Bata; (B and J) Koitor poa; (C) Ghaura; (D) Chapila; (E and J) Bashpata; (F) Kachki; (G) Catla and (H, I, K) numerous small fishes
and the converse the Station 6 (Pathor ghata) contains the least fish species richness (Table 7). Simpson gave the probability of any two individuals drawn at random from an infinitely large community belonging to different species. It is a species richness index. The Simpson index is therefore expressed as $1-D$ or $1/D$. $D$ is the diversity index. It’s a diversity index derived by Simpson in 1949 [25]. Simpson’s index is heavily weighted towards the most abundant species in the sample while being less sensitive to species richness. As $D$ increases, diversity decreases. That way it is effectively used in Environmental Impact Assessment to identify perturbation.

Simpson index ranges from 0 to 1, with 0 representing infinite diversity and 1 representing no diversity. A low Simpson index value equates high diversity, whereas a high value correlates to a low diversity (Table 6). The highest species richness was observed by the Station 7 (Balur char) and least for the Station 6 (Pathor ghata) (Fig. 5 and Table 7).

Table 4. List of the number of phylum, class, order, family, genus and species of the present study

| Serial no. | Features | No. of observation |
|------------|----------|--------------------|
| 1          | Phylum   | 02                 |
| 2          | Class    | 02                 |
| 3          | Order    | 07                 |
| 4          | Family   | 13                 |
| 5          | Genus    | 20                 |
| 6          | Species  | 20                 |

Fig. 2. (ii). Identified fish species of the river Dhaleshwari; (A) Ghaura along small indigenous fishes; (B) Shilong; (C) Chingri; (D) Beti; (E) Kachki, baila and baim; (F) Punti; (G) Meni, baim and punti; (H) Mola and (I) Baim.
The Margaleff index value denotes the species richness of any certain habitat or place. The lowest index value of 4.79 was recorded for the Station 1 (Tulshikhali) and highest value of 7.44 for the Station 7 (Balur char) (Fig. 6). The index value for all the sampling stations showed a gradual increase from the first (Station 1 (Tulshikhali)) sampling station toward the last sampling station (Station 7 (Balur char)). The values of the Margaleff index interprets that the fish species richness shows inclination from the first sampling station (Tulshikhali) towards the Station 7 (Balur char). In other way it could be concluded that the Station 7 (Balur char) has the highest fish species richness and station 1 (Tulshikhali) has the lowest, than all other sampling stations (Table 7).

Margaleff index is also a measurement of species richness likewise the Simpson’s index. It is having a very good discriminating ability. However it is sensitive to sample size. It is a measure of the number of species present for a given number of individuals. However it is weighed towards species richness. The advantage of this index over the Simpson index is that the values can come more than 1 unlike in the other index where the values will be varying from 0 to 1. This way comparing the species richness between different samples collected from various habitats is easy. Margaleff index has no limited value and it shows a variation depending upon the number of species. Thus, it is used for comparison of the sites [27]. In the present study Margaleff index resulted similarly as the Simpson’s index as the Station 7 (Balur char) showed the highest index value of 7.44 denoting the highest species richness whereas, the Station 1 (Tulshikhali) showed least value of 4.79 depicting lowest richness and rest of the sampling stations showed value as their order of abundance (Fig. 6 and Table 7).

3.1.1.5 Brillouin index

The highest index value of 0.56 was recorded for the Station 7 (Balur char) and lowest of 0.12 for the Station 6 (Pathor ghata). The rest of the sampling stations showed index value as their order of occurrence (Fig. 7). For the present study the index value shows the highest fish species diversity for the Station 7 (Balur char) and least for the Station 6 (Pathor ghata) (Table 7).

The Brillouin index also determines species diversity and used instead of the Shannon index when diversity of non-random samples or collections is being estimated. The Brillouin index

### Table 5. Shannon index value as an indicator of water quality

| Serial no. | Shannon index value | Indications          |
|------------|---------------------|----------------------|
| 1.         | Above 3.00          | Clean water          |
| 2.         | 1.00 to 3.00        | Moderate clean water |
| 3.         | Below 1.00          | Polluted water       |

# Adopted from Wilhm and Dorris [24]

### Table 6. Simpson’s index as an indicator of diversity pattern

| Serial number | Simpson’s index value | Indications           |
|---------------|-----------------------|-----------------------|
| 1.            | 0                     | Infinite diversity    |
| 2.            | 0 to 1                | Moderate diversity    |
| 3.            | 1                     | No diversity          |

# Adopted and modified from Vyas et. al., (2012)

3.1.1.3 Pielou’s evenness index

It was derived from Shannon index by Pielou in 1966. The ratio of the observed value of Shannon index to the maximum value gives the Pielou evenness index result. The values are between 0 – 1. When the value is getting closer to 1, it means that the individuals are distributed equally [26]. The lowest index value of 0.12 was recorded for the Station 6 (Pathor ghata) and conversely highest value of 0.59 was found for the Station 7 (Balur char) (Fig. 8). The rest of the sampling stations show the value as there order of presence. The result shows that the fish species of the Station 7 (Balur char) has the most fish species evenness than all the other sampling stations whereas the Station 6 (Pathor ghata) shows the least (Table 7).

Evenness index is also an important component of the diversity indices. This expresses how evenly the individuals are distributed among the different species. Pielou’s evenness index is commonly used. The highest Pielou’s index value of 0.59 was recorded for the sampling Station 7 and lowest of 0.12 for the Station 6 and rest of the stations adds as their frequency of presence. The Pielou’s index value illustrates the most even fish species distribution for the Station 7 (Balur char) whereas the Station 6 (Pathor ghata) showed least evenness. The rest of the sampling stations showed value close to the station 6 thus their species distribution is less even (Fig. 8 and Table 7).

3.1.1.4 Margaleff index

The Margaleff index value denotes the species richness of any certain habitat or place. The
is used here to calculate the diversity of fishes collected by a specific gear. The result of Brillouin index resulted similarly as the Shannon index giving the highest value of 0.60 for the sampling Station 7 (Balur char) and lowest of 0.12 for the Station 6 (Pathor ghata) and rest of the stations contributed as their level of presence. The Brillouin index also showed similar results as the Shannon index (Fig. 4 and 7).

3.1.1.6 Berger-Parker index

Berger-Parker dominance (\(d\)) showed value 1.08 (Lowest) for the Station 1 (Tulshikhali) whereas, the Station 7 (Balur char) showed the value 1.93 (Highest) (Table 7). The rest of the stations showed values as there order of dominance. An increase in the value of the index accompanies an increase in species richness and a reduction in dominance. Hence, the Station 1 (Tulshikhali) showed least richness value synergistically reduction in dominance for particular species whereas, the Station 7 (Balur char) has been resulted reciprocally (Fig. 9).

The Berger-Parker index is another index of species richness. This simple intrinsic index expresses the proportional importance of the most abundant species. As with the Simpson index, the reciprocal form of the Berger-Parker index is usually adopted so that an increase in the value of the index accompanies an increase in diversity and a reduction in dominance. The highest Berger-Parker index value of 0.92 calculated for the Station 1 (Tulshikhali) and lowest value of 0.52 for the Station 7 (Balur char). The rest of the station showed values close to the Station 1 (Tulshikhali) value. Thus the Station 1 (Tulshikhali) includes highest proportional importance of the most abundant species whereas the Station 7 (Balur char) showed the least. The other stations also showed higher proportion of abundance as their order of occurrence (Fig. 9 and Table 7).

3.1.1.7 Mackintosh index

The Mackintosh index resulted similarly as Shannon index, and showed the value of 1.02 (least) for Station 6 (Pathor ghata) and the value of 1.07 (highest) to the last sampling station, Station 7 (Balur char) (Fig. 10).

3.1.1.8 Hill's number

The Hill's number \((H_1)\) showed highest value of 11.86 for the Station 7 (Balur char) and least value of 2.16 for the Station 6 (Pathor ghata), which means the fish species distribution is most even in the Station 7 (Balur char) and least even in the Station 6 (Pathor ghata) (Fig. 11 and Table 7).

Table 7. List of different biodiversity indices value for all the sampling stations

| Biodiversity indices     | Stat. 1 | Stat. 2 | Stat. 3 | Stat. 4 | Stat. 5 | Stat. 6 | Stat. 7 |
|--------------------------|---------|---------|---------|---------|---------|---------|---------|
| Shannon index            | 0.133   | 0.156   | 0.149   | 0.260   | 0.245   | 0.122   | 0.634   |
| Simpson's index          | 0.856   | 0.820   | 0.853   | 0.718   | 0.739   | 0.893   | 0.325   |
| Margaleff index          | 4.793   | 4.961   | 4.927   | 5.030   | 5.028   | 5.108   | 7.438   |
| Brillouin index          | 0.132   | 0.154   | 0.147   | 0.256   | 0.241   | 0.119   | 0.597   |
| Pielou's evenness index  | 0.128   | 0.153   | 0.138   | 0.241   | 0.193   | 0.117   | 0.588   |
| Berger-Parker index      | 1.084   | 1.110   | 1.085   | 1.192   | 1.172   | 1.059   | 1.930   |
| Mackintosh index         | 1.017   | 1.019   | 1.019   | 1.020   | 1.020   | 1.021   | 1.065   |
| Hill's number \((H_1)\)  | 2.246   | 2.423   | 2.367   | 3.418   | 3.252   | 2.164   | 11.855  |
| Chao Sp. Richness        | 25.6    | 39.48   | 53.9    | 77.62   | 73.08   | 73.23   | 94.06   |
| Jack-knife index         | 12      | 16      | 17.27   | 18.15   | 19.6    | 20.7    | 22.29   |
Hill’s number is an added species diversity measurement. Hill [29] proposed a unification of several diversity measures in a single statistic. The advantage is that instead of calculating various indices for diversity, richness and evenness, it can be used to calculate all these measures. That is its advantage. Hill’s number also resulted similarly to Pielou’s index resulting the most even fish species distribution for the Station 7 (Balur char) whereas the Station 6 (Pathor ghata) showed least evenness (Table 7 and Fig. 11).

3.1.1.9 Rarefaction plot

The rarefaction plot for the Station 7 (Balur char) showed exponential increase whereas, the Station 4 (Kuchiamora) showed an increase initially like the Station 7 (Balur char) then maintain a more or less linear relationship between number of individual, n and expected number of species, ES(n). Station 4 (Kuchiamora) and 5 (Dhaleshwari bridge 2) (Fig. 12) both showed similarly curvilinear relationship between n and ES (n). The rest of the stations showed almost linear relationship between n and ES (n).

Rarefaction index (plot) is another index of species richness. Even though it is used for standardizing the sample size, it is also used as an index [30]. This index relates sample size (number of organisms) with numbers of species. This is very much helpful in comparing the diversity of organisms living in healthy and degraded environments. The rarefaction plot for the Station 7 (Balur char) showed exponential increase but, the Station 6 (Pathor ghata) showed an increase primarily then maintains a curvilinear relationship between number of individual (sample size) and number of species. Station 5 (Dhaleshwari bridge 2) and 6 (Pathor ghata) both showed similar trend likewise the Station 6. The rest of the stations showed more or less linear relationship between number of individual, n and expected number of species, ES (n) (Fig. 12). The result showed that the Station 7 (Balur char) is richer in terms of species than all the other sampling stations whereas the Station 1 (Tulshikhali) showed the least species richness. The result of rarefaction index is similar to Berger-Parker index.

3.1.1.10 Abundance (Rank) plot

The Fig. 13 shows the ranked abundance plot of the sampling stations of the river Dhaleshwari. The highest abundance of species was recorded for the Station 1 (Tulshikhali) and lowest for the Station 7 (Balur char) (Fig. 13). The rest of the sampling stations showed abundance according to their order of abundance.

3.1.1.11 K-dominance plot

The K-dominance plot shows the cumulative percentage (the percentage of the k-th most dominant plus all more dominant species) in relation to species (k) rank or log species (k) rank. Station 7 (Balur char) (Figure 14) showed a sharp incline in the abundance of k-dominant species as the rank increases, whereas, the rest of the sampling station showed slight incline initially but later on showed more or less linear relationship between abundance and rank.

![Alpha Index Results](image)

**Fig. 3.** Schematic representation of alpha index value of all the sampling stations
Fig. 4. Graph showing Shannon index value for all the sampling sites

Fig. 5. Schematic presentation of Simpson’s index value for all the sampling sites

Fig. 6. Schematic representation of Margaleff index value of all the sampling stations
Fig. 7. Graph showing Brillouin index value for all the sampling sites.

Fig. 8. Schematic illustration of Pielou’s evenness index value for all the sampling stations.

Fig. 9. Graph depicting Berger-Parker index value for all the sampling sites.
Fig. 10. Graphical presentation of Mackintosh index value for all the sampling sites

Fig. 11. Schematic illustration of Hill’s number for all the sampling stations.

Fig. 12. Graph showing rarefaction plot of all the sampling sites
Fig. 13. Line chart presentation of abundance according to rank for all the sampling sites

Fig. 14. Schematic demonstration of K-dominance abundance plot for all the sampling stations

Fig. 15. Graph showing Caswell model for all the sampling sites
Dominance plot is also called as the ranked species abundance plot. This can be computed for abundance, biomass, % cover or other biotic measure representing quantity of each taxon. For each sample, or pooled set of samples, species are ranked in decreasing order of abundance. Relative abundance is then defined as their abundance expressed as a percentage of the total abundance in the sample, and this is plotted across the species, against the increasing rank as the x axis, the latter on a log scale. On the y axis either the relative abundance itself or the cumulative relative abundance is plotted, the former therefore always decreasing and the later always increasing. The cumulative plot is often referred to as a k-dominance plot. The cumulative curve is used for comparing the biodiversity. When k-dominance curve is used for comparing the biodiversity between many habitats, it is called as multiple k-dominance curves. Here the sample representing the lower line has the higher diversity. In the relative dominance curve, the curves representing samples from polluted sites will be J-shaped, showing high dominance of abundant species, whereas the curves for less polluted habitats will be flatter. In the cumulative dominance plot, the curves for the unpolluted sites will be sigma shaped and the curves for the polluted habitats will be elevated [23]. In this study purposes the k-dominance plot is obtained for relative abundance. Since Station 7 (Balur char) showed lower line illustrating the highest diversity, conversely Station 6 (Pathoth ghata) which showed higher line depicts lowest diversity. The Station 7 (Balur char) showed “J” shaped curve depicting polluted site but having higher dominance of abundant species. The curve for the rest of the stations showed more or less linear shape illustrating that there might be less or no pollution (Fig. 14).

3.1.2 Beta diversity

Beta diversity is also a measurement regarding biodiversity likewise alpha diversity but, it connotes the variation of species in habitat composition. It accounts the ratio of an individual habitat toward its whole community structure.

3.1.2.1 Community species distribution

The Fig. 16 shows community wise species distribution towards all the sampling station of the present study. In total, the community showed aggregation pattern towards the entire studying area regarding the study period. The community also showed discordant pattern regarding the heterogeneity of the community which means there exists more or less similar or resembling or homogenous community structure in the present study area.

3.1.2.2 Individual species distribution

The Fig. 16 represents the individual species distribution of the present study area throughout the study period. The fish species those showed aggregated aggregation pattern were kachki, chapila, mola, punti, meni and bacha (Table 2 and 3). Chingri, kajuli, beti, ghaura, baim, bailla, tengra, shing, catia, kakila and poa showed random aggregation pattern whereas the rest of the species showed regular pattern throughout the entire study period in the study area.
Concerning the community wise species distribution the entire community showed aggregation pattern towards the complete study area of the river Dhaleshwari during study period. The community showed discordant pattern considering the heterogeneity of the community which resembles comparatively alike or resembling or identical community structure in the present study area of the river Dhaleshwari. Regarding the individual species distribution, the only species naming kholisha showed regular aggregation pattern whereas, kachki, chapila, mola, punti, meni and bacha (Table 3) showed aggregated pattern. Chingri, kajuli, beti, ghaura, baim, bailla, tengra, shing, catla, kakila and poa showed random aggregation pattern throughout the entire study period in the study area (Fig. 16).

3.1.2.3 SHE analysis

The Fig. 17 illustrates the SHE analysis result for the study area. The only positive value was observed for the H, whereas Ln (E) (e based logarithm of evenness) and the Ln (E)/Ln(S) (ratio of e based logarithm of evenness and number of species) showed negative value. The value was recorded least for the Ln (E)/Ln(S) whereas; H showed the highest value for all the sampling stations (Fig. 17). That means the species diversity along the study area showed positive result.

The SHE indexing method [32, 33] is expressed by the Shannon index, H (a measure of the system's entropy) as the composition of two factors representing respectively the number of species in the sample (S) and the distribution uniformity (E). The SHE index doesn’t only describe in a through way the system’s biodiversity, but as a function of abundance and evenness [34]. The Fig. 17 illustrates that only the species diversity showed positive value but species abundance and evenness showed negative value. In the present study only the Shannon index of SHE showed positive trend whereas number of species and uniformity showed negative trend.

Fig. 16. Schematic illustration of community and individual species distribution of all the sampling stations

Fig. 17. Graphical presentation of SHE analysis result for all the sampling sites
3.1.2.4 Species richness

Species richness (S) is the total number of species found in an environment or habitat or more precisely to a sample. It is the measurement of how plenty the number of species are in an individual targeted region. The number of species per sample is a measure of richness. The more species present in a sample, the ‘richer’ the sample.

Species richness as a measure on its own takes no account of the number of individuals of each species present. It gives as much weight to those species which have very few individuals as to those which have many individuals. Both the number of individual species and singleton species richness showed increasing value from the Station 1 (Tulshikhali) towards the Station 7 (Balur char) and regarding total number of species also resulted similarly (Fig. 22 and 23). Conversely species richness regarding unique species index showed highest value of 6.2 for the Station 1 (Tulshikhali) and drops further towards the downstream sampling stations and showed lowest value of 0 for the Station 7 (Balur char) (Fig. 25). That means the Station 1 (Tulshikhali) has the maximum number of unique species whereas the Station 7 (Balur char) has no unique species.

**Chao species richness:** The Fig. 18 shows the Chao species richness value for all the sampling stations. The highest estimator value was found for the Station 7 (Balur char) and lowest for the Station 1 (Tulshikhali) (Fig. 18). The rest of the stations showed value as the order of their occurrence. The Station 7 (Balur char) showed highest species richness and the Station 1 (Tulshikhali) showed least (Table 7).

**Jack-knife species richness index:** The Fig. 19 shows the Jack-knife species richness index value for all the sampling stations. The Station 7 (Balur char) showed highest species richness as the estimator value was highest for that site and the Station 1 (Tulshikhali) showed least because lowest estimator value. The second highest estimator value was found for the Station 6 (Pathor ghata) and second lowest for the Station 2 (Syedpur) followed by Station 3 (Gaberpara) and 4 (Fig. 19). The rest of the stations showed estimator value as their order of occurrence (Table 7).

The Chao and Jack-knife species richness index showed similar result likewise Berger-Parker index and rarefaction index results, both Chao and Jack-knife showed highest species diversity for the Station 7 (Balur char) whereas, Station 1 (Tulshikhali) showed least species richness and rest of the sampling stations showed species richness as their order of abundance (Figs. 18 and 19).

**Species richness regarding doubletons:** The species richness regarding doubletons showed lowest estimator value for the Station 1 (Tulshikhali) and the highest for the Station 7 (Balur char). The value for the Station 7 (Balur char) was almost tenfold to the lowest value of the Station 1 (Tulshikhali). The lowest value of the Station 1 (Tulshikhali) showed that there exist the least doubletons, where the higher value of the Station 7 (Balur char) showed opposite result (Fig. 20). There exists a sharp incline from the Station 1 (Tulshikhali) towards the Station 7 (Balur char).

**Species richness including duplicates:** The species richness regarding the number of duplicates showed highest estimator value for the Station 1 (Tulshikhali) and the least for the Station 4 (Kuchiamora). The value for the Station 1 (Tulshikhali) was almost third fold to the lowest value of the Station 4 (Kuchiamora). The higher value of the Station 1 (Tulshikhali) showed that there exists the highest number of duplicates, where the lowest value of the Station 4 (Kuchiamora) showed the opposite result (Fig. 21).

**Species richness regarding individuals:** The Fig. 22 shows the individual species richness estimator values for all the sampling stations. The Station 7 (Balur char) showed highest species richness regarding individuals as the estimator value was 18 (highest) for that site and the Station 1 (Tulshikhali) showed least because of lowest estimator value of 11.2. The second highest estimator value of 17.2 was found for the Station 6 (Pathor ghata) and second lowest for the Station 2 (Syedpur) followed by Station 3 (Gaberpara) and 4 (Kuchiamora) (Fig. 22). The rest of the stations showed estimator value as their order of occurrence. The highest estimator value for the Station 7 (Balur char) depicts the highest individual species of that site.

**Singletons species richness:** The species richness regarding singletons showed lowest estimator value of 6.4 for the Station 1 (Tulshikhali) and the highest value of 46 for the Station 7 (Balur char). The value for the Station 7
(Balur char) was almost eightfold to the lowest value of the Station 1 (Tulshikhali). The lowest value of the Station 1 (Tulshikhali) showed that there exist the least singletons, where the higher value of the Station 7 (Balur char) showed opposite result (Fig. 23). There exists a sharp incline from the Station 1 (Tulshikhali) towards the Station 7 (Balur char). The relationship between pooled sample and the number of singletons showed almost perfect linear relationship.

**Species richness regarding no. of species**: The Fig. 24 shows the species richness regarding number of species estimator values for all the sampling stations. The Station 7 (Balur char) showed highest species richness regarding number of species as the estimator value was highest for that site and the Station 1 (Tulshikhali) showed least because lowest estimator value. The second highest estimator value was found for the Station 6 (Pathor ghata) and second lowest for the Station 2 (Syedpur) followed by Station 3 (Gaberpara) and 4 (Kuchiamora) (Fig. 24). The rest of the stations showed estimator value as their order of occurrence. The highest estimator value for the Station 7 (Balur char) depicts the highest number of species of that site.

**Species richness regarding no. of unique species**: The Fig. 25 shows the species richness regarding unique species estimator values for all the sampling stations. The Station 7 (Balur char) showed 0 estimators value illustrating absence of unique species whereas, the highest estimator value of 6.2 was found for the Station 1 (Tulshikhali) illuminating higher number of unique species. The second highest estimator value was found for the Station 2 (Syedpur) and second lowest for the Station 5 (Dhaleshwari bridge 2) followed by Station 5 (Dhaleshwari bridge 2) and 4 (Kuchiamora) (Fig. 25). The rest of the stations showed estimator value as their order of occurrence.
Fig. 20. Schematic exhibition of species richness including doubletons for all the sampling sites

Fig. 21. Diagram illuminating species richness regarding duplicates towards all the sampling stations

Fig. 22. Schematic exhibition of species richness concerning individuals for all the sampling sites
Fig. 23. Schematic exhibition of species richness including singletons for all the sampling sites

Fig. 24. Line chart illuminating species richness regarding number of species towards all the sampling stations

Fig. 25. Graph illuminating species richness regarding number of unique of all the sampling stations
3.1.3 Other Biodiversity analysis

3.1.3.1 Species accumulation graph

The Fig. 26 shows the species accumulation graph in the sampling stations throughout the entire study period. The independent axis endures the stations and the species count is corresponded to the vertical axis. In the graph, S curve shows the observed species counts. It was lowest for the Station 1 (Tulshikhali) and highest for the Station 7 (Balur char). Chao 1 represents the Chao's estimator based on number of rare species and the value of 35 (Highest) was recorded for the Station 3 (Gaberpara) and 11 (Lowest value) for the Station 1 (Tulshikhali) which illustrates that the higher number of rare species were recorded from the Station 3 (Gaberpara) and lowest from the Station 1 (Tulshikhali). Chao 2 depicts Chao's estimator using just presence-absence data. The Chao 2 shows similar patterns like the Chao 1 but magnitudes were less than the previous (Fig. 26).

Jackknife 1 and Jackknife 2 denotes respectively the Jackknife estimator based on species that only occur in one sample and second order Jackknife estimator. The value for both the indices showed highest value of respectively 22.29 and 25.86 for the Station 7 (Balur char) and least value of 11 for the Station 1 (Tulshikhali) respectively for both the indices. Both of the index value depicts the highest species richness in the Station 7 (Balur char) and least for the Station 1 (Tulshikhali). The Bootstrap signifies the Bootstrap estimator based on proportion of quadrats containing each species. MM illustrates Michaelis-Menton curve fitted to observed S curve. Finally, UGE denotes the calculated species accumulation curve [35]. The combined species accumulation curve shows that highest species accumulation occurs in the station 7 (Balur char) and lowest for the Station 1 (Tulshikhali) but highest number of rare species accumulation occurs in the Station 3 (Gaberpara) and lowest number of rare species is also recorded for the Station 1(Tulshikhali) (Fig. 26).

3.1.3.2 Geometric abundance class plot

These are essentially frequency polygons, plotted for each sample (Sampling stations), of the number of species that fall into a set of geometric (x2) abundance classes. That is, it plots the number of species represented in the sample by a single individual (class 1), 2 or 3 individuals (class 2), 4-7 individuals (class 3), 8-15 individuals (class 4) etc. It has been suggested that impact on assemblages tends to change the form of this distribution, lengthening the right tail (some species become very abundant and many rare species disappear) and giving a jagged curve. The geometric abundance class plot plots the number of species in geometric abundance classes. Species are ranked in order of importance along the x axis. The largest percentage of the total species was recorded from the Station 1 (Tulshikhali) whereas, the least from the Station 4 (Kuchiamora) for the first geometric class. But, the second class showed highest value for the Station 4 (Kuchiamora) and lowest for the Station 1 (Tulshikhali) and 2 (Syedpur) (Fig. 27).

Almost 73% of species recorded from the Station 1 (Tulshikhali) contained only single individual and rest of the species contains more than one individual. About 42% of species recorded from the Station 2 (Syedpur) contained only single individual and rest of the species contains more than one individual. Approximately 58% of species recorded from the Station 3 (Gaberpara) contained only single individual and rest of the species contains more than two individuals. More or less 46% of species recorded from the Station 4 (Kuchiamora) contained 1 and 2 individuals and rest of the species contains more than two individuals. Nearly 58% of species recorded from the Station 5 (Dholeshwari bridge 2) contained 1-3 individuals and rest of the species contains more than three individuals. Roughly 64% of species recorded from the Station 6 (Pathor ghata) contained 1-2 individuals and rest of the species contains more than two individuals. Round about 58% of species recorded from the Station 7 (Balur char) contained only 1-2 individuals and rest of the species contains more than two individuals (Fig. 27).

The abundance (rank) plot is one of the best known and most informative methods. In this plot species are ranked in sequence from most to least abundant along the horizontal (or x) axis. Their abundances are typically displayed in a log10 format on the y axis, so that species whose abundances span several orders of magnitude can be easily accommodated on the same graph. In addition proportional and or percentage abundances are often used. The Station 1 (Tulshikhali) initially showed higher abundance and then showed sharp fall in abundance as the rank increase through the x-axis. The Station 7 (Balur char) showed a more or less linear
abundance as the rank increases. That means the first species (Kachki) is most abundant among all the sampling stations and as the ranking increase their abundance drops suddenly towards the next and then the abundance declines further in a reduced rate (Fig. 13).

3.1.3.3 Link-tree

The basic idea behind the link-tree is that it is able to give a local explanation of just parts of the resemblance structure. It is the tree of binary splits of the data by choosing the variable and selection of samples into 2 groups that maximizes the R statistic between the groups. It is an alternative to the best analysis, but does not make the assumption of additively. In the Fig. 28 the value of R statistic and B% for A, B and C are respectively 0.87, 95; 0.96, 66 and 1.00, 34. The C links the Stations 2 (Syedpur) and 4 (Kuchiamora) to the Station 5 (Dhaleshwari bridge 2) and B links C to Station 6 (Pathor ghata) and 7 (Balur char). Finally, A is linked the B to the Station 1 (Tulshikhali) (Fig. 28). The Station 2 (Syedpur) to Station 4 (Kuchiamora) showed 34% resemblance with Station 5 (Dhaleshwari bridge 2); Station 6 (Pathor ghata) and 7 (Balur char) showed about 66% resemblance with Station 2 (Syedpur), 3 (Gaberpara), 4 (Kuchiamora) and 5 (Dhaleshwari bridge 2). However, Station 1 (Tulshikhali) showed about 95% resemblance with combined B and C cluster.

3.1.3.4 DOMDIS matrix

DOMDIS matrix shows the distance between k-dominance curves (Fig. 14) as a resemblance matrix. The Table 8 shows the DOMDIS resemblance matrix of all the sampling stations. The Station 7 (Balur char) showed the very much significant resemblance with the Station 6 (Pathor ghata) and least with Station 4 (Kuchiamora). The Station 6 (Pathor ghata) shows very little resemblance towards all the other sampling stations. Station 5 (Dhaleshwari bridge 2) showed highest similarity or resemblance with Station 1 (Tulshikhali) and least with Station 4 (Kuchiamora). The Station 4 (Kuchiamora) showed highest and lowest resemblance to Station 1 (Tulshikhali) and Station 3 (Gaberpara) respectively whereas, Station 3 (Gaberpara) showed lowest and highest resemblance to Station 2 (Syedpur) and Station 1 (Tulshikhali) respectively (Table 8).

![Fig. 26. The Species accumulation graph](image)

![Fig. 27. The geometric abundance class plot for the sampling stations](image)
3.1.4 Statistics regarding biodiversity

The statistical analysis for the biodiversity of the river Dhaleshwari includes descriptive statistics, correlation, correspondence, loading plot and cluster plot.

3.1.4.1 Descriptive statistics

The highest number of 12 species was recorded from the Station 3 (Gaberpara), 4 (Kuchiamora), 5 (Dhaleshwari bridge 2) and 7 (Balur char). 11 species from the Station 1 (Tulshikhali) and 6 (Pathor ghata), whereas only 10 species from the Station 2 (Syedpur). The highest number of individual were recorded Station 1 (Tulshikhali) and lowest from the Station 7 (Balur char) and rest of the stations contribute as their order of abundance. The highest mean value and variance of 196±180 and 584672 was recorded for the Station 1 (Tulshikhali). However, least mean and variance of 011±006, 598 respectively were found for the Station 7 (Balur char). The rest of the Station contributes as their order of occurrence. Likewise the total individuals mean and variance the Station 1 (Tulshikhali) showed highest value ranging from 0 to 3251 throughout the entire study period and Station 7 (Balur char) showed the opposite result (Table 9).

Table 9. Variation of fish biodiversity and species composition along all the sampling stations

| Stations                        | Total species | Total individuals | Mean±SEM | Variance | Range |
|---------------------------------|---------------|-------------------|----------|----------|-------|
| Station 1 (Tulshikhali)         | 11            | 3523              | 196±180  | 584672   | 0-3251|
| Station 2 (Syedpur)             | 10            | 2672              | 148±134  | 321065   | 0-2407|
| Station 3 (Gabberpara)          | 12            | 2823              | 157±144  | 373633   | 0-2601|
| Station 4 (Kuchiamora)          | 12            | 2399              | 133±112  | 224394   | 0-2053|
| Station 5 (Dhaleshwari bridge 2)| 12            | 2406              | 134±114  | 232816   | 0-2053|
| Station 6 (Pathor ghata)        | 11            | 2129              | 118±111  | 223397   | 0-2011|
| Station 7 (Balur char)          | 12            | 0193              | 011±006  | 00598    | 0-0100|
3.1.4.2 Correspondence

The Fig. 29 illustrates the correspondence analysis for all the seven samples or seven sampling stations. The Station 1 (Tulshikhali) showed positive value along the entire three axis. Station 2 (Syedpur), 3 (Gaberpara) and 4 (Kuchiamora) showed positive value only for the axis 1, but negative for the axis 2 and 3 respectively. Station 5 (Dhaleshwari bridge 2) shows positive value for axis 1 and 3, but negative for axis 2. The Station 6 (Pathor ghata) showed positive value for the axis 1 and 2, whereas negative for the axis 3. However, Station 7 (Balur char) showed negative value for three axis (Fig 29).

3.1.4.3 Loading plot

The axis 2 of the figure corresponds to the loading for component 1, axis 1 and axis 3 corresponds to the component 2 and 3 respectively. The Station 1 (Tulshikhali), 6 (Pathor ghata) and 7 (Balur char) showed positive loading for the entire three component. The Station 2 (Syedpur), 3 (Gaberpara), 4 (Kuchiamora) and 5 (Dhaleshwari bridge 2) showed negative for Component 2 and positive for the Component 1 and 3 (Fig 30).

3.1.4.4 Cluster plot

For the purpose of the Bray- Curtis cluster analysis for the entire study period and study area all the sampling stations were considered as variables.

In the Fig. 31, cluster 6 joins to Station 4 (Kuchiamora) and 5 (Dhaleshwari bridge 2) showing 98.02% similarity which means 98.02% (Highest) similarity of community pattern between those two stations, cluster 5 joins to Station 4 (Kuchiamora) and 6 (Pathor ghata) showing 93.99% similarity that illustrates about 94% resemblance between community structure or fish diversity pattern between those two

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Fig. 29. Graph elucidating correspondence analysis for all the sampling stations

Fig. 30. Loading plot for all the sampling stations
Fig. 31. Schematic cluster dendogram and groupings revealed with seven samples (variables) with percent similarity

sampling stations, cluster 4 combines with Station 2 (Syedpur) and 3 (Gaberpara) depicting 93.90% similarity, cluster 3 adds with station 2 (Syedpur) and 4 (Kuchiamora) illustrating 90.82% similarity, cluster 2 joins with Station 1 (Tulshikhali) and 2 (Syedpur) embodying 83.61% similarity. Finally cluster 1 combines with Station 1 (Tulshikhali) and 7 (Balur char) and shows least amount of similarity of just only 13.95%, which means there exists only a few degree of similarity regarding biodiversity pattern between those two sampling stations.

4. CONCLUSION

The present study expounds the concomitant resource structure and habitat characterization concerning the existing resource richness with the help of biodiversity appraisal of the river Dhaleshwari of Bangladesh. The fish species diversity showed spatial variation among the sampling stations. The upstream sampling station Tulshikhali showed the lowest species diversity and species richness whereas, the downstream sampling station Balur char showed highest species diversity and richness. The Balur char showed the most evenness in terms of species conversely Pathor ghata showed the least evenness. However, the highest numbers of unique species were recorded from Tulshikhali and least from the Balur char. Moreover, the current study correspondingly has ascertained the pragmatism and efficacy of biodiversity assessment to scrutinize and epitomize fisheries resources for better management of the river Dhaleshwari. Deviation from optimum fish diversity observed possibly due to the causes of overexploitation or climate change or both. As optimum water quality were indispensable for successful spawning, healthy growth and survival for the most of the freshwater fishes and other aquatic organisms of the river, any modification in water quality of the study area due to human interference (water pollution, industrial effluent discharge or, sewage dumping, overexploitation) or, global climate change might turn out to be traumatic for most of the freshwater fishes alongside aquatic organisms and may obstruct their spawning, recruitment and survival, consequently may hinder the entire fish community of the concerned river. If the existing circumstances are not taken under greater concern and apt management practice through better planning and decision making for the proper regulation, conservation and diligent attention is not implemented as early as possible, then it would be nearly impossible to keep intact the fish habitat structure, health and ecosystem condition of the concerned river. Effective management approach should be applied for precisely maintaining the fish habitat health and ecological condition intact before it’s too late.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Lawson OE, Olusanya OM. Fish diversity in three tributaries of River Ore, south
2. Revenga C, Mock G. Freshwater biodiversity in crisis. Earth Trends World Resources Institute. 2000;1–4. Available: http://earthtrends.wri.org
3. Saunders DL, Meeuwing JJ, Vincent CJ. Freshwater protected areas: Strategies for conservation. Conservation Biology. 2002;16:30–41.
4. Malmqvist B, Rundle SR. Threats to the running water ecosystems of the world. Environmental Conservation. 2002;29:134–153.
5. Allan JD, Flecker AS. Biodiversity conservation in running waters. Identifying the major factors that threaten destruction of riverine species and ecosystems. BioScience. 1993;43:32–43.
6. Collares-Pereira MJ, Cowx IG. The role of catchment scale environmental management in freshwater fish conservation. Fisheries Management and Ecology. 2004;11:303–312.
7. Prenda J, Clavero M, Garrido FB, Menor A, Hermoso V. Threats to the conservation of biotic integrity in Iberian fluvial ecosystems. Linnetica. 2006;25:377–388.
8. DoF. National Fish Week 2012 Compendium (in Bengali). Department of Fisheries, Ministry of Fisheries and livestock, Bangladesh; 2012.
9. Chowdhury S. ‘Saving Our Oceans: Some Thoughts on Fisheries Conservation.’ The Daily Star. 1998;2(100).
10. Anon. Bangladesh State of Environment (SoE) Report. ‘Preparation for Rio +10.’ Bangladesh Environmental Newsletter. 2000;11(2).
11. Strayer DL, Dudgeon D. Freshwater biodiversity conservation: Recent progress and future challenges. Journal of the North American Benthological Society. 2010;29:344–358.
12. MEA. Ecosystems and Human Well-Being: A Framework for Assessment. Millennium Ecosystem Assessment. Island Press, Washington DC, USA; 2005.
13. Schuyl K, Brander L. Living waters conserving the source of life. The Economic Value of the World’s Wetlands. WWF, Gland, Switzerland; 2004.
14. Neiland AE, Bene C (eds.). Tropical river fisheries valuation: background papers to a global synthesis. The World Fish Centre Studies and Reviews. 2008;1836:290. The World Fish Center, Penang, Malaysia.
15. Dugin P, Delaporte A, Andrew N, O’Keefe M, Welcommre R. Blue harvest. Inland Fisheries as an Ecosystem Service. World Fish Centre, Penang, Malaysia; 2010.
16. Vyas V, Damde D, Parashar V. Fish biodiversity of Betwa River in Madhya Pradesh India with special reference to a sacred ghat. International Journal of Biodiversity and Conservation. 2012;4(2): 71–77.
17. Shafi M, Quddus MMA. Bangladesher Matsho Shampad (Fisheries of Bangladesh). Kabir publications, Dhaka, Bangladesh; 2001.
18. Rahman AK. Freshwater fishes of Bangladesh. 2nd edition. Zool. Soc. Bangladesh, Dhaka, Bangladesh; 2005.
19. Siddiqui KU, Islam MA, Kabir SMH, Ahmad M, Rahman ATA, Haque EU, Ahmed ZU, Begum ZNT, Hassan MA, Khondker M, Rahman MM (eds.). Encyclopedia of Flora and Fauna of Bangladesh. Vol. 23. Freshwater Fishes. Asiatic Society of Bangladesh, Dhaka; 2007.
20. Gaston KJ, Spicer Ji. Biodiversity: An introduction. Oxford: Blackwell Science Ltd; 1998.
21. Huston MA. Biological diversity: The coexistence of species on changing landscapes. Cambridge: Cambridge University Press; 1994.
22. Meerman J. Rapid ecological assessment Columbia River forest reserve past hurricane iris. Belmopan, Belize; 2004.
23. Clarke K, Warwick R. Change in marine communities: An approach to statistical analysis and interpretation, 2nd ed.; PRIMER-E: Plymouth, UK; 2001.
24. Wilhm JL, Dorris TC. Species diversity of benthic macroinvertebrates in stream receiving domestic and oil refinery effluents. Amn. Midl.Nat. 1966;76:427–449.
25. Mandaville SM. Benthic Macroinvertebrates in Freshwater – Taxa Tolerance Values, Metrics, and Protocols, Project H - 1. (Nova Scotia: Soil and Water Conservation Society of Metro Halifax); 2002.
26. Pielou EC. The measurement of diversity in different types of biological collections. J. Theoret. Biol. 1966;13:131-144.
27. Kocatas A. Ecology and environmental biology, University of the Aegean printing, Izmir. 1992;564.
28. Mackintosh RP. An index of diversity and the relation of certain concepts to diversity; 1967.
29. Hill MO. Diversity and evenness: A unifying notation and its consequences. Ecology. 1973;54:427-432.
30. Hsieh HL, Li LA. Rarefaction diversity: A case study of polychaetes communities using an amended FORTRAN program. Zoological Studies. 1998;37(1):13-21.
31. Caswell H. Community structure: A neutral model analysis. ESA: Ecological Society of America. Ecological Monograph. 1976;46(3).
32. Buzas MA, Hayek LC. Biodiversity resolution: An integrated approach. – Biodiversity Letters. 1996;3:40-43.
33. Buzas MA, Hayek LC. SHE analysis for biofacies identification. Journal of Foraminiferal Research. 1998;28:233-239.
34. Mana D. A test application of the SHE method as a biostratigraphical parameter. Geol. Alp. 2005;2:99-106.
35. Ugland KI, Gray JS, Ellingsen KE. The species-accumulation curve and estimation of richness. Journal of Animal Ecology. 2003;72:888-897.