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

Mehady Islam[1*] and Rumana Yasmin[2]

[1]AgroVet Division, Square Pharmaceuticals Ltd., Dhaka, Bangladesh.
[2]Bangladesh Fisheries Research Institute, Freshwater Station, Mymensingh, Bangladesh.

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.

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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 Balur char, Munshigonj. The geographical locations of the sampling stations were between 90° 17′ E to 90° 25′ E and 23º 40′ N to 23º 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

**Corresponding author: E-mail: mislam.nayan@gmail.com;*

lowest in Pathor ghata; Simpson's index (0.325-0.893) with utmost valuation for the Pathor ghata and lowermost for Balur char; Pielou's evenness index (0.117-0.588) with maximum value for the Balur char and least for Pathor ghata; Margaleff index (4.793-7.438) with uppermost value for the Balur char and minimum in Tulshikhali; topmost abundance of fish was recorded from Tulshikhali and least for Balur char and maximum number of unique species was recorded for Tulshikhali and minimum from 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. Effective management approach should be applied for precisely maintaining the fish habitat health and ecological condition intact before it's too late.

Keywords: River; Dhaleshwari; assemblage; abundance; fish biodiversity; Bangladesh; biodiversity indices.

1. INTRODUCTION

Biodiversity is often obscurely squandered or overused to elucidate population dynamics of a locale or commune, however in realism it is a measure of the adherents of species that epitomize a biological community and cogitated to be one of the extremely imperative facets of commune establishment and edifice. Species richness and relative abundance express vital constituents regarding biodiversity. Former is the number of varied species in a specified region and this is the elementary unit in which to appraise the homogeneity of a milieu and exercised frequently in conservation reviews to resolve the sensitivity of ecosystems and their denizen species, whereas the later portrays how common or rare a species is proportional to added species in a prearranged community and are customarily enunciate for a distinct trophic level [1].

Freshwater ecosystems are among the richest and more diverse ecosystems on earth [2], and freshwater fish make up a hefty part of this biodiversity [3]. However, the magnitude of this ecosystem to human ethnicity, wellbeing and expansion has led to progressively harsh and convoluted influences to freshwater biodiversity and ecology [4]. Five foremost causes of ethnicity, disquiet are accountable for this: (1) induction and translocation of exotic species, (2) river regulation and water diversion, (3) descent of water quality (pollution or eutrophication), (4) mortification and shattering of habitats and (5) overexploitation [5,6,7]. Consequently, many freshwater fish species have become extinct or are presently exceedingly endangered. Predominantly rivers in arid and semi-arid regions [6] are imperiled to an augmented degree of alteration with synergistic consequences between the causes of fracas cited above and the products of climate change.

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 furthermost 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 all the worlds' continents and countless livelihoods are reliant on freshwater biodiversity which offer food safety for the destitute of societies. In India nearly 5.5 million livelihoods are devoted in inland fisheries, 72% of them are women. Bangladesh possesses 50 million domiciliary adherents those are upheld through inland fisheries, affording on average over 50% of overall protein consumption, of which 50–80% is from small indigenous species [15]. The study regarding the fish biodiversity is a very much needed concern 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 (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 23º 40′ N to 23º 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

Table 1. Geographic position of sampling stations along the River Dhaleshwari

Sampling stations	Geographic locations		Name of the locations	Districts (On both sides of the River)
	Longitude	Latitude		
1	90.287º E	23.669º N	Tulshikahli	Keranigonj(Dhaka)-Munshigonj
2	90.307º E	23.662º N	Syedpur	Keranigonj(Dhaka)-Munshigonj
3	90.331º E	23.654º N	Gaberpara	Munshigonj
4	90.358º E	23.637º N	Kuchiamora	Munshigonj
5	90.351º E	23.636º N	Dhaleshwari bridge 2	Munshigonj
6	90.391º E	23.624º N	Pathor ghata	Munshigonj
7	90.431º E	23.614º N	Balur Char	Narayangonj-Munshigonj

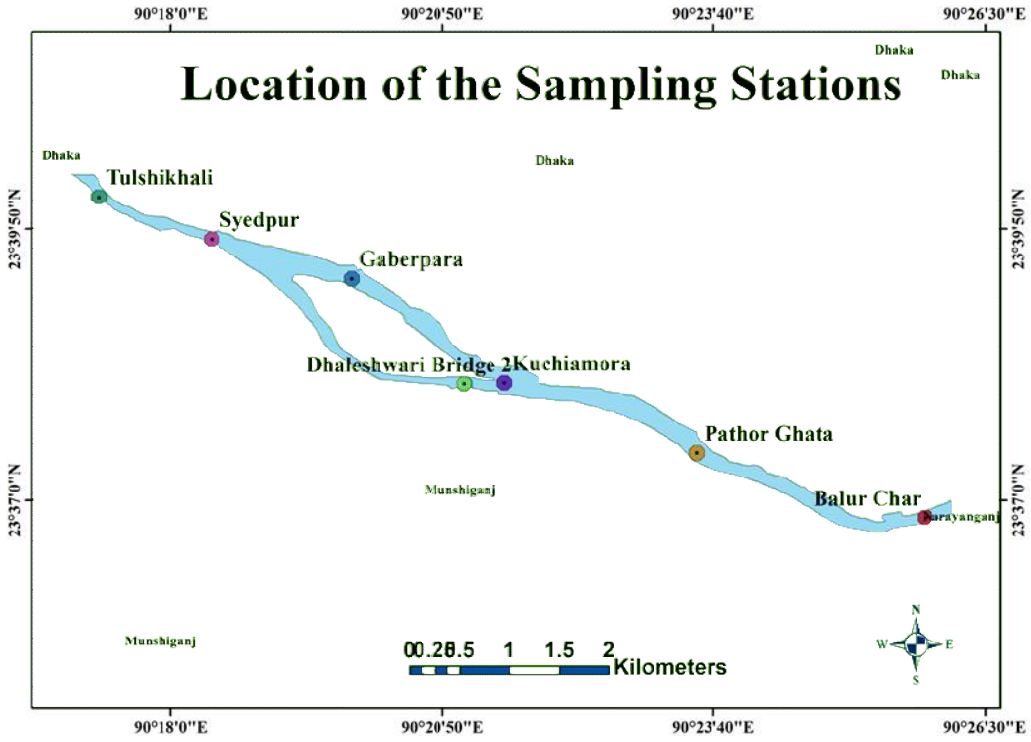

Fig. 1. Location of sampling stations

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 ghata) (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	3	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
Tengra	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
Kakhle	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	*Amblypharyngodon*	*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*	Bailla	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-tengra	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	*Eutropiichthys*	*E. vacha*	Bacha	Bacha (EN)
Synbranchiformes	Mastacembelidae	*Mastacembelus*	*Mastacembelus Sp.*	Baim	Eel

3.1.1.2 Simpson's index

The sampling Station 6 (Pathor 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 there 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

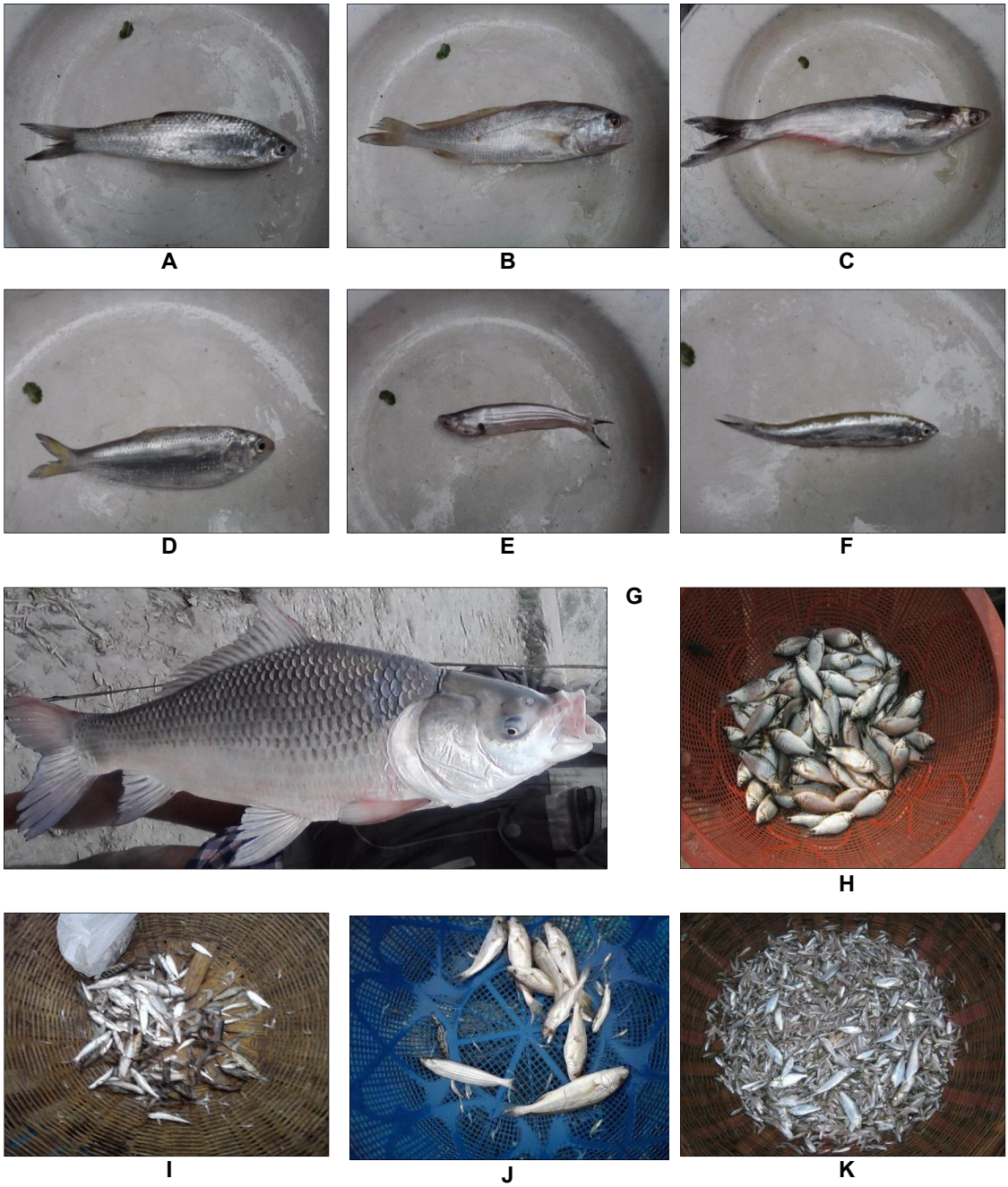

Fig. 2. (i). Identified fish species of the river Dhaleshwari; (A) Bata; (B and J) Koitor poa; (C) Ghaura; (D) Chapila; (E and J) Bashpata; (F) Kachki; (G) Catla and (H, I, K) nemerous small fishes

Fig. 2. (ii). Identified fish species of the river dhaleshwari; (A) Ghaura along small indegenous fishes; (B) Shilong; (C) Chingri; (D) Beti; (E) Kachki, bailla and baim; (F) Punti; (G) Meni, baim and punti; (H) Mola and (I) Baim.

and the conversely 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 indices 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

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 Dorrris [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 Margalefff 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 Brilluion 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

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 contributes 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).

Mackintosh index is another measure of species diversity. Mackintosh proposed that a community could be envisaged as a point in an S dimensional hyper volume and that the Euclidian distance of the assemblage from the origin could be used as a measure of diversity [28]. The Macintosh index values showed a gradual incline from the Station 1 (Tulshikhali) towards the Station 7 (Balur char). Thus, the Station 1 (Tulshikhali) showed least value of 0.93 and the Station 7 (Balur char) showed the highest value of 2.28. The higher value of the Station 7 (Balur char) illustrates the highest fish species diversity among all the sampling stations and conversely Station 1 (Tulshikhali) showed the least. The fish diversity showed an increasing trend from the first sampling station towards the last (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
Brilluion 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 (H1)	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.

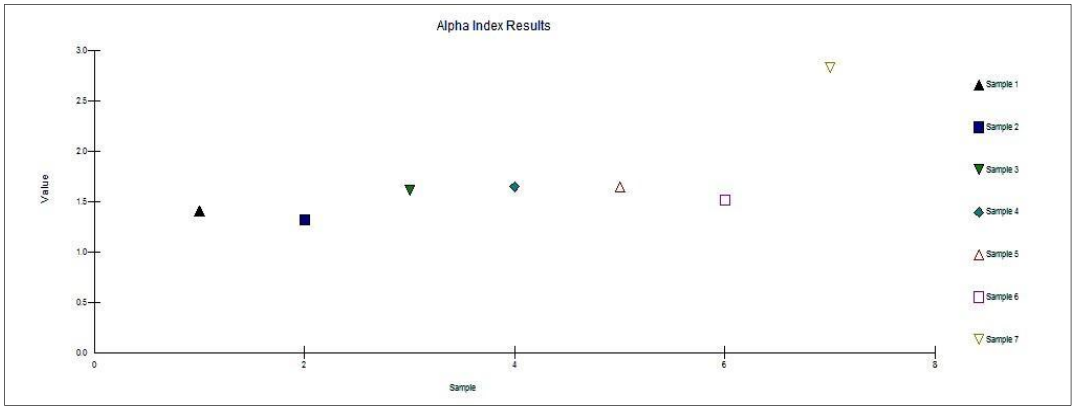

Fig. 3. Schematic representation of alpha index value of all the sampling stations

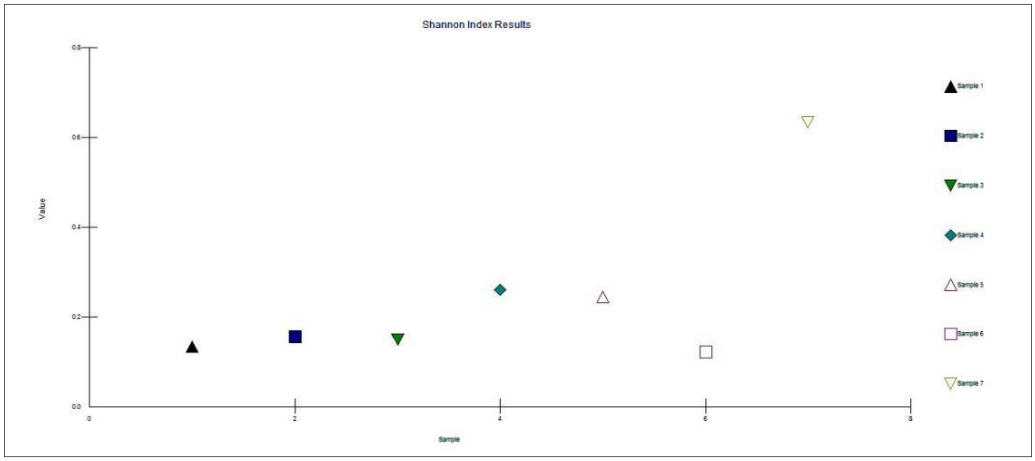

Fig. 4. Graph showing Shannon index value for all the sampling sites

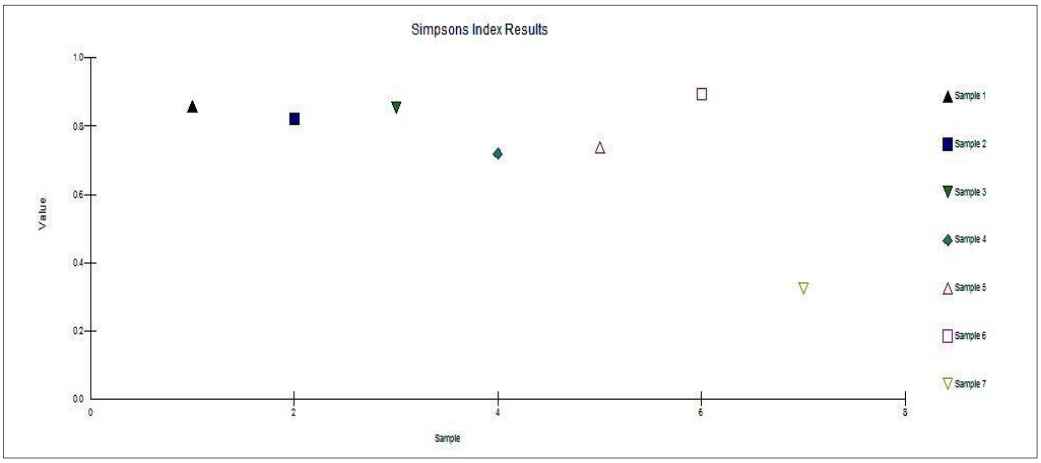

Fig. 5. Schematic presentation of Simpson's index value for all the sampling sites

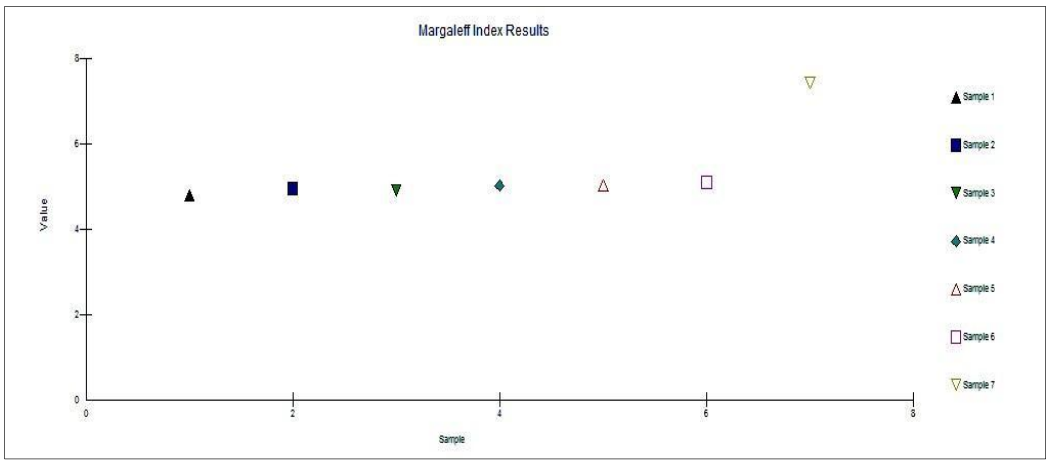

Fig. 6. Schematic representation of Margaleff index value of all the sampling stations

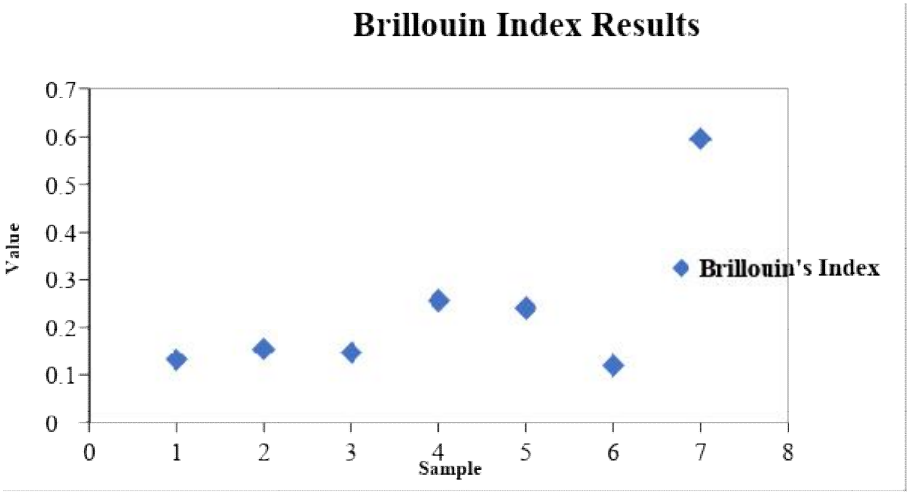

Fig. 7. Graph showing Brillouin index value for all the sampling sites

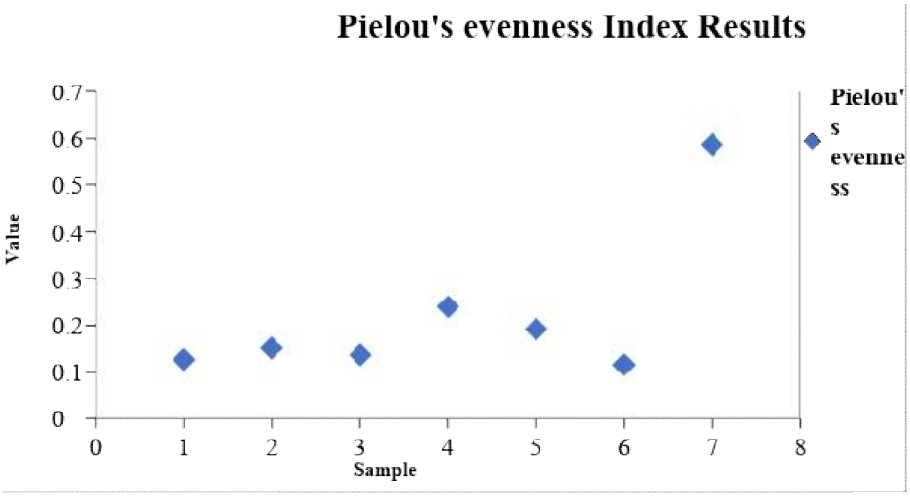

Fig. 8. Schematic illustration of Pielou's evenness index value for all the sampling stations

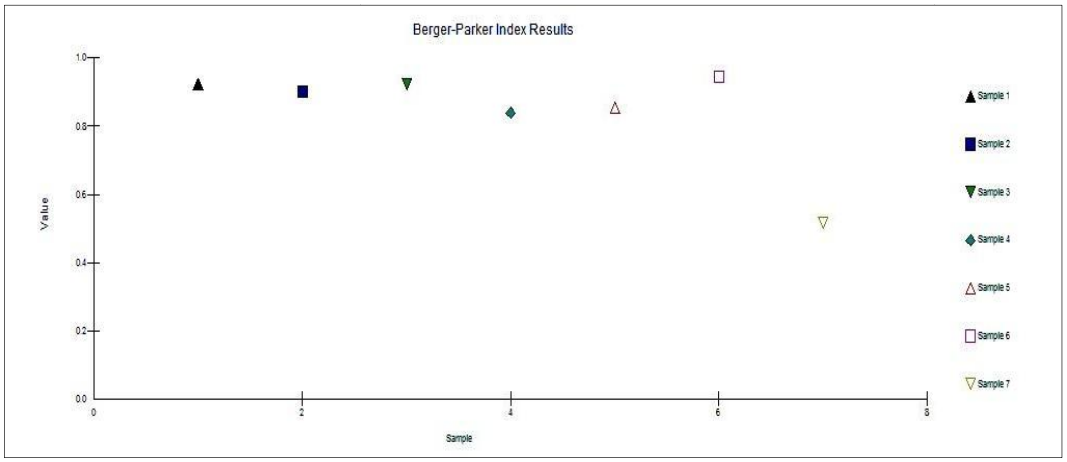

Fig. 9. Graph depicting Berger-Parker index value for all the sampling sites

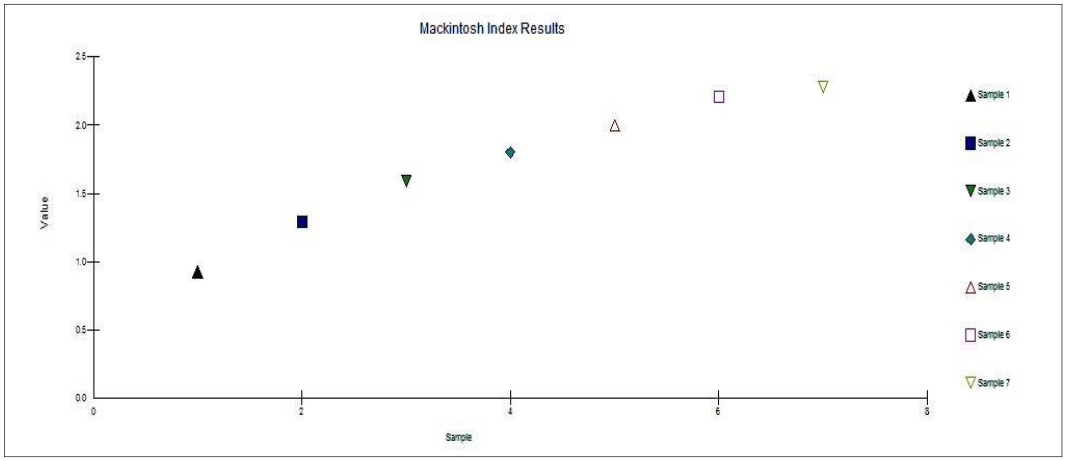

Fig. 10. Graphical presentation of Mackintosh index value for all the sampling sites

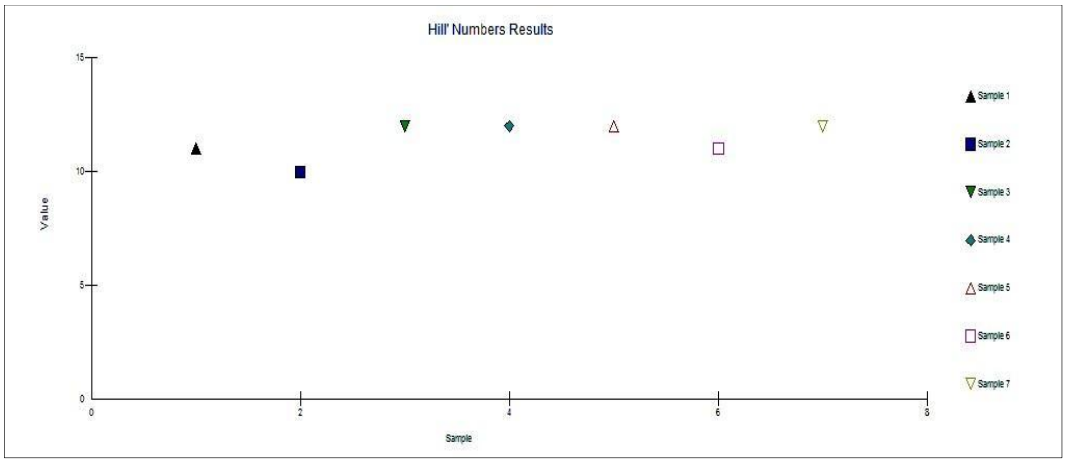

Fig. 11. Schematic illustration of Hill's number for all the sampling stations.

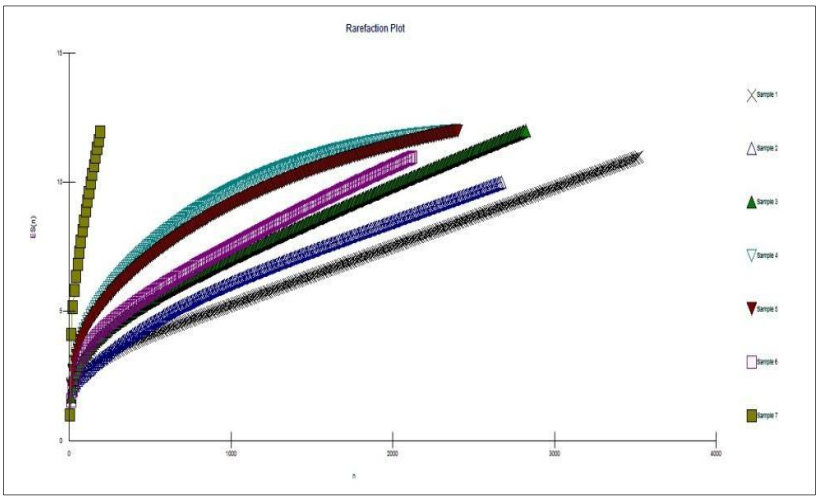

Fig. 12. Graph showing rarefaction plot of all the sampling sites

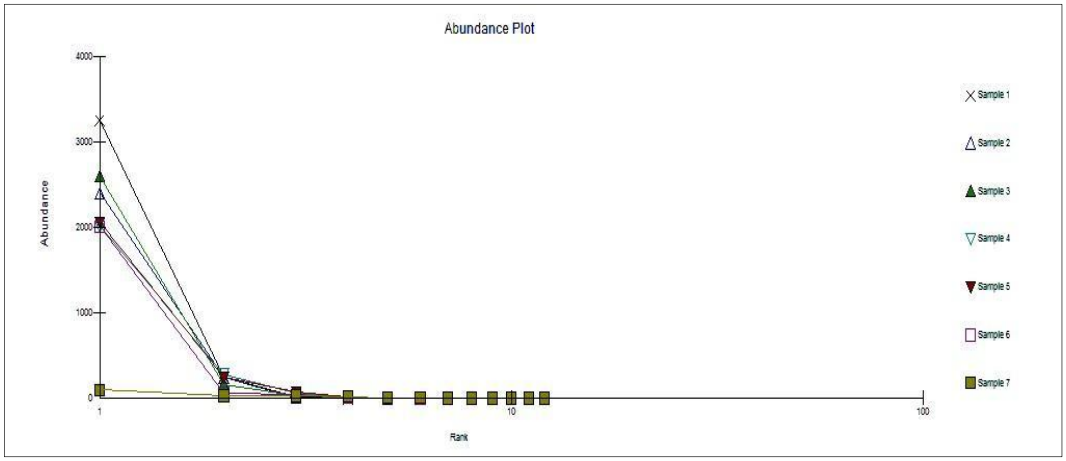

Fig. 13. Line chart presentation of abundance according to rank for all the sampling sites

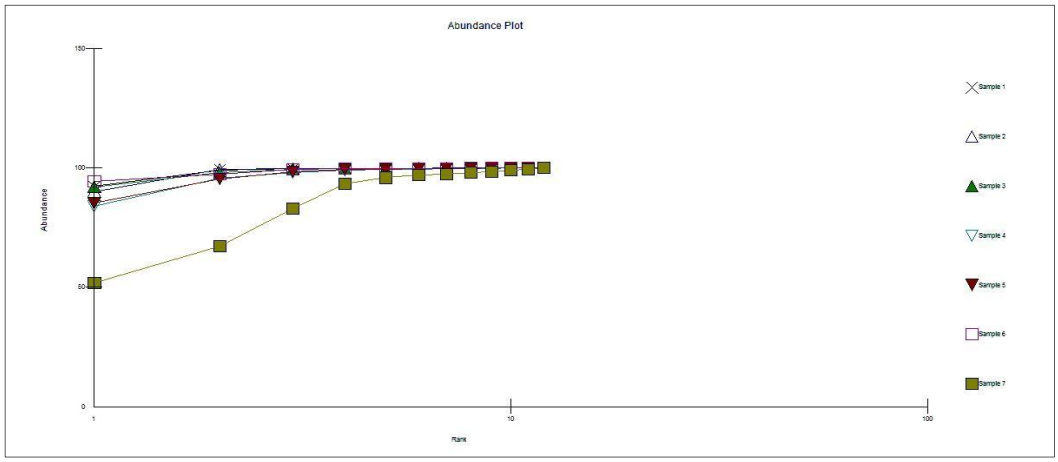

Fig. 14. Schematic demonstration of K-dominance abundance plot for all the sampling stations

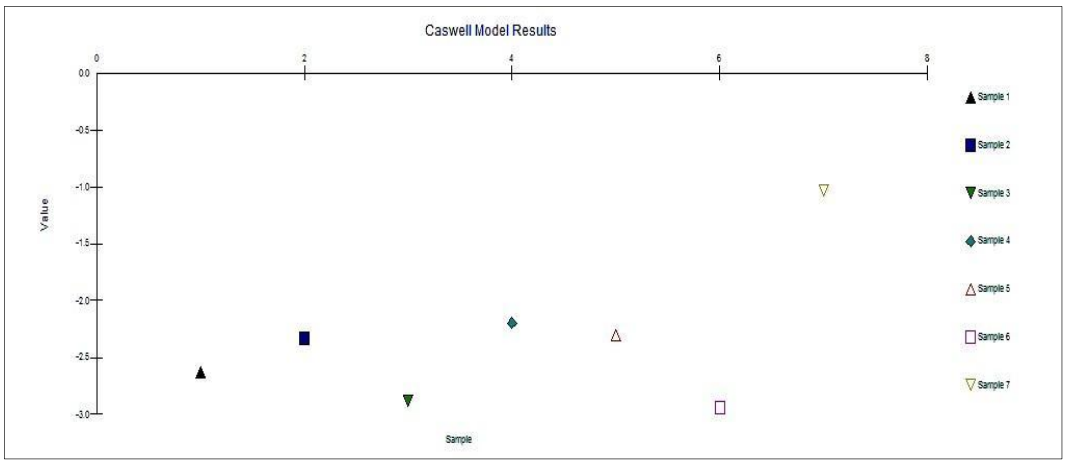

Fig. 15. Graph showing Caswell model for all the sampling sites

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 (Pathor 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).

3.1.1.12 Caswell model

The Caswell model showed highest value for the Station 7 (Balur char) thus having most even species whereas lowest evenness value was shown by the Station 6 (Pathor ghata). The rest of the sampling station of the present study showed the value between the two extreme value of the Station 6 (Pathor ghata) and 7 (Balur char) (Fig. 15).

Caswell model is helpful in comparing the observed diversity with the diversity provided by the neutral model. This model constructs an ecologically neutral community with the same number of species and individuals as the observed community assuming certain community assembly rules (random birth/deaths and random immigration/emigrations and no interactions between species). The deviation statistics 'V' is then determined which compares the observed diversity (H') with that predicted from the neutral model [E (H)]. While the 'V' value of zero indicates neutrality, positive values indicate greater diversity than predicted and negative values lower diversity. Values > +2 or <-2 indicate significant departure from neutrality [31]. The "V" value recorded highest of -1.03 for the Station 7 (Balur char) and least value of -2.94 for the Station 6 (Pathor ghata). Since the Station showed value more than -2 thus the species diversity for Station 7 (Balur char) lower diversity having insignificant departure from neutrality. The rest of the stations showed values less than -2, depicting lower diversity and significant departure from neutrality (Fig. 15). The Caswell model also resulted similarly likewise Pielou's index and Hill's number (Table 7).

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, catla, 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.

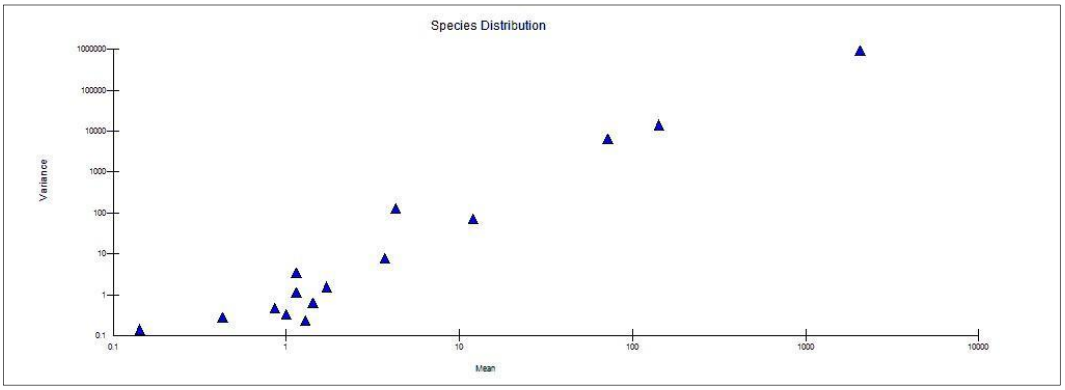

Fig. 16. Schematic illustration of community and individual species distribution of all the sampling stations

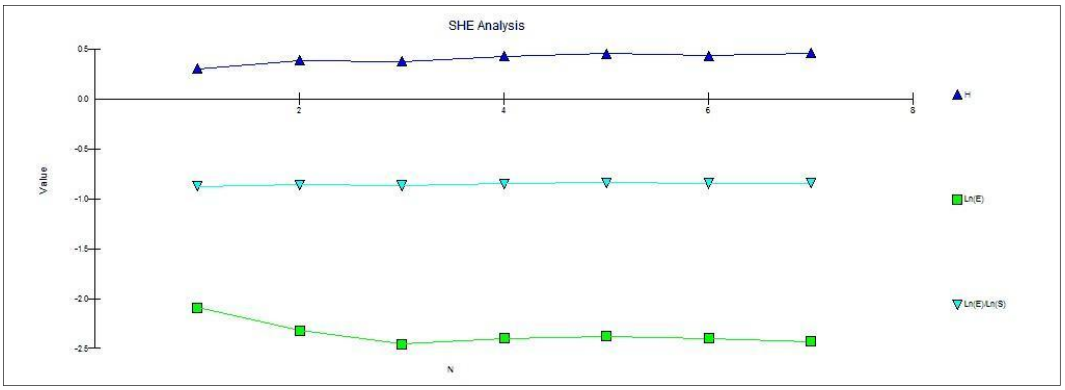

Fig. 17. Graphical presentation of SHE analysis result for all the sampling sites

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.

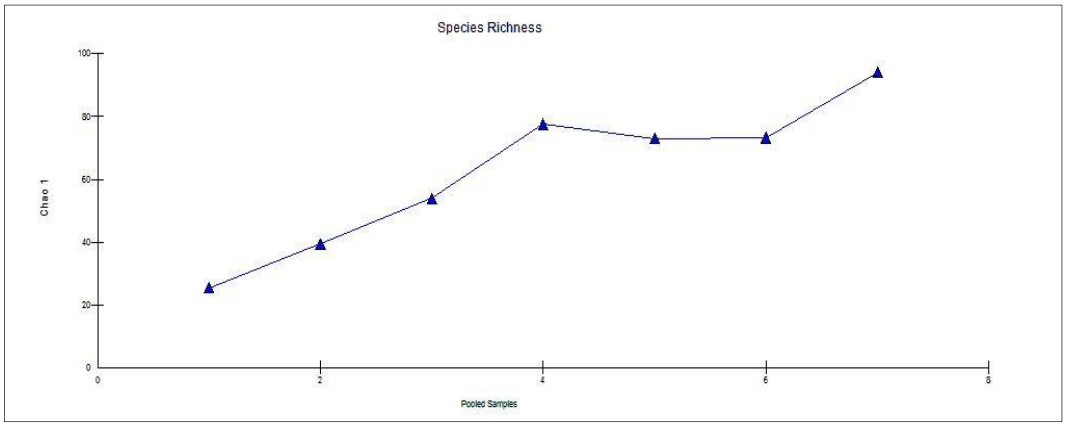

Fig. 18. Schematic expression of Chao species richness in all the sampling stations

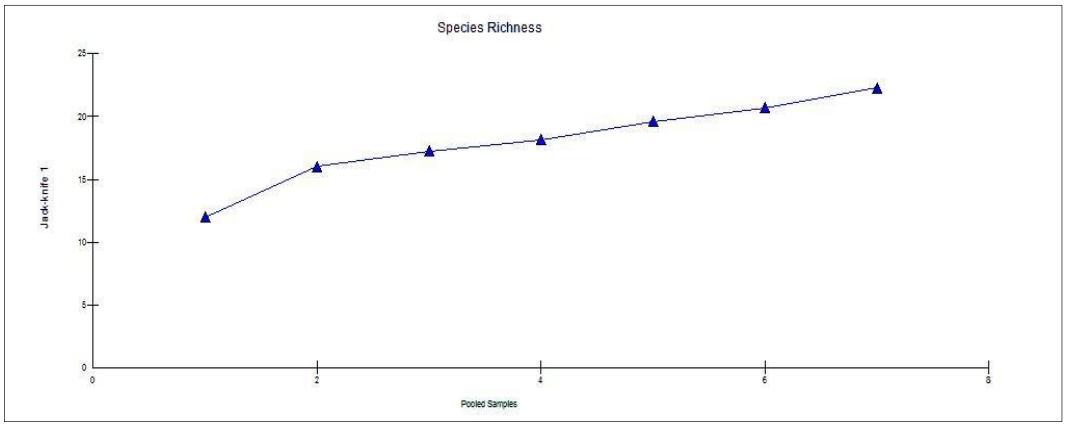

Fig. 19. Graph elucidating Jack-knife species richness index of all the sampling stations

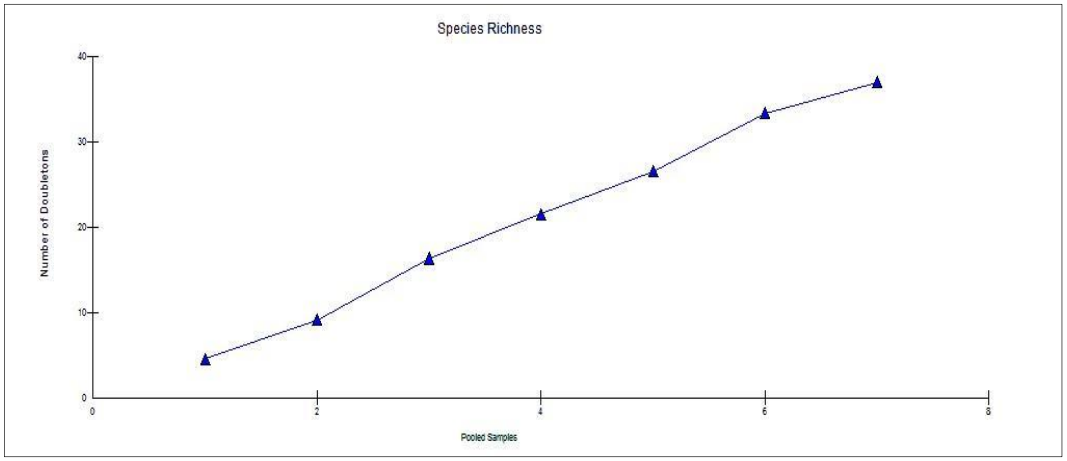

Fig. 20. Schematic exhibition of species richness including doubletons for all the sampling sites

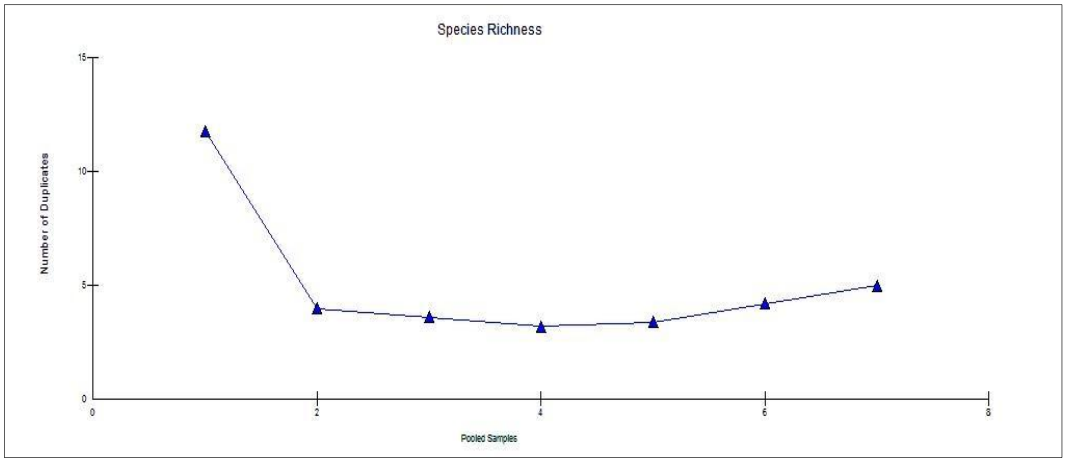

Fig. 21. Diagram illuminating species richness regarding duplicates towards all the sampling stations

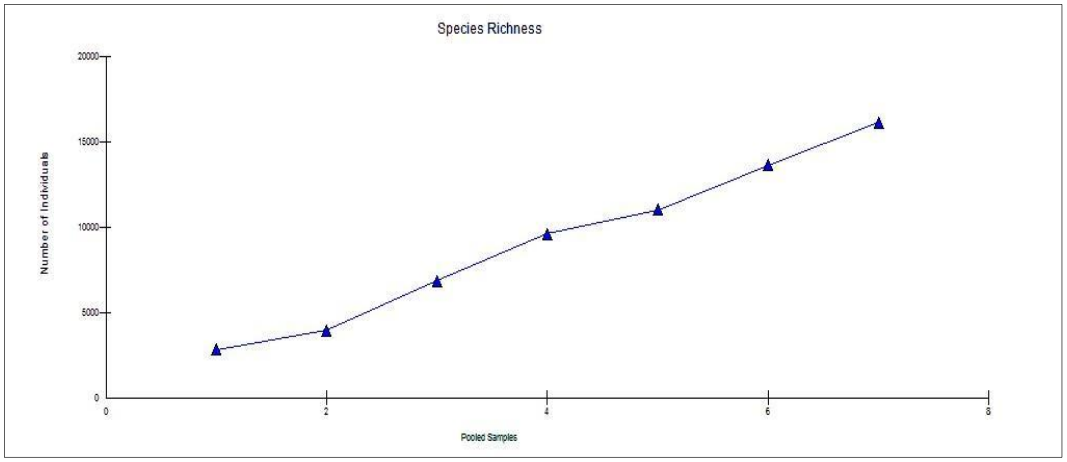

Fig. 22. Schematic exhibition of species richness concerning individuals for all the sampling sites

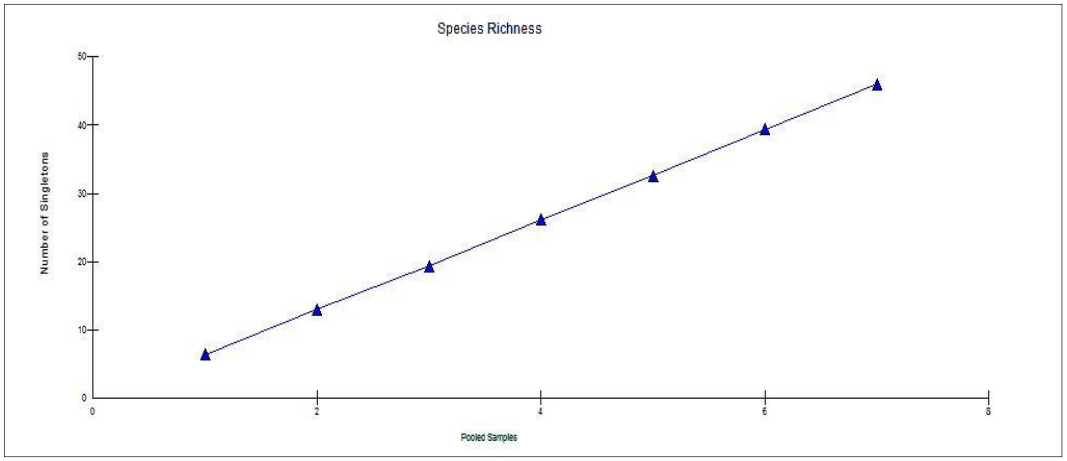

Fig. 23. Schematic exhibition of species richness including singletons for all the sampling sites

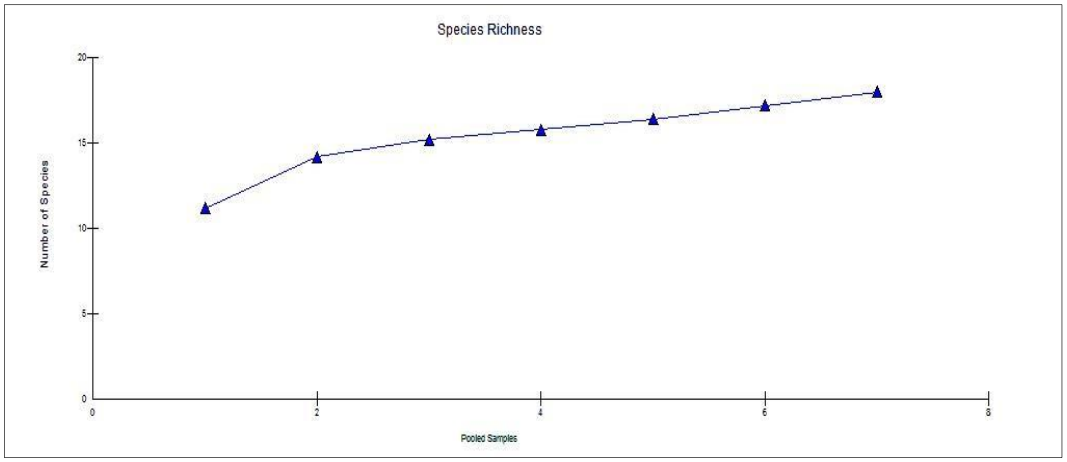

Fig. 24. Line chart illuminating species richness regarding number of species towards all the sampling stations

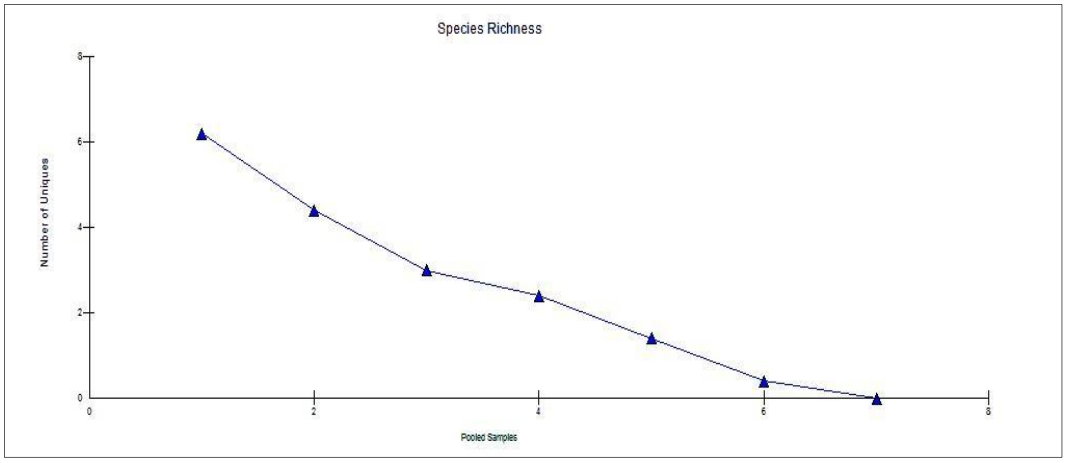

Fig. 25. Graph illuminating species richness regarding number of unique of all the sampling stations

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).

Jacknife 1 and Jacknife 2 denotes respectively the Jacknife estimator based on species that only occur in one sample and second order Jacknife 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 one individual. 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 (Dhaleshwari 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), 3 (Gaberpara) 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).

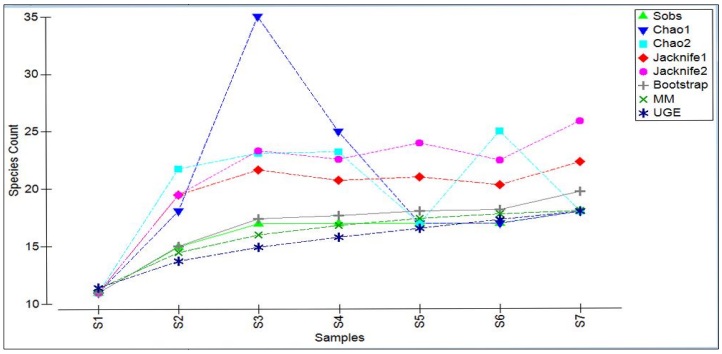

Fig. 26. The Species accumulation graph

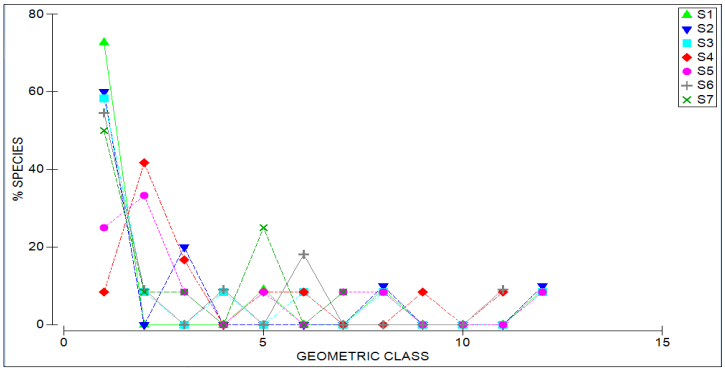

Fig. 27. The geometric abundance class plot for the sampling stations

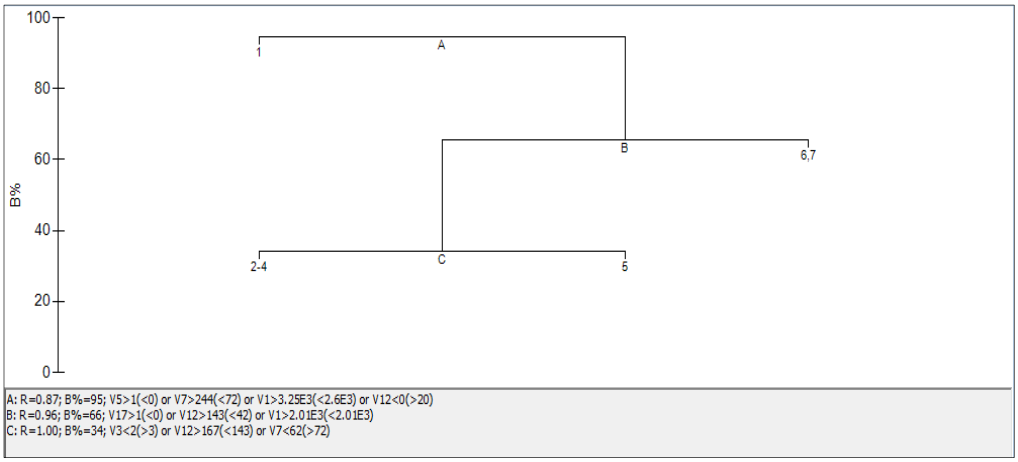

Fig. 28. Graph of the link-tree for all the sampling stations

Table 8. DOMDIS resemblance matrix for all the sampling stations

	S1	S2	S3	S4	S5	S6	S7
S1							
S2	4.5956						
S3	8.3027	10.889					
S4	41.946	39.265	33.643				
S5	30.633	27.952	22.33	12.881			
S6	13.31	16.31	6.9834	34.921	23.608		
S7	332.08	329.4	323.78	290.14	301.45	325.06	

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 (Gaberpara)	12	2823	157±144	373633	0-2601
Station 4 (Kuchiamora)	12	2399	133±112	224394	0-2013
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

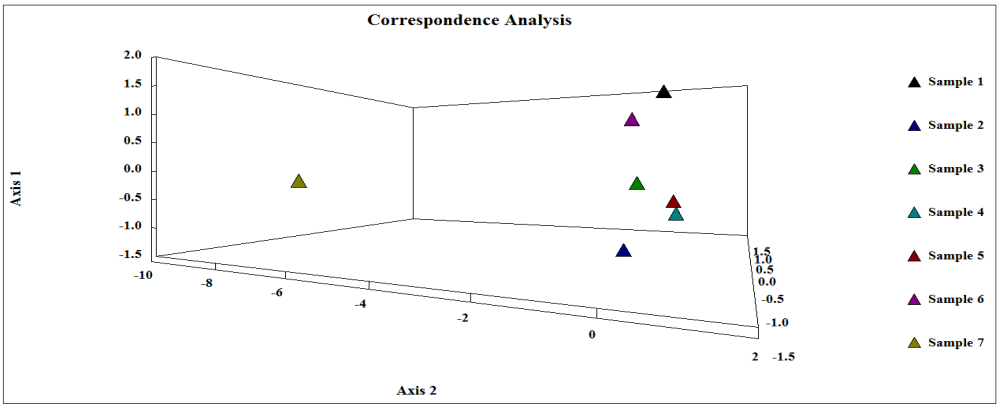

Fig. 29. Graph elucidating correspondence analysis for all the sampling stations

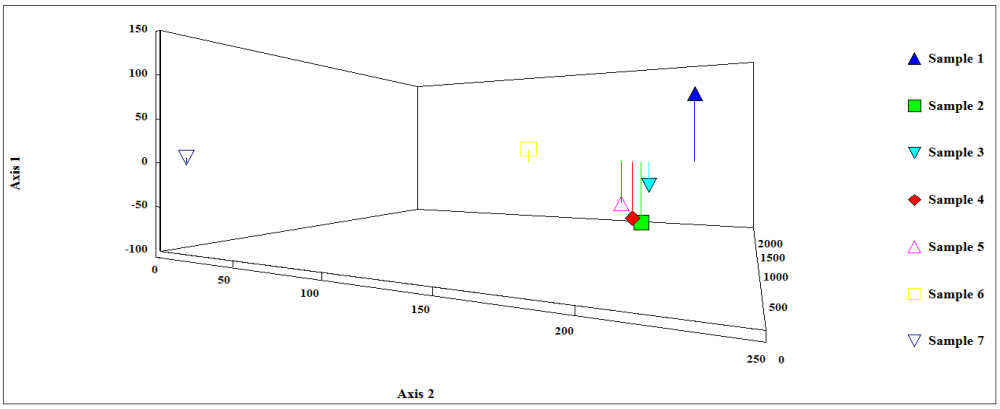

Fig. 30. Loading plot for all the sampling stations

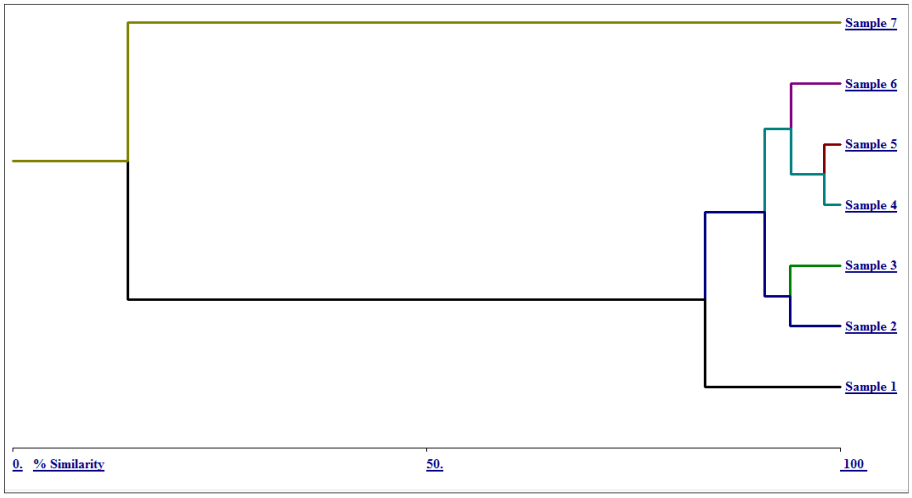

Fig. 31. Schematic cluster dendogram and groupings revealed with seven samples (variables) with percent similarity

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.

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