How seasonal fish biodiversity is impacting local river fisheries and fishers socioeconomic condition: A case study in Bangladesh

Momi M.M.A.[1,2]; Islam M.S.[1]; Farhana T.[3]; Iqbal S.[4]; Paul A.K.[2]; Atique U.[4,5*]

Received: May 2020 Accepted: November 2020

Abstract

River fisheries are critical to ensure the sustainable provision of quality food and nutrition as well as economic stability of the millions of local populations in developing nations. The Fakirni River is home to a diversity of fish species. Here, we present the status and seasonal abundance of fish species in the Fakirni River and their impact on the fishermen's livelihood compared to other small rivers in Bangladesh. Monthly sampling was carried out using a lift net, and a total of 26 fish species belonging to 18 genera, ten families, and six orders were recorded during 12 months. The Shannon-Weiner diversity, species richness, evenness index, dominance, Simpson index, Brillouin index, equitability, and Berger-Parker indices provided 1.61±0.47, 1.93±0.53, 0.52±0.41, 0.29±0.17, 0.70±0.17, 1.47±0.41, 0.68±0.17, and 0.42±0.18, respectively. The Bray-Curtis similarity cluster analysis was performed among the diversity indices and observed three available fish species. Almost all the fishermen (91%) were Muslim of age 38.67±15.05 years and possessed fishing experience for 19.94±15.42 years, with a monthly income of BDT 4166.67±1331.85. The fishermen community neither received any training nor involvement with the NGOs or other organizations to get any financial support or loans. In conclusion, despite significantly vulnerable contexts of the community-based fisheries management system and inadequate resources, fishing's livelihood outcomes were positive. However, stringent measures must be taken to manage the river fisheries sustainably by the active involvement of the local fishermen communities.

Keywords: Fakirni River, Biodiversity indexes, Socioeconomic status, Fishermen community, Fish conservation, River fisheries

1-College of Food Engineering and Biotechnology, Tianjin University of Science and Technology University, Tianjin 300457, China
2-Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Rajshahi-6205, Bangladesh
3-Noakhali Science and Technology University, Sonapur, Noakhali, Bangladesh.
4-Department of Fisheries and Aquaculture, University of Veterinary and Animal Sciences, Lahore, Pakistan
5-Department of Bioscience and Biotechnology, Chungnam National University, South Korea
*Corresponding author's Email: physioatique@gmail.com

[DOI: 10.18331/SFS2021.7.2.7]

Introduction

Catch fisheries perform a plethora of functions to ensure quality food and nutrition and sustainable employment opportunities for millions of local populations in developing nations (World Bank, 2012). Freshwater biodiversity, particularly river fisheries, is suffering from colossal damages of overfishing, uncontrolled pollution, and development actions resulting from decades-long human exploitation of accessible riverine and lake resources (Ramos *et al*., 2006; Atique and An, 2019; Atique *et al.,* 2020a; Atique *et al.,* 2020b; Hara *et al.,* 2020; Khanom *et al.,* 2020). The ecological degradation causes ultimate disruptions to the stream and riverine ecosystem biota (Stoddard *et al*., 2006; Atique and An, 2018; Atique *et al.,* 2019; Atique and An, 2020; Saeed *et al.,* 2020). Moreover, habitat loss and environmental degradations cause accelerated deterioration of the biological heterogeneity, which is a crucial test and product of the growing population (Vyas *et al*., 2012; Kim *et al.,* 2021). Asia is the most populated continent, with approximately 60% of the global population posing a cumbersome burden on the declining riverine fisheries (Gondal *et al.,* 2020; Jewel *et al.,* 2020; Rahman *et al.,* 2020).

Bangladesh, known as a riverine country, appears like a fitting example of the declining fish biodiversity in its riverine resources (Haque *et al.,* 2020). The range of fish biodiversity is frequently admitted as a bioindicator of the riverine ecosystem's natural health (Alam *et al*., 2013). Bangladesh is richly blessed with abundant fish diversity thriving in the diverse inland water bodies (rivers, floodplains, lakes, canals, ditches, ponds). Relatively large numbers of big rivers with their tributaries and branches crisscross the country and act as a drainage outlet for a vast river basin complex made up of the Ganges- Brahmaputra-Meghna river system and rich in various fisheries resources (Joadder, 2012). Approximately 700 small and large rivers are flowing in Bangladesh with characteristic geographical, hydrological, sedimentary, and biological features (Alam *et al*., 2013). These rivers enlarge the immense potential of augmenting local fish production and offer socioeconomic security to the people living there (Rahman *et al*., 2015).

Fish is a verified source of high-quality protein, minerals, vitamins, and polyunsaturated fatty acids (PUFA). After the meat, fish proteins contain every essential amino acid in the appropriate proportion (Haider *et al.,* 2018; Iqbal *et al.,* 2020). Perhaps the reason is called a "complete protein" diet, which accounts for approximately 60% of animal protein intake (DoF, 2018; Iqbal *et al.,* 2020). In 2017-18, the fisheries sector contributed 3.57 % to the national GDP and more than one-fourth (25.30 %) to the agricultural GDP. More than 11 % of Bangladesh's total population is engaged in this sector on a full-time and part-time basis (DoF, 2018). The per capita annual fish

[DOI: 10.18331/SFS2021.7.2.7]

intake in Bangladesh is 19.30 kg, with a per capita fish consumption of 62.58 g/day, which is higher than the set target of 60 g/day (DoF, 2015).

Research focusing on specific rivers and their fisheries diversity could be striking, helping explain their current status and affiliated socioeconomic aspects for sustainable management (Imteazzaman and Galib, 2013). This is interesting because most researchers targeted fish species' availability and various biodiversity indices (Galib *et al*., 2013; Akhi *et al*., 2020). River fisheries in developing countries opulently contribute to underprivileged communities' livelihood as food and income sources, reducing vulnerability to poverty (Béné , 2006). Similarly, river fishing in Bangladesh has traditionally been an occupation of particular lower castes Hindus, i.e., Ragbansi, Malo, Halder, Jaladash, and Kaibsrto (Farhana and Naser, 2006). The Fakirni River is a tributary of the Atrai River (Murshed, 2015) originating at Jothbazar in the Manda Upazila of Naogaon district and meets with the Barnai River at Bagrama Thanar Mor in Bagmara Upazila of Rajshahi, Bangladesh. The river length is roughly 100 km with a varying width of 200-250 meters. However, the mean depth during monsoon extends nearly to 15-20 feet, while it remains 1-2 feet during the rest of the year.

No explicit findings describe how riverine fish diversity influences the livelihood status of the fisherman in Fakirni River. By considering the significance of the Fakirni River and its socioeconomic contributions, our research aimed to update the existing fish species list, their conservation status, the fishermen community's socioeconomic fabric, and their lifestyle. Furthermore, we focused on the potential applicability and explanations offered by the numerous biodiversity indices, which could be useful in conservation and sustainable management.

Material and methods

Study area

This research was carried in the Fakirni River near Bagmara Upazila in Rajshahi district, Bangladesh. It is locally known as Mansinghpur and located approximately at $88^0$48’ East and $24^0$38’ North (Fig. 1).

Fish sampling and classification

A fish sampling was performed monthly using a traditional net, called *Khora Jal* (lift net), with a mesh size of 10 mm, 12 meters long, and 5 meters wide. The gear was operated at the same sampling spots for the identical hauling time between 6.00 am and 7:00 pm (about 10 hours long daytime). During this period, about 30 hauls took place. We considered the five hauls data for statistical analysis. Fish species that were difficult to identify on the spot were transported to the Aquatic Biodiversity Laboratory in the Department of Fisheries, University of Rajshahi, for prudish taxonomic classification. Only rare species were

[DOI: 10.18331/SFS2021.7.2.7]

preserved in the laboratory in a 10% buffered formalin solution. The fish species were identified based on morphometric and meristic counts after following the standard keys (Bhuiyan, 1964; Rahman, 1989, 2005; Talwar and Jhingran, 1991). After identification, fish species were classified systematically following Nelson (2006).

Biodiversity indices

We enlightened the seasonal diversity of fish species on the monthly data by applying the diversity, evenness, and richness indices. We used the following formulae.

Dominance (D) = $\sum_i(\frac{n_i}{N})^2$ (Simpson, 1949) (*Equation 1*)

where n_i is the number of individuals of taxon *i*; and *N* is the total number of individuals.

Simpson index (1-D) = 1-$\sum_i(\frac{n_i}{N})^2$ (Simpson, 1949) (*Equation 2*)

where n_i is the number of individuals of taxon *i*; and *N* is the total number of individuals.

However, dominance and Simpson indices are often interchanged. As D increases, diversity decreases. Simpson index is, therefore, usually expressed as 1-D or 1/D (Magurran, 2004).

Shannon-Weiner diversity index **(**H) =$-\sum_i \frac{ni}{N}\ln\frac{ni}{N}$(Shannon and Weiner, 1949) (*Equation 3*)

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

Sheldon's evenness index = $\frac{e^H}{S}$ (Sheldon, 1969) (*Equation 4*)

Where *S* is the total number of species, and *H* is the Shannon-Weiner index.

Brillouin's index, H_B= $\frac{\ln(N!)-\sum_i ln(n_i!)}{N}$ (Magurran, 2004) (*Equation 5*)

where H_B is the Brillouin's index; *N* is the total number of individuals, and n_i is the number of individuals in the i^{th} species.

Margalef's richness index (D) = $\frac{S-1}{\ln N}$ (Margalef, 1968) (*Equation 6*)

D is the richness index, *N* is the total number of individuals, and *S* is the total number of species.

Equitability or Pielou's evenness index (J) = $\frac{H}{\ln S}$ (Pielou, 1966) (*Equation 7*)

J is the evenness index; H is the Shannon diversity index, and S is a taxa number. This measures the evenness with which individuals are divided among the taxa present.

Berger-Parker dominance (d) = $\frac{N_{max}}{N}$ (Berger and Parker, 1970) (*Equation 8*)

where *d* is the Berger-Parker dominance; N_{max} is the number of individuals in the most abundant species, and *N* is the total number of individuals in the sample.

Conservation status of fishes

The local and global conservation status of fishes were determined following the list published by IUCN Bangladesh (2000) and the IUCN (2015) red-list database.

[DOI: 10.18331/SFS2021.7.2.7]

Figure 1: Study area map showing the location of the Bagmara Upazila, Rajshahi district, Bangladesh. The red circle denotes the place where Fakirni River sampling sites are located.

Fishermen community data collection

A monthly field survey was conducted to manage the necessary demographic and socioeconomic data of 50 fishers on a random basis to avoid biases by using various participatory rural appraisal (PRA) tools, especially interviews and focus group discussions (FGD). Interviews were taken with a prepared questionnaire, which was purposively developed and pretested under field situation. The FGDs were conducted to identify the problems and collect fishermen's recommendations regarding the identified issues to communicate effective solutions. The secondary data collection targeted various published journal articles, textbooks, yearly reports by the Department of Fisheries (DoF), Ministry of Fisheries and Livestock. Paramount photographs were taken using a digital camera.

Data analyses

Biodiversity indices were calculated using PAST software. Various graphical illustrations of data were prepared with PAST software and Microsoft Excel 2016. Data on fishermen's livelihood were analyzed with SPSS (Statistical Packages for Social Sciences, ver. 15.00). The similarity trends (Cluster analysis) were calculated for various diversity indices by using the Bray-Curtis similarity cluster analysis to show the level of similarity between the monthly availability of fish species.

[DOI: 10.18331/SFS2021.7.2.7]

Results

Fish diversity of Fakirni River

Table 1 presents the list of fish species documented from the Fakirni River families, and six orders were recorded, which can also be clustered into three main groups: Small indigenous fish species (SIS) constituted 58 % (15 species), 34% white fish (9 species) and 8% catfishes represented by two species (Fig. 2). The number of fish individuals varied from 878 in August and 58 recorded in January and April (Fig. 3). On the other hand, the number of fish species ranged from six in September to 13 in December, showing disparities among the fish species existence and preference for the riverine habitat and other suitable conditions. The small indigenous fish species (SIS) are defined as fish species that attain a maximum length of 25 cm and considerably contribute to overall fish intake from the local produce.

Conservation status

after sampling during this study. A total of 26 fish species belonging to 18 genera, ten

We ascertained the global and local conservation status of the study sites in the Fakirni River, appropriating with the IUCN (2015) database and IUCN Bangladesh (2000), and presented the main findings in Figure 4. No globally threatened fish species were detected in the sampling area. The bulk of the fish species (85%) in the Fakirni River were characterized as Least Concern (LC). However, eleven percent of the total fish species listed from the Fakirni River are yet to be appraised hence designated as Not Assessed (NA), while four percent are categorized as vulnerable (Fig. 4a). On the other hand, more than half of the fish species (54%) examined from the Fakirni River were described as Not Threatened (NT), and 23 % as vulnerable (Fig. 4b).

[DOI: 10.18331/SFS2021.7.2.7]

Table 1: Taxonomic classification and conservation status of recorded fish species as the study area of the Fakirni River, Bangladesh.

Order	Family	Scientific name	Conservation status	
			Global*	Local**
Cypriniformes	Cobitidae	*Acanthocobitis botia*	LC	NO
		Acanthocobitis zonalternans	LC	DD
		Lepidocephalus guntea	LC	NO
		Lepidocephalus irrorata	LC	DD
	Cyprinidae	*Amblypharyngodon mola*	LC	NO
		Puntius sophore	LC	NO
		Puntius ticto	LC	VU
		Puntius sarana	LC	CR
		Puntius conchonius	LC	NO
		Esomus danricus	LC	DD
		Cirrhinus reba	LC	VU
		Cirrhinus cirrhosus	VU	NO
		Labeo bata	LC	EN
		Salmo stomaphulo	LC	NO
Beloniformes	Belonidae	*Xenentodon cancila*	LC	NO
Siluriformes	Bagridae	*Mystus cavasius*	LC	VU
		Mystus tengara	LC	NO
	Schilbeidae	*Pseudeutropius atherinoides*	NA	NO
Perciformes	Gobiidae	*Glossogobius giuris*	LC	NO
	Osphronemidae	*Colisa lalius*	LC	NO
	Ambassidae	*Chanda nama*	LC	VU
		Chanda lala	LC	DD
		Pseudambassisranga	LC	VU
Cyprinodontiformes	Aplocheildae	*Aplocheilus panchax*	LC	NO
Synbranchiformes	Mastacembelidae	*Mastacembelus pancalus*	NA	NO
		Macrognathus aculeatus	NA	VU

* according to IUCN (2015)

** according to IUCN Bangladesh (2000)

Conservation status: LC=Least Concern, NO=Not Threatened, DD=Data Deficient, VU=Vulnerable, CR=Critically Endangered, NA=Not Assessed, EN=Endangered, NT=Near Threatened.

[DOI: 10.18331/SFS2021.7.2.7]

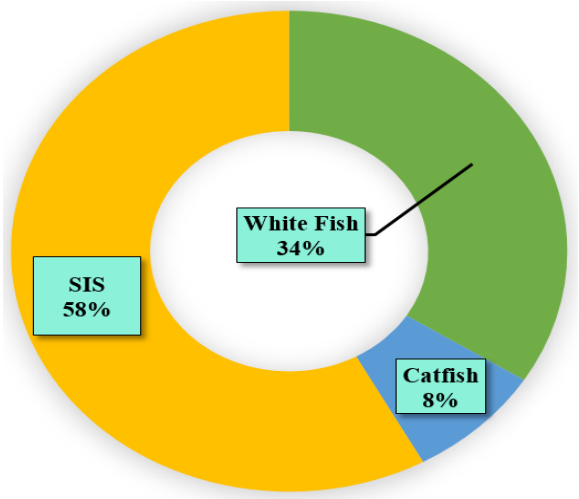

Figure 2: Grouping of the fish catch shown as white fish, catfish and SIS (Small indigenous fish species) recorded from the Fakirni River.

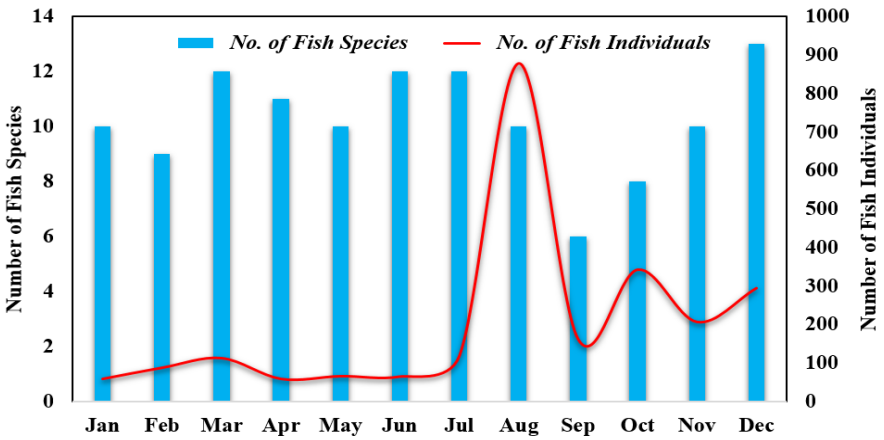

Figure 3: Monthly comparisons between the number of fish species and number of fish individuals in Fakirni River

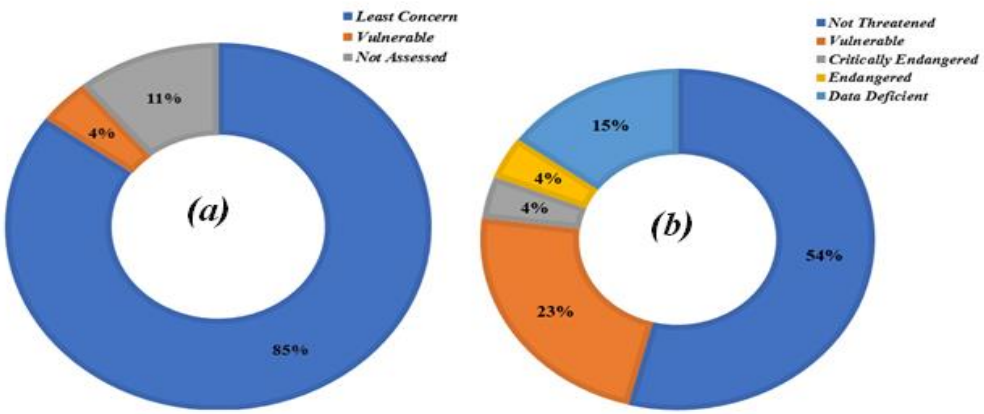

Figure 4: Conservation status of fish species recorded from the Fakirni River (a) global conservation status, (b) local conservation status.

[DOI: 10.18331/SFS2021.7.2.7]

Biodiversity indices and the interplay between dominance and diversity

The dominance index varied between 0.15 (June) and 0.78 in (September) at the Fakirni River (Table 2). However, the maximum index value was found 84.77 (June), and the lowest at 0.2181 (September), revealing large disparities among the absolute dominance of selected fish species. The maximum value of the Shannon-Weiner index (H) was reported as 2.09 (Jun), and the lowest as at 0.528 (September), with the average H 1.61±0.47. The highest evenness value was 0.7455 recorded during May. The mean evenness for the sampling site was 0.52±0.15. From the Brillouin index (HB) result, a noticeable variance, from 1.847 in June to 0.481 in September, existed with the mean index value as 1.47±0.41. The highest and lowest Margalef's richness value was recorded in July (2.645) and September (0.984), respectively. Furthermore, the equitability or Pielou's evenness index was higher in May (0.8724), whereas the lowest was in September (0.2947), while the mean was calculated as 0.68±0.17. The maximum Berger-Parker index denoting the dominance was observed 0.882 (September), and the lowest at 0.2154 (May) while the average value was 0.42±0.18.

Fig. 5 depicts the negative association between dominance and diversity. Dominance and Simpson indices are often applied reciprocally. The value of the Brillouin index rarely exceeds 4.5, while the value is always lower than that of the Shannon index (H) value. The equitability evenness index showed whether a higher diversity in one assemblage could be attributed mainly to the addition of some higher taxa or diversification of the same higher taxa present in the low-diverse assemblage. Figure 6 displayed the Bray-Curtis similarity cluster analysis among the diversity indices to attest to the level of similarity between the availability of fish species in different months. Thus we detected major fish species groups with similarities. Group 1 explained the highest fish diversity than the other groups during January, March, July, and December. On the other hand, group 2 exhibited the lowest diversity, with group 3 explaining the moderate range of biodiversity in the Fakirni River.

[DOI: 10.18331/SFS2021.7.2.7]

Table 2: Monthly trends and mean values of various biodiversity indices describing the level of biodiversity and dominance of fish species in Fakirni River.

Month	*Dominance index (D)*	*Simpson index (1-D)*	*Shannon-Weiner index*	*Evenness index*	*Brillouin index values*	*Margalef index*	*Equitability index*	*Berger-Parker index*
Jan	0.214	0.786	1.815	0.6142	1.596	2.217	0.7883	0.3448
Feb	0.2052	0.7948	1.809	0.6779	1.654	1.791	0.8231	0.2989
Mar	0.2701	0.7299	1.758	0.4835	1.606	2.331	0.7076	0.4732
Apr	0.1587	0.8413	2.02	0.6854	1.777	2.463	0.8424	0.2414
May	0.1617	0.8383	2.009	0.7455	1.791	2.156	0.8724	0.2154
Jun	0.1523	0.8477	2.092	0.6751	1.847	2.645	0.8419	0.2656
Jul	0.2577	0.7423	1.767	0.4876	1.621	2.31	0.7109	0.453
Aug	0.4788	0.5212	0.9183	0.2505	0.9006	1.328	0.3988	0.6048
Sep	0.7819	0.2181	0.528	0.2826	0.4818	0.984	0.2947	0.882
Oct	0.3351	0.6649	1.309	0.4629	1.269	1.2	0.6296	0.4298
Nov	0.3293	0.6707	1.48	0.4392	1.403	1.689	0.6427	0.5243
Dec	0.2075	0.7925	1.838	0.4835	1.764	2.111	0.7167	0.3265
Mean± SD	0.29±0.17	0.70±0.17	1.61±0.47	0.52±0.15	1.47±0.41	1.93±0.53	0.68±0.17	0.42±0.18

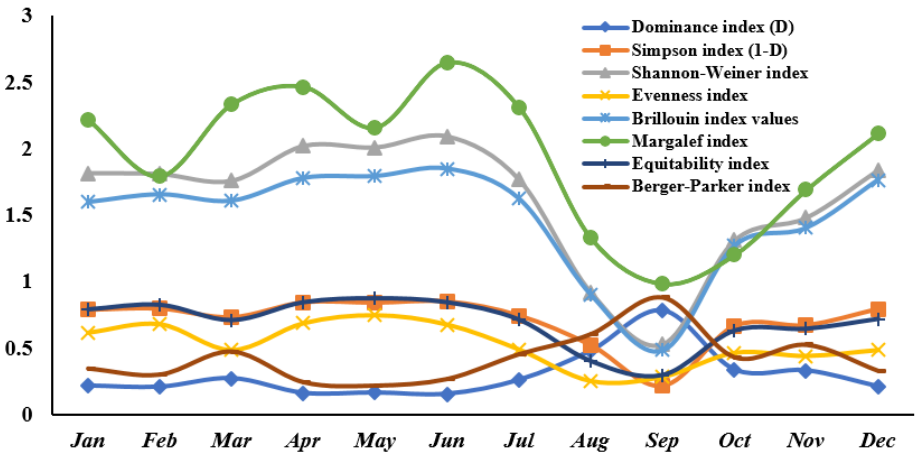

Figure 5: Monthly comparison of evaluated diversity and dominance indices in the Fakirni River

The socioeconomic status of the fishermen community

The mean age of the 50 respondents representing the fishermen community was 38.67±15.05 years (22-60 years). All the respondents were male, and their working experience in the fishing sector was calculated as 19.94±15.42 years (5-45 years). Table 3 shows the comparisons between the previously conducted studies reporting different age groups involved in the fishing business in other Bangladesh rivers. The Fakirni River fishing force work was mainly dominated by the Muslims, while only one fisherman was Hindu (Fig. 7a). We have provided comparisons between the religious affiliations of fishermen communities in previous studies in Table 4. All of the respondents reportedly have more than two occupations; with one as the primary occupation and the principal primary occupation (in terms of

[DOI: 10.18331/SFS2021.7.2.7]

income) was fishing (60%), with remaining dependent on crop farming (Fig. 7b).

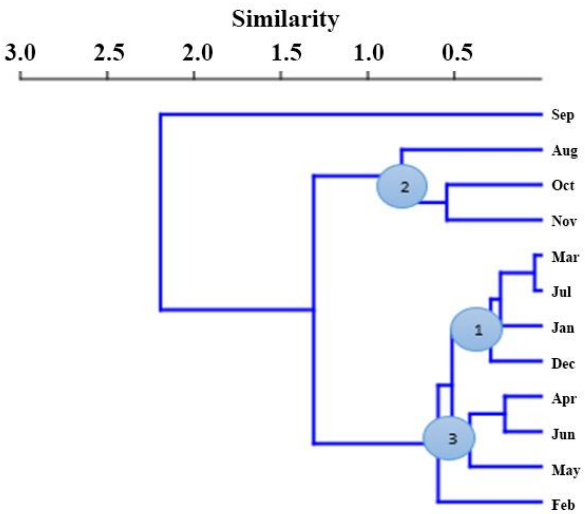

Figure 6: Dendrogram illustrating the similarity trends explained through Bray-Curtis similarity analysis.

Table 3: The comparative records showing the difference between age groups of the fishermen community of different rivers in Bangladesh.

Location	Age group (Years)	References
Fakirni River	22 to 60	This Study
Punorvaba River	18 to 45	Hossain *et al*., (2015)
Titas River	15 to 50	Afrad *et al*., (2019)
Dhaleshwari River	20 to 50	Kamruzzaman and Hakim, (2016)
Dekharhaor River	10 to 51	Trina *et al*., (2016)
Lohalia River	10 to 60	Ali *et al*., (2014)
Padma River	15 to 55	Islam *et al*., (2017)
Monirampur Upazila	20 to 80	Islam *et al*., (2013)

Table 4: Religious dynamics of the fishermen communities of different rivers in Bangladesh.

Location	Religion	References
Fakirni River	Muslims 93% & Hindus 7%	This Study
Punorvaba River	Muslims 90% & Hindus 10%	Hossain *et al*., (2015)
Dhaleshwari River	Muslims 78.57% & Hindus 21.43%	Kamruzzaman and Hakim, (2016)
Dekharhaor River	Muslims 80% & Hindus 20%	Trina *et al*., (2016)
Lohalia River	Muslims 75% Hindus 20% & Buddhists 5%	Ali *et al*., (2014)
Padma River	Muslims 94% & Hindus 6%	Islam *et al*., (2017)
Dhamrail River	Muslims 68% & Hindus 32%	Karim, (2004)

On the other hand, half of the respondents claimed fishing as their secondary occupation (Fig. 7c), followed by crop farming (41%) and daily waged labour (09%). The 27% of the fishermen were illiterate, followed by 33%, each reporting to have primary and secondary level education, while only 7% claimed to have obtained higher secondary level schooling (Fig.

[DOI: 10.18331/SFS2021.7.2.7]

7d). Table 5 shows comparisons between the educational statuses of the fishermen communities benefiting from different rivers in Bangladesh.

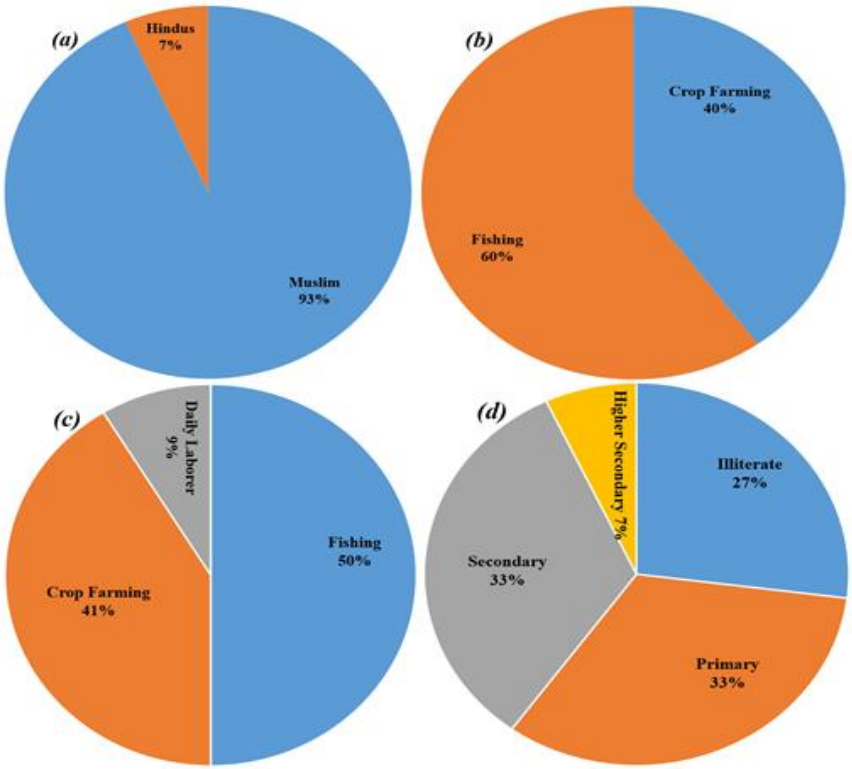

Figure 7: Demographic status and comparisons between the religion (a), primary (b) and secondary (c) occupations, along with the educational status (d) of the fishermen community directly attached with the Fakirni River.

Our survey reported the average family members as 3.4±1.05 (2 to 5) in each household in our study area. We have presented a comparison between the family extents of other rivers in Bangladesh previously reported by other researchers (Table 6). Furthermore, a fisherman's income is the most critical determinant of a reliable perception of the fishing community's socio-economic circumstances. The average monthly income was observed as 4166.67±1331.85 BDT (3000 BDT to 7000 BDT), and the annual income varied between 36000 BDT to 84000 BDT (Table 7). A little more depth into the fishermen families' living conditions indicated that the fishermen's lands were divided into three major categories: household, agricultural land and water area. The mean household land was recorded 6.07±1.23 decimal (5-8 decimal), whereas the mean agricultural land area was recorded 89.04±63.63 decimal (0-231 decimal), while no fisher reported allocating any land for the water area.

[DOI: 10.18331/SFS2021.7.2.7]

Table 5: Comparison between the educational statuses of the fishermen communities benefiting from different rivers in Bangladesh.

Location	Level of Education / Status	References
Fakirni River	Illiterate 40%, Primary 33%, Secondary 33%, Higher secondary 7%	This Study
Punorvaba River	Illiterate 50%, Primary 20% Secondary 23%, Higher secondary 7%	Hossain *et al*., (2015)
Titas River	Illiterate 26 %, Can sign only 41.3 %, Primary 22.7 %, Secondary 10 %	Afrad *et al*., (2019)
Dhaleshwari River	Illiterate 65%, Primary 31.42%, Secondary 2.86%	Kamruzzaman and Hakim, (2016)
Dekharhaor River	Can sign only 57%, Illiterate 7%, Primary 26%, Secondary 10%	Trina *et al*., (2016)
Lohalia River	Illiterate 60%, Primary 35% Secondary 5%	Ali *et al*., (2014)
Padma River	Illiterate 49 %, Can sign only 32%, Primary 12 %Secondary 7 %	Islam *et al*., (2017)

Table 6: Comparisons between the numbers of family members of the fishermen communities attached with different rivers in Bangladesh.

Location	Household Members	References
Fakirni River	2 to 5	This Study
Punorvaba River	2 to 7	Hossain *et al*., (2015)
Titas River	2 to 6	Afrad *et al*., (2019)
Dhaleshwari River	2 to 7	Kamruzzaman and Hakim, (2016)
Lohalia River	2 to 10	Ali *et al*., (2014)
Padma River	1 to 6	Islam *et al*., (2017)
Monirampur Upazila	2 to 8	Islam *et al*., (2013)

Table 7: Comparison between the annual income of fishermen communities in different rivers in Bangladesh

Location	Annual Income (BDT)	References
Fakirni River	36000 to 84000	This Study
Titas River	71000 to 100000	Afrad *et al*., (2019)
Dhaleshwari River	25000 to 55000	Kamruzzaman and Hakim, (2016)
Dekharhaor	40000 to 100000	Trina *et al*., (2016)
Lohalia River	32000 to 68000	Ali *et al*., (2014)
Padma River	36000 to 108000	Islam *et al*., (2017)

1 BDT = 78 USD

[DOI: 10.18331/SFS2021.7.2.7]

The fishermen received no training before or during taking onto the fishing and other crop culture activities. It denotes the level of understanding and resilience among the fishermen communities in case of adverse circumstances. Fishers were not involved with non-governmental organizations (NGOs) or other organizations or obtained loans from these organizations. Most of the fishermen cultivated paddy during the Boro season. The mean production of paddy during the *Boro* season was 1525.34±1154.96 kg (0-4000 kg). Some fishermen also became seasonal laborers to stock rice as a food reserve for their services. Their mean earning of the paddy harvest was 233.34±73.39 kg (120-320 kg) during Boro season. The average production of paddy during Aman season was 506.67±356.07 kg (0-1200 kg). As a laborer, their mean earning rate of paddy was 186.67±60.23 kg (120-280 kg) during Aman season. On the other hand, all households (100%) consumed SIS at the rate of 4273.33±2182.55 g/month (range: 600-7000 g/month). However, the average consumption was recorded as 6933.34±4182 g/month (1000-15000 g/month). The meat was consumed in almost all households. These households consumed meat at the rate of 1466.67±639.95 g/month (1000-3000 g/month). Eggs were consumed as an additional protein source at the rate of 16.4±6.24 pieces/month (8-25). Consumption of milk was occasionally recorded at the rate of 7733.34±3788.46 mLl/year (5000-20000 mL/year), which is very low.

One of the significantly vulnerable circumstances of Fakirni River is the community-based fisheries management (CBFM) system. The natural water bodies, especially beels/floodplains, are subjugated to this system, where fishers are less bound to address the critical issues faced by these water bodies and continue their livelihood smoothly. Two fifth (40%) of the total fishermen had limited fishing opportunities due to the CBFM system. Nearly one third (27%) of the total fishermen were critically vulnerable to flood events during *Boro* season. One of the essential vulnerable contexts was 30% of the fishermen households affected by floods during the intensive rainy season. Despite having inadequate resources, the livelihood outcomes of fishing were positive. A total of 65% of fishers described better socioeconomic standings during this survey.

Discussion

Fisheries diversity

The findings of this study can be matched with the results of Mohsin *et al*. (2014), who reported the maximum number of fish species as 45 in November and the lowest number of fish species in May in River Andharmanik, Patuakhali, Bangladesh. These observations are in close resemblance to our findings. Simialrly, Mohsin *et al*. (2013) reported another research on River Padma, Rajshahi, Bangladesh, and showed the highest

[DOI: 10.18331/SFS2021.7.2.7]

number of fish species (67) in May, June, August, September, and December, while the lowest was reported to be at 65 in April. Table 8 presents the total number of fish species reported in previous studies conducted in different rivers and Bangladesh's inland water bodies. Galib *et al*. (2013) reported the highest number of fish species (59) in November and the lowest number of species in June (45) in River Choto Jamuna.

Table 8: Number of fish species reported in previous studies conducted in different rivers and inland water bodies of Bangladesh.

Fish Species	Region/River	References
45	Andharmanik River	Mohsin *et al*., (2014)
67	Padma River	Mohsin *et al*., (2013)
63	Halti Beel (Chalan Beel)	Imteazzman and Galib, (2013)
114	Chalan Beel	Hossain *et al*., (2009)
62	Mahananda River	Galib *et al*., (2016)
61	Sibsa River	Islam *et al*., (2015)
63	Choto Jamuna River	Galib *et al*., (2013)
72	Dakatia River	Hasan *et al*., (2018)
55	old Brahmaputra River	Raushon *et al*., (2017)
55	Titas River	Arfad *et al*., (2019)
74	Dekharhaor	Trina *et al*., (2016)
46	Betna River	Chakroborty and Rahman, (2017)
30	Lohalia River	Rubel *et al*., (2016)
107	Meghna River	Pramanik *et al*., (2017)
67	Tilai River	Ahmed *et al*., (2020)

Galib *et al*. (2013) reported that 41.27% of fish species in the Choto Jamuna River were threatened to extinct fish species in Bangladesh. Similarly, Mohsin *et al*. (2013) recorded 24 threatened to extinct fish species from the Padma River in Rajshahi district. They also observed that 13.04%, 15.94%, and 8.70% of the total fish species were considered as Vulnerable, Endangered, and Critically Endangered in Bangladesh, respectively. The comparatively lower percentage of threatened to extinct fish species was recorded in the River Andharmanik of Patuakhali district by Mohsin *et al*. (2014), with 4%, 6%, and 9% fish species as Vulnerable, Endangered and Critically Endangered, respectively. Chaki *et al*. (2014) reported that 8.11% of the total fish species in the Atrai River were Critically Endangered, which is much higher than the percentage of similar fishes in the present study. Also, they recorded 18.92% Endangered, 13.51% Vulnerable fish species in the Atrai River, which differs from the current result in the Fakirni River.

Biodiversity and dominance indices

As we noticed a negative relationship between dominance (D) and diversity, we discovered after comparisons that fish diversity was higher in June (0.1523), while the lowest diversity was

[DOI: 10.18331/SFS2021.7.2.7]

recorded in September (0.7819) in Fakirni River. The Simpson index measures the 'evenness' of the community, and it ranges from 0 to 1. Since evenness and dominance are simply two sides of the same coin, their measures are complimentary. This index provides an inherent proportional dimension of species diversity that is comparatively less sensitive to the species richness (Kerkhoff, 2010). When a sample's randomness cannot be guaranteed, the Brillouin index (HB) is preferable to the Shannon index (Southwood and Henderson, 2000). Magurran (2004) stated that HB value rarely exceeds 4.5, and our results in the current investigation also verified the same opinion. Magurran (2004) also mentioned that HB value is always lower than that of the Shannon weaver index (H) value as it describes a known collection about which there is no uncertainty. The results found in the present study confirmed this statement too. The mean value of Margalef richness was 1.93±0.53, which is in line with several previous studies dealing with riverine fish communities.

Galib *et al*. (2013) has described that fish species richness in the Choto Jamuna River of Bangladesh varied between 6.973 (in June) and 8.932 (in November) with an average of 6.954. Equitability is an evenness measure index that estimates how individuals are divided among the present taxa. In a study by Galib *et al*. (2013), the evenness index ranged from 0.891 (July) to 0.983 (December) in Bangladesh's Choto Jamuna River. Berger-Parker simply determined the number of individuals in the dominant taxon relative to the number of taxa. It is essential to allude that the calculations on fish diversity using the Berger-Parker index are relatively rare in the Bangladesh perspective. John *et al*. (2013) studied this index to learn microbenthic variety in Malaysia and recorded the index value between 0.263 and 0.474, which was higher than our findings. Galib *et al*. (2016) also revealed the similarity trends by using Bray-Curtis cluster analysis showing similar tendencies among different indigenous fish families based on the number of individuals belonging to each family from the Mahananda River.

Livelihood status

The average age and fishing experience of fishers involved in fishing activities in the Fakirni River matched with the findings of Islam *et al*. (2013). In other studies, Karim (2004), Ali *et al*. (2014), Hossain *et al*. (2015), Kamruzzaman and Hakim, (2016), Trina *et al*. (2016), and Islam *et al*. (2017) observed the religion of fisherman of different locations as shown in Table 3. Karim (2004) also published that the Muslim community's dominance was understood on the ground of changing socioeconomic structure, the demand for an employment opportunity, and realization of the river fishing potential as a source of income.

Islam *et al*. (2013) reported the 90% of the respondents' primary occupation

[DOI: 10.18331/SFS2021.7.2.7]

was fishing in the Monirampur Upazila of Jessore district. Three types of secondary employments were also recorded. The principal secondary work was fishing (40%), followed by crop farming (33%) and daily laborers (7%). Our results differ from the results reported by Islam *et al*. (2013). Variation in the educational level was observed from different studies such as from Ali *et al*. (2014), Hossain *et al*. (2015), Kamruzzaman and Hakim (2016), Trina *et al*. (2016), Islam *et al*. (2017), and Afrad *et al*. (2019). These educational status variations were associated with the potential availability of schools nearby study areas (the fishermen communities), the socioeconomic circumstance of the fisherman families, and transport facilities.

We have reported that different income levels exist in various study areas where the riverine fishing communities thrive. The potential reasons for household income variation in other study areas were rapid urbanization, developing transport facilities, preservation facilities, regular fishing equipment availability, and assistance in the fish selling process. Trina *et al*. (2016) stated that the majority of fishers had no land in Dekharhaor area under Sunamganj district. A study on the Tista River by Khan *et al*. (2013) reported that approximately 24% of the fishermen owned a small house and little agricultural land, while nearly 70% (the highest percentage) possessed no agricultural land, except the only ancestral home. Islam *et al*. (2013) reported that only a meager portion (4%) of fishers was trained in fishing and fish culture and received training both from government organizations (2%) and non-government organizations (2%). Hossain *et al*. (2015) observed that only 20% of fishers obtained training on one or more than one fishing-related aspect, while the bulk (80%) never received any training. Kamruzzaman and Hakim (2016) found that 38.57% of fishers took a loan from their neighbors, and 21.43% took a loan from NGOs. A study by Zaman *et al*. (2006) revealed that poor fish farmers had no access to bank loans due to a lack of mortgage assets. Islam *et al*. (2013) reported that most fishermen's (80%) households in Monirampur Upazila consumed SIS at the rate of 4.60±2.64 kg/month, which is similar to the result of our study. Kostori (2012) mentioned that the Chalan Beel fishers did not buy meat except for special events like Eid and wedding ceremonies. Occasional intake of milk by the fishermen was also reported by Kostori (2012). In another study, Islam *et al*. (2013) reported only 40% of the households consumed milk at the rate of 11.10±15.54 liter/month, which also differed from the present result. Islam *et al*. (2013) reported that a waterlogging took place in fishermen's village in Manirampur Upazila of Jessore district, which caused considerable losses to their households

[DOI: 10.18331/SFS2021.7.2.7]

and jeopardized their healthy and sustainable living style.

Existing problems

In the present research, several Fakirni River problems have been identified from the study and interviews with the fishermen communities. We have identified the following issues: reduced catch (of fishes) in the river, siltation in several parts of the river, illegal fishing gears for harvesting fishes, indiscriminate catching of fry and brood fish, and extinction of certain fish species at the local level. Since the maintenance of fish biodiversity and other biotic resources has been viewed as a prerequisite for even human beings' wellbeing, it is essential to prevent further decline of fish resources by devising all possible conservation and rehabilitation measures. The conservation policy should promote the management practices that could help maintain the aquatic ecosystem integrity, prevent endangerment of crucial species, and improve the threatened species' recovery rate. We suggest the following measures may be taken into consideration with the governing authorities to improve the declining fisheries biodiversity in Fakirni River:

a) Habitat management and development
b) Habitat restoration and maintenance
c) Native fish stock replenishment
d) Eradication of nonnative species
e) Data-driven fisheries management and monitoring

Conclusion

The present investigation is the maiden research effort exploring the Fakirni River to unveil the current status of fish diversity and the socioeconomic conditions of the fisher communities. The number of fish species recorded in the present study is relatively low compared to other rivers and beels/floodplains of Bangladesh. From this study, through the interviews of the fishermen, it has been revealed that several species of fishes were found in the past, but those species have become locally extinct from this river. The amount of catch in the fishing nets was also higher in the past. Major causes of this continuous decline in yields could be the reduced or no water in some parts of the river during the dry season, river depth reduction due to siltation, resultant damages to the habitat due to siltation and feeding grounds, and over-exploitation of fisheries resources using illegal fishing gears. Future research efforts on the biology of threatened and rapidly declining species are recommended, and the research projects that establish the relationship between declining fish abundance and worsening water quality. Furthermore, it is essential to improve the living conditions of the fishermen communities to consider the importance of sustainable fishing and preservation of Fakirni River Fisheries.

Conflict of interest

The authors declare that there is no conflict of interest.

[DOI: 10.18331/SFS2021.7.2.7]

References

Afrad, M.S.I., Yeasmin, S., Haque, M.E., Sultana, N., Barau, A.A. and Rana, S., 2019. Fish Biodiversity and Livelihood Status of Fishermen Living Around the Titas River of Bangladesh. *Journal of Biological Science*, 27, 59-67.

Ahmed, S., Shajamal, M., Hasan, N.A., Hasan, K.R., Chowdhury, P., Kawsar, M.A., Akhter, P. and Mou, M.H., 2020. Status of fish biodiversity of tilai river in the northern part of Bangladesh. *Journal of Entomology and Zoology Studies*, 8(**2**), 1361-1367.

Akhi, M.M., Jewel, M.A.S., Haque, M.A., Sarker, B.K., Khatun, M.S., Paul, A.K., Islam, M.S. and Das, S.K., 2020. Multivariate approaches to determine the relationship between fish assemblage structure and environmental variables in Karatoya River, Bangladesh. *Community Ecology*. https://doi.org/10.1007/s42974-020-00015-6

Alam, M.S., Hossain, M.S., Monwar, M.M. and Hoque, M.E., **2013.** Assessment of fish distribution and biodiversity status in Upper Halda River, Chittagong, Bangladesh. *International Journal of Biodiversity and Conservation*, 5(**6**), 349-357.

Ali, M.M., Hossain, M.B., Minar, M.H., Rahman, S. and Islam, M.S., 2014. Socio-Economic Aspects of the Fishermen of Lohalia Rive. *Bangladesh Middle-East Journal of Scientific Research* 19(**2**), 191-195.

Atique, U. and An. K.-G., 2019. Reservoir Water Quality Assessment Based on Chemical Parameters and the Chlorophyll Dynamics in Relation to Nutrient Regime. *Polish Journal of Environmental Studies.* 28(**3**): 1043–1061.

Atique, U. and An. K.-G., 2020. Landscape heterogeneity impacts water chemistry, nutrient regime, organic matter and chlorophyll dynamics in agricultural reservoirs. *Ecological Indicators*. 110: 105813.

Atique, U., and An. K.-G., 2018. Stream health evaluation using a combined approach of multi-metric chemical pollution and biological integrity models. *Water* 10(**5**):661.

Atique, U., Byungjin, L., Johee, Y. and An. K.-G., 2019. Biological Health Assessments of Lotic Waters by Biotic Integrity Indices and their Relations to Water Chemistry. *Water* 11(**3**):436.

Atique, U., Iqbal, S., Khan, N., Qazi, B., Javeed, A., Anjum, K.M., Haider, M.S., Khan, T.A., Mahmood, S. and Sherzada. S., 2020b. Multivariate Assessment of Water Chemistry and Metals in a River Impacted by Tanning Industry. *Fresenius Environmental Bulletin* 29(**04**): 3013–3025.

Atique, U., Kwon, S. and An. K.-G., 2020a. Linking weir imprints with riverine water chemistry, microhabitat alterations, fish assemblages, chlorophyll-nutrient

[DOI: 10.18331/SFS2021.7.2.7]

dynamics, and ecological health assessments. *Ecological Indicators*. 117:106652.

Béné, C., 2006. Small-scale fisheries: assessing their contribution to rural livelihoods in developing countries. *FAO Fisheries Circular*. No. 1008. Rome, 46P.

Berger, W.H. and Parker, F.L., 1970. Diversity of planktonic Foraminifera in deep sea sediments. *Science,* 168, 1345-1347.

Bhuiyan, A.L., 1964. Fishes of Dacca, Asiatic Society of PakistanPublication.pp 148.

Chaki, N., Jahan, S., Fahad, M.F.H., Galib, S.M. and Mohsin, A.B.M., 2014. Environment and fish fauna of the Atrai River: Global and Local conservation prospective. *Journal of Fisheries*, 2(**3**), 163-172.

Chakroborty, T. and Rahman, M.M., 2017. An Introductory Study of Fish Biodiversity and Fishing Practices in the Betna River of Southwestern Bangladesh. *Academic Journal of Life Sciences*, 3(**4**), 18-23

DoF (Department of Fisheries), 2015. Compendium of National Fish Week 2015. Department of Fisheries, Dhaka, Bangladesh. 144P.

DoF (Department of Fisheries), 2018. Year Book of Fisheries Statistics of Bangladesh: 2017-18. 2P.

Farhana, Z. and Naser, M.N., 2006. Livelihoods of the two fishermen communities from Sirajganj and Chandpur districts of Bangladesh, Abstracts, 2nd Fisheries Conference and Research Fair 2006, pp. 73-74.

Galib, S.M., Samad, M.A., Mohsin, A.B.M., Flowra, F.A. and Alam, M.T., 2009. Presaent Status of Fishes in the Chalan Beel- the Largest Beel (Wetland of Bangladesh). *International Journal of Animal and Fisheris Science*, 2(**3**), 214-218.

Glib, S.M., Samad, M.A., Kamal, M.M., Haque, M.A. and Hasan, M.M., 2009. A Study on Fishing Gears and Methods in the Chalan Beel of North-West Bangladesh. *Journal of Environmental Science &Natural Resources*, 2(**2**),213-218

Galib, S.M., Naser, S.M.A., Mohsin, A.B.M., Chaki, N. and Fahad, M.F.H., 2013. Fish Diversity of the River Choto Jamuna, Bangladesh Present Status and Conservation Needs. *International Journal of Biodiversity and Conservation*, 5(**6**), 389-395. DOI: 10.5897/IJBC.2013.0552.

Galib, S.M., Rashid, M.A., Chaki, N., Mohsin, A.B.M., Joadder, M.A.R., 2016. Seasonal variation and community structure of fishes in the Mahananda River with special reference to conservation issues. *Journal of Fisheries*, 4(**1**),325-334.

Gondal, M.A., Iqbal, S., Atique, U., Saher, N.U., Qureshi, N.A., Mahboob, S., Al-Ghanim, K.A. and Al-misned, F., 2020. Linking fish and crustacean taxonomic composition with seasonal contrasts in the soft-bottom intertidal zone. *Brazilian Journal of Biology*. 6984:1–14.

[DOI: 10.18331/SFS2021.7.2.7]

Haider, M.S., Javid, A., Azmat, H., Abbas, S., Ashraf, S., Altaf, M., Atique, U., Iqbal, S., Iqbal, K.J. and Baool. M., 2018. Effect of Processed Fish Waste on Growth Rate and Digestive Enzymes Activities in *Cyprinus carpio*. *Pakistan Journal of Zoology*. Suppl. Ser(**13**): 191–198.

Haque, M.A., Jewel, M.A.S., Atique, U., Paul, A.K. and Iqbal. S., 2020. Seasonal and spatial variation of flagellate communities in a tropical river. *Limnologica.* 85: 125824.

Hara, J., Atique, U. and An. K. G., 2020. Multiyear links between water chemistry, algal chlorophyll, drought-flood regime, and nutrient enrichment in a morphologically complex reservoir. *International Journal of Environmental Research and Public Health.* 17(**9**): 1–22.

Hasan, M.M., Bosu, A., Hossain, A.B.M.A., Bisshas, S., Biswas, T.K. and Pramanik, M.M.H., 2018. Fish biodiversity of river Dakatia and its conservation aspects in Bangladesh. *International Journal of Fisheries and Aquatic Studies,* 6(**2**), 128-134

Hossain, F.I., Miah, M.I., Hosen, M.H.A., Pervin, R. and Haque, M.R., 2015. Study on the Socio-economic Condition of Fishermen of the Punorvaba River under SadarUpazila, Dinajpur. *Journal of Fisheries,* 3(**1**), 239-244.

Hossain, M.A.R., Nahiduzzaman, M., Sayeed, M.A., Azim, M.E., Wahab, M.A. and Olin, P.G., 2009. The Chalan beelin Bangladesh: Habitat and biodiversity degradation, and implications for future management. *Lakes & Reservoirs: Research and Management,* 14, 3-19.

Imteazzaman, A.M., Galib, S.M., 2013. Fish Fauna of Halti Beel, Bangladesh. *International Journal of Current Research*, 5(**1**), 187-190.

Iqbal, K.J., Javid, A., Khan, N., Baboo, I., Ali, A., Mohsin, K., Anwer, A., Atique, U., Altaf, M., Hussain, D. and Chaudhry. A., 2020. Consumer attitude towards wild-caught and farm-raised fish in Bahawalpur. *Biologia (Pakistan).* 66(**1**): 11–17.

Iqbal, S., Atique, U., Mughal, M.S., Younus, M., Rafique, M.K., Haider, M.S., Iqbal, H.S., Sherzada, S. and Khan. T.A., 2020. Selenium-Supplemented Diet Influences Histological Features of Liver and Kidney in Tilapia (*Oreochromis niloticus*). *Jordan Journal of Biological Sciences.* 13(**4**): 453–461.

Islam, M.K., Habib, K.A., Ahsan, M.E., Ali, M.M., Basak, S.K., 2015. Fish biodiversity at Sibsa River in South- Western Bangladesh: status and conservation Requirements. *International Journal of Fisheries and Aquatic Studies,* 4(**1**), 24-28

Islam, M.R., Das, B., Buruah, D., Biswas, S.P. and Gupta, A., 2013. Fish Diversity and Fishing Gears Usead in the Kulsi River of Assam,

[DOI: 10.18331/SFS2021.7.2.7]

India. *Annals of Biological Research*, 4(**1**), 289-293.

Islam, M.R., Hoque, M.N., Galib, S.M., and Rahman, M.A., 2013. Livelihood of the fishermen in MonirampurUpazila of Jessore District, Bangladesh. *Journal of Fisheries*, 1(**1**), 37-41.

Islam, S., Reza, M.S., Roknuzzaman Joadder, M.A.R., Alam, M.S., Khatun, M.A., Tasnin, M.M. and Mahmud, S., 2017. Socio-economic status of fishermen of the Padma River in Chapai Nawabganj district, Bangladesh. *International Journal of Fisheries and Aquatic Studies*, 5(**1**), 101-104.

IUCN Bangladesh, 2000. *Red book of threatened fishes of Bangladesh*, IUCN- The world conservation union. pp Xii+ 116.

IUCN, 2015. *The IUCN Red List of Threatened Species*. Version 2015.2. <www.iucnredlist.org>.

Joadder, M.A.R., 2012. A Comprehensive study on the availability of fishes and non-fin fishes in Atrai river of Naogaon District: A case study in Northern part of Bangladesh. *J. Fisher. Int*., 7(**1**), 42- 45.

Jewel, M.A.S., Ali, S.M.W., Haque, M.A., Ahmed, M.G.U., Iqbal, S., Atique, U., Pervin, M.E. and Paul. A.K., 2020. Growth and Economics of Silver Barb (*Barbonymus gonionotus*) in Rice-fish-vegetable Integrated Culture System at Different Stocking Densities in a Rainfed Arid Zone. *Egyptian Journal of Aquatic Biology & Fisheries*. 24(**6**): 459 – 476.

John, B.A., Jalaland, K.C.A. and Kamruzzaman, B.Y., 2013. Macrobenthic diversity in horseshoe crab nesting ground-Balok Station, Pahang, Malaysia. *Oriental Journal of Chemistry*, 29(**4**), 1311-1318.

Kamruzzaman, M. and Hakim, M.A., 2016. Livelihood Status of Fishing Community of Dhaleshwari River in Central Bangladesh. *International Journal of Bioinformatics and Biomedical Engineering*, 2(**1**), 25-29.

Khanom, D.A., Nesa, A., Jewel, M.A.S. Haque, M.A., Paul, A.K., Iqbal, S., Atique, U. and Alam. L., 2020. Muscular Tissue Bioaccumulation and Health Risk Assessment of Heavy Metals in Two Edible Fish Species (*Gudusia chapra* and *Eutropiichthys vacha*) in Padma River, Bangladesh. *Punjab University Journal of Zoology*. 35(**1**):81–89.

Karim, M.M., 2004. Community based fishing activities and socio-economic status of fishermen in Dhamharail beel under Kapasia upazila of Gazipur District. M.S. Thesis, Department of Fisheries Management, BAU, Mymensingh, pp. 41-55.

Kerkhoff, A.J., 2010. *Measuring biodiversity of ecological communities*. Ecology Lab, Biology, Kenyon College, USA. pp.1-3.

Khan, M.A.R, Miah, M.I., Hossain, M.B., Begum, A., Minar, M.H. and

[DOI: 10.18331/SFS2021.7.2.7]

Rajaulkarim, M., 2013. Fish Biodiversity and Livelihood Status of Fishing Community of Tista River, Bangladesh. *Global Veterinaria,* 10(**4**), 417-423.

Kim, J.-Y., Atique, U. and An. K.-G., 2021. Relative Abundance and Invasion Dynamics of Alien Fish Species Linked to Chemical Conditions, Ecosystem Health, Native Fish Assemblage, and Stream Order. *Water* 13(**2**):158.

Kostori, M.F.A., 2012. Socio-economic condition of fishermen of the Chalan Beel under TarashThaha of Sirajganj in Bangladesh. *Bangladesh Research Publications Journal*, 6(**4**), 393-402.

Magurran, A.E., 2004.*Measuring biological diversity*. Blackwell Science Ltd., Blackwell Publishing. 215P.

Margalef, R., 1968. *Perspectives in Ecological Theory*. Chicago: University of Chicago Press.

Mohsin, A.B.M, Haque, S.K.M.M., Galib, S.M., Fahad, M.F.H., Islam, M.N. and Rahman, M.M., 2013. Seasonal Abundance of Fin Fishes in the Padma River at Rajshahi District, Bangladesh.*World Journal of Fish and Marine Sciences,* 5(**6**), 680-685.

Mohsin, A.B.M., Yeasmin, F., Galib, S.M., Alam, B. and Haque, S.M.M., 2014. Fish fauna of the Andharmanik River of Patuakhali, Bangladesh. *Middle-East Journal of Scientific Research,* 21(**5**), 802-807.

Murshed, M.M., 2015. Shiba-Baranai-Gurnai River. Banglapedia- The National Encyclopedia of Bangladesh. Asiatic Society of Bangladesh, Dhaka, Bangladesh. Accessed on 10 August 2015. http://en.banglapedia.org/index.php?title=Shiba-Baranai-Gurnai_River

Nelson, J.S., 2006. Fishes of the world, fourth edition. John Wiley & Sons, Inc. 601P.

Pielou, E.C., 1966. Species diversity and pattern diversity in the study of ecological succession. *Journal of Theoretical Biology*, 13,131-144.

Pramanik, M.M.H, Hasan, M.M., Bisshas, S., Hossain, A.B.M.A. and Biswas, T.K., 2017. Fish biodiversity and their present conservation status in the Meghna River of Bangladesh. *International Journal of Fisheries and Aquatic Studies*, 5(**1**), 446-455

Rahman, A.K.A., 1989. Freshwater Fishes of Bangladesh, first edition, Zoological Society of Bangladesh, University of Dhaka, Dhaka, Bangladesh, 364P.

Rahman, A.K.A., 2005. *Freshwater Fishes of Bangladesh*, second edition. Zoological Society of Bangladesh, University of Dhaka, Dhaka, Bangladesh.263P.

Rahman, M.M, Hossain, M.Y., Ahamed, F., FatematuzzhuraSubba, B.R., Abdallah, E.M., Ohtomi, J., 2012. Biodiversity in the Padma Distributary of the Ganges River, Northwestern Bangladesh: Recommendations for Conservation.

[DOI: 10.18331/SFS2021.7.2.7]

World Journal of Zoology, 7(**4**), 328-337.

Rahman, M.A., Mondal, M.N., Hannan, M.A. and Habib, K.A., 2015. Present status of Fish Biodiversity in Talma River at Northern part of Bangladesh. *International Journal of Fisheries and Aquatic Study*, 5(**1**), 341-348.

Rahman, M.M., Haque, S.M., Islam, M.A., Paul, A.K., Iqbal, S., Atique, U., Wahab, A., Egna, H. and Brown. C., 2020. Assessment of mud crab fattening and culture practices in coastal Bangladesh : understanding the current technologies and development. *AACL Bioflux* 13(**2**): 582–596.

Ramos, S., Cowen, R.K., Re. P., Bordalo, A.A., 2006. Temporal and Spatial distribution of larval fish assemblages in the Lima estuary (Portugal). *Estuarine, Coastal and Shelf Science*, 66, 303-314.

Raushon, N.A., Riar, M.G.S., Soniya, S.K.U., Mondal, R.P. and Haq, M.S., 2017. Fish biodiversity of the old Brahmaputra river, Mymensingh. *Journal of Bioscience and Agricultural Research*, 13(**01**), 1109-1115.

Rubel, M.R.I, Hashem, S., Jaman, N., Rana, K.M.S., Ferdousi, K., Hossain, M.S., 2016. A Study on the Fish Biodiversity of Lohalia River of Bangladesh. *International Journal of Environmental Biology*, 6(**1**), 11-15.

Saeed, F., Iqbal, K.J., Atique, U., Javid, A., Khan, N., Iqbal, S., Majeed, H., Azmat, H., Khan, B.Y.A., Baboo, I., Shahid, M.T. and Afzal. G., 2020. Toxic trace metals assessment in selected organs of edible fish species, sediment and water in Head Punjnad, Punjab, Pakistan. *Punjab University Journal of Zoology*. 35(**1**):43–50.

Shannon C.E., Weaver W., 1949. *The Mathematical Theory of Communication*. Urbana, IL: University of Illinois Press.

Sheldon, A.L., 1969. Equitability indices: dependence on the species count. *Ecology* 50:466-7.

Simpson E.H., 1949. Measurement of diversity. *Nature*, 163, 688.

Southwood, T.R.E. and Henderson, P.A., 2000. *Ecological Methods*, third edition. Oxford, Blackwell Science. 575P.

Stoddard, J.L., Larsen, D.P., Hakins, C.P., Johnson, R.K., Norris, R.H., 2006. Setting expectations for the ecological conditions of streams: The concept of reference condition. Reference conditions – Ecological applications (available on internet at http://watersheds.motana.edu).

Talwar, P.K., Jhingran, A.G., **1991.** *Inland Fishes of India and Adjacent Countries*, Vol. 1 and 2, Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi-Calcutta, 1158P.

Trina, B.D., Rasul, M.G., Hasan, M.M., Ferdous, J., Ferdausi, H.J. and Roy, N.C., 2016. Status of Fish Biodiversity and Livelihood of Fisher's Community in Dekharhaor of Bangladesh. *American-Eurasian*

[DOI: 10.18331/SFS2021.7.2.7]

Journal of Agricultural & Environmental Science, 16(**8**), 1417-1423.

Vyas, V., Damde, V., Parashar, V., 2012. Fish Biodiversity of Betwa River in Madhya Pradesh, India with special reference to a sacred ghat. *Biological Conservation*, 4(**2**), 71-77.

World Bank, 2012. Hidden Harvest. The Global Contribution of Capture Fisheries. World Bank, Washington.

Zaman, T., Jewel, M.A.S. and Bhuiyan, A.S., 2006. Present status of pond fishery resources and livelihood of the fish farmers of MohanpurUpazila in Rajshahi District. *University Journal of Zoology, Rajshahi University*, 25, 31-35.

[DOI: 10.18331/SFS2021.7.2.7]