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

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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

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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
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 Kaibsrtro (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°48’ East and 24°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
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 \( (D) = \sum \left( \frac{n_i}{N} \right)^2 \) (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 \( (1-D) = 1-\sum \left( \frac{n_i}{N} \right)^2 \) (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 \( (H) = -\sum \frac{n_i}{N} \ln \frac{n_i}{N} \) (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.
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.
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).
| Order          | Family      | Scientific name                  | Conservation status |
|---------------|-------------|----------------------------------|---------------------|
|               |             |                                  | Global*             |
|               |             |                                  | Local**             |
| Cypriniformes | Cobitidae   | *Acanthocobitis botia*           | LC                  |
|               |             | *Acanthocobitis zonalternans*    | LC                  |
|               |             | *Lepidocephalus guntea*          | LC                  |
|               |             | *Lepidocephalus irradiata*       | LC                  |
|               | Cyprinidae  | *Amblypharyngodon mola*          | LC                  |
|               |             | *Puntius sophore*                | LC                  |
|               |             | *Puntius ticto*                  | LC                  |
|               |             | *Puntius sarana*                 | LC                  |
|               |             | *Puntius conchonius*             | LC                  |
|               |             | *Esomus danricus*                | LC                  |
|               |             | *Cirrhinus reba*                 | LC                  |
|               |             | *Cirrhinus cirrhosus*            | VU                  |
|               |             | *Labeo bata*                     | LC                  |
|               |             | *Salmo stomaphulo*               | LC                  |
| Beloniformes  | Belonidae   | *Xenentodon canicola*            | LC                  |
| Siluriformes  | Bagridae    | *Mystus cavatus*                 | LC                  |
|               |             | *Mystus tengara*                 | LC                  |
| Schilbeidae   |             | *Pseudeutropius atherinoides*    | NA                  |
| Perciformes   | Gobiidae    | *Glossogobius giuris*            | LC                  |
|               | Osphronemidae| *Colisa lalius*                  | LC                  |
| Ambassidae    |             | *Chanda nama*                    | LC                  |
|               |             | *Chanda lala*                    | LC                  |
|               |             | *Pseudambassiranga*              | LC                  |
| Cyprinodontiformes | Aplocheilidae | *Aplocheilus panchax*          | LC                  |
| Synbranchiformes | Mastacembelidae | *Mastacembelus panchalus* | NA                  |
|               |             | *Macrognathus aculeatus*         | NA                  |

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

![Dendrogram illustrating the similarity trends explained through Bray-Curtis similarity analysis.](image)

**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)        |
| Titus 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.
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.
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%                      | 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%                      | 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
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 mL/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. Similarly, Mohsin et al. (2013) reported another research on River Padma, Rajshahi, Bangladesh, and showed the highest
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
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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
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.
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.
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