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Research article

Impacts of brush pile fishing on fish biodiversity: A case study of the Shari-Goyain River in Bangladesh

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ABSTRACT

Brush pile (*katha*), a fish aggregating device, has been widely used in the Shari-Goyain River since 2003 to congregate fish for easier catch. *Katha* is usually used during the winter season when the water depth decreases. Hence, this experiment was conducted from November 2018 to March 2019 on *katha* fishing to investigate its status and impacts on fisheries resources of the Shari-Goyain River in the Sylhet district of Bangladesh. The study was based on the hypothesis that *katha* fishing might have detrimental impacts to fish biodiversity and production. Data were obtained through a questionnaire-based survey, personal interviews, catch assessment (CA), focus group discussions, and key informant interviews. A total of 54 species were documented, including two exotic fish species (tilapia and common carp) and 3 species of prawn during harvesting of the *kathas*. The catch per unit effort (CPUE) (kg/gear/ha/person/hour) was the highest in December (1.13 ± 0.37), followed by November (1.06 ± 0.40), January (0.80 ± 0.25), February (0.71 ± 0.23), and March (0.52 ± 0.21). The catch per unit area (CPUA) (kg/ha) was the highest in November (264.66 ± 18.21), followed by December (205.05 ± 27.77), January (175.02 ± 76.04), February (147.73 ± 52.11), and March (102.08 ± 41.04) where significant differences ($p < 0.05$) among the months were observed. Average catch per *katha* in a month ranged from 41.09 ± 16.11 to 12.42 ± 5.89 kg, with a mean of 24.29 ± 11.08 kg, and a significant decrease in average catch was observed with the progression of months. The most species richness was noticed in December (38), followed by November (35), January (34), February (28), and March (25). Siluriformes (39.123%) was the most dominant order, followed by Cypriniformes (33.956%), Decapoda (14.661%), and Ovalentaria (3.278%). According to the CA and respondents' perception, indiscriminate harvesting of fish by *katha* fishing can be a cause of fish biodiversity loss as it reduces open water catches, total production, and disturbs the ecosystem. From the research findings, it is suggested that *katha* fishing should be stopped for sustainable management and conservation of fisheries resources in the Shari-Goyain River. Research on the effects of *katha* fishing should be conducted in other open waters of Bangladesh where this type of fishing is common.

1. Introduction

Bangladesh is an important inland fishery resourceful country, blessed with a large number of inland waterbodies like rivers, freshwater marshes, canals, brackish water impoundments, natural and manmade lakes, *beels*, *haors*, and floodplains (DoF, 2020; Saha et al., 2021). It has the third largest aquatic biodiversity in Asia, and the presence of the world's largest flooded wetland makes the country one of the most suitable areas for fish in the world (Shamsuzzaman et al., 2017). However, illegal fishing and fishing pressure on the aquatic ecosystem are increasing due to the rapid increase in the human population and the growing demand for animal protein. Hence, the annual harvests from the rivers and estuaries are on increasing trends (DoF, 2009; DoF, 2020). In 2007–08, the annual fish production from rivers and estuaries was only 1,36,812 MT (DoF, 2009). The riverine production of fish increased from 3,25,478 MT in 2018–19 to 3,31,793 MT in 2019–20 with a growth rate of 1.94% (DoF, 2020). As a result, overharvesting of fish using illegal fishing gears and indiscriminate methods of fishing is very common in waterbodies, particularly in the inland open waters of Bangladesh (Galib et al., 2009; Sufian et al., 2017; Arefin et al., 2018; Akter et al., 2020; Pandit et al., 2020, 2021, 2022; Saha et al., 2021; Mia et al., 2022). Consequently, 64 indigenous fish species of Bangladesh have become red

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listed as threatened, where 52% of those are riverine species (IUCN Bangladesh, 2015). Thus, the biodiversity of riverine fishes is in great danger and many of them are vulnerable, endangered, or critically endangered. Therefore, it is necessary to find out the destructive fishing methods responsible for overfishing and indiscriminate killing of fish.

Katha or brush pile fishing is a traditional fishing method widely used in the rivers and other natural wetlands of Bangladesh. In general, traditional *katha* fishing is not a destructive method of fishing. However, nowadays, various destructive gears and methods are used during the harvesting of *katha*. As a result, it needs to be explored whether *katha* fishing is truly harmful to fish biodiversity. The term *katha* has many Bengali synonyms, such as *katta*, *jhag*, *jhata*, etc. It is also called *komar* when operated in oxbow lakes (Middendorp et al., 1996). *Katha* is also known as Fish Aggregating Device (FAD), brush pile, brush shelter, or brush park (Mustafa, 2017; Uddin et al., 2015). *Katha* acts like a short-time shelter for fish and works as a nursing and feeding ground for them. Moreover, fish also use *katha* as a hiding place and protection from predators. Therefore, schools of various fish species accumulate in *katha*, which makes it a fish aggregating device in freshwater environments, similar to the marine FAD (Cressey, 2014). In freshwater *katha* preparation, substrates like branches of bamboo, *hijol*(*Barringtonia acutangula*), *koroch* (*Millettia pinnata*), mango (*Mangifera indica*), blackberry (*Syzygium cumini*), etc. are used as a medium for shelter and algal attachment. Thus, *katha* is a manmade artificial object or brush park suspended in the water column and fixed to the bottom to attract fishes so that they are aggregated for the purpose of shelter, food, protection from predators, nursing, breeding, and other purposes (van Dam et al., 2002; Wahab and Kibria, 1994). Different species of fish at different ages take shelter inside *katha*. Its structure materials are usually selected according to the preferences of species by analyzing their behavior and characteristics. Usually, *katha* is established and operated during the dry season (November to March). Joadder et al. (2016) mentioned *katha* fishing as prohibited method of fishing according to the fisheries regulation which were practiced in the Beel Kumari of Bangladesh. *Katha* usually ranges from 6-9 m in length, 2–6 m in width, and is installed along the edge of waterbodies with a depth of around 1.25 m (van Dam et al., 2002). During harvesting, the entire *katha* is enclosed with a fine meshed net to make sure that no fish can escape, and then the brush piles are taken out from the net enclosure (van Dam et al., 2002). Afterwards, harvesting is done with cast net, wounding gears, hand picking, push net, and finally with the net that encloses the *katha*. Small non-mechanized boats called dinghi are used inside the *katha* for fishing. The size of *katha* usually ranges from 0.12 to 1.17 ha, with an average of 0.35 ha (Ahmed and Akther, 2008). Each of the *katha* is fished for around 2–3 times a year, especially in the lean season (Mustafa, 2017). Fishing pressure has been increased in the rivers due to the establishment of *katha* and its indiscriminate harvesting. Both fishers and non-fishers place *katha* in the river. Unplanned and unregulated use of this fishing device causes a serious threat both to the natural stocks and to the effectiveness of stock enhancement as all kinds of fish of different sizes and ages are harvested (Galib et al., 2009**)**. Thus, *katha* fishing in the river or any waterbody has a detrimental impact on fisheries resources, also reducing fishing opportunities for poor and marginal fishers (Mustafa, 2017).

The Shari-Goyain River is a transboundary river that originates from the Meghalaya hills of India and enters Bangladesh through the northern part of Jaintiapur upazila of Sylhet district and meets with the Surma River near *Chhatak upazila* in Sunamganj district (Talukder et al., 2021). The average width of this river is about 100 m (Shumi et al., 2019). Thousands of families are directly involved in fishing in this river for their livelihood (Shumi et al., 2019). Various types of fishing gears and methods are used for the harvesting of fish by the fishers. However, according to the fishers' statements, *katha* fishing has been widely used in the Shari-Goyain River since 2003. At present, *katha* fishing has become very common in the Shari-Goyain River during the dry season. In the dry season, water flow is reduced to a precise level, and the river serves as a reserve for a variety of aquatic species that are important for breeding in next spawning seasons. Hundreds of *kathas* are constructed in the river during this time, and fishers harvest fishes as much as they can, including juveniles and brood fishes, which accumulate in the *kathas* as their preferred shelter. This sort of indiscriminate fishing has become more popular in the river, which could have a serious impact on natural fish supplies from the river. However, determination of the damage caused by *katha* fishing and saving the riverine environment are extremely challenging. Thus, the present study was conducted in the Shari-Goyain River to assess the present status of *katha* fishing and its impact on the fisheries resources of the river. This research has potential to assist wetland management authorities in taking steps to regulate *katha* fishing in order to protect the riverine fisheries resources of Bangladesh.

2. Materials and methods

2.1. Selection of study period and area

In the Shari-Goyain River, *kathas* are usually established at the end of the rainy season when the water level starts getting lower and are usually removed at the beginning of the rainy season. Therefore, this study was conducted from November 2018 to March 2019 as *katha* fishing was performed during this period. Each *katha* was operated for an average of 2.21 times per year, shifting the place of establishment to a nearby area of the river. With a frequent visit to the whole river the study area was selected from Gowainghat to Salutikor Bazar, covering an area of 27 km along the length of the Shari-Goyain River (Figure 1).

2.2. Description of the katha fishing method

Katha is a manmade artificial structure (Figure 2) where different species and ages of fish take shelter. During harvesting, the entire *katha* is surrounded by a fine-mesh synthetic net to ensure that fishes cannot escape and the brush piles are subsequently removed from the net enclosure. Inside the *katha* small non-mechanized boats called *dinghi* are used for fishing. Cast nets, wounding gears, manual picking, push nets, and lastly the net that encloses the *katha* are used to harvest entire fishes.

2.3. Selection of target group

A large number of fishermen and people from different walks of life are engaged in *katha* fishing activities. Many non-fishers also establish *katha* and invest money in the preparation of *katha.* These people are known as *katha* owners. A total of 56 fisher and non-fisher *katha* owners were interviewed from Jalurmukh, Motorghat, Dariakandi, Salutikor, Alinagar, Gowainghat, Meuarkandi, Satkulikandi, and Kachuarpar villages of the Nandirgaon union and Purnanagar, Mugambari, Lengura, and Nihain villages of the Alirgaon union. These villages are situated on the banks of the Shari-Goyain River. The fishermen are highly dependent on the river for their livelihood.

2.4. Preparation of the questionnaire

A draft questionnaire was developed for pre-testing by a few of the respondents. Based on the results gathered from the pre-test, the questionnaire was then modified and rearranged. *Katha* materials, fishing gears, fishing crafts, fish availability, catch composition, amount and number of fish caught, etc. were included in the questionnaire. During data collection, it was confirmed that informed consent was obtained from all survey participants of the present study.

2.5. Data collection procedure

Primary data were collected from *katha* fishers, local fish traders, and *katha* owners through Catch Assessment (CA), Personal Interview (PI), Focus Group Discussion (FGD), and Key Informant Interview (KII). Upazila Fisheries Officers (UFOs), experienced people, and local leaders

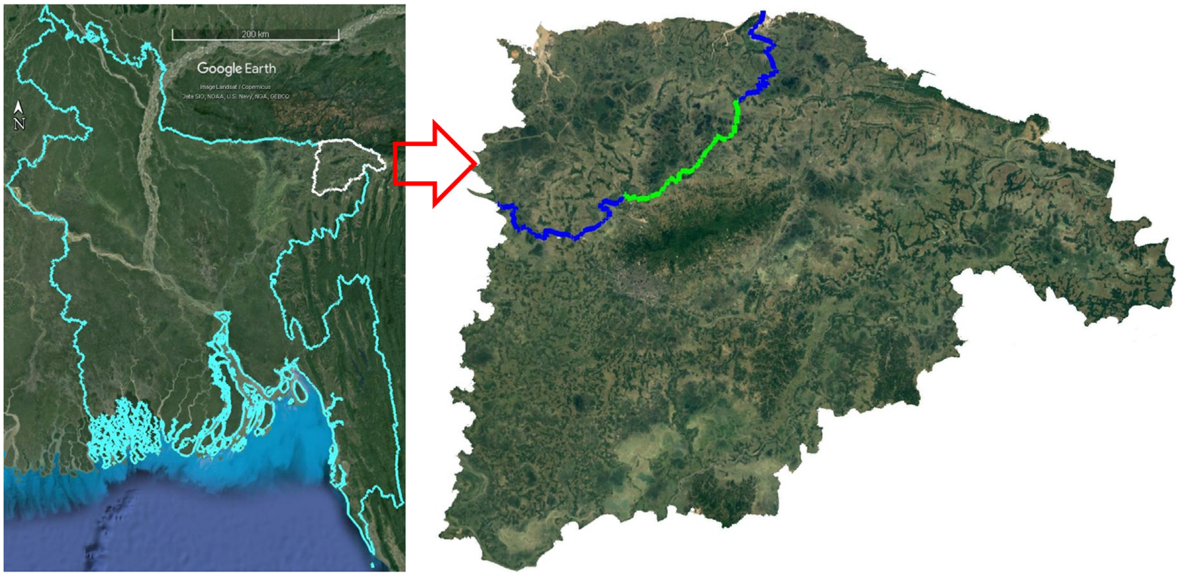

Figure 1. Map of the study area showing in light-green colour (Source: Google Earth Pro).

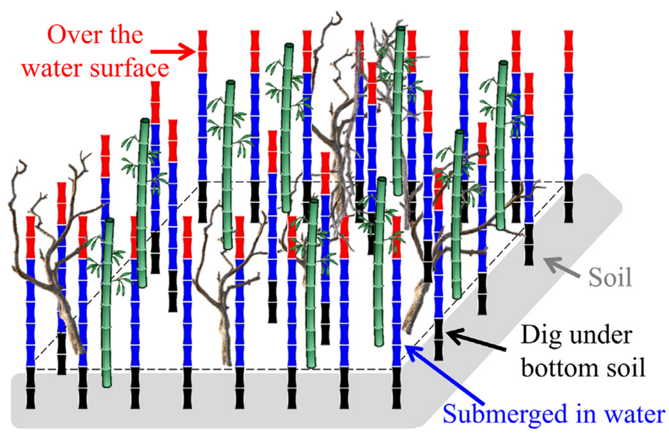

Figure 2. A schematic diagram of traditional *katha* in the Shari-Goyain River.

were interviewed as key informants. In FGDs, fishers, *katha* owners, fish traders, and local people were encouraged to gather in a place and talk about river fishery, *katha* fishing, biodiversity of fishes, the causes of fish depletion, etc. Each of the FGDs was organized with 8–15 members. A total of 56 fishers and non-fisher *katha* owners were interviewed during catch data collection and recorded as PI. All of the existing *kathas* in the Shari-Goyain River were counted by a direct visit to the entire study area. Moreover, the number of operations of each *katha* in the entire study area was also recorded.

2.6. Catch assessment procedure

Catch assessment was performed four times per month during the study period. Fishers were interviewed about their catch, previous catches, available fish species, and abundance of the fish. Normally, *katha* fishing starts at 7:00 to 10:00 am and finishes at 3:00 to 4:00 pm. Sometimes, it takes more time depending on the size of the *katha*. A group of fishermen consisting of 8–15 members encircled the entire *katha* with a fine meshed long seine net and the *katha* materials such as bamboo, *hijol*, *koroch*, etc. were gradually removed. Harvesting of *katha* was done by hand picking, cast net, push net, drag net and finally using the encircled seine net. Catch per unit area (CPUA) and catch per unit effort (CPUE) were used as a measurement of fish production in the total area of *katha* (Mustafa, 2017).

$$\text{CPUA} = \frac{\text{Total catch (kg)}}{\text{Total area of } katha \text{ (ha)}} \tag{1}$$

$$\text{CPUE} = \{\text{Total catch (kg)}\}/\{(\text{Number of gears} \times \text{total area of } katha \text{ (ha)} \times \text{number of fishermen} \times \text{total fishing time (hour)}\} \tag{2}$$

The name of the fish species, the number and weight of fishes were recorded on the spot during the *katha* fishing. In the case of small fishes, a portion of catches comprising small fishes were weighed and counted. Thus, the total weight and total number of fishes were estimated. For medium-sized fish, a total of 4–5 fish were taken for each species. The average *katha* catch of each month was recorded and compared. By compiling the monthly harvest of all the *katha,* the total catch of *katha* for that season was estimated.

2.7. Total catch (kg) estimation of the katha

$$\text{Total catch of a } katha \text{ (kg)} = \text{Average } katha \text{ catch (kg)} \times \text{total number of harvests in a season} \tag{3}$$

$$\text{Total production (kg)} = \text{Total catch of a } katha \text{ (kg)} \times \text{total number of } katha \tag{4}$$

$$\text{Average } katha \text{ catch per month (kg)} = \text{Total catch in a month (kg)} / \text{total number of fishing days in a month} \tag{5}$$

2.8. Fish species diversity indices

Biodiversity indices such as the Shannon-Weiner diversity index (H′) (Shannon and Weiner, 1949), Margalef's richness index (d) (Margalef, 1968), Simpson's dominance index (D) (Simpson, 1949), and Pielou's evenness index (J) (Pielou, 1966) were calculated.

The Shannon-Weiner index (H′) was calculated as:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \tag{6}$$

Where, H' = Shannon-Weiner diversity index,

S = Number of species,
$p_i = n_i/N$,
n_i = Number of individuals of a species, and.
N = Total number of individuals.
Margalef's richness index (d) was calculated by this formula:

$$d = (S - 1)/\log(N) \tag{7}$$

Where,
S = Total number of species and
N = Total number of individuals.
Simpson's dominance index was calculated by the following formula:

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right) \tag{8}$$

Where
n = The total number of individuals of a species and
N = The total individuals of all species.
Pielou's evenness index (J) is defined as:

$$J = H_{(S)}/H_{(max)} \tag{9}$$

Where,
$H_{(S)}$ = The Shannon-Weiner diversity index and
$H_{(max)}$ = The maximum possible value of the Shannon-Weiner index if all the values are identical.

2.9. Statistical analyses

Collected data were edited, coded, and computed for analysis. These data were verified to eliminate all possible errors. For instance the normality of the data, their homogeneity, and independence of units were checked. For the processing of data, a tabular technique was applied by using simple statistical tools like averages and percentages. Data were analyzed using Microsoft Office Excel 2010, as well as the Statistical Package for the Social Sciences (SPSS version 20). One-way Analysis of Variance (ANOVA) was used for statistical analysis at 5% level of significance. Finally, Kruskal-Wallis ANOVA by ranks (Fakayode et al., 2012) was used to evaluate the negative impact of *katha* fishing.

3. Results

3.1. Status of katha and katha fishing in the Shari-Goyain River

A total of 187 *kathas* were found in the study area, and each of the *kathas* was harvested 2.21 ± 0.78 times a year. It was estimated that total *kathas* were harvested 413 times during the study period, of which 76 catches were sampled for the current study. The average *katha* size in the study site was 0.13 ± 0.06 ha. The mean construction cost of an individual *katha* was 7,857.14 ± 5,536.57 Bangladeshi Taka (BDT), depending on its size. The benefit-cost ratio of a single *katha* was 1.11. The average group size of the *katha* fishers was 10.2 ± 2.9 person. The average fishing time of *kathas* was 5.97 ± 1.2 h. *Dinghi,* with an average length of 8.28 ± 1.21 m and a width of 1.40 ± 0.49 m, were used to operate the net and other fishing gears. The boats are also used to keep the harvested fishes. Notably, most of the *katha* owners were to be found non-fishers, and they got around 50% share of the total *katha* catch. A fisherman can earn approximately 15,000 ± 350 BDT per month during the *katha* fishing season.

3.2. The diversity and abundance of aquatic species in the katha

A total of 54 species were recorded, including two exotic species (*Oreochromis niloticus*, *Cyprinus carpio*) and 3 species of prawn under 3 classes, 14 orders, and 23 families from the *katha* during the harvesting period (Table 1). Siluriformes was the most dominant order, constituting about 39.123% of the total catch, followed by Cypriniformes (33.956%), Decapoda (14.661%), Ovalentaria (3.278%), Tetraodontiformes (3.186%), Synbranchiformes (2.068%), Beloniformes (1.032%), Clupeiformes (0.857%), and the rest 1.837% were comprised by Gobiiformes, Cichliformes, Mugiliformes, Osteoglossiformes, Anabantiformes, and Cyprinidontiformes. Among all the species, *Macrobrachium malcolmsonii* was the most abundant species in the capture (relative abundance 37.179%), followed by *M. lamarrei* (relative abundance 30.027%) and *Parambassis ranga* (relative abundance 3.427%). On the other hand, as a single species, *Wallago attu* dominated the catch by weight and contributed 13.098% to the total catch.

3.3. Species diversity in different months

During the study period, variation was observed in species composition in different months. All the species were not continuously available throughout the study period. Monthly species richness was found to be the highest in December, followed by November (35), January (34), February (28), and March (25) (Figure 3).

3.4. Indices of diversity

The Shannon-Weiner diversity index (H′): The Shannon-Weiner diversity index (H′) was used to identify the biodiversity condition of the Shari-Goyain River in different months. The highest Shannon-Weiner diversity index indicates a high number of individuals and vice-versa. The species diversity index value was the highest in December (1.994), followed by January (1.959), February (1.864), March (1.827), and November (1.805). In November, species diversity was found to be the lowest (Figure 4).

Margalef's richness index (d): Margalef's richness index counts the number of different species in a given area and is dependent on sampling size and effort. In the study area, Margalef's richness value (d) was found to be the highest in December (3.430), and 3.120, 2.899, 2.552, and 2.325 in November, January, February, and March, respectively (Figure 4).

Pielou's evenness index (J): Pielou's evenness index reveals how individuals are distributed in a study area. Figure 4 shows the evenness index was 0.508, 0.544, 0.555, 0.554, and 0.561 in November, December, January, February, and March, respectively. The evenness index was the highest in March and the lowest in November.

Simpson's dominance index (D): A maximum value was recorded in November (0.294) and a minimum was recorded in January (0.244) (Figure 4).

3.5. Production of fish from katha

A total of 76 individual catches were taken and the total production was 1,635.10 kg. The average estimated production of each *katha* catch was 21.51 ± 12.91 kg. It was found that on an averageeach *katha* was harvested 2.21 ± 0.78 times in that season. As total 187 *kathas* were harvested in the study area, the estimated total production was 8,889.98 kg.

The mean catch (kg) for each *katha* varied in different months. The individual average *katha* catch was the highest in November (41.09 ± 16.11 kg), followed by December (27.01 ± 12.21 kg), January (21.13 ± 9.60 kg), February (19.79 ± 11.58 kg), and March (12.42 ± 5.89 kg) (Figure 5). Variation in the mean individual *katha* catch was highly significant ($p < 0.05$) among the months (Table 2).

3.6. Katha catch per unit effort

Analysis of *katha* catches was done for the months using catch monitoring records. The CPUE of *katha* is presented in Figure 6. The CPUE (kg/gear/ha/person/hour) was the highest in December

Table 1. Species composition of fishes from *katha* fishing in the Shari-Goyain River.

Order	Family	Local name	Scientific name	IUCN status	Relative abundance (%)	Catch composition (%)
Siluriformes	Bagridae	Golsha	*Mystus cavasius* (Hamilton, 1822)	NT	1.968	7.115
		Rita	*Rita* (Hamilton, 1822)	EN	0.062	1.365
		Ghagla	*Hemibagrus menoda* (Hamilton, 1822)	NT	0.063	3.809
		Air	*Sperata seenghala* (Shykes, 1839)	VU	0.073	6.989
		Guijja air	*Sperata aor* (Hamilton, 1822)	VU	0.006	0.595
		Bujuri	*Mystus tengara* (Hamilton, 1822)	LC	2.816	1.142
	Schilbeidae	Bacha	*Eutropiichthys vacha* (Hamilton, 1822)	LC	0.045	0.152
		Batashi	*Pachypterus atherinoides* (Bloch, 1794)	LC	2.564	1.729
	Ailiidae	Kajuli	*Ailia coila* (Hamilton, 1822)	LC	0.079	0.607
	Siluridae	Boal	*Wallago attu* (Bloch and Schneider, 1801)	VU	0.071	13.098
		Boali pabda	*Ompok bimaculatus* (Bloch, 1794)	EN	0.059	0.303
		Pabda	*Ompok pabo* (Hamilton, 1822)	CR	0.379	1.078
		Modhu pabda	*Ompok pabda* (Hamilton, 1822)	EN	0.053	0.186
	Sisoridae	Baghair	*Bagarius* (Hamilton, 1822)	CR	0.015	0.653
	Chacidae	Chaka	*Chaca* (Hamilton, 1822)	EN	0.009	0.302
Mugiliformes	Mugilidae	Khorsula	*Rhinomugil corsula* (Hamilton, 1822)	LC	0.084	0.365
Cypriniformes	Botiidae	Rani	*Botia dario* (Hamilton, 1822)	EN	1.191	1.538
	Cobitidae	Gutum	*Lepidocephalichthys guntea* (Hamilton, 1822)	LC	1.641	1.426
	Cyprinidae	Dhela	*Osteobrama cotio* (Hamilton, 1822)	NT	0.832	0.459
		Sarpunti	*Systomus sarana* (Hamilton, 1822)	NT	0.056	1.254
		Mrigal	*Cirrhinus cirrhosus* (Bloch, 1795)	NT	0.001	0.088
		Common carp	*Cyprinus carpio* (Linnaeus, 1758)	-	0.021	1.214
		Tit punti	*Pethia ticto* (Hamilton, 1822)	VU	0.536	0.455
		Phutani punti	*Pethia phutunio* (Hamilton, 1822)	LC	0.398	0.251
		Jat punti	*Puntius sophore* (Hamilton, 1822)	LC	1.809	3.909
		Kalibaos/Kalia	*Labeo calbasu* (Hamilton, 1822)	LC	0.115	9.578
		Bata	*Labeo bata* (Hamilton, 1822)	NT	0.057	0.910
		Gonia	*Labeo gonius* (Hamilton, 1822)	NT	0.011	0.826
		Laccho	*Cirrhinus reba* (Hamilton, 1822)	NT	1.357	7.215
	Danionidae	Patharchata	*Opsarius tileo* (Hamilton, 1822)	EN	0.014	0.455
		Mola	*Amblypharyngodon mola* (Hamilton, 1822)	LC	1.669	1.465
		Ful chela	*Salmostoma phulo* (Hamilton, 1822)	NT	1.766	1.396
		Narkeli chela	*Salmostoma bacaila* (Hamilton, 1822)	LC	0.094	1.062
		Chhep chela	*Devario* (Hamilton, 1822)	VU	0.289	0.091
		Darkina	*Esomus danrica* (Hamilton, 1822)	LC	1.035	0.364
Cyprinidontiformes	Aplocheilidae	Kanpona	*Aplocheilus Panchax* (Hamilton, 1822)	LC	0.717	0.152
Anabantiformes	Nandidae	Meni	*Nandus* (Hamilton, 1822)	NT	0.006	0.067
	Anabantidae	Koi	*Anabas testudineus* (Bloch, 1792)	LC	0.119	0.228
Ovalentaria	Ambassidae	*Gol chanda*	*Parambassis ranga* (Hamilton, 1822)	LC	3.427	1.760
		Lomba chanda	*Chanda nama* (Hamilton, 1822)	LC	3.11	1.442
		Lal chanda	*Parambassis lala* (Hamilton, 1822)	LC	0.407	0.076
Beloniformes	Belonidae	Kankila	*Xenentodon cancila* (Hamilton, 1822)	LC	0.651	1.032
Gobiiformes	Gobiidae	Bele	*Glossogobius giuris* (Hamilton, 1822)	LC	0.303	0.419
Tetraodontiformes	Tetraodontidae	Potka	*Leiodon cutcutia* (Hamilton, 1822)	LC	0.159	3.186
Cichliformes	Cichlidae	Tilapia	*Oreochromis niloticus* (Linnaeus, 1758)	-	0.014	0.394
Osteoglossiformes	Notopteridae	Foli	*Notopterus* (Pallus, 1769)	VU	0.022	0.212
Clupeiformes	Clupeidae	Kachki	*Corica soborna* (Hamilton, 1822)	LC	2.405	0.365
		Chapila	*Gudusia chapra* (Hamilton, 1822)	VU	0.018	0.492
Synbranchiformes	Mastacembelidae	Guchi baim	*Macrognathus pancalus* (Hamilton, 1822)	LC	0.039	0.728
		Tara baim	*Macrognathus aculeatus* (Bloch, 1786)	NT	0.018	0.303
		Sal baim	*Mastacembelus armatus* (Lacepede, 1800)	EN	0.041	1.037
Decapoda	Palaemonidae	Gura chingri	*Macrobrachium lamarrei* (H. Milne Edwards, 1837)	LC	30.027	6.559
		Chatka icha	*Macrobrachium malcolmsonii* (H, Milne Edwards, 1844)	LC	37.179	6.958
		Golda	*Macrobrachium rosenbergii* (De Man, 1879)	LC	0.099	1.144
Total					**100**	**100**

NT = Near threatened, LC = Least concerned, VU = Vulnerable, EN = Endangered, DD = Data deficient, CR = Critically endangered.

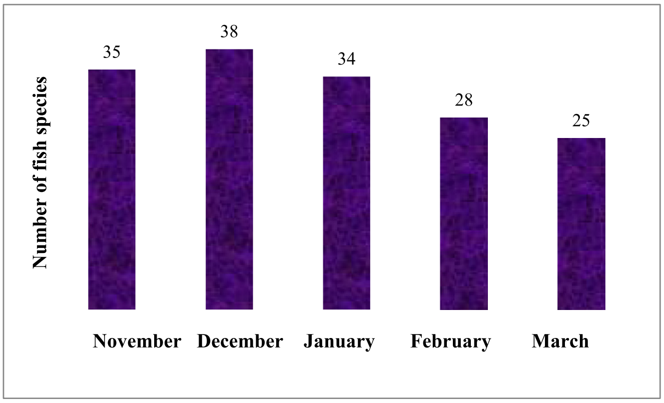

Figure 3. Monthly variation in species diversity.

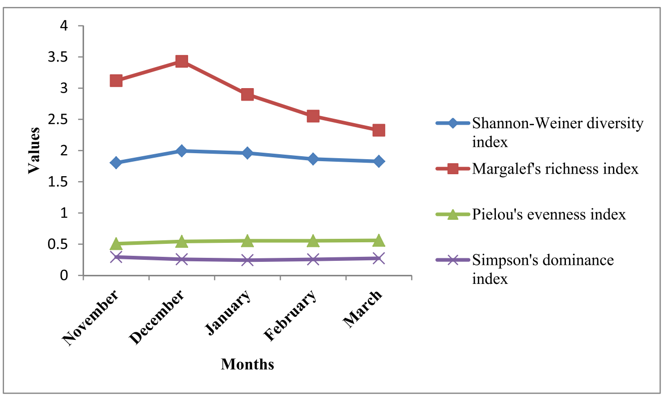

Figure 4. Values of different diversity indices in different months.

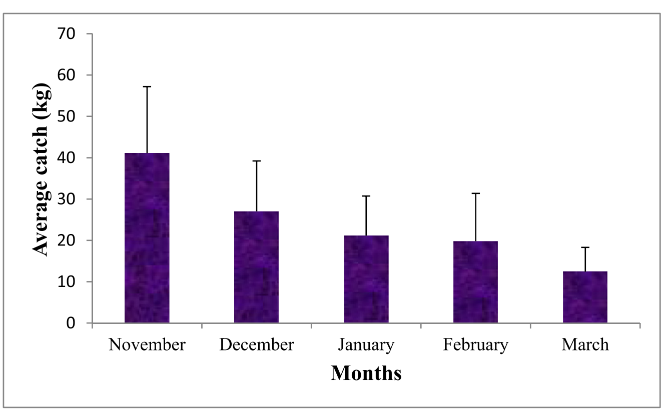

Figure 5. Average catch (kg) per *katha* in different months.

(1.13 ± 0.37) followed by November (1.06 ± 0.4), January (0.8 ± 0.25), February (0.71 ± 0.23), and March (0.52 ± 0.21).

3.7. *Katha catch per unit area (CPUA)*

The CPUA (kg/ha) of *katha* is presented in Figure 7. CPUA was the highest in November (264.66 ± 18.21), followed by December (205.05 ± 27.77), January (175.02 ± 76.04), February (147.73 ± 52.11), and March (102.08 ± 41.04). The variation of CPUA among different months was found to be significantly different ($p < 0.05$) (Table 2).

3.8. *Different types of fishing gear are used in fishing in the Shari-Goyain River*

Fishing gears used in the Shari-Goyain River were fishing nets, hooks and lines, wounding gear, and FADs. Different types of fish nets such as gill nets, seine nets, lift nets, cast nets, and dragged nets were used in this river. Hook and line, wounding gears such as *koach*, and traps such as *katha* were also used by the fishermen to catch fish.

3.9. *Fishing nets and crafts used in katha fishing*

Different types of fish nets and crafts were used in *katha* fishing of the Shari-Goyain River (Table 3). Three types of nets were used in *katha* fishing, such as the *jhakijal* (cast net), *berjal* (seine net), and *hutarjal*. The diameters of the *jhakijal* and *hutarjal* were 8.67 ± 0.63 m and 34.73 ± 26.18 m, respectively; the length and width of the *berjal* were 129.44 ± 11.86 m and 12.15 ± 1.08 m, respectively. There were small to medium-sized boats (*dinghies*) of 8.28 ± 1.21 m length and 1.40 ± 0.49 m width operated by one or two fishermen, and used during *katha* fishing. *Dinghi* was used to keep the fishes during harvesting and nets and to operate nets to catch fish.

3.10. *Impact of katha fishing in the Shari-Goyain River*

A total of 56 respondents were interviewed who were engaged in fishing directly or indirectly. It was found that there were many positive and negative impacts of *katha* and *katha* fishing.

3.11. *Positive impacts of katha*

Total 56 fishers and non-fishers were interviewed about the positive impacts of *katha* fishing. All the respondents stated that fish used *katha* as a shelter, 57.14% of respondents stated that fish used *katha* as a nursing ground for juveniles, 83.93% of respondents said that *kathas* were good sources of food, and 92.86% of respondents thought that harvesting rates were higher in *katha* than that of openwater catch (Table 4).

3.12. *Negative impacts of katha fishing*

Katha fishing has some negative impacts, which have been highlighted by the respondents (Table 5). Kruskal-Wallis One-way analysis of

Table 2. One-way ANOVA table showing the variation of CPUA (kg/ha) and individual *katha* catch for 5 months (November 2018 to March 2019).

Mean scores	Source of variation	Sum of squares	df	Mean square	F	Sig. (p)
CPUA (kg/ha)	Between groups	167,473.639	4	41,868.410	14.796	0.000
	Within groups	200,907.994	71	2,829.690		
	Total	368,381.633	75			
Individual *katha* catch (kg)	Between groups	4,590.011	4	1,147.503	10.301	0.000
	Within groups	7,908.903	71	111.393		
	Total	12,498.914	75			

*df = Degree of freedom, F = The F statistic used with ANOVA, Sig. = Significance.
The mean difference is significant at the 5% level.

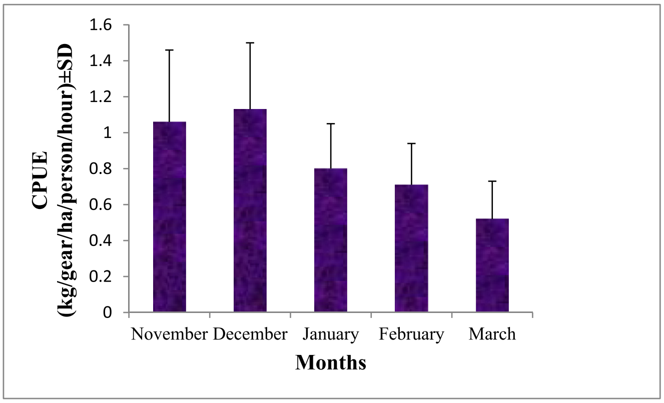

Figure 6. CPUE (kg/gear/ha/person/hour) of *katha*

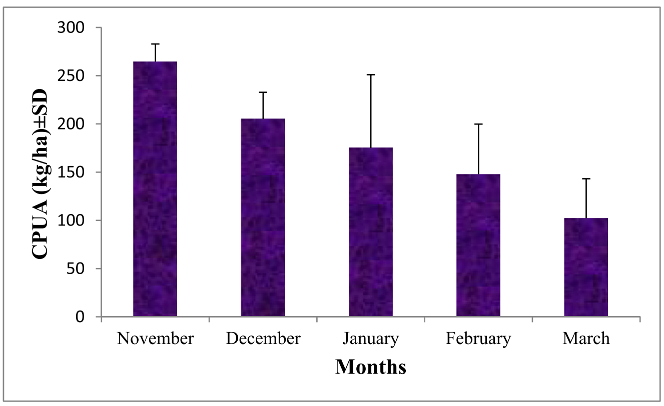

Figure 7. CPUA (kg/ha) of *katha*.

Table 3. Fishing nets and craft used in *katha* fishing.

	Local name	Length (m)	Width (m)	Diameter (m)
Net	*Jhakijal*	-	-	8.67 ± 0.63
	Berjal	129.44 ± 11.86	12.15 ± 1.08	
	Hutarjal	-	-	34.73 ± 26.18
Craft	*Dinghi*	8.28 ± 1.21	1.40 ± 0.49	-

variance (ANOVA) by ranks was used to summarize respondents' perceptions of the major negative impacts of *katha* fishing. They were arranged in a numbering system ranging from 1 to 7, representing the highest to lowest ranked impacts on the Shari-Goyain River ecosystem, respectively. According to the perception of the fishers', the most negative impact of *katha* fishing was reduction in open water fish catch (mean 92.50 units), followed by fish diversity decline (mean 140.50 units), damage of brood fishes due to indiscriminate fishing (mean 192.50 units), water pollution due to use of poison during *katha* fishing (mean 211.50 units), increasing siltation (mean 220.50 units), disturbing ecosystem (mean 246.50 units), and others (social conflict, boating problem, etc.) (Table 5). Notably, all the impacts identified and ranked by the respondents were statistically significant from each other.

4. Discussion

4.1. The abundance of aquatic species in the katha

A total of 54 species of fish and prawn were harvested from the *katha* and Siluriformes (catfishes) was the most dominant order constituting about 39.123% of the total catch, followed by Cypriniformes (33.956%), and Decapoda (14.661%). Talukder et al. (2021) found 66 fish species in the Shari-Goyain River and catfishes (28.79%) dominated among the 14 groups. As the authors studied for one year and collected data from both *katha* and open water fishing, the number of available fish species was different to the present study. Ahmed and Akther (2008) and Uddin et al. (2015) also reported that Siluriformes was the dominant order in the brush shelter of the Titas River (47%) and Kaptai Lake (37%), respectively. The abundance of Siluriformes was due to food (prey) availability, a hazard-free environment, and shelter for breeding and nursing. Based on relative abundance (%), *Macrobrachium malcolmsonii* was the most abundant species in the capture (relative abundance of 37.179%), followed by *M. lamarrei* (30.027%) and *Parambassis ranga* (3.427%). Most of the catfishes are predatory and find available preys in the *katha*. Notably, *Wallago attu* topped the capture by bulk weight, accounting for 13.098% of the total *katha* catch in the Shari-Goyain River. Gut content analysis of this species harvested from *katha* was performed by Islam et al. (2006) and found 14 different prey items. Among the main diet categories, fish supplied 74.3% by weight and 80.9% by occurrence to the entire diet, prawns 18.5% by weight and 11.0% by occurrence to the total diet, and plants 7.2% by weight and 8.1% by occurrence to the total diet (Islam et al., 2006). Despite the great degree of seasonality in *katha* fisheries, they are often controlled by a number of predators due to the abundance of their food in and around the *kathas*. The trophic diversity of *kathas* provides ideal feeding conditions for herbivores and planktivores, attracting high numbers of carnivores and piscivores. As a result, a specific food web based on *kathas* emerges, starting with herbivory and ending with piscivory. *Wallago attu* is an aggressive and voracious predator that could have an impact on the prey fish species' community structure and population growth (Islam et al., 2006). On the other hand, Rahman et al. (2016a) and Miah (2012) observed that Cypriniformes was dominant in Hakaluki *Haor* contributed 36% and 54%, respectively. Uddin et al. (2015) also found one exotic species (tilapia) and 2 species of prawn from the *katha* during the harvesting period. All these findings coincided with the present study.

Table 4. Positive impacts of *katha*

Sl. no.	Impacts	Percentage (%)
1	Used as temporary shelter for fishes	100.00
2	Harvesting rate is higher than open water as the fishes are aggregated in *katha*	92.86
3	Good food source for fish	83.93
4	Used as nursing ground for juveniles	57.14

4.2. Production from katha fishing

Fishing was done by hand picking, using wounding gear such as *koach* (spear), nets such as seine nets and cast nets with an average mesh size of 1.04 ± 0.85 cm. This mesh size is very small, so that undersized fish are also captured, and these kinds of nets are illegal for harvesting. The

Table 5. Results of Kruskal-Wallis test for ranking the negative impacts of *katha* fishing.

Impacts	Mean	Rank
Reduction in open water fish catch	92.50	1
Fish diversity decline	140.50	2
Damage of brood fishes due to indiscriminate fishing	192.50	3
Water pollution due to use of poison during *katha* fishing	211.50	4
Increasing siltation	220.50	5
Disturbing ecosystem	246.50	6
Others (social conflict, boating problem, etc.)	271.50	7
Chi-square	101.95	
Degree of freedom	6	
Asymptotic significance	0.000	

average *katha* catch was highest in November and lowest in March and the variation in the mean individual *katha* catch was significantly different ($p < 0.05$) among the months. In November, the average catch was higher because at that time, *katha* fishing had just started as the water started receding and fish availability was higher. The *katha* catch decreased as the intensity of *katha* fishing increased, reaching its lowest point in March. It might be due to the gradual decrease of total stock in the river. Notably, the monsoon (June–September) is the breeding season for almost all fish species in Bangladesh, and no natural recruitment occurs during the *katha* fishing period. Again, there was no chance to enter any fish from the nearby waterbodies as those were dried up or detached from the river, and there was less chance to migrate fish from the Surma River as it is deeper than the Shari-Goyain River. CPUA was the highest in November because water depth was lowering and *katha* harvesting started when fish stock was available in the river. The declination in CPUA (kg/ha) from November to the following months may be the resulted of increasing fishing pressure from *katha* fishing and open water catch. The CPUE (kg/gear/ha/person/hour) was found to be the highest in December (1.13 ± 0.37) and the lowest in March (0.52 ± 0.21). This variation in CPUE occurred due to fishing pressure in the earlier months, and as the water level was very low, fish migration stopped. To the best of the authors' knowledge, no references dealing with the CPUE of *katha* are available to validate and compare with this study.

4.3. Monthly variation of diversity indices

The Shannon-Wiener diversity index considers the richness and proportion of each species. According to the Shannon-Weiner diversity index (H′), the species diversity was the highest in December and the lowest in November. As in the case of the Shannon-Weiner diversity index (H′), the highest diversity index indicates high individuality and the lowest diversity indicates a low number of individuals. Diversity index was lowest in November because small numbers of *katha* were harvested in November. Species diversity decreased after December because the water level started receding and the harvesting rate was also higher in December. Mustafa (2017) recorded Shannon-Weiner diversity index (H′) values of 2.77, 2.98, 2.92, 2.89, 2.81, and 2.85 in the Titas River from 1997 to 2002. Iqbal et al. (2015) recorded Shannon-Weiner diversity index (H′) values ranging from 1.8 to 3.40 in the Hakaluki *Haor* and Hossain et al. (2017) found H′ values ranging from 2.07 to 2.41 in the Kushiara River. Chowdhury et al. (2019) recorded that the Shannon-Weiner diversity index fluctuated between 2 and 2.5, with a mean value of 2.30 ± 0.14 in the Surma River. In the present study, H′ ranged from 1.805 to 1.994, which indicates the less diversified fish population in the Shari-Goyain River. It might be related to changes in geographical location, the effects of coal mining drainage, fish biological condition, water quality, different fishing techniques, and harvesting frequency. The Margalef's richness index was the highest in December (3.430) and the lowest in March (2.325). That means the sample size of fish was the highest in December and also the number of individuals, as new individuals were added to the stocks, which increased the species richness. Siddique et al. (2016) recorded the average highest richness (d) value of 8.39 in December and the lowest, 4.53, in July in the entire Chalan *Beel*. Galib et al. (2013) recorded a richness value that varied from 6.973 in June to 8.932 in November for the Choto Jamuna River in Bangladesh. According to Nair et al. (1989), to some extent, the Margalef's richness index may be different from the actual diversity value because it depends on sample size, not on the evenness and species richness of the data.

The evenness index was calculated at 0.508, 0.544, 0.555, 0.554, and 0.561 in November, December, January, February, and March, respectively. The study revealed that the distribution of species in the Shari-Goyain River was equally distributed in different months. Hossain et al. (2017) found Pielou's evenness index (J) between 0.99 and 1.15 in the Kushiara River and Iqbal et al. (2015) recorded evenness index fluctuating from 0.79 to 0.9 for the Surma River. Jannatul et al. (2015) showed an evenness index of 0.36–0.76 for the Halda River. Chowdhury et al. (2019) found the maximum Pielou's evenness index value was 2.2 in April and the minimum value was 1.47 in July, with a mean value of 1.93 ± 0.23 for the Surma River. Dominance index represents the fraction of common species. Simpson's dominance index (d) values were the highest in November (0.294) and the lowest in January (0.244) found in the Shari-Goyain River. The greater the index value, the greater the sample diversity of the dominant species suppressing others. Hossain et al. (2017) recorded the Simpson's dominance index at 2.78 to 7.23 for the Kushiara River. Chowdhury et al. (2019) recorded the highest value of the Simpson's dominance index at 7.98 in August and the lowest value of 5.32 in October, with an average value of 6.99 ± 0.86. Rahman et al. (2016b) recorded a dominance index of 0.064 to 0.0133 in the Bishkhali River of Barguna district. The possible causes of the difference in the diversity indices during the study period might be the high intensity of fishing pressure and the drastic reduction of water from the river.

4.4. Impact of katha fishing in the Shari-Goyain River

During the study period, 38 species were found available in December, followed by November (35), January (34), February (28), and March (25). Significant differences in species availability were noticed due to gradual lowering of water depth, high harvesting frequency, efficiency of gears, deterioration of water quality, and the biological condition of fishes. Islam et al. (2019) observed 49 and 39 fish species in November and December, respectively in the Juri River of Sylhet district, which are higher than those of the present study. Possible reasons behind this difference are variations in location and the catch was from open river catch, not only from *katha*. In the study area, *katha* was harvested 2.21 ± 0.78 times after establishment in a season. Mustafa (2017) also found that a single *katha* was harvested 2 to 3 times repeatedly in a season, which supports the present study. Various *katha* materials were used in *katha*, such as bamboo, branches of trees, etc. which make it a temporary shelter where fish can take shelter, and be used as a feeding, breeding, and nursing ground (Uddin et al., 2015; Sharma et al., 2014; Joadder et al., 2016; Kunda et al., 2022). *Katha* materials acted as substrates for periphyton growth, which is used as fish food. Thus, *katha* provides a short-term shelter and food for various types of fishes (Mustafa, 2017). For the above reasons, many threatened species were found available in the *katha*. On the classification table, all species are classified according to the IUCN Red List in Bangladesh (IUCN Bangladesh, 2015), and a total of 16 threatened fish species are found, including 2 critically endangered, 7 endangered, and 7 vulnerable. This is an encouraging sign that the *katha* shelter can be helpful for the conservation of threatened fish species if it is not harvested.

On the other hand, the main perceived negative consequence of *katha* fishing is a decrease in open water capture fisheries, followed by a decline in fish diversity, destruction of brood fishes, water pollution owing to poison use during *katha* fishing, increased siltation, and disturbance to the ecosystem. Uddin et al. (2015) also found *katha* fishing destructive because of indiscriminate and complete harvest of *katha*. Mustafa (2017) also stated that *katha* fishing is a destructive fishing method. Sultana et al. (2017) found *katha* fishing as a threat to Bhawal *Beel* biodiversity. Galib et al. (2009), Pandit et al. (2015), Rahman et al. (2016a) and Pandit et al. (2021) also stated the negative impact of *katha* fishing, which coincided with the present study. Though this type of fishing is prohibited according to fisheries regulations in Bangladesh (Joadder et al., 2016), its intensity in the Shari-Goyain River is increasing day by day. According to the Protection and Conservation of Fish Act (1950), the construction of permanent or temporary structures in the wetlands, the use of nets of below prescribed mesh sizes, in addition to the catching of undersized fish, are strictly prohibited. However, the poor people engaged in *katha* fishing are compelled to disregard the regulations to meet their financial and basic needs, which are not monitored by the respective authorities. As of now, this is more of a preliminary description of *katha* fishing and the biodiversity associated with a fished *katha*. However, it provides the message that to conserve species diversity in the river, *katha* fishing should be stopped or converted into permanent fish sanctuaries (Kunda et al., 2022).

5. Conclusion

The Shari-Goyain River is an important river in Bangladesh, and *katha* fishing is very common in this river, which has impacts on fish biodiversity. Soon after the monsoon, the water level in this river began to fall, and from January to March, there was insufficient water to provide shelter, feeding, and nursing for fish, except in a few deeper sections of the river. *Kathas* are being operated in the deeper portions, and fish enter the *katha* for their shelter and are badly harvested by the fishers, resulting in very few of the brood fish being left for next year's breeding. Thus, this fishing method increases the vulnerability of rare and endangered fish species in the river. According to the key informant and the observation of our study team, *katha* fishing should be stopped and several effective sanctuaries need to be established to revive and enhance fish biodiversity in the Shari-Goyain River.

Declarations

Author contribution statement

Sumi Rani Das: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Debasish Pandit: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Ahmed Harun-Al-Rashid: Analyzed and interpreted the data; Wrote the paper.

Nishat Tasnim: Performed the experiments.

Mrityunjoy Kunda: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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