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Bangladesh J. Fish. Res., 20(1-2), 2021 : 1-6

Induced breeding performance of Dhela (*Osteobrama cotio*) with pituitary gland (PG) Extract

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Abstract
The experiment was conducted to develop an induced breeding technique for Dhela (*Osteobrama cotio*). Three different treatments were carried out on induced breeding of Dhela at the hatchery complex under the Freshwater Station, Bangladesh Fisheries Research Institute, Mymensingh from May to June 2021. To develop the induced breeding technique three different doses viz. 2, 4 and 6mg PGkg^{-1}body weight of the females fish were used. Three different PG doses were designated as T_1, T_2 and T_3, respectively. Oppositely, male fish were treated with only 2mg PGkg^{-1}body weight. Single PG doses were applied in both female and male fish at the same time. After 6 hours of PG induction, fish exposed a minimum response in T_1 and T_2 but T_3 showed a good response in consideration of spawning, fertilization and hatching. The highest average ovulation rate 95.5 ± 0.50 was recorded in T_3 while the lowest value 25.10 ± 3.5 was found in T_1. The highest fertilization rate 97.22 ± 11.10 was recorded in T_3 while the lowest 40.52 ± 3.12 was found in T_1. The recommended dose for the successful induced breeding of Dhela was 6mg PGkg^{-1}body weight for females and 2mg PGkg^{-1} body weight for males. The findings of the present study can be used in the induced breeding of Dhela for the development of hatchery propagation as well as to conserve and manage this species.

Keywords: *Osteobrama cotio,* induced breeding, spawning and fertilization

Introduction

Osteobrama cotio locally known as Dhela is one of the most favourite and tasty fish which was once abundant in Bangladesh. Being a small indigenous species (SIS), it provides nutritional supplements to a large section of economically backward populations. Dhela is one of the prime nutrient-rich small indigenous fishes that contain about 31 mg dehydroretinol, and 22 mg retinol per 100 mg of fresh edible tissue within a 2.7 to 3.0 g of fish (Zafri and Ahmed, 1981). Dhela is an essential source of vitamins and minerals and is mainly consumed in fresh conditions where the fish is caught in the Brahmaputra, Barak, and lower parts of the Teesta river (Kumar and Goswami, 2013). Dhela plays an important role in the diet for the healthy growth and development of lactating mothers. In addition to other nutrients, it is a source of vitamin-A, calcium, iron, zinc, and other micronutrients. This species is red-listed as a near threatened (NT) species by IUCN (2015) due to the significant declination of population and if it continues and the threats are not removed the species will face the risk of extinction (IUCN, 2015). Therefore, scientific information about Dhela is crucial for the conservation of the species. The decline of the Dhela population in Bangladesh is taking place due to many factors especially overpopulation, habitat destruction, overfishing, and water pollution. Some man-made interventions and environmental factors declined the fish stock by affecting fish migration, spawning, and nursing ground. However, due to such problems, this species is now under severe threat of extinction. There is no evidence of seed production technology and cultural practice of Dhela in Bangladesh. Therefore, the present study was taken to develop the induced breeding technique of Dhela.

Materials and methods

Experimental Site

Induced breeding trials were conducted in the hatchery complex of Freshwater Station, Bangladesh Fisheries Research Institute**,** Mymensingh from May to June 2021.

Collection of Dhela fish

A total of three thousand Dhela were collected from the River Brahmaputra of Mymensingh from May to September 2020. Collected Dhela were transported in an oxygenated polythene bag to the Freshwater Station, Mymensingh. After transportation, the fry was stocked in a brood-rearing pond. The average initial length and weight of Dhela were 5.18 ± 2.05cm and 3 ± 2.04g, respectively. The stocked fishes were reared with 28% protein-contained feed at the rate of 8-4% body weight of fish twice a day. Additionally, the ponds were treated with fertilizer application using Urea and TSP at the rate of 25 kg/ha and 12 kg/ha, respectively.

Experimental design

In this experiment, three treatments were carried out for the development of induced breeding of Dhela. Three different doses of PG viz. 2.0, 4.0 and 6.0mgkg^{-1} body weight of female fish were used in three treatments which were designated as T_1, T_2, and T_3, respectively to develop an induced breeding technique. Ninety females and ninety males were collected and divided into three treatment groups (30 females and 30 males) in each treatment and kept in separate glass nylon hapa which was previously set up in a cistern. On the other hand, in the case of males, only 2mg PGkg^{-1}body weight was used in all treatments.

Sex identification

The gravid females were easily identified by their swollen abdomen and round or oval and swollen urogenital papillae and also female fish is larger than male. The mature males were identified by their flat abdomens.

Selection of the brood fish

The brood fish were caught from the brood-rearing pond and transferred to the hatchery. Selected matured females and males were weighed and kept into hapa which is set up in a cistern for conditioning for about 6 hrs before being treated with carp PG extract. The males and females were kept in separate hapa and continuous water flow was maintained to ensure dissolved oxygen for the brood fish. However, no feed was provided during the conditioning period.

Injecting the PG extract into fish

Based on the body weight of the gravid female fish, the required volume of extract (1.0ml kg^{-1}) was taken in a graduated 1.0ml hypodermic syringe. The selected brood fish were carefully taken for injecting the PG extract. The extract was injected intramuscularly just below the pectoral fin of the fish. The whole dose was injected into the females at a time. All the males were injected at the dose of 2mg PGkg^{-1} body.

Indices of the effectiveness of PG dose

The following parameters were recorded as the indices of the effectiveness of different PG doses, percent spawning, percent fertilization; and percent hatching was calculated using the following formula:

- Ovulation rate = $\dfrac{\text{No. of ovulated fish}}{\text{Total no. of injected fish}} \times 100$

- Fertilization rate = $\dfrac{\text{No. of fertilized eggs}}{\text{Total no. of eggs (fertilized + unfertilized)}} \times 100$

- Hatching rate = $\dfrac{\text{No. of hatched eggs}}{\text{Total no. of eggs}} \times 100$

Data analysis

Several indices of the effectiveness of PG dose were analyzed by Microsoft Excel 2016 package as descriptive values such as mean and percentage. The statistical data analysis was carried out with the aid of the computer software SPSS version 21 (Statistical Package for Social Science).

Results and discussion

Three treatments were conducted for induced breeding of Dhela with PG extract during the months of May to June 2021. Data representing the effects of PG doses on the spawning of female fish, the rates of fertilization, and the hatching of eggs are presented in (Table 1). To develop induced breeding, three different doses of PG viz., 2.0, 4.0, and 6.0mg kg^{-1} body weight were used in treatments T_1, T_2, and T_3, respectively.

The treatment results the partial spawning with the 1st dose applied in T_1 but with the 2nd and 3rd doses applied in T_2, and T_3 showed moderate and good response respectively in consideration of spawning, fertilization and hatching. Fish showed partial response with the 2.0mg kg^{-1} body weight dose applied in T_1 but the 4.0 and 6 g kg^{-1} body weight doses applied in T_2 and T_3 respectively showed moderate and good response in consideration of ovulation, fertilization & hatching rates.

Table 1. Response of different doses of Pituitary Gland (PG) extract for induced breeding of Dhela

Treatment	Mean Body weight (g)		1st Injection dose (mg/kg^{-1})		Spawning period (hr)	Spawning rate (%)	Fertilization rate (%)	Hatching period (hr)	Hatching Rate (%)	Incubation Temp. (^{o}C)	Remarks
	Male	Female	Male	Female							
T_1	5.01± 0.61	10.24± 2.2	2	2	7-8	25.1 ±3.5^{d}	40.52± 3.12^{d}	22	35.04± 8.22^{d}	32	partial ovulation
T_2	5.07± 0.22	11.42± 2.1	2	4	7-8	50.1 ±4^{c}	50.62± 5.07^{c}	22	43.44± 10.73^{c}	32	moderate ovulation
T_3	4.83± 0.74	10.03± 4.0	2	6	7-8	95.5 ±0.5^{a}	97.22± 11.10^{a}	22	95.36± 11.26^{a}	32	complete ovulation, successful fertilization & hatching

*Figures with the same letter are not significantly ($p<0.05$) different.

From the study, the spawning rate showed noticeable differences in effectiveness among the three doses. The spawning rates were recorded as 25.1%, 50.1% and 95.5% in the treatments of T_1 (2mg PGkg^{-1}), T_2 (4mg PGkg^{-1}), and T_3 (6mg PGkg^{-1}), respectively (Table 1). The time interval between the injection of PG extract and spawning (latency period) varied between 6 hrs. of injection in all cases. The highest average spawning rate (95.5±0.5%) was recorded in T_3 whereas the lowest value (25.1 ±3.5%) was found in T_1 (Table:1). Among three doses of PG in consideration of the spawning rate in T_3 showed the highest result followed by T_2 and T_1. The results from the DMRT test indicated that there was a significant difference among the treatments, T_3 showed a significantly ($p<0.05$) higher spawning rate than T_1 and T_2 (Table 1). Bhuiyan *et al*., (2006) used PG doses at the rate of 3, 6, 9, 12 and 15mg kg^{-1} body weight and found that the dose of 6mg kg^{-1} body weight was most efficient for induced breeding for *P. gonionotus*. Siddik *et al.*, (2008) showed better results in terms of ovulation when using 5.5mg PGkg^{-1}body weight of females for Sarputi (*P. sarana*). Selina *et al.*, (2021) found better spawning performances of *P. sophore* at 6.0 mg kg^{-1} body weight PG. For induced breeding of *P. sarana* dose of 5-8 mg PGkg^{-1} body weight was recommended for the female, while a single dose of 4 mg PGkg^{-1} was recommended for males (Mazid and Kohinoor, 2003). In this experiment, 6.0mg PGkg^{-1}body weight of female were used for Dhela, which showed better results in case of spawning which is near to the result of Siddik *et al.*, (2008). Chakraborty *et al.*, (2002) showed better results in terms of ovulation when using 6.5 mg PGkg^{-1}body weight of female Sarputi which is close to Dhela, in the present study. Differences in the spawning rate can be attributed to the differences in species, maturity and size of broods, PG doses, seasonal variations, and water temperature.

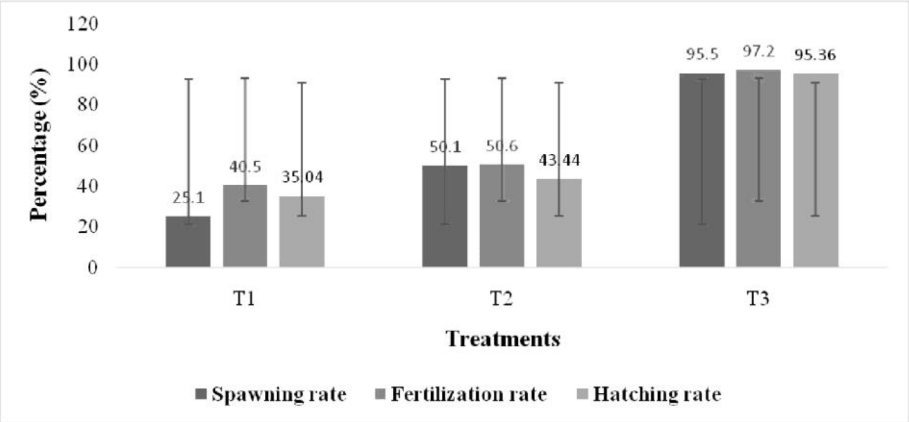

Fig. 1. Effects of different doses of PG in terms of spawning, fertilization, and hatching rate

The average fertilization rate was recorded as 40.52 ± 3.12, 50.62 ± 5.07, and 97.22 ± 11.10 in treatments T_1, T_2, and T_3, respectively. The highest fertilization rate (97.22%) was recorded in T_3 while the lowest (40.52%) was found in T_1. The results from the DMRT test indicate T_3 showed a significantly (p<0.05) higher fertilization rate than that of treatments T_1 and T_2 (Table 1). Siddik *et al.*, (2008) found better results in terms of fertilization when using 5.5mg PGkg^{-1}body weight of females for *P. sarana*. In this experiment, 6.0mg PGkg^{-1}body weight of female was used for Dhela, which showed better results in the case of fertilization which is similar to the result of Siddik *et al.*, (2008). Chakraborty *et al.*, (2002) showed better results in terms of fertilization when using 6.5mg PGkg^{-1}body body weight of the female Sarputi, which is close to Dhela. Some little variation might be due to species differences, water quality, water temperature, and brood management.

The hatching rate was found at 35.04%, 43.44%, and 95.36% in treatments of T_1, T_2, and T_3 respectively (Table 1). The highest hatching rate was recorded at 95.36% in T_3 and the lowest hatching rate was recorded at 35.04%, in treatment T_1. The result from the DMRT test indicated that there was a significant difference between the three doses. It was found that the hatching rate in T_3 was significantly (p<0.05) higher than that of T_1 and T_2. Siddik *et al.*, (2008) observed better results in terms of hatching when using 5.5mg PGkg^{-1}body weight of female Sarputi (*P. sarana*). In this experiment, 6mg PGkg^{-1}body weight of female were used for Dhela, which showed better results in the case of hatching rate which is similar to the result of Siddik *et al.*, (2008). Chakraborty *et al.*, (2002) found better results in terms of hatching rate when using 6.5 mg PGkg^{-1}body weight of females for Sarputi which is similar to Dhela.

Conclusion

The present work on induced breeding of Dhela was conducted to develop successful induced breeding at the hatchery for mass seed production that would tremendously be helpful at the farmer level. The results of the present study showed that PG at 6mg PGkg^{-1}body weight for females and 2mg PGkg^{-1}body weight for a male is appropriate for induced breeding in Dhela**.**

From the study, it can be concluded that Dhela can easily be induced, reared and conserved.

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Bangladesh J. Fish. Res., 20(1-2), 2021 : 7-15

Blooms of *Microcystis* spp. in the Cox's Bazar Coast of Bangladesh

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Abstract
The dynamic environmental conditions of the Bay of Bengal possess several unique features that lead the bay as a conformable zone for different harmful algal bloom species. This study presents a bloom event of cyanobacteria *Microcystis* spp. along the coastal waters of Bangladesh that appeared in winter and disappeared abruptly during spring. A clear high-range concentration of *Microcystis* spp. was observed in the Maheshkhali Channel (26.4×10^4 colonies/L) and Bakkhali River Estuary (21.9×10^4 colonies/L) along the Cox's Bazar coast of the Bay of Bengal. During mid-winter, the highest percent composition of the bloom-forming species was found in the Maheshkhali Channel. The three distinct morphologies of *Microcystis* spp. ("Large", "Medium" and "Small" colonies) were depicted as major types whereas small colonies contribute the highest percentage than other forms. The abundance of *Microcystis* spp. observed in the present research indicate the necessity of regular monitoring of the coastal waters of Bangladesh and to take proper measures to avoid harmful algal blooms.

Keywords: Cyanobacterial bloom; *Microcystis* spp.; Colony; Density; Bay of Bengal

Introduction

The history of marine pollution goes back to the very beginning of the history of human civilization. Most of the coastal areas of the world have been reported to be damaged by pollution, significantly affecting commercial coastal and marine fisheries, triggering the potential extent of eutrophication. Due to the production of food and energy to support the overgrowing people, land-based nutrients (such as nitrogen and phosphorus) inputs to coastal systems in the Bay of Bengal have been markedly increased in recent times. The resulting nutrient enrichment has contributed to coastal eutrophication, deterioration of water quality and coastal habitats, and increases in hypoxic waters, which in turn has facilitated the occurrence of harmful algae and their noxious blooms along the biologically rich marine and coastal ecosystems of the Bay of Bengal.

Microcystis is a cosmopolitan genus of cyanobacteria and occurs in many different forms. The notorious blooms of *Microcystis* spp. can cause serious environmental and ecological damage, such as reduction in water clarity and quality, production of foul odours, and drinking water crises (Qin *et al.,* 2010; Xiao *et al.,* 2018). Some *Microcystis* spp. can produce toxic microcystins that are hazardous to the health of aquatic organisms and even human beings (Rastogi *et al.,* 2014; Xiao *et al.,* 2018). Many environmental factors promote *Microcystis* spp.

bloom formation, such as warmer temperatures, weak turbulence, algae cells with sufficient buoyancy, and increased nutrient input (Reynolds and Walsby, 1975; Yin *et al.*, 2016; Yu *et al.*, 2018; Richardson *et al.*, 2019). Among these factors, excessive nutrient inputs, especially nitrogen, are widely accepted as one of the most important causes for outbreaks of harmful *Microcystis* spp. in marine ecosystems.

A number of publications are available on the occurrence of *Microcystis* spp. in brackish and marine waters (Thajuddin *et al.*, 2002; Selvakumar and Sundararaman, 2007; Velankar & Chaugule, 2007; Reginald, 2007). However, the present study attempts to investigate the occurrence of *Microcystis* spp. bloom in the coastal waters of the Bay of Bengal, Bangladesh. Our findings along this renowned Bay reveal a bloom of *Microcystis* spp. during winter especially mid-winter.

Materials and Methods

Study Area

The present study was carried out in the Bakkhali River Estuary and Maheshkhali channel, situated at the south-eastern coast of the Bay of Bengal. Three sampling stations (S) were selected from each site; S_1, S_2 and S_3 in the Bakkhali River Estuary and S_4, S_5 and S_6 in the Maheshkhali Channel along the Cox's Bazar coast of Bangladesh. Bakkhali River brings huge amount of domestic, agricultural and industrial wastes, and opens into the Bay of Bengal in the south. The Maheshkhali channel is very important as a large fishing area. Different traditional capture fisheries and commercial shrimp farms have developed around both the Estuary and the Channel. These sites are considered as highly productive because of excessive nutrients invaded from industrial wastes, agricultural lands, rural and urban sewages and from adjacent shrimp/bivalve farms, which sometimes induce the growth of many harmful algal blooms.

Method

Water samples were collected from January to March, covering three seasons: mid-winter (January), late-winter (February), and spring (March). Monthly plankton samples were collected using a 25 µm mesh plankton net. The samplings were made during day time at high tide. For qualitative plankton study, a plankton net was towed just under the water surface for 1 minute at a speed of approximately 1 m/s. From the net, the collected samples were drained in a polyethylene bottle and preserved with 5% buffered formalin in seawater. For quantitative study, a known volume of sub-surface water was passed through a plankton net (mesh 25 µm) and the concentrate was collected from the bucket and preserved in 5% buffered formalin in seawater. The quantitative estimation of phytoplankton was done by counting colonies in a 1 mL Sedgewick-Rafter counting chamber under an Optima Biological microscope (G-206) following the sedimentation method (Utermöhl, 1958). A subsample (1 mL) was drawn from the concentrated sample and dispensed into the counting chamber, which was scanned thoroughly, ensuring that all colonies were counted. As the extensive bloom of *Microcystis* spp. colonies was observed in the samples, they were counted following the dilution technique. *Microcystis* spp. was identified following the morphological description given by Feng *et al.* (2019) and Radkova *et al.* (2020). Differences between different groups were analyzed by one-way ANOVA with LSD (Least Significant Difference) with SPSS.

Results

Microcystis spp. was determined as the bloom-forming species during the study period (Fig. 1). The highest abundance of the species was counted as 26.4 × 10^4 colonies/L during mid-winter at S6. The second highest abundance was found as 24.7 × 10^4 colonies/L at S_4 during the same period of mid-winter.

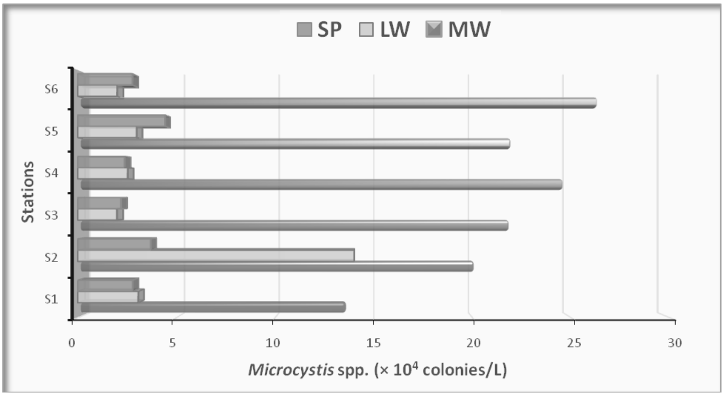


Fig. 1. The abundance of *Microcystis* spp. colony along the Cox's Bazar coast of Bangladesh (MW = Mid-Winter, LW = Late Winter, SP = Spring).

The present study reported that *Microcystis* spp. dominated over the total phytoplankton biomass during the bloom-period (mid-winter). This species accounted for significant proportions of the total phytoplankton biomass in the surface water. Massive growth of bloom-forming *Microcystis* spp. found primarily in nutrient-enriched waters of the Bakkhali River Estuary and the Maheshkhali Channel. The percent composition of *Microcystis* spp. in three different seasons were recorded at both sites (Fig. 2 & 3). The highest percent composition of the species was found during mid-winter representing 81% and 67% in the Maheshkhali Channel and in the Bakkhali River Estuary, respectively.

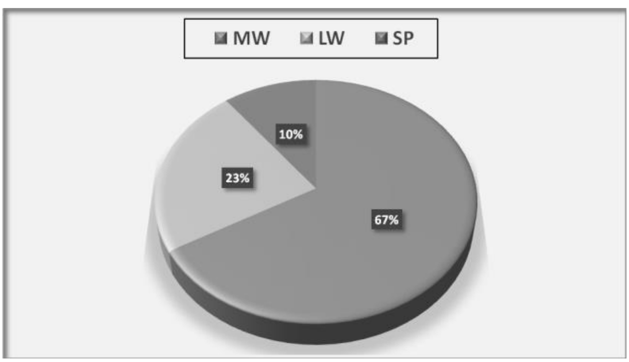


Fig. 2. Percent composition of *Microcystis* spp. colony along the Bakkhali River Estuary, Bay of Bengal, Bangladesh (MW = Mid-Winter, LW = Late Winter, SP = Spring).

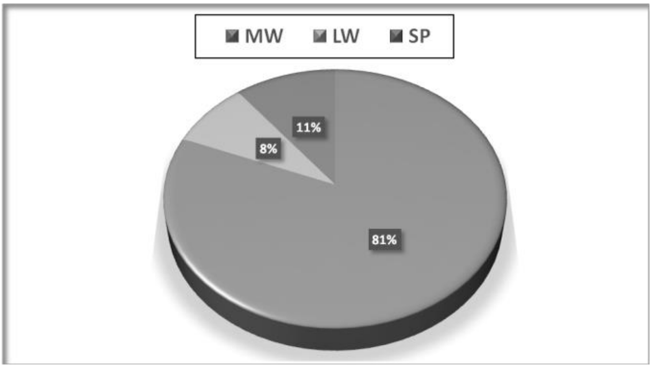
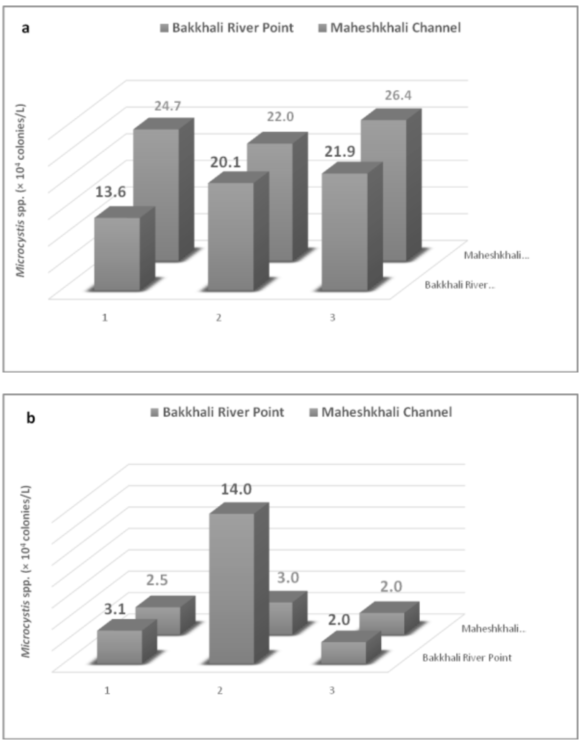


Fig. 3. Percent composition of *Microcystis* spp. colony along the Maheshkhali Channel, Bay of Bengal, Bangladesh (MW = Mid-Winter, LW = Late Winter, SP = Spring).

In mid-winter, the highest colonial density of *Microcystis* spp. was recorded compared to both late-winter and spring (Fig. 4). In late-winter, the highest abundance of *Microcystis* spp. reached 14 × 10^4 colonies/L along Bakkhali River Estuary at S_2 and also the lowest abundance (2× 10^4 colonies/L) was recorded both at S_3 and S_6. In spring, the abundance was decreased to less than 14 × 10^4 colonies/L at each sampling station.



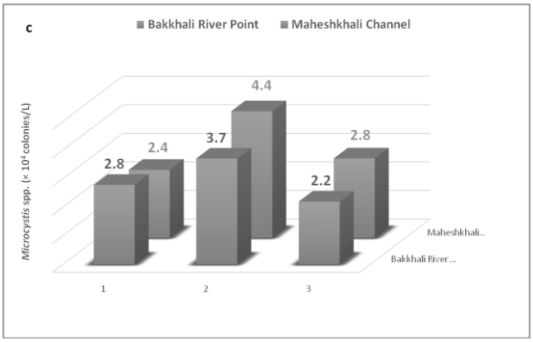


Fig. 4. The abundance of *Microcystis* spp. colonies during (**a**) Mid-Winter, (**b**) Late Winter, and (**c**) Spring along the Cox's Bazar coast of Bangladesh.

The algal blooms of *Microcystis* spp. observed as colonial, which means that the single cells joined together in groups as colonies which tend to float near the water surface. These colonial morphologies were divided into three forms - large, medium and small colonies (Fig. 5). Small colonies contributed the highest percentage (64%) than the other forms. The variation of the percent composition of large, medium and small colonies of *Microcystis* spp. in the Cox's Bazar coast, Bangladesh are illustrated during the three different months (Fig. 6).

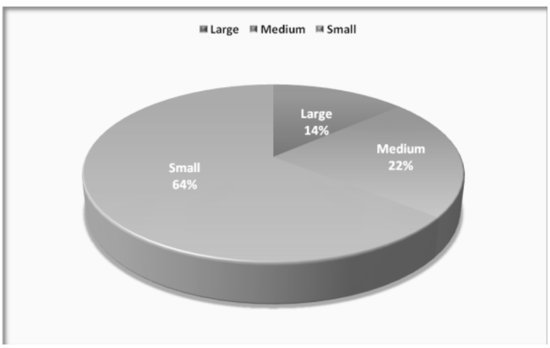
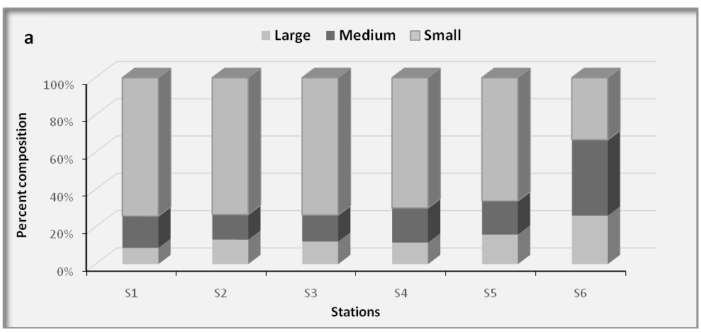


Fig. 5. Percent composition of different morphologies of *Microcystis* spp. colonies along the Cox's Bazar coast of Bangladesh.



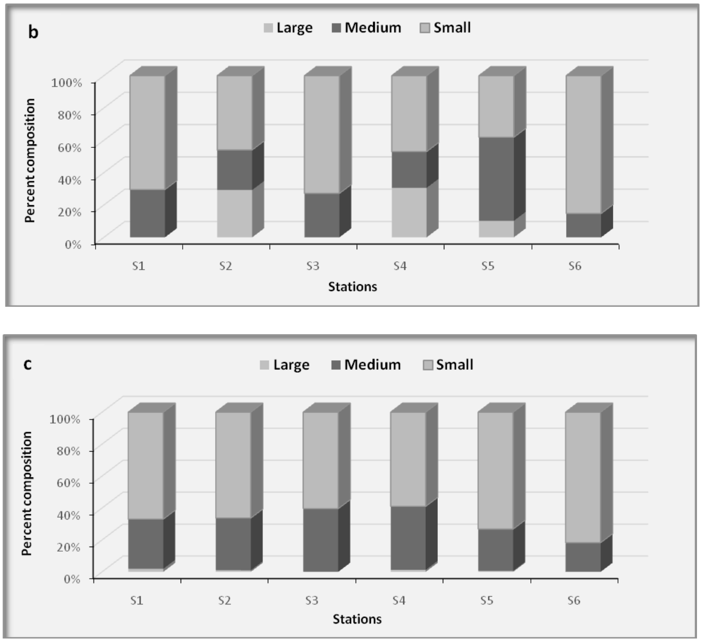


Fig. 6. Percent composition of large, medium and small colonies of *Microcystis* spp. during (a) mid-winter, (b) late winter, and (c) spring along the Cox's Bazar coast of Bangladesh.

Discussion

Harmful cyanobacterial blooms (CyanoHABs) can thrive under a wide range of environmental conditions and often associated with eutrophic waters. Although nutrient loading is a strong risk factor for bloom promotion, no single anthropogenic or environmental factor has been specified to cause bloom formation. Large scale ecological disturbances associated with urbanization, rising agricultural activities, and introduction of invasive species (Bykova *et al.*, 2006), combined with climate change have escalated the intensity, frequency and geographic distribution of CyanoHABs (Carey *et al.*, 2012, Paerl and Huisman, 2009, Paerl and Paul, 2012, Visser *et al.*, 2016). Pedde *et al.* (2017) analyzed the current and future trends in river export of nutrients to the Bay of Bengal Large Marine Ecosystem (BOBLME) up to 2050, and the associated potential for coastal eutrophication. Loads of nutrients exported by rivers to the coastal waters have been increasing in the BOBLME during the past decades (Sattar *et al.*, 2014), leading to changes in nutrient stoichiometry (Tripathy *et al.* 2005), and as an outcome, harmful algae blooms.

A bloom of *Microcystis* spp. on the water surface of the Bay of Bengal, Bangladesh was observed during the cruise track in the present study. The highest *Microcystis* spp. density was 26.4×10^4 colonies/L and 21.9×10^4 colonies/L at bloom sites of the Maheshkhali Channel and Bakkhali River Estuary, respectively during mid-winter. Similar winter blooms of

Microcystis spp. which have contributed to most of the total algal biovolumes were reported by Ma *et al.* (2016).

At the beginning of January, *Microcystis* spp. was the dominant species found in the present investigation, comprising most of the phytoplankton volume. The *Microcystis* spp. blooms dominated during the winter period and this species flourished in the studied coastal waters of Bangladesh. At Vellar Estuary, southeast coast of India, *Microcystis* spp. was the dominant species during December (Santhosh Kumar *et al.* 2010). In general, cyanobacterial dominance often occurs when water temperature rises above 20°C, this pattern also occurs in subtropical waters, including coastal systems (Murrell and Lores, 2004).

In this study, morphological variation was also found in *Microcystis* spp. which are differed by large, medium and small colonies. Small colonies showed the highest percent composition than the other two forms. Balaji Prasath *et al.* (2014) observed colonial blooms of *M. aeruginosa* in the Muttukkadu Backwater, southeast coast of India on 1st June 2012. Hence, the morphological variation of *Microcystis* spp. colonies in culture were reported by Otsuka *et al.* (2000).

Various physico-chemical and biological factors may be responsible for the existence of dominant *Microcystis* spp. in an environment (Takamura, 1988). *Microcystis* can affect phytoplankton community composition through allelopathy (Legrand *et al.*, 2003). In nature, the response of the plankton community is variable and probably depends on environmental conditions (Graneli *et al.*, 2008), but the full impact of *Microcystis* on plankton communities in the field is poorly understood. *Microcystis* spp. cell abundances and toxin concentrations in the coastal waters of Bakkhali River Estuary and Maheshkhali Channel are needed to be monitored for the welfare of the people because the said waterbodies are used for fisheries and other commercial activities. Moreover, pollution sources which accelerate to eutrophication process of these regions needed to be obstructed. The toxic effects and the risks to the population due to the presence of cyanobacteria in water sources are very big and the critical examples are diarrhea, nausea, muscle weakness, cutaneous paleness and liver tumors (Falconer *et al.*, 1994). This paper documents the occurrence of a harmful algal bloom of the colonial form of *Microcystis* spp. along the Bay of Bengal, Bangladesh.

Conclusion

This study records the significant winter blooms of *Microcystis* spp. in the Cox's Bazar coast of Bangladesh. In general, the blooms can rise to a film on the surface of the water, decreases water clarity and prevent normal oxygenation of the water. These, in turn, may cause the mortality of fishes. Pollution from various non-point sources are seen to trigger algal blooms and upset the normal phytoplankton composition of the study area. The pollution abatement facilities like the sewage and domestic waste treatment at Bay area are inefficient, resulting in indiscriminate discharge of wastes into the waters. The present investigation highlights the need for regular monitoring of harmful algal blooms and the physico-chemical characteristics of the coastal waters of the Bay of Bengal, Bangladesh in order to conserve fish stocks and safeguard human beings.

Acknowledgments

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Impact of Fishing Ban in the Major Spawning Grounds of Hilsa, *Tenualosa ilisha* (Hamilton, 1822) in Bangladesh

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Abstract

The study was conducted to evaluate the impact of twenty-two days fishing ban (October 14 to November 04, 2020) on the spawning success of Hilsa in the major spawning grounds. The fishing ban during the spawning season have substantial impact on the successful reproduction of Hilsa. In order to determine the breeding success of Hilsa, Bangladesh Fisheries Research Institute, Riverine Station, Chandpur, conducted comprehensive research with research vessel "MV Rupali Ilish", speedboat and experimental fishing net in and around the spawning ground areas (about 7,000 sq km, including Moulvirchar, Monpura, Dhalchar and Kalirchar). Additionally, the data on percentage of spent Hilsa (locally called pite), oozing or spawning Hilsa were also collected from landing stations (via terrestrial cruises) near the spawning ground areas as well as from some selected locations at the upper stretches of the river Padma and Meghna following the standard protocol. Among all the Hilsa captured in and around the spawning grounds, the proportion of male and female were 4-35% and 62-96%, respectively of the total catch, suggesting a male and female sex ratio 1:2.7. The breeding success rate in 2020 was 51.2% i.e., 51.2% Hilsa successfully participated in the breeding process which is 102% higher than the base year (2001-02). The approximate amount of fertilized eggs in 2020 was 758,075 kg. Increased production of Hilsa eggs and Jatka indicates a positive impact of twenty-two days fishing ban during the spawning season. The percentages of gravid and oozing Hilsa were also found higher compared to previous years. In the spawning grounds, relatively higher amount of spent Hilsa and Jatka were observed whereas fewer spent Hilsa and Jatka were found in the adjacent areas of spawning grounds. Due to the prohibition of all types of fishing, the percentage of female Hilsa in the spawning ground areas were increased up to 88-100%. In the first week of Hilsa breeding, the average rate of spent Hilsa was 8% that augmented up to 51.2% in the last week of fishing ban. Overall, the twenty-two days fishing ban was found very effective for successful spawning of Hilsa.

Keywords: *Tenualosa ilisha,* Impact assessment, Ban, Spawning Ground, Spawning success and Spent Hilsa.

Introduction

The national fish Hilsa (*Tenualosa ilisha*, Hamilton, 1822) is the single most important species in open water in Bangladesh and playing a pivotal role in ensuring national economy, income, poverty alleviation, employment and food security. At present, Hilsa contributes about 12% of the total fish production and about 1% to the GDP of the country (DoF, 2016). Bangladesh earns about 12.5 million US dollars per year by exporting Hilsa (DoF 2014). About 2 million people are directly or indirectly involved with the catching and trading of Hilsa fish in the country (DoF, 2016). Hilsa is an anadromous shad and has a typical life cycle. Hilsa breeds in the upstream rivers and the larvae hatch from free floating eggs. The immature young stages grow out in river channels and then descend to the sea for feeding and growing before returning to the rivers as matured gravid Hilsa to complete the life cycle. Hilsa being a highly fecund fish may produce up to 2 million eggs (Rahman *et al.*, 2017a). Although Hilsa spawn all the year round, they have a major spawning season during the Bengali month of Ashwin-Kartik (September-October) based on the full moon phase. Matured gravid Hilsa has been extensively caught during the major spawning season from the major spawning grounds. The juveniles of Hilsa known as Jatka have also been caught during their seaward migration in some of the major rivers of the country. These are the most important reasons along with some other reasons are responsible for the decline of Hilsa fishery in the country.

In the above circumstances, considering the importance of Hilsa in nutrition, employment and economy, the Hilsa Fishery Management Action Plan (HFMAP) was prepared for the development, management and conservation of Hilsa incorporating the objectives of protecting the nursery and spawning grounds and banning indiscriminate killing of illegal sized Hilsa. Till to date, six Hilsa sanctuaries and four major spawning grounds in the coastal and freshwater areas of the country have been established under the "Fish Protection and Conservation Act-1950" for the effective conservation of Jatka and brood Hilsa in the major nursery and spawning grounds (Fig. 1 and 2; Table 2 and 3). It has been observed from the research findings of BFRI, Riverine Station (RS) that during the peak spawning period, vast number of matured gravid Hilsa congregate at the spawning grounds for breeding following the lunar periodicity or specifically during the full moon phase. At this time, matured gravid Hilsa are captured indiscriminately and has a negative impact on the spawning and stocks as well. Therefore, to ensure safe and successful spawning of Hilsa, restriction has been imposed in compliance with the guidelines of HFMAP. This restriction includes a ban period, 4 days before the full moon day of the Bengali month of Ashwin (1427 Bengali year) risen moon, full moon day and 17 days after the full moon days altogether 22 days from 14th October to 04th November of this year (2020). During this time, fishing in the sea, coastal areas along with the rivers is prohibited by all sorts of commercial trawlers under the Marine Fisheries Ordinance 1983, Section 55, Sub-section 2 (D) for safe migration and smooth spawning of Hilsa.

The fishing ban was implemented by the Department of Fisheries (DoF) with related stakeholders including the law enforcing agencies such as Navy, Coast Guards, River Police and Air Force. The Ministry of Fisheries and Livestock (MoFL) coordinates this banning program based on the research findings of Bangladesh Fisheries Research Institute (BFRI), Riverine Station (RS) (Table 1). The impact of 22-days fishing ban seems to be very promising.

Table 1. Management system for Jatka and brood Hilsa conservation in Bangladesh.

Year	Management system	Considering issues
2001-02	Conventional	Without any management
2002-03	Conventional	Traditional (improved) management
2003-04	Jatka conservation	Protection system
2004-05	Jatka conservation	Protection system
2005-06	Jatka conservation+sanctuary	Full Moon basis
2006-07	Jatka conservation+sanctuary+10 days Hilsa fishing ban	Full Moon basis
2007-08	Jatka conservation+sanctuary+10 days Hilsa fishing ban	Full Moon basis
2008-09	Jatka conservation+sanctuary+10 days Hilsa fishing ban	Full Moon basis
2009-10	Jatka conservation+sanctuary+10 days Hilsa fishing ban	Full Moon basis
2010-11	Jatka conservation+sanctuary+10 days Hilsa fishing ban	Full Moon basis
2011-12	Jatka conservation+sanctuary+11 days Hilsa fishing ban	Full Moon basis
2012-13	Jatka conservation+sanctuary+11 days Hilsa fishing ban	Full Moon basis
2013-14	Jatka conservation+sanctuary+11 days Hilsa fishing ban	Full Moon basis
2014-15	Jatka conservation+sanctuary+15 days Hilsa fishing ban	Full Moon basis
2015-16	Jatka conservation+sanctuary+15 days Hilsa fishing ban	Full Moon basis
2016-17	Jatka conservation+sanctuary+22 days Hilsa fishing ban	Full Moon + New Moon
2017-18	Jatka conservation+sanctuary+22 days Hilsa fishing ban	Full Moon + New Moon + GSI study
2018-19	Jatka conservation+sanctuary+22 days Hilsa fishing ban	Full Moon + New Moon + GSI study
2019-20	Jatka conservation+sanctuary+22 days Hilsa fishing ban	Full Moon + New Moon + GSI study

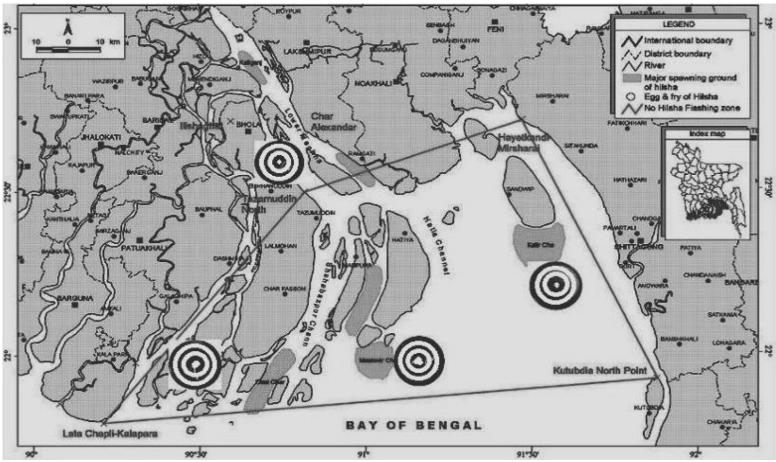

Fig. 1. Major spawning grounds of Hilsa in the Meghna River estuary (Source: BFRI and GEF).

Methodology

Preparation of Hilsa Research Team

The Hilsa Research Team of BFRI, RS, Chandpur carried out all the investigations. Two ways were selected for sampling and data collection such as:

a. Research vessel (*M.V. Rupali Ilish* with speed boat) trip (Fig. 2) and
b. Research trip with necessary research equipment's by using local transport system

The entire study was conducted from the Riverine Station of BFRI. Five research teams were formulated to carry out comprehensive investigation in the demarked sanctuary (Table 2), spawning ground (Table 3) and other adjacent areas. The reasons behind selecting the nursery grounds as a sampling sites are- (a) during the breeding time, Hilsa shed their eggs in almost all major river systems of the country, but the spawning grounds (Fig. 1) harbor 80-90% of them (b) immediately after spawning, Hilsa eggs and larvae starts drifting and shifting to the upstream rivers (c) Hilsa is a migratory fish and it may travel a large distance after the spawning event and captured over there. Therefore, to get the accurate information on the percentage of spent, oozing and gravid Hilsa, a vast area for sampling was selected.

The structure of BFRI Hilsa Research Team was as follows:

a) Team 1: Headed by the Principal Investigator (PSO) + Scientific Officer (SO) + Two field assistants (FA) +Four support service staffs
b) Team 2: Headed by Senior Scientific Officer (SSO) + Two field assistants (FA) + One support service staff
c) Team 3: Headed by Senior Scientific Officer (SSO) + One field assistant (FA) + One support service staff
d) Team 4: Headed by Scientific Officer (SO) + One Research assistant (RA) + One support service

e) Team 5: Headed by Scientific Officer (SO) + One Research assistant (RA) + One support service

Table 2. Six established sanctuary areas of *T. ilisha* in Bangladesh.

Sl. No.	Sanctuary area	Length	River	Ban period	District
1.	From Shatnol to Char Alexander	100 km	Lower Meghna estuary	March-April	Chandpur-Laxmipur
2.	Char Ilisha to Char Pial	90 km	Stretch of Shahbajpur Channel, a tributary of the Meghna river	March-April	Bhola
3.	Bheduria to Char Rustam	100 km	Stretch of Tetulia river	March-April	Bhola-Patuakhali
4.	Kalapara Golbunia point to the Confluence of Bay of Bengal and Andharmanik river	40 km	Andharmanik river	November-January	Patuakhali
5.	Tarabunia to Vomkora	20 km	Lower Padma river	March-April	Shariatpur
6.	Hizla to Mehendiganj	82 Km	Meghna River	March-April	Barisal

Source: Bangladesh gazette 28 May, 2014, MoFL

Fig. 2. Hilsa research vessel 'MV Rupali Ilish.

Table 3. Four established spawning ground areas of *T. ilisha* in Bangladesh.

Sl. No.	Spawning grounds	Area in sq. km	District
1.	Mayani point, Mirsarai	125	Chittagong
2.	Paschim Syed Awlia point, Tajumuddin	80	Bhola
3.	North Kutubdia point, Kutubdia	120	Cox's Bazar
4.	Lata Chapali point, Kalapara	194	Patuakhali

Source: Bangladesh gazette 28 May, 2014, MoFL

Standard formula (Rahman et al., 2009 and Rahman et al., 2017a)

The approximate no. of Hilsa saved and total fertilized eggs due to fishing ban was calculated using the following standard formula:

Total No. of Hilsa saved due to fishing ban (TN) = Nos. of fishing boat*Nos. of haul/day*Nos. of fish captured/ Nos. of haul* Nos. of days -- (1)

Total fertilized eggs (Kg) = (TN*FF*SF*EF)/1000 --- (2)

Where, TN = Total No. of Hilsa excluded due to fishing ban;
EF = % of female fishes in the study areas;
SF = % of spent/oozing fish, and
EF = Average egg (g) per fish

Site selection

Major spawning grounds of Hilsa and adjacent sites were selected and visited by the Hilsa Research Team for comprehensive study (Fig. 3).

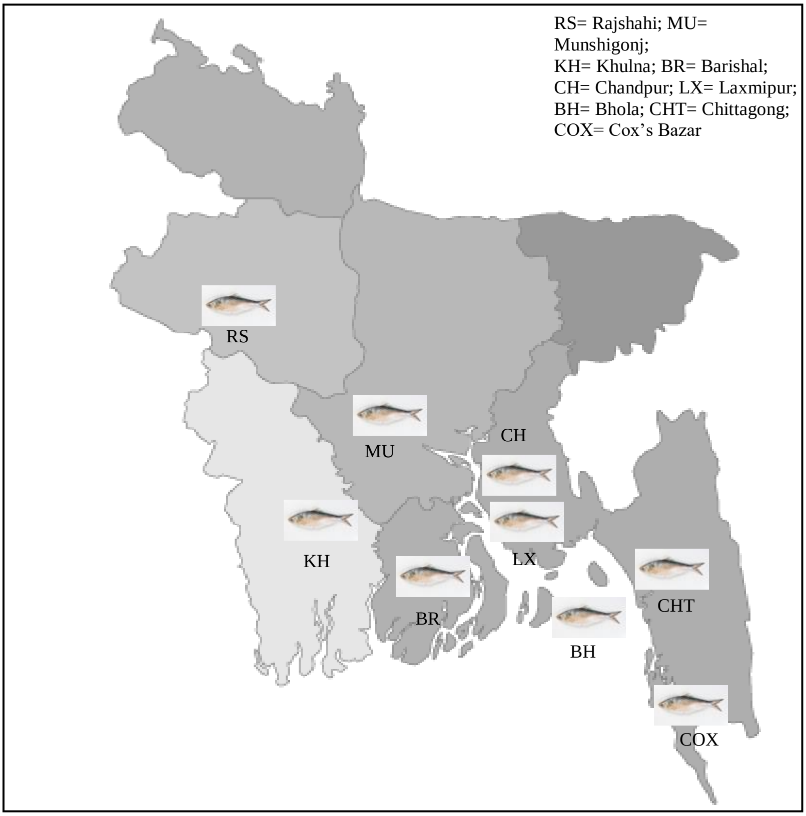

Fig. 3. Map of Bangladesh showing selected 9 districts for sampling and data collection.

Data collection time frame

Three sequential time frames were selected for sampling and data acquisition by the Hilsa Research Team, such as:

i) Before the ban period (05 days)
ii) Whole ban period (22 days)
iii) After the ban period (05 days)

In order to protect mature Hilsa and to ensure their successful participation in breeding, fishing ban has been implementing since 2006-07 under the Fish Conservation and Protection Act, 1950. This year (2020) the fishing ban period was declared from 14 October to 04 November.

Determination of size, sex and percent composition of gravid/berried Hilsa

Data on length (cm) and weight (g) of Hilsa were collected from selected sampling sites (Fig. 3). The length and weight of Hilsa were taken through wooden scale and digital balance, respectively. The sex of Hilsa fish was determined by applying constant light pressure from the tip of the ventral squat to the anus of the abdomen and by external observation. If milky or liquid cream comes out during stripping, it is male and if it comes out with egg and light reddish substance, it was marked as female Hilsa. The potbellied Hilsa with reddish and bigger anus was also identified as female Hilsa. And if this type of milk-like liquid does not come out, it is considered as immature (Jatka) or partially mature. Normally, female Hilsa were found larger in length than male Hilsa.

Identification of spent ('pite' in local language) and Oozing (spawning) Hilsa

Spent Hilsa was mainly characterized by external features such as sick, thin, compressed stomach and elongated slender body. After applying gentle pressure on the abdomen if watery liquid or blood erupts with the separated and deformed eggs, it was designated as spent Hilsa ('pite' in the local language). Spent Hilsa were very frail after being captured from the river. Usually, they are not brought to the market as it reduces the market value of other fish. Oozing Hilsa was identified by observing their egg-laying condition, i.e. a condition when the mature eggs come out spontaneously without any pressure on Hilsa's stomach (Fig. 4).

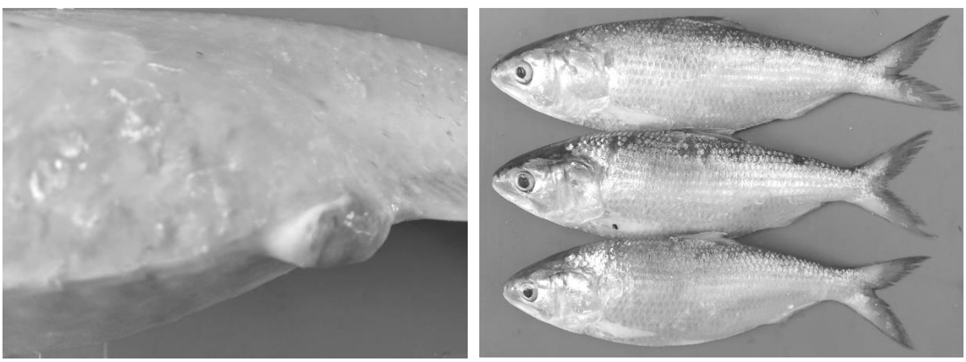

Fig. 4. Pictorial views of spent and oozing Hilsa.

During the banning period data were collected from 9 sampling sites (Fig. 3). These sites represent the major shares of Hilsa spawning during the peak spawning time through which major river system of the country have been flowing. Samples were also collected from Chattagram and Cox's Bazar where most of marine Hilsa are fetched for vending.

Determining the (%) of Spent (Pite) Hilsa

Determining the number and rate of spent Hilsa were calculated mainly from the Hilsa captured through the experimental nets in the main breeding grounds by the Hilsa Research Team of BFRI and observation of commercial fish landing sites in and around the breeding grounds.

Calculation of fertilized eggs

During the fishing ban the approximate amount of fertilized eggs (Fig. 6) released by Hilsa in the spawning grounds is an indicator of spawning success and it was estimated using the following formula:

The plausible amount of egg production due to the fishing ban was:

- Nos. of matured Hilsa captured in per unit effort = 27 (Two haul/day; = 54) (BFRI Investigation)
- Total nos. of ban days = 22 days
- Approximate number of fishing boats = 15500 [Total area of spawning ground =7000 sq km, on an average 2 fishing boats are operated in per sq. km]
- Average percentage of matured female during the fishing ban = 73% (BFRI investigation)
- Average percentage of spent Hilsa during the fishing ban = 51.2% (BFRI investigation)
- Average weight of gonad of matured female = 110 g (BFRI investigation)
- One kilogram = 1000 g

Approximate Egg Production = {(54*22*15500*73/100) *(51.2/100*110)}/1000 = 7,57,065 kg

Calculation of Jatka production

The number of fry and Jatka production were estimated by considering 50% hatching rate of the fertilized eggs and 10% survival rate of hatched larvae.

Size, weight, age and CPUE calculation of Hilsa fry and Jatka

Hilsa larvae were collected by BFRI experimental fishing net (made of glass nylon fiber) from the spawning grounds and adjacent sites. Length and weight of Hilsa larvae and Jatka were measured by measuring scale and digital balance. Approximate age of Hilsa fry and Jatka were configured by the external observations and following previous literatures. Catch per unit effort (CPUE) was estimated by calculating the amount of Jatka (kg) captured in 100 m net per hour per boat.

Observations of other impacts of fishing ban

To observe the supplementary benefit of 22 days fishing ban, the larvae and juveniles were collected by BFRI experimental fishing net (made of glass nylon fiber: mouth diameter - 15 ft, length from the mouth to the end - 25 ft, loop size - zero and fishing time was 30 minutes) (Fig. 12) from the spawning grounds and adjacent sites. Their proportion were calculated and compared with the Hilsa and other fish species' larvae as well as with the larvae found in the previous years. This helped us to know impact of fishing ban on the diversity of other fish species.

Data analysis

After collecting, data were analyzed using Microsoft Excel (version 2010).

Result and Discussion

Size and sex ratio of Hilsa

Length-weight (L-W) data of Hilsa collected from selected sampling sites during the prohibition period was calculated. The length-frequency (L-F) distribution of Hilsa was analyzed with an interval of 5 cm. Spatial variation in the L-F distribution of Hilsa was observed. Most of the Hilsa were less than 35 cm in the upstream areas (about 55% in Chandpur) whereas in the downstream areas most of the Hilsa were larger than 35 cm (about 75% in Bhola) (Fig. 5) and most of them were mature gravid. Rahman *et al.,* (2017a) studied the impact of fishing ban during the peak spawning time of Hilsa and found similar results, higher percentage of Hilsa with length group greater than 40 cm were observed in Monpura and Hatia region.

In addition to this spatial distribution of L-F, an ostensible temporal change in the length class of Hilsa were also observed. Normally, 30-35 cm length class was predominant before the ban period; on the contrary, during and after the prohibition period mature Hilsa (egg bearing female, >40 cm) was predominant. Rahman *et al.,* (2017a) also found similar transformation of Hilsa length class before, during and after the spawning time. The results indicate that large school of mature and gravid Hilsa congregate at the spawning grounds for breeding purposes and imposing fishing ban seems appropriate to instigate their successful breeding.

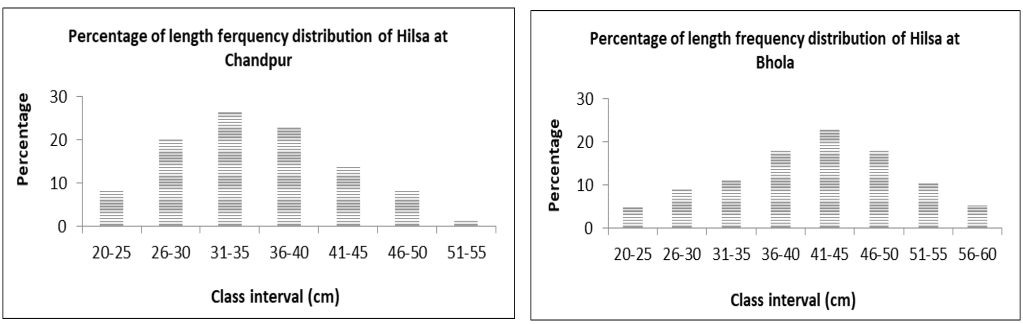

Fig. 5. Percentage of length frequency distribution of Hilsa at Chandpur and Bhola before, after and during the ban period.

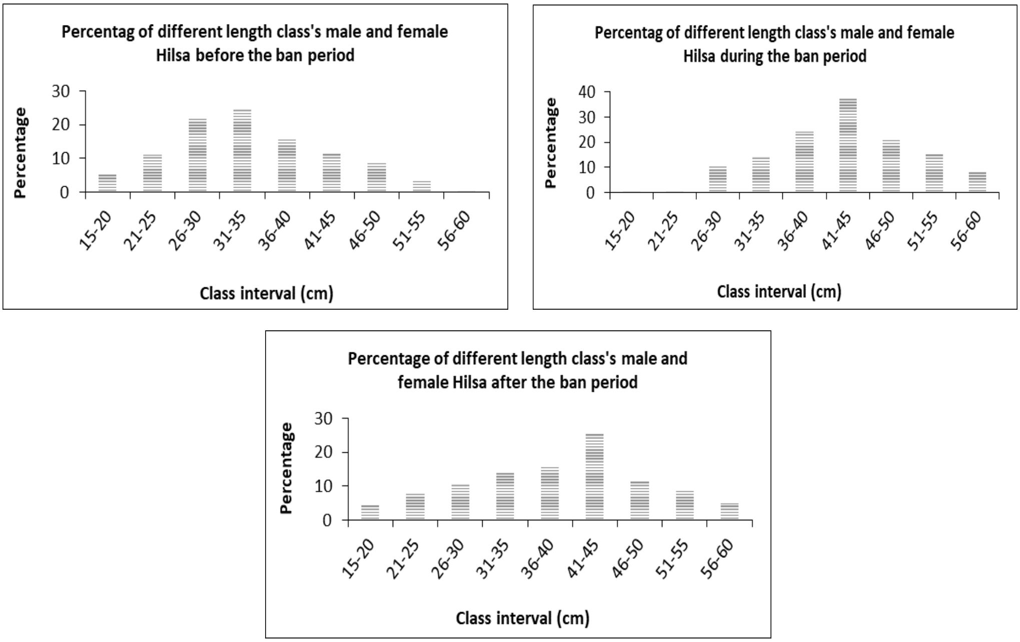

Fig. 6. Percentage of different length class's male and female Hilsa before, after and during the ban period.

The proportion of male and female Hilsa also demonstrated considerable variation before and after the ban period and an imbalanced sex ration of Hilsa was observed. The average percentage of male Hilsa was 2-12% before and after the ban period that increased up to 4-35% during the ban period (October 14-November 4). On the other hand, before and after the ban period the average percentage of female Hilsa were 82-98% which increased up to 80-100% during the ban period (October 14-November 4). These findings were different than Haldar *et al.,* (2004) to some extent who found male-female sex ratio 1:2 in the major spawning grounds of Hilsa. In another investigation, Islam *et al.,* (1987) reported male-female sex ratio of Hilsa 1:1.08 in the upstream region (Chandpur). Quereshi (1968) recorded male-female sex ratio 1:1 during the monsoon but the female was found dominant in the month of October. Blaber, *et al.,* (2001) reported that male is more abundant among the smaller fishes. In the present study, most of the Hilsa captured through experimental fishing were gravid female (80-90%) and larger than 40 cm that confirmed the results obtained by previous investigators. Therefore, it was obvious that fishing ban during (October 14-November 4) ensured successful breeding of about 80-90% Hilsa.

Percent composition of spent and oozing Hilsa

During this investigation, about 3000 Hilsa were examined and the proportion of spent and oozing Hilsa were calculated to know the breeding success. A large number of spent and oozing Hilsa were observed. In Ramgoti, the proportion of oozing and spent Hilsa were 60%

and 29%; in Chandpur, the proportion were found 15% and 41%; in Patuakhali, the proportion were 19% and 65% and in Monpura, 37% and 61%, respectively (Table 4). Considering the results of all sampling locations, the overall proportion of oozing and spent Hilsa were recorded 32% and 51% (about 83.4%, combing both). This result implied that a large number of Hilsa shed their eggs successfully due to the fishing enclosure during the peak spawning time. In 2017, Rahman *et al.,* confirmed the similar positive impact of fishing ban through their findings.

Table 4. Percent composition of spent and oozing Hilsa during the ban period.

Status of Hilsa breeding	Sampling points					
	Cox's Bazar	Ramgoti	Chandpur	Potuakhali	Monpura	Average
Oozing	111 (29%)	988 (60%)	94 (15%)	7 (19%)	13 (37%)	32%
Spent	189 (50%)	467 (29%)	260 (41%)	27 (75%)	22 (61%)	51%
Total Number	378	1635	633	36	36	2717

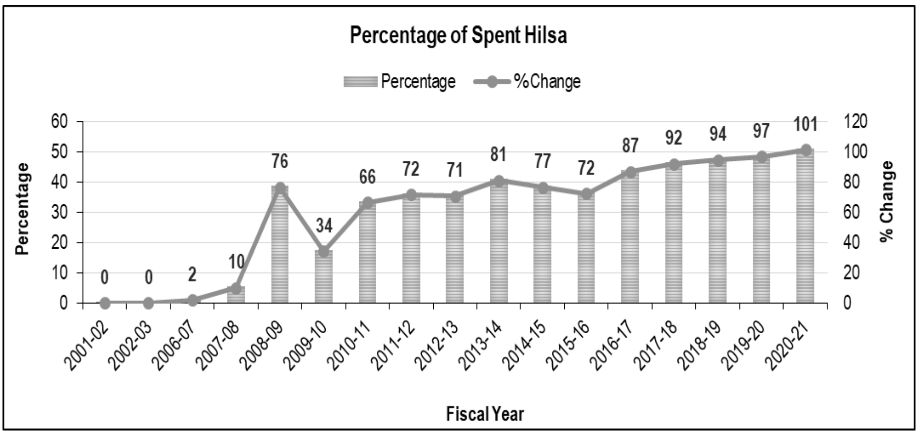

Fig. 7. Percentage and change of spent Hilsa in different years in Bangladesh.

In Bangladesh, 2001-02 is considered as the base year since no management interventions were adopted at that time for the conservation of Jatka and no fishing enclosure was implemented to ensure the breeding of mature and gravid Hilsa during the peak spawning time. Thereafter, based on the research findings of BFRI, different management interventions were adopted, initially started with the Jatka conservation during March-April. Triple action (Jatka conservation, sanctuary declaration and fishing ban during the peak spawning time) was started since 2006-07. Through successful implementation these management interventions with the help of law enforcing agencies brought tremendous success in Hilsa breeding and overall Hilsa production of the country. In 2001-02, the percentage of spent Hilsa were almost nil. Fishing enclosure during the peak spawning time started in 2006-07 and the percentage of spent Hilsa showed a jump start (from 11% to 77%). Thereafter, it declined again in the subsequent year (2008-09), perhaps due to the devastating consequences of cyclone "*Sidr*" on the coastal ecosystem and dependent flora and fauna. The data collection was also difficult at that time for the destruction of coastal infrastructure. From 2009-10 onward to recent years, the percentage of spent Hilsa has stably increased (102% more in 2020-21 than the base year) and it has been possible due to the successful implementation of fishing enclosure during the peak spawning time (Fig. 7).

Production of fertilized eggs and Jatka during the fishing ban period and spawning success

The total egg production of Hilsa has been calculated using the standard formula of BFRI (Rahman *et al.,* 2017b). The present investigation revealed that approximately 7,57,065 kg Hilsa eggs (Fig. 8) were produced in 2020-21 due to fishing ban. If 50% of the produced eggs are fertilized and hatched and 10% of them are survived, then it can be assumed that about 3,78,533 crores of Hilsa fry and 37,853 crores of Jatka (Fig. 9) were recruited to the Hilsa population. These findings indicated that increased number of banning days (10 days from 2007-08 to 2010-11; 11 days from 2011-12 to 2013-14; 15 days from 2014-15 to 2015-16 and 22 days from 2016-17 to till date) achieved more positive impacts on eggs and Jatka production. The egg production increased about 17 times and fry and Jatka production increased up to about 16.2 times in the current fiscal year (2020-21) compared to the commencement year 2007-08 (fishing enclosure during the peak spawning time started to enact). The recruitment of a large number of Jatka to Hilsa population due to implementation of fishing ban from 2007-08 onwards, resulted a steady and higher production of Hilsa in Bangladesh (Fig. 11). Haldar (2004) and Rahman *et al.,* (2017) also stated that complete fishing ban has a strong positive impact on Jatka abundance as well as on the overall Hilsa production of the country.

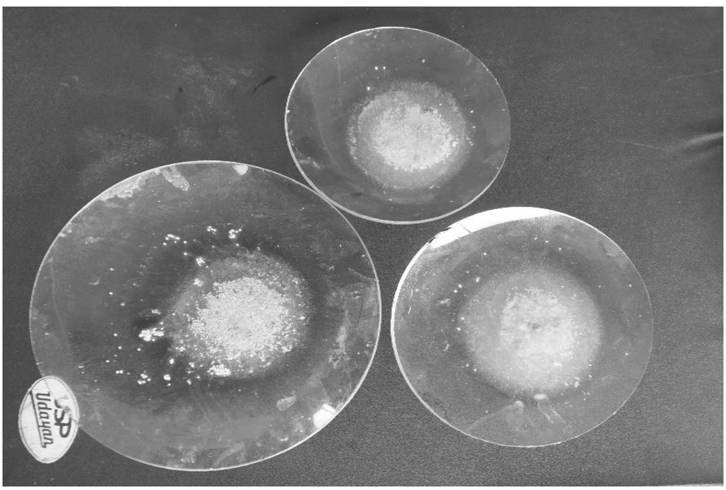

Fig. 8. Pictorial views of Hilsa eggs.

Size, weight, age and CPUE of Hilsa fry and Jatka

Fishing enclosure during the peak breeding time of Hilsa also augmented the catch per unit effort (CPUE) of Jatka. Due to successful breeding, a large number of Jatka were distributed in and around the spawning grounds of Hilsa and it was reflected during the experimental Jatka catching through BFRI experimental net. Jatka conservation started in Bangladesh in 2003-04 and effect should be visible with increased number of Jatka in per unit catch immediately from the next year 2004-05. Hence, in case of quantifying the percent increase of CUPE of Jatka, 2004-05 is considered as the base year. And if the CPUE of Jatka (10.5 kg/100 m net/boat/hr) of the current year (2019-20) is compared with the base year, the CPUE is 15 times higher and from the last year (2018-19), it was about 2 times higher in amount (Fig. 10). Nevertheless, present CPUE of Jatka is almost 3.4 times higher than the study conducted by Rahman *et al.*, (2017). Augmented CPUE of Jatka was manifested through increased Hilsa production in the country (Fig. 11).

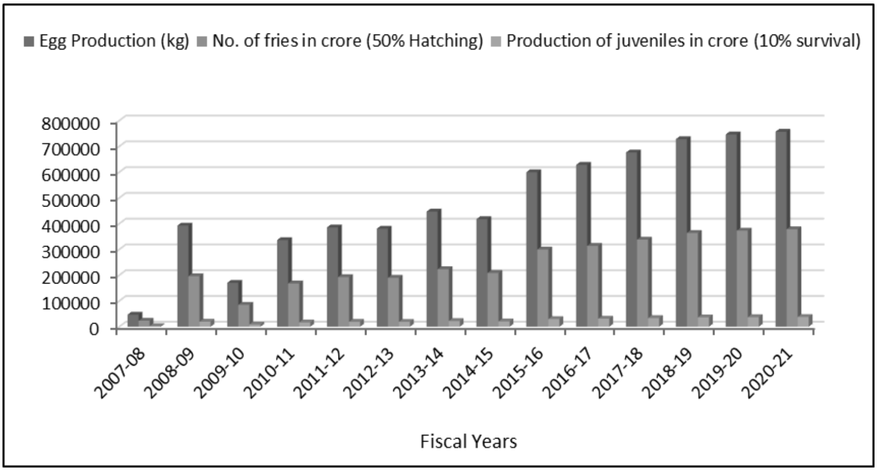

Fig. 9. Approximate amount of eggs, fry and Jatka production in the major spawning grounds.

Total Hilsa production of the country

All most all management interventions, from traditional to improve had a cumulative impact on the total Hilsa production of the country. Traditional management intervention through enforcing Jatka conservation was started in 2002-03 and improved intervention immediately from the next year, 2003-04. Moreover, fishing enclosure during the peak breeding time of Hilsa was activated from 2006-07. The overall Hilsa production of the country in 2002-03 was 1,99,032 MT; in 2006-07, the production was 2,79,189 MT and last year (2019-20) the production reached up to 5,50,428 MT. This result implies that the overall Hilsa production of the country has increased about 2.77 times than 2002-03 and about 2.0 times than 2006-07. If the conservation approach and fishing ban continues to be enacted through the inclusion of all relevant Government agencies, Hilsa production will be boosted up in the upcoming years (Fig. 11).

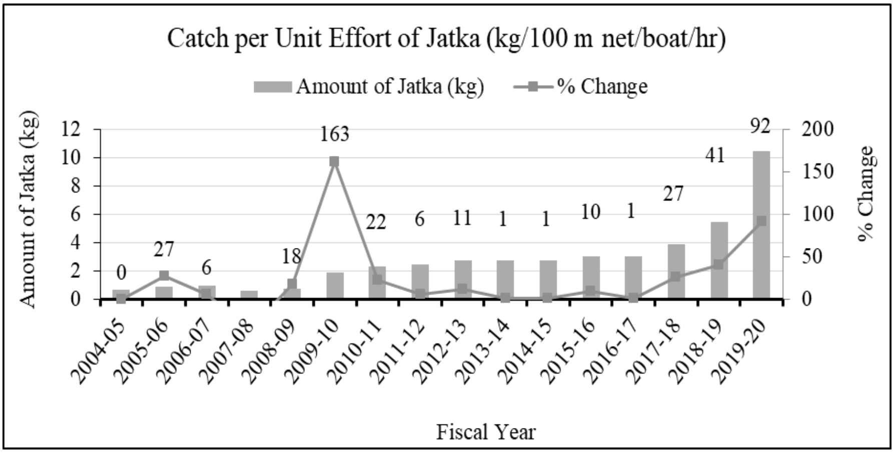

Fig. 10. CPUE of Jatka in the selected sampling sites.

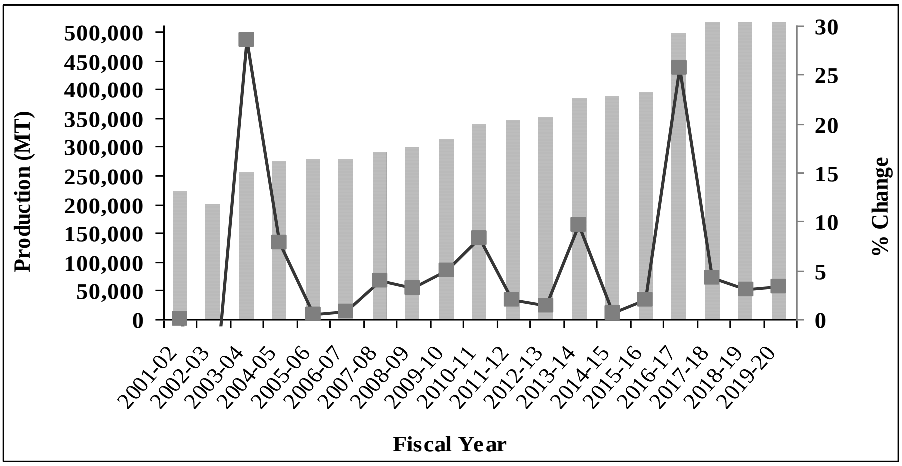

Fig. 11. Total Hilsa production (MT) in Bangladesh (2001-2020).

Availability of Hilsa and other fish's larvae in experimental nets (indicator of breeding success)

For collection of larvae, glass nylon fiber net was operated during high and low tide in the breeding grounds (Fig. 12). It was observed that during the low tide, about 60% Hilsa larvae were found in the experimental net and 40% were other fish's larvae. On the contrary, during the high tide, Hilsa larvae were 43%, whereas other fish's larvae were 57%. Overall, 50% of Hilsa larvae were found during high and low tide together (Fig. 13). Total larvae collected during high and low tide exhibited considerable variations, at high tide, the number of larvae was higher than the low tide (Fig. 14). Among the other fish's larvae (shrimp, kachki, chewa, poa, shillong, kakila, baim, chanda, kuchia etc.) were found. Many of these species have biodiversity concern (vulnerable, endangered or least concerned) according to the International Union for the Conservation of Nature (IUCN, 2015) biodiversity status of Bangladesh and global (Table 5).

Table 5. Identified fish species list with Bengali name, scientific name and conservation status.

Sl. No.	Local name	Group name	Scientific name	IUCN (2015) BD status*	IUCN (2015) GB status*
1.	Bele	Mudskippers	*Glossogobius giuris*	LC	LC
2.	Chela	Barbs and Minnows	*Salmostoma acinace*	LC	LC
3.	Cuchia	Eels	*Monopterus cuchia*	VU	LC
4.	Red Chewa	Mudskippers	*Odontamblyopus rubicundus*	LC	NE
5.	Vacha	Catfishes	*Eutropiichthys vacha*	LC	LC
6.	Sada Chewa	Mudskippers	*Trypauchen vagina*	LC	NE
7.	Kakila	Gars	*Xenentodon cancila*	LC	LC
8.	Baim	Eels	*Mastacembelus armatus*	EN	LC
9.	Pangus	Catfishes	*Pangasius pangasius*	EN	LC
10.	Poa	Flatheads	*Otolithoides pama*	LC	NE
11.	Silong	Catfishes	*Silonia silondia*	LC	LC
12.	Khorsula	Mullets	*Rhinomugil corsula*	LC	LC
13.	Kholisa	Labyrinth fishes	*Trichogaster fasciata*	LC	NE

*BD = Bangladesh; GB = Global; En = Endangered; Vu = Vulnerable; Lc = Least Concerned; NE = Not endangered

After the breeding time, Hilsa larvae gradually starts shifting and drifting to the major nursery grounds and grows as juveniles and thereafter as Jatka. Hilsa larvae grows about 2-2.5 cm in a month (Haldar, 2004). The abundance of Hilsa juveniles in different nursery grounds/sanctuary areas indicates the spawning success of Hilsa. During BFRI’s experimental fishing, plenty of Hilsa juveniles were found in the nursery grounds (Fig. 15) and approximate age of these juveniles were about 30-45 days.

Fig. 12. Experimental fishing net (Behundi jal) for collecting juvenile Hilsa.

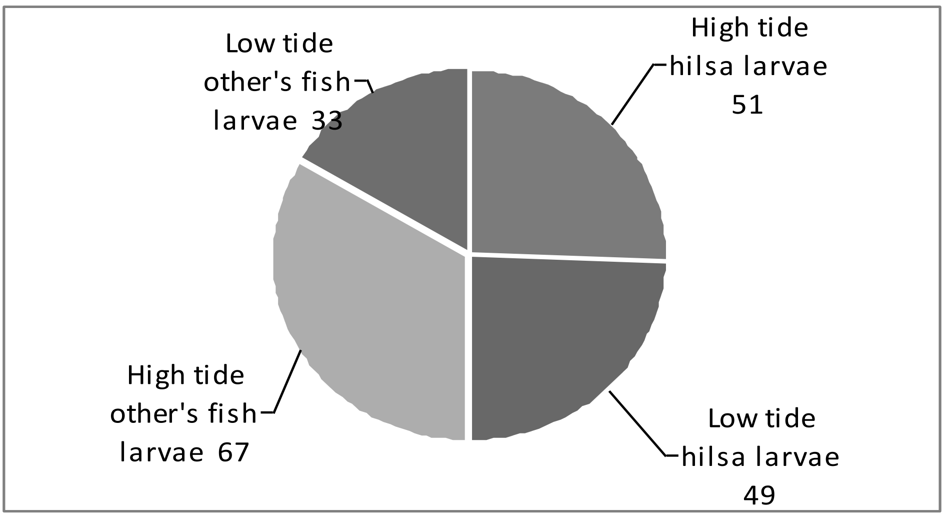

Fig. 13. Percentage of Hilsa and other's fish larvae during high and low tide.

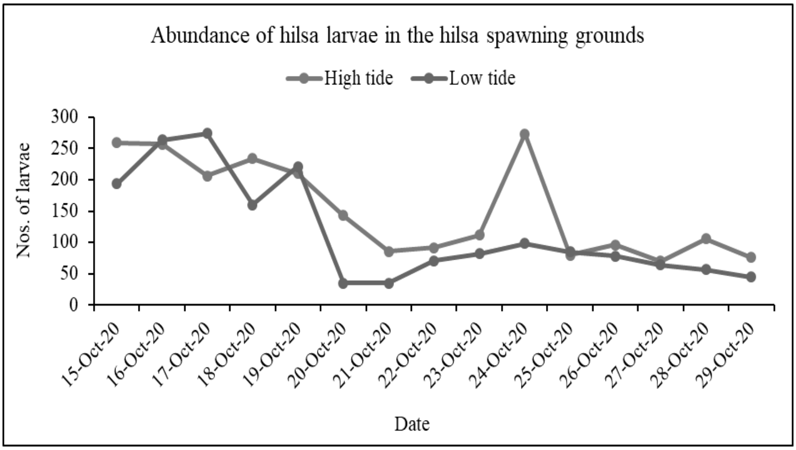

Fig. 14. Abundance of Hilsa larvae in the spawning grounds.

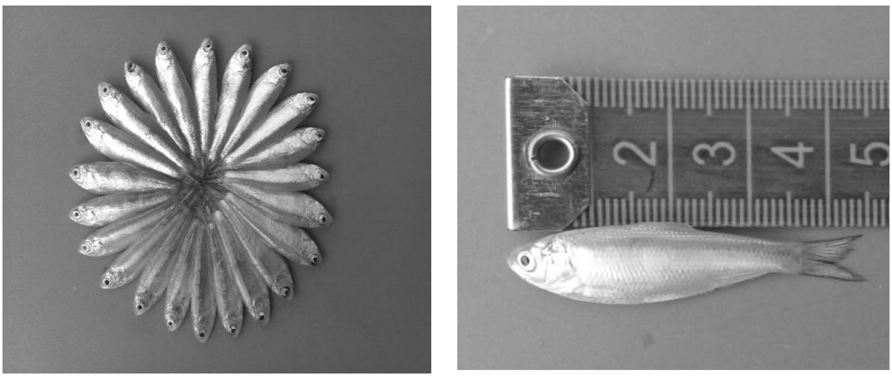

Fig. 15. Observations of Hilsa juveniles.

Conclusion

The result found in the present investigation is an approximation and subjected to be changed for various factors such as the number of fishing boats, those who were refrained from fishing, the number of specimens used in the calculation of spent Hilsa and the weight of the ovary of the female Hilsa. Moreover, a number of biotic and abiotic factors such as (plankton composition, temperature, dissolved oxygen, pH, carbon dioxide, alkalinity, hardness, turbidity, transparency, conductivity, rainfall and river discharge etc.) may have significant role and affect the egg production and hatching of Hilsa larvae in different years as well as the total breeding success of Hilsa. Furthermore, without controlled laboratory experiment, it is difficult to say which factors are mostly responsible for the breeding success of Hilsa and augmented Hilsa production (successful implementation of different management interventions or ecological suitability of biotic or abiotic factors). However, as Hilsa production is gradually increasing after the adoption of management interventions, it could be assumed that this might have some positive impacts.

Recommendations

Based upon the above conclusion, following recommendations can be implemented:

1. Conservation of Jatka through fishing ban should be continued.
2. Fishing ban for the protection of matured gravid Hilsa for successful reproduction during the spawning season should be continued.
3. Existing four major spawning grounds and six nursery grounds should be conserved and properly managed.
4. New nursery and breeding grounds of Hilsa need to be identified through further investigations.
5. Impact of climate change on Hilsa fishery resource in Bangladesh should be assessed.
6. River water pollution, navigation blockage, river breaching should be minimized.
7. Improvement of Hilsa landing centers and trading system and adoption of digital data recording system should be established.
8. Development of socio-economic condition and awareness building of fisher's community is necessary to uplift the livelihood of poor hilsa fisher's community of the country.

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Potentialities of Seaweed Culture in Kuakata Coast of Patuakhali, Bangladesh

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Abstract

The seaweed culture trials were conducted for a period of 60 days during January to February 2021 at Gangamati Estuary of Kuakata coast under Patuakhali, Bangladesh with three seaweed species (*Ulva conglobata*, *Hypnea musciformes* and *Enteromorpha intestinalis*). A square net frame of 4 m x 4 m size fabricated with coir rope (obtained from coconut husk) was used as culture materials and support to hold the seaweed seedlings. The maximum daily growth rate (4.81±0.02%/day) was observed at 30th day of culture in case of *H. musciformes*, while the minimum daily growth rate (0.26±0.01 %/day) was observed at 15th day in case of *E. intestinalis*. *H. musciformes* produced significantly higher seaweed biomass (10.47±0.11 kg fresh wt./m^2) than *U. conglobata* (p<0.05) and *E. intestinalis* (p<0.05). The water transparency, salinity, temperature, pH, and dissolved oxygen were acceptable for seaweed growth, particularly for *H. musciformes*. This was the first attempt to cultivate seaweeds in Kuakata coast of Bangladesh, suggested that the Kuakata coast line could be utilized for seaweed culture.

Keywords: Seaweed, *Hypnea musciformes,* Kuakata Coast, Bangladesh.

Introduction

The seaweeds are an essential component of the marine ecosystem. Seaweed is a primitive plant that doesn't have proper roots, stems, or leaves and. Seaweeds are currently mostly utilized to produce the hydrocolloids alginate, agar, and carrageenan, which are used as thickeners in the food industry (Bixler and Porse 2011). Seaweed is high in important nutrients, particularly trace elements and a variety of other bioactive compounds. Seaweed protein is of extremely high quality, containing all required and non-essential amino acids. Seaweed can also be used to make food and food additives (Holdt and Kraan, 2011), be fed to animals (Wilding *et al*., 2006; Soler-Vila *et al*., 2009; Bikker *et al.*, 2013), and be used to make green chemicals (Mata *et al*., 2010; Wal *et al*., 2013). Seaweed is considered a delicacy by the Japanese, Chinese, Filipinos, and Hawaiians, who have used it in their meals for millennia (Armisen, 1995). Coastal area with both sandy and muddy beaches, estuaries and mangrove swamps provides substrates and habitats for the cultivation of various kinds of seaweeds and these seaweed species are notable for their economic importance in the production of agar, human food, animal feed, fertilizer, drugs, and biofuel (Siddique *et al.,* 2019). Worldwide food and fertilizer are produced from seaweed. In addition, seaweeds are also used in industrial sectors (García-Poza *et al.,* 2020). Seaweeds are found as important source of bioactive compounds and have antioxidant activities (Rimmer *et al.,* 2021). It is interesting that, eastern and southeastern Asia is contributing in most of the seaweed production which is about 99.6% of global production (Islam *et al.,* 2019). Seaweed farming in Bangladesh is an emerging sector (Sarker *et al*., 2019). Coastal zone of Bangladesh covers about 47201 km2 area which is about 32% of the country (Sarker *et al.,* 2021). The coastal zone of Bangladesh is relatively income-poor compared to the rest of the country. Marginalized coastal communities are mainly involved with fishing, agriculture, livestock rearing and day laboring (Sarker *et al.,* 2021a). However, due to socioeconomic and technological constraints, Bangladesh's seaweed sector is still in its early stages and is not widely used. If seaweed culture extended to coastal areas of the country, it will become a valuable agricultural commodity for coastal residents, as well as a food source and raw material for pharmaceutical and cosmetic industries. Considering the above circumstances, the present study was undertaken to identify viable seaweed farming areas in Kuakata coast of Patuakhali, Bangladesh based on environmental characteristics and seaweed abundance.

Materials and Methods

Study area and experimental design

The research was conducted at the Gangamati Estuary ($21^0$48`11.7``N and $90^0$12`03.5``E) at Kuakata, Patuakhali, Bangladesh, from January to February 2021 due to high salinity influx. For seaweed culture, a square net frame of 4 m x 4 m size fabricated with coir rope (obtained from coconut husk) was chosen as a support since it has loose braids to hold the seaweed seedlings. Coir rope with 70 mm diameter was used and the mesh size of the coir rope nets on the culture frame was maintained as 22 cm. Young growing fragments of seaweed species like *Ulva conglobata*, *Hypnea musciformes*, and *Enteromorpha intestinalis* were collected from Bakkhali, Cox's Bazar. Seaweed species were transported to the Kuakata Coast by icebox with proper aeration. Seaweed seeding was accomplished by placing immature fragments of *Ulva conglobata*, *Hypnea musciformes,* and *Enteromorpha intestinalis* in the twists of the coir ropes with short length of string. Initially, each seedling density was calculated using an average of 1.0±0.04 kg fresh weight/m^2 and an average length of 20±1.36 cm. Culture nets were anchored by bamboo poles and kept afloat at the surface level with plastics floats. The frame was tied loosely to the poles and fixed in submerged condition to facilitate its vertical movement with the tide.

Monitoring of water quality parameters

Water temperature, salinity, transperancy, pH, and dissolved oxygen (DO) were measured fortnightly. Temperature and salinity were measured with a standard thermometer and a hand Refractometer (Atago, Japan), respectively. Water transparency was measured with a Secchi disk (30 cm in diameter), and water pH was determined with a pH meter (S327535, HANNA

Instruments). The Hanna multiparameter was used to measure dissolved oxygen (Model: HI98194).

Daily Growth Rate (DGR)

Every 15 days of culture, the daily growth rate (DGR) percent/day was computed using following methods of Hung *et al*., (2009) formula.

$$DGR = [(W_t / W_0)^{1/t} - 1] \times 100\ \%/\mathrm{day}$$

Where, W_0 is the initial fresh weight, W_t is the final fresh weight, and t is days of culture.

Seaweed biomass

Seaweed biomass was calculated following the modified formula of Doty (1986) and given as fresh weight of seaweed per unit culture area (kg/m^2): $Y = (W_t - W_0)/A$, where: Y= biomass production; W_t= Fresh weight at day t; W_0 = Initial fresh weight; A= Area of 4m × 4m net.

Statistical analysis

Statistical Package for Social Sciences (SPSS) software version V25.0 and Microsoft Office Excel 2019 were used to analyze the data. For multiple comparisons, ANOVA was used with Tukey's HSD post-hoc analysis. In this investigation, the level of significance was set at $p<0.05$. The correlation between the water quality variables and growth rate of seaweed were determined using Pearson correlation.

Results and Discussion

Water quality parameters

During the 60-days culture period, water quality parameters such as water temperature, water transparency, dissolved oxygen, pH and salinity were significantly different (Table 1). The temperature of the Gangamati estuary varied from 27.6°C to 29.4°C. Although the effect varies from species to species, temperature is a critical environmental factor that controls the growth rate of seaweeds. *H. musciformes* grew rapidly at temperatures ranging from 15 to 25 °C (Ding *et al*., 2013). Temperatures ranging from 27.6 to 29.4 °C were shown to be ideal for culture of *H. musciformes*, and this optimum temperature significantly accelerated the typical growth of *H. musciformes* at Gangamati estuary. The ideal water temperature near seaweed is 22-30 °C (Anggadiredja *et al*., 2011), which is consistent with our findings.

Table 1. Water quality parameters (mean ± SE) of seaweed culture site at Gangamoti, Kuakata, Patuakhali

Duration (day)	Water quality parameters				
	Water Temperature (°C)	Water Transparency (cm)	DO (mg/L)	pH	Salinity (ppt)
15	27.6 ± 0.5^{b}	62.3 ± 0.2^{ab}	6.3 ± 0.2^{a}	7.9 ± 0.1^{ab}	23.4 ± 0.3^{b}
30	28.3 ± 0.3^{b}	65.8 ± 0.1^{a}	5.8 ± 0.3^{ab}	8.1 ± 0.3^{a}	24.7 ± 0.4^{a}
45	28.7 ± 0.3^{b}	60.3 ± 0.5^{b}	5.2 ± 0.2^{b}	7.5 ± 0.2^{b}	22.6 ± 0.6^{b}
60	29.4 ± 0.4^{b}	64.6 ± 0.3^{a}	5.3 ± 0.1^{b}	7.8 ± 0.3^{ab}	23.2 ± 0.5^{b}

Different superscript in a column indicates significant variation ($p<0.05$).

Water transparency in the Gangamati estuary ranged from 60.3 cm to 65.8 cm (Table 1). The achieved level of water transparency was ideal for seaweed growth. Islam *et al.,* (2021) observed water transparency 68.5 cm and 60.2 cm at Inani and Bakkhali, Cox's Bazar which is more or less similar to our study. High turbidity, as well as the amount of dissolved and suspended organic matter, floating objects, and light intensity, can all contribute to low brightness ratings (Mubarak *et al.,* 1990) which could hamper the growth of seaweed. The concentration of dissolved oxygen at the experimental site ranged from 5.2 to 6.3 mg/L. Because the lowest dissolved oxygen value was roughly 5 mg/L, it was possible that the water had been disturbed because dissolved oxygen was lower than that value. Though the oxygen level was not too high but the growth rate was good because the dissolved oxygen level doesn't go under the lowest level. Moreover, the pH range can have an impact on seaweed yields. The pH of the water from Gangamati estuary ranged from 7.5 to 8.1. According to Harun *et al*., (2013), a pH range of 7.5-8.5 increased yield whereas pH 9 lowered it that is similar to the current findings. Water salinity is a critical factor for growing seaweeds. Salinity of the Gangamati estuary ranged from 22.6 ppt to 24.7 ppt which is suitable for seaweed cultivation. When *Gracilaria verrucosa* was moved from high to low salinity, Wang *et al*., (1993) found that its growth rate decreased and when salinity falls below 24 ppt, Zafar (2007) detected reduced growth of *Hypnea musciformes* from Saint Martin's, but better growth was observed when salinity increases to >30 ppt. As a result, consistent and moderate salinity was the most important component in achieving the largest biomass production of seaweed. Rohman *et al*., (2018) discovered that the salinity concentration in the seaweed pond region in Muara Gembong District was between 10 and 11 ppt. According to them, the ideal salinity for maintaining *Gracilaria* sp. in a pond is around 15-25 ppt. Furthermore, according to Atmadja *et al.,* (2012), high salinity will hinder seaweed reproduction. In the current study, the salinity range was suitable for the production of seaweeds. Overall, all the water quality parameters in the Gangamati estuary were suitable for the production of seaweed.

Daily growth rate

The maximum daily growth rate of 4.81±0.02 %/day was found in *H. musciformes* on the 30th day, while the minimum daily growth rate of 0.26±0.01 %/day was found in case of *E. intestinalis* on the 15th day. The DGR of three seaweed species in the experimental site was attributed to successive significant changes ($p<0.05$) from the 60th to the 15th day, with the value at the 60th day being substantially higher than the rest. The DGR of three different seaweed species was found to be significantly different from each other. That is, the DGR of the 30th day from three species was highly significant ($p<0.05$) when compared to the DGR of the 45th, 30th, and 15th days except *E. intestinalis* (60th days) (Fig. 1). In comparison to *U. conglobata* and *E. intestinalis,* the daily growth rate of three seaweed species was shown to be higher in *H. musciformes*. Every species' growth rate grew gradually from the initial (15 days) to the last (60 days) phase of sampling. *H. musciformes* had a much higher mean DGR than the other two species. In a 60-day culture period, Islam *et al.,* (2021) found maximum daily growth rate of 3.21±0.01%/day, 2.97±0.04%/day and 2.65±0.02 %/day with seaweed *Hypnea* sp. in Saint Martin, Bakkhlai and Inani, Cox's Bazar respectively. Islam *et al.,* (2017) observed daily growth rate of cultured *Hypnea* sp. was higher (3.21 ± 0.01% day-1) in Saint Martin while Inani had the lowest (0.41 ± 0.06% day-1).

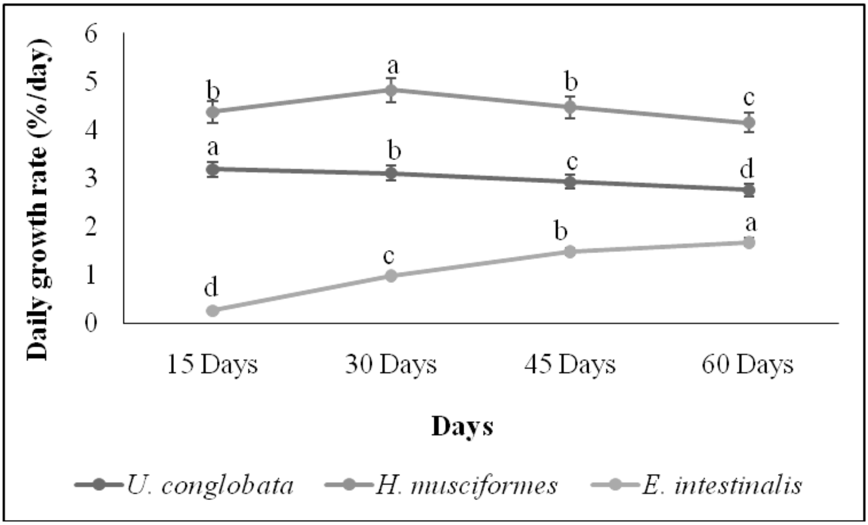

Fig. 1. The daily growth rate (%/day) of some commercially important seaweed in Gangamoti, Kuakata, Patuakhali.

In case of green seaweed, *E. intestinalis,* maximum daily growth rate of 6.55±0.15 % day-1 was portrayed at 15-day in St. Martin's Island and minimum daily growth rate of 0.65±0.03 % day-1 was observed at 60-day (Islam *et al.*, 2021). Zafar (2007) used two types of culture systems (net and suspended rope methods) and discovered growth rates of 1.06 cm/day and 0.95 cm/day for *Hypnea* sp. in Saint Martin Island, which is similar to the current result.

Biomass yield

There was significant variation among the three-seaweed species throughout the study period, though mean production grew in all three. The lowest value was reported in the 15-day culture, and then it increased significantly until 60 days (Table 2). In *H. musciformes*, a maximum biomass yield of 4.3 kg/m^2 was obtained after 60 days of culture, whereas in *E. intestinalis*, a minimum biomass yield of 0.04 kg/m^2 was obtained after 15 days of sampling. Every culture time demonstrated a similar changing trend in biomass output, which steadily rose in all three-seaweed species.

The present study found a higher production of *H. musciformes* in the Gangamati estuary, which could be related to favorable water factors for this species. *U. conglobata* and *E. intestinalis* produced less quantity, which could be owing to a lack of adaptation to the waterbody. *H. musciformes* was usually farmed in calm waters, ideally in lagoons, all over the world (Abreu *et al*., 2011; Reddy *et al.*, 2014).

Hoq *et al.*, (2016) stated that maximum *H. musciformes* biomass yield of 11.05±0.10 kg fresh wt./m^2 was found in 60-day culture duration from St. Martin, which is consistent with our findings. Islam *et al.,* (2021) reported that highest biomass yield of *H. musciformes* was

30.23±0.40 kg fresh wt./m^2 whereas 24.50±0.08 kg fresh wt./m^2 biomass yield of *E. intestinalis* was found in Saint Martin Island. From July to January, a suitable season for *H. musciformis* cultivation was reported in the Gulf of Mannar, Bay of Bengal coast, India, with a peak between August and September (Reddy *et al*., 2014). The largest abundance was recorded on the Cox's Bazar coast during the winter, with a peak in December and January (Islam *et al*., 2017). However, we discovered that the highest production was detected in January and February in our experiment. If the culture period could be extended, the seaweed DGR might be increased (Islam *et al*., 2017).

Table 2. Biomass yield (mean ± SE) of some commercially important seaweeds in Gangamoti, Kuakata, Patuakhali

Duration (day)	Production (kg/m^2) of seaweed		
	Ulva conglobata	*Hypnea musciformes*	*Enteromorpha intestinalis*
15	0.6 ± 0.01^b	0.9 ± 0.03^a	0.04 ± 0.01^c
30	0.9 ± 0.03^b	2.2 ± 0.02^a	0.3 ± 0.01^c
45	1.15 ± 0.02^b	3.07 ± 0.17^a	0.6 ± 0.03^c
60	1.45 ± 0.06^b	4.3 ± 0.13^a	0.76 ± 0.02^c
Total	4.10 ±0.04^b	10.47 ± 0.11^a	1.70 ± 0.02^c

Different superscript in a row indicates significant variation ($p<0.05$).

Correlation among growth rate and different water quality parameters

The growth rate of *U. conglobata* was found to be significantly correlated with water salinity and negatively correlated with water temperature and the majority of the other parameters had a non-significant correlation. The growth rate was found to have a substantial positive association with water salinity and dissolved oxygen in *H. musciformes* but the majority of the other parameters had a non-significant correlation. The growth rate of *E. intestinalis* had a strong positive association with water temperature and a substantial negative correlation with dissolved oxygen and the majority of the other factors had a non-significant link (Table 3).

Table 3. Correlation matrix among growth rate and different water quality parameters in Mid-Southern coast of Bangladesh

Species	Temp.	W. T.	DO	pH	Salinity
U. conglobata	-0.975^*	-0.007	0.880	0.514	0.489^*
H. musciformes	-0.428	0.260	0.232^*	0.453	0.700^*
E. intestinalis	0.962^*	0.028	-0.977^*	-0.497	-0.345

*Correlation is significant at the 0.05 level (2-tailed). Temp.= Temperature; W. T.= Water Transparency; DO= Dissolved Oxygen.

The current study found a link between seaweed growth rate and salinity, temperature, and dissolved oxygen, implying that salinity, temperature, and dissolved oxygen can all affect seaweed growth. Out of the studied two species, *H. musciformis* had the highest growth rate as a result of nitrogen and phosphorus supplementation in mariculture (Guist *et al*., 1982). *H. musciformes* had a much greater daily growth rate than *U. conglobata* and *E. intestinalis*, and the yield after 60 days was similarly significantly higher. The Gangamati estuary's water quality may be better for *H. musciformes* than for the other two species. Taking all of these considerations into account, the current study concluded that the cultivation of *H. musciformes* is viable and that fishermen can engage in such activities as a source of income while also reducing fishing pressure along mid-southern coast.

Conclusion

This is the first attempt to cultivate seaweed at the Kuakata coast of Bangladesh. Seaweeds have the potential to become a stand-alone export business in Bangladesh. As a result, more detailed research on the current state of naturally available seaweeds and their current condition of exploitation should be done, as well as the establishment of a long-term plan for the utilization of these resources. However, the current study found that seaweed, particularly *H. musciformes*, can be grown in the winter season in January and February throughout the mid-southern coast, notably in Kuakata, Bangladesh adding a new dimension to Bangladesh's mariculture prospects.

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Identification of suitable host fish species for freshwater mussel, *Lamellidens marginalis* glochidia larval attachment

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Abstract
The present study, was attempt to find out the suitable host fish for mussel larval infestation in freshwater mussel dated from 2017 July to 2018 June. A pond of 10 decimal was selected and stocked with 80 mussels and 100 fishes per decimal so that 50 fishes per decimal can examine monthly from each different species. The selected fish species were *Catla catla, Labeo rohita, Cirrhinus cirrhosus, Heteropneustes fossilis, Channa punctatus, Cyprinus carpio, Barbodes gonionotus, Oreochromis niloticus, Ompok pabda* and *Aristichthys nobilis* respectively. Five samples of each fishes were collected monthly. Slime and different fish organ such as fin, gills were collected and 5mm^2 of sample used to identify the glochidia under microscope. Among the experimental fish species, highest number (35/ 5mm^2) of glochidia were attached in *Barbodes gonionotus*, followed by *Heteropneustes fossilis* (11/ 5mm^2), and *Ompok pabda* (11/ 5mm^2) and *Oreochromis niloticus* (9/ 5mm^2) which were proved to be the suited host fish species for the attachment, parasitism and recovery of the glochidium larvae and juveniles. During the experimental period the water quality parameter were monitored and recorded on 15 days interval. Temperature ranged from 20.40±0.50 to 26.61±0.30, dissolved oxygen ranged between 3.08± 0.26 and 6.29±0.09, pH in 6.69±0.12 to 8.34±0.16, ammonia 0.002±0.001 to 0.050±0.00, alkalinity 100±19.00 to 190±17.32 respectively. The water quality parameter was in optimum range for glochidia infestation. In this study it was observed that, the large number of glochidia were recorded in the last week of October to first week of November while more or less glochidia were present all the year round in selected host fish body. It can be concluded that, among 10 sample species *Barbodes gonionotus, Heteropneustes fossilis,Ompok pabda* and *Oreochromis niloticus* are suitable host fish for *Lamellidens marginalis*. On the other hand, October to November is the peak time of glochidia infestation when the temperature remaining at 24°C.

Keywords: Glochidia, *Lamellidens marginalis,* host fish, freshwater mussel.

Introduction

The life cycle of freshwater mussel is very complicated because of its parasitic stage and reproductive behavior. The reproduction of freshwater mussel is seasonally and condition-dependant. When environment are favorable, male mussels discharge gametes (sperm) so that female mussel can receive them by siphoning process and fertilize the eggs in her gills. The fertilized eggs develop into glochidia and then female mussels release larvae into the water column which looks like a fish food source. When the host fish eats them, the larvae turn into dislodged from conglutinates and attached in gills or fins of the host fish. After attachments of glochidia, the fish's body enclosed the larvae in a cyst. These glochidia live as parasites for several weeks, growing and feeding on the bodily fluids of the host fish, until the juvenile mussel matures and is large enough to drop off into the substrate to start the process again. A single brood mussel can produce over 200,000 tiny larvae, but without the presence of the suitable host fish, they will never mature into adults. The relationship between specific mussels with specific host fish species has been well-documented in some species, but information on freshwater mussel (*Lamellidens marginalis*) is limited, and suitable host fish species are unknown (Kat 1984; Barnhart et al., 2008; Lefevre and Curtis, 1910; Watters and O'Dee, 1998; Meyers *et al.,* 1980; Kirk and Layzer, 1997; O'Connell and Neves, 1999). In the recent years, freshwater pearl culture is the rising issue in aquaculture sector (Behera, 1996). A recent survey report also described the past history and present status of natural pearl culture and suggested the bright prospect of pearl culture in Bangladesh (Mazid, 2001). Freshwater pearl culture is growing as a source of employment and income in many Southeast Asian countries (Janakiram 1997). Production of pearl depends on the type of species of the freshwater mussel (*L. marginalis*). Based on the prospect and significance of pearl culture in Bangladesh, Bangladesh Fisheries Research Institute is trying to culture freshwater mussels in pond condition. Like other aquatic organisms, mussel seeds are not so available on mass scale and for this reason potential benefit of this important group of aquatic organisms is a matter of concern (Behera *et al.,* 2014). Aquatic atmosphere is self-motivated and ever altering to play the key function in scattering and distribution of mussel population and the success or failure of a brood in reaching its appropriate destinations. It is pertinent to note that a majority of freshwater mussels have indirect larval development with a mandatory parasitic glochidium stage, making seed production under controlled condition more difficult (Janakiram 1989, Kotpal 1995). Considering the above facts, an attempt was made to examine the juvenile stage in life history of freshwater mussels in captive conditions and to find out the fish host- mussel larval relationship and target organs of the host for larval attachment.

Materials and Methods

A pond of 10 decimal was selected and stocked with 80 mussels and 100 fishes per decimal so that 50 fishes per decimal can examine monthly from each different species. Species of fish stocked were *Catla catla, Labeo rohita, Cirrhinus cirrhosus, Heteropneustes fossilis, Channa punctatus, Cyprinus carpio, Barbodes gonionotus, Oreochromis niloticus, Ompok pabda* and *Aristichthys nobilis*. Fishes were fed commercial feed at the rate of 5% body weight of fish twice daily. Aquatic vegetation such as *Enhydra fluctuans, Alternanthera phyloxeroides* were planted to provide natural environment. Five (05) samples of each fish species were collected monthly during the experimental period. Different fish organ such as fin and gills were collected and fin, gills of fish were sliced into 5 mm^2 to identify the glochidia under microscope. The size and number of the glochidium larvae were measured and counted by the digital Leica microscope (Leica DM 1000 LED). Microphotographs were taken using a Leica microscope of fertilized eggs, glochidium, developing glochidium in fish host and juvenile mussels after metamorphosis.

Water quality monitoring

Water quality parameters were monitored fortnightly and data were recorded during the study period. Water temperature, dissolved oxygen (DO), pH, alkalinity, ammonia and calcium were measured by Celsius thermometer, digital Oxygen meter (YSI, model 58) and digital pH meter (Jenway, model 3020), Spectrophotometer (DDR-2800), flame photometer determine (Buck Scientific FPF-7), Haemacyto meter, respectively. The plankton population was determined by using the following formula (Rahman, 1992)

$$\mathbf{N} = \frac{A \times 1000 \times C}{V \times F \times L}$$

Where N= No. of plankton cells per liter of original water, A= Total no. of plankton counted, C- Volume of final concentrated sample in ml, V= Volume of a field=1mm$^{-3,}$ F= No. of fields counted, L=Volume of original water in liter. The numbers of phytoplankton and zooplankton were expressed as cells/l.

Results and Discussions

It was observed that the freshwater mussels, *L. marginalis* is a prolific breeder and it spawns round the year. It exhibited a prolonged spawning period from February to November when water temperature remains above 22^0C (Niogee *et al*., 2019). It has been observed that glochidia larvae were attached to different host fish (Table 1) to reach the juvenile stage. However, the duration of larval metamorphosis was different with respect to different fish hosts tried. The glochidia larvae infestation was recorded on the gills and fins of the experimental fish but no glochidia were observed in fish slime.

Table 1. Presence of Glochidia in the gill or fin of host fishes.

Sample no.	Host fish	Average no. of Glochidia/5 mm^2 sample
1	*Catla catla*	2±0.19
2	*Labeo rohita*	2±0.21
3	*Cirrhinus cirrhosus*	2±0.66
4	*Heteropneustes fossilis*	11±1.24
5	*Channa punctatus*	7±1.49
6	*Cyprinus carpio*	4±1.63
7	*Barbodes gonionotus*	35±2.32
8	*Oreochromis niloticus*	9±1.76
9	*Ompok pabda*	11±1.24
10	*Aristichthys nobilis*	7±1.49

Among the species observed under microscope, highest number of glochidia (35/5mm^2) was found in *Barbodes gonionotus* and lowest number of glochidia (2/5mm^2) found in *Cirrhinus cirrhosus, Catla catla, Labeo rohita* (Table 1). Presence of high number of glochidia (Fig. 1) in *Barbodes gonionotus* may be due to its behavior. Because it is found in the middle of the water column to the bottom in ponds, rivers, streams, floodplains, and sometimes in reservoirs (Froese and Pauly, 2017).

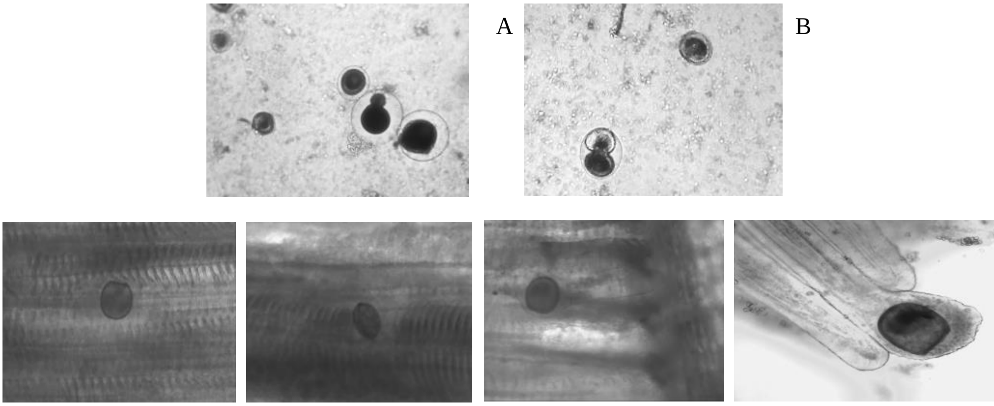

Fig.1. A.B-Different stages of glochidia development and presence of glochidia in gill and fin of host fishes

Water quality parameters were monitored fortnightly and data were recorded. Temperature, dissolve oxygen, pH, ammonia and alkalinity were recorded as 20.40-26.61^{0}C, 3.08-6.29 mg/l, 7.03-8.34, 0.002-0.04 mg/l and 100-190 mg/l, respectively (Table 2). According to Dan *et al*., (2001), water quality parameters as recorded in the present study were in suitable range both for fish and mussel culture. The spawning of bivalve molluscs depends on water quality parameters such as temperature, salinity, food availability, light, lunar phase, dissolved oxygen, pH (Barber and Blake, 1991). Among the parameter temperature is the most important parameter for maturation and spawning (Baba *et al*., 1999). Water temperature recorded during study period from 20.40°C to 26.61°C. During the study period it was observed that all the year round glochidia was present in host fish body but the highest number of glochidia was present During last week of October to first week of November. It can be said that October to November is the peak time of glochidia infestation when the temperature remaining at 24°C.

The process of finding appropriate host fish for glochidia infestation in freshwater mussel is very hard. The main objective of this study was to identify the suitable host fish for glochidia infestation of freshwater mussel. The glochidia larvae were examined on the gills, fins and slimes of different host fishes. It has been stated that when glochidium larvae come in contact with proper host, it clings to the skin, gill and fins by closing their hooked valves (Dharamraj *et al.,* 1991). Under microscopic observation, the highest number of glochidia among all the species of host fish was detected in the gills and fins part of *B. gonionotus.* This result was found in one year observation. Some species of mussels require certain species of fish as a specific host, while in other mussel species several kinds of fish will serve as hosts (Kotpal, 1995). It was reported that three fish species, green sun fish (*Lepomi scyanellus*), black bull head (*Ictalurus melas*) and channel catfish (*Ictalurus punctatus*) act as fish hosts for glochidium stage of *M. nervosa* in host specificity studies (Kafuku and lkenoue, 1983).

Table 2. Water quality parameters in the experimental pond

Parameters→ Months↓	Temperature (°C)	DO (mg/l)	pH	Ammonia (mg/l)	Alkalinity (mg/l)	Plankton (10^3 cell/L)
July	25.60±0.40	5.39 ±0.30	7.20±0.21	0.002±0.001	190±17.32	51.29±3.5
August	25.02±0.50	4.97±0.04	7.03±0.21	0.040±0.00	160±15.28	59.18±2.8
September	25.30±0.30	5.31±0.12	8.17±0.19	0.050±0.00	190±25.46	60.25±5.5
October	24.30±0.30	4.73±0.14	7.37±0.14	0.003±0.001	140±21.46	55.21±1.5
November	24.10±0.60	4.37±0.18	7.40±0.17	0.010±0.001	170±11.00	60.29±3.2
December	20.40±0.50	3.08±0.26	6.69±0.12	0.030±0.001	100±19.00	58.13±1.2
January	20.45±0.78	5.55±0.15	8.27±0.17	0.025±0.001	170±14.14	51.69±3.9
February	22.95±0.56	6.29±0.09	8.34±0.16	0.030±0.00	155±7.070	51.88±4.2
March	24.15±0.49	5.46±0.11	8.00±0.18	0.020±0.001	165±7.070	53.04±3.8
April	24.40±0.14	5.72±0.21	7.90±0.19	0.020±0.001	170±28.28	59.82±2.9
May	25.40±0.13	5.72±0.21	7.80±0.13	0.020±0.001	170±9.310	55.05±3.7
June	26.61±0.30	5.29±0.30	8.20±0.12	0.003±0.00	180±11.32	57.12±3.3

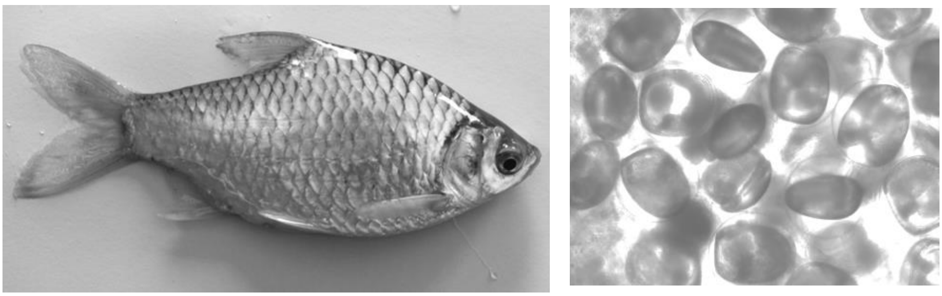

Fig.2. Highest number of glochidia presence in *Barbodes gonionotus*

The presence of highest number of glochidia was found in *B. gonionotus* due to its fast moving behavior and its habitat. It was also reported that in case of *H. schlegelli*, glochidium larvae clamp to gill filaments of fish being brought through respiratory water current (Kotpal, 1995).The presence of glochidiain other fishes was less than *B. gonionotus*. In this study, the lowest number of glochidia was detected in gills and fins of *Cirrhinus cirrhosus, Catla catla and Labeo rohita* due to its behavior. But there was no glochidia found in the slimes of any experimental host fishes.

In the current study the size of the glochidium larva of *L. marginalis* was observed under microscope to be 0.18 to 0.2 mm by using Leica microscope. It was reported that size of glochidium of freshwater mussels in general ranges between 0.1 and 0.5 mm (Kotpal, 1995; Behera *et al.,* 2014). The larval size of the *H. shlegelli*is reported to be 0.3 mm (Janakiram 1989). However, in the present investigation it has been observed that larva takes 30-40 days of duration to reach the juvenile mussel stage at 24-26 oC. When the brood mussel started to release glohcidium larvae from that time we continuously observed the glochidia in mussel and fish organ. After 30-40 days we found no glochidia for both mussel and fish organ but we found juvenile mussel from the experimental pond. The glochidium larvae of *L. marginalis* were taken about 10 weeks for completion of metamorphosis to attain juvenile stage (Kotpal, 1995). It was mentioned that mussel larvae requires 26-28 days for larval metamorphosis at 17^{o}C. In another trial it was shown that the glochidium required 56 days for larval metamorphosis in Channel catfish, *I. punctatus*, White suckers (*Catastomus commersoni*) and Yellow perch (*Perca flavescens*) retained glochidium up to 23-26 days, however no juveniles were produced (Kafuku and Ikenoue, 1983). In contrast the present study showed that fins of fish *B. gonionotus* were infected by glochidium larvae at an average of 35 per 5mm^2 and after duration of 30-40 days an average number of 23 juveniles per fish were recovered at 24-26^{o} C. In a similar way *Ompok pabda* were infected at an average of 11 per 5mm^2 resulting in 7 numbers of juveniles. In case of fish host *Heteropneustes fossilis,* the average larval infection rate was 11 per 5mm^2 and the juvenile recovery was 7 per 5mm^2 host. *Oreochromis niloticus* were infected by glochidium larvae at an average of 9 per 5mm^2 resulting 5 numbers of juvenile mussels. However, further detailed studies are required to establish the precise host related factors influencing the mussel larval metamorphosis.

In the present studies, infection of glochidium larvae in the gills and skin of the fish host were not recorded while glochidium could only be seen on different fins of fish host. It has been observed that glochidium larvae do possess certain specificity for infection on gill and fins such as pelvic, anal and caudal fins. The reason for this selective infection on fins could be that these fins normally come in contact with sediment on which benthic glochidium larvae are naturally dispersed. In *B. gonionotus*, nearly all the fins and gills were uniformly infested with the larvae; the reason may be due to *B. gonionotus* is an active swimmer which moves middle water level to the bottom substratum and large gill size as compared to other test fishes. Therefore, glochidium larvae get more chance for attachment to all the fins of *B. gonionotus*. Further, the *B. gonionotus* has long anal fin and large disc-shaped pelvic fins compared to other short finned test fishes, which increases the chance of infestation area on fins.

Conclusion

From this experiment, it can be concluded that among all fish species screened for host specificity study, *B. gonionotus* was found to be the ideal fish host because of its active moving behavior and it is found from the middle of the water column to the bottom in pond. Adequate mussel seeds can be produced using the practice as developed under the present study not only for pearl culture but also for rehabilitation of this species to protect it from being endangered.

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Diversity and periodic variation of fish assemblages in Dingapota haor, an eutrophic wetland of Northeastern Bangladesh

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Abstract
As a part of the conservation measures needed for wetland ecosystem, the present study was undertaken to examine the abundance and diversity status of Dingapota wetland of Bangladesh and to identify the governing environmental factors influencing the fish assemblage. A total of 52 fish species were recorded from 7 orders during the study period. Cypriniformes comprises the most abundant order (47.91%) followed by Perciformes (20.71%) and Clupeformes (20.22%). Post-monsoon was the most specious and diversified season compared to monsoon and pre-monsoon. Fish assemblage was significantly differentiated among the three seasons (ANOSIM, Global $R = 0.803$, $P < 0.05$) while the overall average differences in the period of three seasons was estimated as 39.92% and similarity percentage analysis (SIMPER) revealed the greater contribution of *Osteobrama cotio cotio*, *Esomus danricus*, *Nandus nandus*, *Gudusia chapra* and *Chanda nama* to ascertain this dissimilarity. Multivariate analysis based on non-metric multidimentional scaling (nMDS) generated three separate groups of each seasonal samplings and cluster analysis assembled the species in three groups according to their abundance. Diversity indices (Shannon-Weiner diversity (*H*), Margalef's richness (*D*) and Pielou's evenness (*e*)) were found to vary significantly among the seasons. Canonical correspondence analysis (CCA) revealed the significant role of temperature, depth, transparency, pH, dissolved oxygen and alkalinity to structuring the community assemblage of fish in Dingapota wetland of Bangladesh.

Keywords: Environmental parameters, Seasonal variation, Fish diversity, Canonical correspondence analysis, wetland ecosystem.

Introduction

The most diverse habitat in Bangladesh is wetlands. Sometimes the deepest portion of the marshes is referred to as haor, a bowl-shaped massive geological depression designated as the sixth hotspot in Bangladesh's Delta Plan 2100. These enormous low-lying plains (haors) are typically submerged during the rainy season and merge with riverine flood waters. Therefore, seasonal flooding in these haors mostly controls the variety and number of fish species. Due to the increase in water areas, fish are not typically present in large numbers during the monsoon. Since the turn of the century, there has been significant human meddling in the natural water bodies, leading to overexploitation, loss of habitats, and terrible conditions for aquatic ecosystems. For this reason, many fish species are currently in danger of going extinct. Bangladesh is now facing a serious problem with the ongoing aquatic biodiversity declining from natural water bodies (Galib *et al.*, 2009 and 2013; Mohsin *et al.,* 2013 and 2014). The decline in fish biodiversity in inland water bodies serves as an example of the need for an extensive study, which is necessary for evaluating the present situation and ensure the effective management approach of a water body (Imteazzaman and Galib, 2013).

Dingapota haor is one of the significant inland freshwater wetland ecosystems, which is situated at Mohanganj upazila of Netrokona District at 24°52′00″N 90°58′00″E / 24.8667°N 90.9667°E (Fig. 1) covering the surface area of 8000 ha. The diversity of fish in the water must be known before implementing any fisheries management technique, but no report on the fish diversity and ecological status of the water has been released (Huda *et al.,* 2009). Therefore, the current study examines seasonal variation in environmental variables as well as changes in various freshwater fish species diversity indices at Dingapota haor, Bangladesh.

Materials and methods

Study area and duration

The study was carried out over a 12-month period from July 2020 to June 2021 at three sampling sites (Karchapur, 24°77'72" N, 91°05'10"E; Mollikpur, 24°80'23" N, 91°03'57"E: Khurshimul, 24°88'66" N, 91°01'99"E) in the Dingapota haor, a wetland at Mohangonj upazila (Sub-district) of Netrokona District, Bangladesh (Fig. 1). It is an important ecosystem that supports many fish species and is regarded as an essential breeding and feeding habitat for inland freshwater fish species. Additionally, this region provides small-scale fishermen and nearby residents with a means of subsistence. Fish and environmental factors were sampled throughout each month, which was further divided into three distinct seasons; a) From July to October is monsoon season; b) from November to February is post-monsoon; and c) from March to June is pre-monsoon.

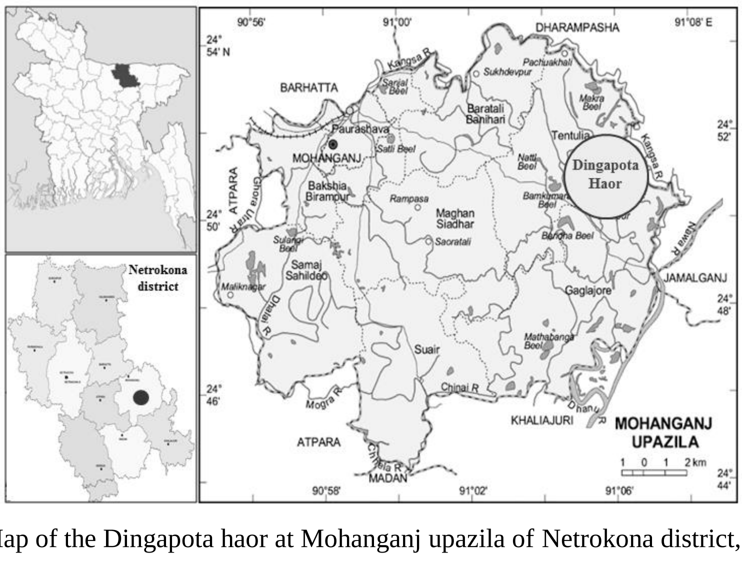

Fig. 1. Map of the Dingapota haor at Mohanganj upazila of Netrokona district, Bangladesh

Measurement of water quality parameters

Temperature, transparency, water depth, dissolved oxygen, pH, NO3-N, PO4-P, alkalinity, and TDS were the water quality parameters measured each month and documented. Water quality parameters were measured between 9:00 am and 12:00 pm throughout every sampling month. A highly advanced Multi-Parameter Water Quality Meter (HANNA, HI 98194, pH/EC/DO multi-parameter) was used to measure the water's temperature (°C), pH, DO, and TDS. Water depth was measured with a measuring tape. A Secchi disk was used to measure the water's transparency (in cm). A spectrophotometer (DR-1900) was used to measure alkalinity (mg/l), NO3-N, and PO4-P.

Species collection and identification

Species were collected from the specified sampling site with the assistance of experienced fisherman on each sampling date. A seine net with a length, width and mesh size of 100 m, 5 m and 1-2 mm, respectively was used for sampling of fishes. After collecting the fishes, they were identified and enumerated. Fishes which were difficult to identify, kept in 10% buffered formalin solution and transported to the laboratory of the Bangladesh Fisheries Research Institute, Mymensingh. Subsequently, morphometric and meristic data were used to identify the fishes up to species level followed by the keys of (Rahman *et al*., 2009). Identified fishes were categorized into taxonomic groups following Nelson *et al.*, (2006).

Diversity indices

Shannon-Weiner diversity, Margalef's richness and Pielou's evenness were calculated by using the following formula-

Shannon-Weiner diversity, $H = -\sum i \frac{n_i}{N} \ln \frac{n_i}{N}$ (Shannon and Weiner, 1949)

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

Margalef's richness, $D = -\frac{s-1}{\ln N}$ (Margalef 1968)

Where, N is the total number of distinct species in the sample, S is the different species in the sample; D is Margarlef's richness index.

Pielou's evenness, $Je = -\frac{H}{L_n s}$ [L_n = the natural logarithm] (Pielou's, 1966)

Where, S indicates the number of distinct species in the sample and H is the Shannon- Weiner index.

Statistical analyses

One-way analysis of variance (ANOVA) was used to assess seasonal fluctuation in water quality parameters using Statistical Package for Social Sciences (version 20.0) software. Seasonal distribution of water quality parameters was analyzed by principal component analysis (PCA). Species abundance and diversity indices were also analyzed by ANOVA. Mean differences among the seasons were determined by Duncan's multiple range test (DMRT) at 5% level of significance. Community assemblage pattern of fish species among the seasons was tested by multivariate analysis. Before analyzing the data, water quality parameters were square root transformed and the fish abundance data was $\log_{10}$ (x+1) transformed for the normalization. Analysis of similarity (ANOSIM) was conducted to assess the differences in fish community assemblage among the seasons. Similarity percentage analysis (SIMPER) was also used to determine the most contributory species causing differences among the seasons (Clarke and Warwick, 1994). The distribution pattern of the fishes among the season was visualized using non-metric multi-dimensional scaling (nMDS), and the species was categorized using a cluster analysis based on Bray-Curtis similarity matrix. The potential correlations between fish species and water quality parameters were determined by canonical corresponding analysis (CCA) using PAST (Paleontological Statistics, Version 4.10) program.

Results

Seasonal variation of water quality parameters

An overview of the water quality metrics that were noticed and noted during the investigation is presented in Table 1. All the water quality measures showed a significant variation across the seasons according to a one-way ANOVA. Pre-monsoon had the greatest water temperature (29.890.65°C), while post-monsoon had the lowest (22.363.98°C). Observed transparency was ranged between 39.59±4.41cm (Post-monsoon) to 24.66±0.81 cm (Monsoon). The highest water depth was observed during the Monsoon (5.96±1.61 m) and the lowest during pre-monsoon (1.66±0.82 m) whereas pH was ranged between 7.00±0.78 (post-monsoon) to 6.38±0.60 (pre-monsoon). In addition DO was between 6.63±0.74 mg/l (post-monsoon) to 4.56±0.53 mg/l (pre-monsoon). In case of NO_3-N and PO_4-P, pre-monsoon showed the greatest levels of (0.33 0.04 and 1.34 0.11 mg/l), while monsoon had the lowest levels (0.13 0.01 mg/l and 1.16 0.02 mg/l). The total alkalinity was 126.89±7.47 mg/l during pre-monsoon and 103.38±4.44 mg/l during monsoon while TDS was also the highest during pre-monsoon (135.73±5.50 mg/l) and the lowest during monsoon (100.97±5.16 mg/l). PCA was also used to explain the seasonal variation of water quality measures, with its first two axes accounting for 85.94% of the variability in the data (Fig. 2). PCA demonstrated a distinct seasonal separation of the samples whereas higher water depth was characterizing the monsoon samples, higher transparency, DO, NO_3-N and PO_4-P illustrated the samples collected during post-monsoon season and higher alkalinity and TDS are described the samples of pre-monsoon season.

Table 1. Water quality parameters (Mean ± SD) in different seasons

Variables	Monsoon	Post-monsoon	Pre-monsoon
Temperature (⁰C)	28.70±0.62^a	22.36±3.98^b	29.89±0.65^a
Transparency (cm)	24.66±0.81^c	38.02±3.29^b	39.59±4.41^a
Depth (m)	5.96±1.61^a	1.93±0.41^b	1.66±0.82^c
pH	6.99±0.85^a	7.00±0.78^a	6.38±0.60^b
DO (mg/l)	5.72±0.52^b	6.63±0.74^a	4.56±0.53^c
NO_3-N (mg/l)	0.13±0.01^c	0.21±0.11^b	0.33±0.04^a
PO_4-P (mg/l)	1.16±0.02^c	1.28±0.09^b	1.34±0.11^a
Total alkalinity (mg/l)	103.38±4.44^c	112.79±2.00^b	126.89±7.47^a
TDS (mg/l)	100.97±5.16^c	116.92±7.38^b	135.73±5.50^a

Mean values in the same row having difference superscript letters indicate significant ($P< 0.05$) differences.

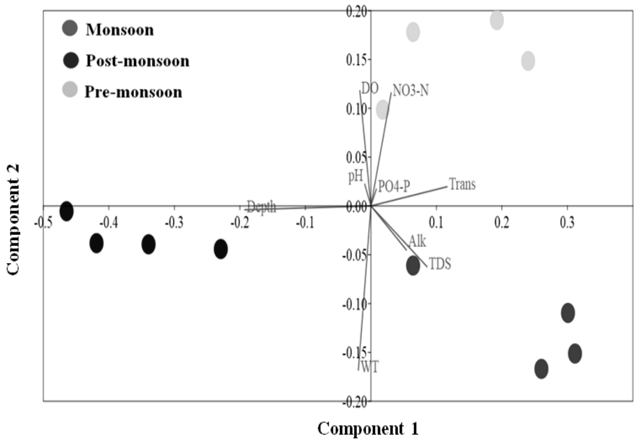

Fig. 2. Water quality parameters during the monsoon, post-monsoon, and pre-monsoon seasons were analyzed using the principle component method (Wt = water temperature, Trans = transparency, Depth, DO = dissolved oxygen, pH, NO_3-N = nitrate-nitrite, PO_4-P = phosphate-phosphorus, Alka = total alkalinity, TDS = total dissolved solids).

Catch composition

During the study period, 52 fish species from 17 families and 7 orders were recorded. Figure 3 demonstrates that the most abundant order was the cypriniformes followed by the perciformes (20.71%) and the clupeformes (20.22%). A total of 1242 individual of fishes was collected during the study period which consists of 52 species (Table 2). The total abundance was significantly higher during post-monsoon season (725) and the lowest in pre-monsoon season (107). Similarly, total number of species was significantly higher during post-monsoon season (47) and the lowest in pre-monsoon season (34). *Amblypharyngodon mola* (11.03%) was the most dominant species followed by *Gudusia chapra* (10.03%) and *Osteobrama cotio cotio* (8.01%).

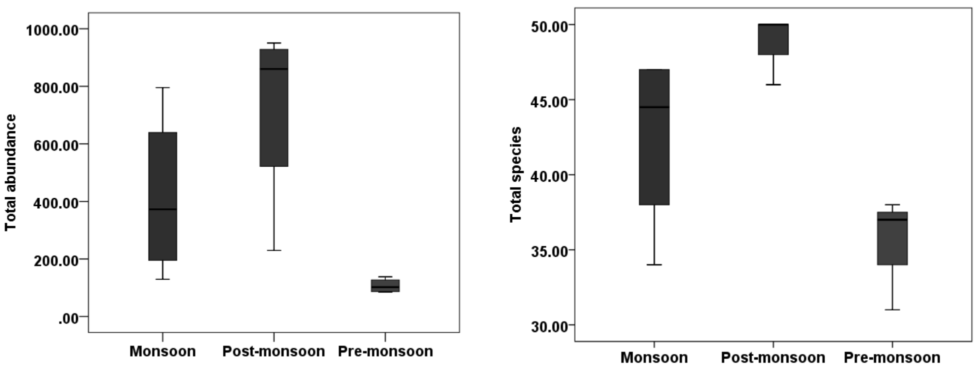

Fig. 3. Seasonal fluctuations in the studied wetland's total fish abundance (a) and species count (b) during the study period

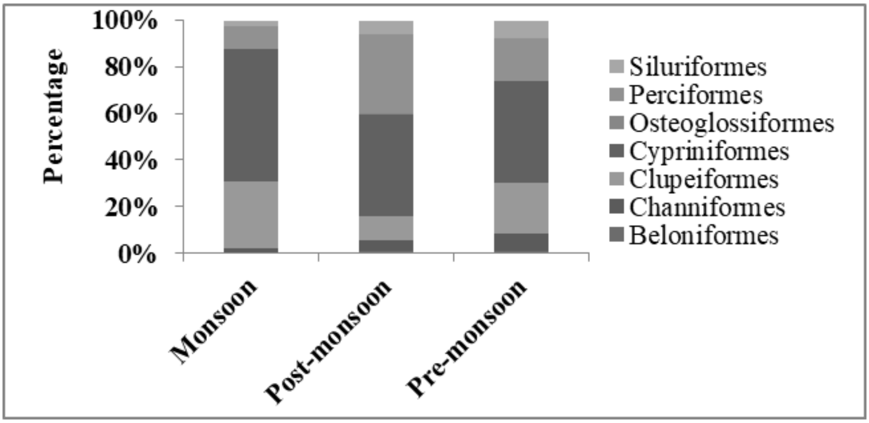

Fig. 4. Percentage composition of different fish taxonomic orders in the studied wetland

Table 2. List of fish species with number of individuals and their contribution (%) in each season.

Sl. No.	Species Name	Code	Total	Overall contribution (%)	Seasonal contribution (%)		
					Monsoon	Post-monsoon	Pre-monsoon
1	*Xenentodon cancila*	Xc	9	0.73	0.54	0.82	0.89
2	*Hyporhamphus limbatus*	Hl	1	0.07	0.21	0.00	0.00
3	*Channa punctatus*	Cp	21	1.65	0.61	1.85	4.35
4	*Channa striatus*	Cs	19	1.56	0.28	2.23	1.94
5	*Channa orientalis*	Co	6	0.52	0.32	0.50	1.36
6	*Channa marulius*	Cm	5	0.42	0.13	0.50	1.02
7	*Corica soborna*	Cso	114	9.20	18.49	3.15	14.24
8	*Gudusia chapra*	Gc	131	10.52	15.60	7.79	9.39
9	*Gibelion catla*	Gca	2	0.16	0.16	0.18	0.00
10	*Labeo rohita*	Lr	1	0.05	0.16	0.00	0.00
11	*Labeo bata*	Lb	11	0.90	0.33	0.66	4.69
12	*Labeo calbasu*	Lc	6	0.47	0.18	0.30	2.70
13	*Labeo gonius*	Lg	10	0.81	0.38	0.87	2.05
14	*Cirrhinus cirrhosus*	Cci	5	0.39	0.27	0.39	0.84
15	*Amblypharyngodon Mola*	Am	137	11.03	21.14	4.98	13.03
16	*Chela Laubuca*	Cl	64	5.19	5.06	5.10	6.35
17	*Osteobrama cotio*	Oc	99	8.01	11.11	7.24	1.26
18	*Pontius sarana*	Ps	10	0.77	0.77	0.57	2.18
19	*Puntius sophore*	Pso	65	5.21	1.09	8.02	2.05
20	*Pethia ticto*	Pt	18	1.43	0.67	1.74	2.28

Sl. No.	Species Name	Code	Total	Overall contribution (%)	Seasonal contribution (%)		
					Monsoon	**Post-monsoon**	**Pre-monsoon**
21	*Salmostoma Bacaila*	Sb	2	0.13	0.11	0.17	0.00
22	*Esomus danricus*	Ed	85	6.84	7.12	7.51	1.15
23	*Botia dario*	Bd	2	0.18	0.31	0.13	0.00
24	*Lepidocephalichthys Guntea*	Leg	17	1.38	1.15	1.71	0.00
25	*Notopterus chitala*	Nc	4	0.35	0.09	0.55	0.00
26	*Notopterus notopterus*	Nn	0	0.04	0.06	0.03	0.00
27	*Anabas testudineus*	At	16	1.30	0.08	1.82	2.49
28	*Chanda nama*	Cn	47	3.79	1.44	5.53	1.02
29	*Pseudambassis ranga*	Pr	13	1.04	0.40	1.56	0.00
30	*Glossogobius giuris*	Gg	12	0.95	0.39	1.40	0.00
31	*Glossogobius chuno*	Goc	49	3.91	1.32	5.68	1.91
32	*Macrognathus aculeatus*	Ma	30	2.45	1.43	3.05	2.28
33	*Macrognathus pancalus*	Mp	37	2.96	1.31	4.05	1.97
34	*Mastacembelus armatus*	Maa	11	0.89	0.30	1.13	1.57
35	*Nandus nandus*	Nan	28	2.22	0.17	3.38	2.25
36	*Colisa fasciata*	Cf	21	1.65	0.37	2.33	2.05
37	*Badis badis*	Bad	0	0.04	0.00	0.07	0.00
38	*Mystus aor*	Mao	10	0.83	0.11	1.21	1.02
39	*Mystus cavassius*	Mc	37	2.96	2.49	3.40	1.76
40	*Mystus vittatus*	Mv	18	1.43	0.83	1.74	1.57
41	*Rita rita*	Rr	1	0.09	0.08	0.10	0.00
42	*Ompok bimaculata*	Ob	6	0.45	0.18	0.49	1.21
43	*Ompok pabda*	Opa	8	0.62	0.42	0.63	1.36
44	*Wallago attu*	Wa	8	0.68	0.32	0.83	1.08
45	*Ailia coila*	Ac	8	0.63	0.54	0.78	0.00
46	*Clupisoma garua*	Clug	9	0.73	0.61	0.91	0.00
47	*Eutropiichthys vacha*	Eucv	1	0.05	0.16	0.00	0.00
48	*Bagarius bagarius*	Bb	2	0.16	0.11	0.22	0.00
49	*Clarias batrachus*	Cb	4	0.33	0.14	0.28	1.39
50	*Heteropneustes fossilis*	Hfo	5	0.41	0.12	0.39	1.65
51	*Chaca chaca*	Cch	3	0.26	0.00	0.21	1.65
52	*Neotropius atherinoides*	NA	14	1.16	0.32	1.80	0.00

Species diversity

The seasonal values of the Pielou's evenness, Margalef's richness, and Shannon-Wiener diversity indices are presented in Fig. 6. The studied haor is more diverse in post-monsoon season with the Shannon–Wiener diversity value of 3.27 ± 0.17. Furthermore, fish species of the studied haor were more evenly distributed for the period of post-monsoon season (Pielou’s evenness value 0.89 ± 0.08). Species richness was also higher in post-monsoon season with the Margalef’s richness value 7.97 ± 0.24.

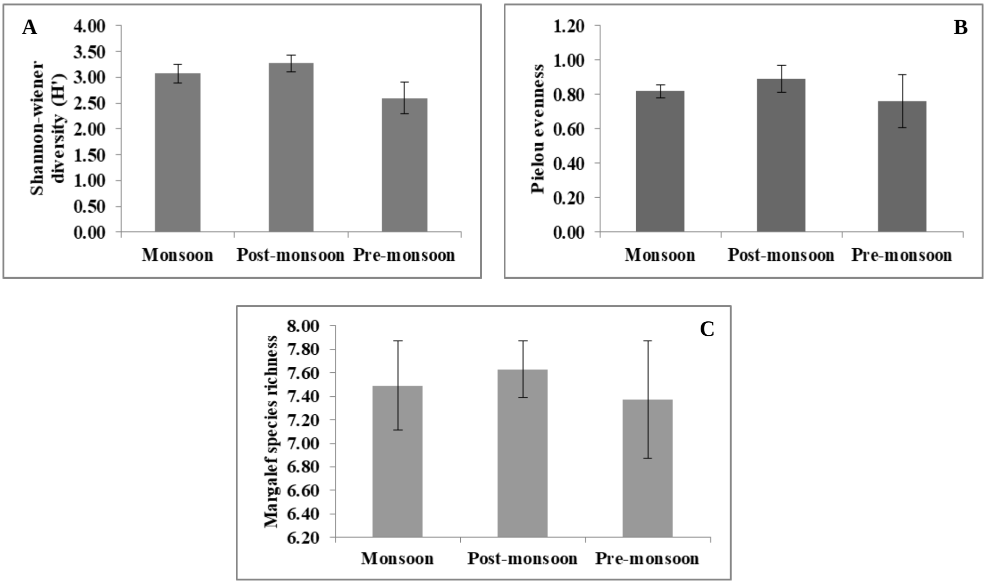

Fig. 5. Seasonal variation of species diversity indices.
(A) Shnnon-wiener, (B) Pielou evenness, (C) Magalef richness.

Species assemblage

According to analysis of similarity (ANOSIM), the species assemblage varied significantly among each of the seasonal groups (Table 3), with global R values of 0.5313, 0.0.8646, and 0.9063 and P values of 0.0477, 0.0293, and 0.0323. According to SIMPER analysis, there is an average dissimilarity of 36.61, 39.89, and 43.25 % between monsoon and post-monsoon, monsoon and pre-monsoon, and post-monsoon and pre-monsoon, respectively, whereas the most contributory species from each group were *Nandus nandus* (5.55%), *Esomus danricus* (5.53%) *and Gudusia chapra* (4.34%). ANOSIM ($P < 0.0007$, $R = 0.8032$) has revealed significant variation in species assemblage among the seasons with an overall average dissimilarity of 39.92% determined by SIMPER analysis. Five most contributory fish species responsible for these seasonal variations are *Osteobrama cotio cotio* (4.04%), *Esomus danricus* (3.96%), *Nandus nandus* (3.90%), *Gudusia chapra* (3.36%) *and Chanda nama* (3.30%).

Table 3. ANOSIM and SIMPER analysis of fish species assemblage

Groups	ANOSIM		Dissimilarity index from SIMPER		% contribution
	R	P	Ave. Diss. (%)	Typical species	
Monsoon vs. Post-monsoon	0.5313	0.0477	36.61	*Nandus nandus*	5.55
				Gudusia chapra	4.17
				Channa striatus	3.83
				Chanda nama	3.57
				Puntius sophore	3.36
Monsoon vs. pre-monsoon	0.0.8646	0.0293	39.89	*Esomus danricus*	5.53
				Osteobrama cotio	5.35
				Gudusia chapra	4.18
				Lepidocephalichthys Guntea	3.80
				Amblypharyngodon Mola	3.65
Post-monsoon vs. Pre-monsoon	0.9063	0.0323	43.25	*Gudusia chapra*	4.34
				Chanda nama	4.15
				Osteobrama cotio	4.07
				Neotropius atherinoides	3.76
				Glossogobius giuris	3.59
overall or pool all groups	0.8032	0.0007	39.92	*Osteobrama cotio*	4.04
				Esomus danricus	3.96
				Nandus nandus	3.90
				Gudusia chapra	3.36
				Chanda nama	3.30

According to the Bray-Curtis similarity index (stress 0.043), three distinct seasonal groupings of fish assemblage were found by nMDS. (Fig. 6). The fish samples from the pre-monsoon season were in the second group (on the right side of Fig. 6), the samples from the post-monsoon season were in the first group (on the left side of Fig. 6), and the samples from the monsoon season were in the third group (at lower side of the Fig. 6).

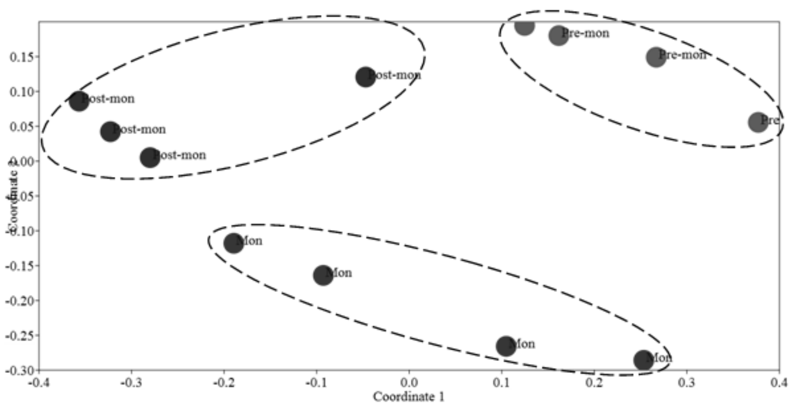

Fig. 6. Non-metric multidimensional scaling (NMDS) of fish species

Cluster analysis also separated the collected fish species into three distinct groups at 50.00% similarity (Fig. 7) whereas the first cluster (from the left side of the Fig. 7) consists of the species which had lower abundance during the study period. However, fish species with a moderate abundance are classified into the second cluster, and the fish species with the greatest abundance are represented by the third cluster.

Fig. 7. Dendrogram demonstrating 2D ordination of a cluster analysis of fish species using the Bray-Curtis similarity matrix.

Canonical correspondence analysis (CCA)

Results obtained from CCA were plotted in Figure 8 whereas the species placed nearer the vector were more closely related to them. The length and direction of the arrows show the relative significance of the water quality parameters. The CCA ordination directs that transparency, depth, DO and TDS are the most influential water quality parameters shaping fish species accumulation in the studied wetland. Water temperature and depth have close affinity with *Esomus danricus*, *Gudusia chapra* and *Amblypharyngodon Mola* which are describing the monsoonal abundance of these species. *Osteobrama cotio, Chanda nama* and *Macrognathus pancalus* are found to influence mainly by DO, pH, NO_3-N and PO_4-P and this interaction is highlighting the post monsoonal species abundance. Transparency, alkalinity and TDS showed their highest value during pre-monsoon season and the fish species *Glossogobius chuno*. *Channa striatus*, *Chela Laubuca* and *Puntius sophore* are found to be influenced mostly by these parameters.

Discussion

The maximum average temperature was 29.89±0.65 °C in pre-monsoon and the minimum temperature was 22.36±3.98°C in post-monsoon. The temperature in Ashulia beel ranged between 28.7 to 31.7ºC and 22.4 to 25.6ºC during wet and dry season, respectively (Islam *et al.*, 2010) During the study period transparency was fluctuated 39.59±4.41 cm (Post-monsoon) to 24.66±0.81 cm (Monsoon) (Chowdhury and Mazumder, 1981) also recorded instances of excessive turbidity during the monsoon season. Productive water body should contain transparency of less than 40 cm (Salauddin and Islam, 2011). The water depth was ranges between 5.96±1.61 m in Monsoon to 1.66±0.82 m during pre-monsoon. The water level in the haor area become lowest from January to March and then starting decline again from August (Salauddin and Islam 2011). The maximum pH was noted 7.00±0.78 in post-monsoon and the lowermost was 6.38±0.60 in pre-monsoon. pH ranged between 7.15 and 7.45 was recorded by (Islam *et al.*, 2017) at Karimganj haor in Kishoreganj which is more or less similar to the present study. The DO contents were ranged from 6.63±0.74 mg/L in post-monsoon to 4.56±0.53 mg/L in pre-monsoon. DO in Hakaluki haor and Karimganj haor (Akter *et al.*, 2017) were ranged between 3.1 to 7.0 and 6.4 to 6.8 mg/L respectively which are mostly similar to the current investigation. NO_3-N was the highest during pre-monsoon (0.33±0.04 mg/L) and the lowest during monsoon (0.13±0.01 mg/L). Nitrate-N (NO_3-N) concentrations ranged from 0.01 to 0.33 mg/L at different locations in Chalan beel, and in Kaptai Lake (Halder *et al.*, 1992) of Bangladesh. The PO_4-P was 1.34±0.11 mg/L in pre-monsoon to 1.16±0.02mg/L in monsoon. The PO_4-P in the Kaptai Lake ranged from 0.32 to 0.41 mg/L with an average of 0.367 mg/L. Khan *et al.*, (1996) also revealed a higher level of PO_4-P in dry season compared to rainy season in their study location. Total alkalinity was 126.89±7.47 mg/L in pre-monsoon to 103.38±4.44 mg/L during monsoon season which is more or less similar to the findings of Ahatun *et al.*, (2020) in Korotoa River (122.05 mg/L). The peak TDS content of the haor was 135.73±5.50 mg/L throughout pre-monsoon mg/L and the lowermost was 100.97±5.16 mg/L in monsoon season. The TDS at various sampling locations of Hakaluki haor was ranged between 80.75 to 184.0 mg/L with the mean value of 132.38 mg/L (Akter *et al.*, 2017) which was comparable to the present study.

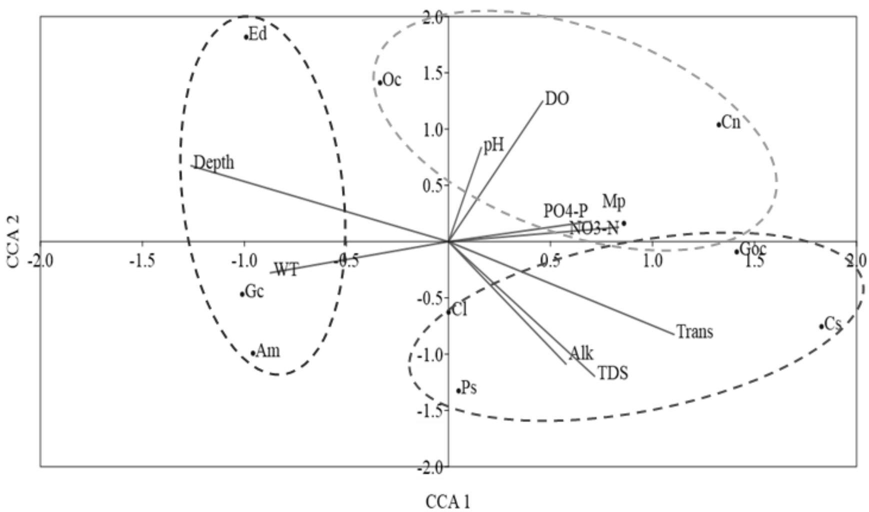

Fig. 8. Biplot for canonical correspondence analysis. Wt = Water temperature, Trans = Transparency, Depth, DO = Dissolved oxygen, pH, NO_3-N = Nitrate-nitrite, PO_4-P = Phosphate-phosphorus, Alk = Total alkalinity, TDS = Total dissolved solids. Species codes are shown in Table 2.

Fifty-two fish species were incurred during the study period which was abundantly belonging to 17 families and the Cypriniformes was the most dominant (47.91%) group. Previous study conducted by Hasan *et al*., (2017) reported 17 families from Kishorgonj haor in Bangladesh. While slightly higher number of families was recorded by Islam *et al*., (2021) And Pandit *et al*., (2015) from Dekhar haor, Bangladesh. Freshwater bodies of Bangladesh are mainly dominated by Cypriniformes as was stated by Jannatul *et al*., (2015), Maria *et al*., (2016), Mazumder *et al*., (2016), Chowdhury *et al*., (2019), Akhi *et al*., (2020), and Sunny *et al*., (2020). Therefore, the current results supported the previous investigations. A total of 52 fish species obtained during the present work was also stayed by the results of Islam *et al*. (2021) who described 57 species of fishes in their study. Seasonal fluctuation in the total species abundance was significant among the seasons with the maximum abundance of species was found in post-monsoon season and the lowest in the pre-monsoon season. *A. mola* (11.03%) was the most dominant species followed by *G. chapra* (10.03%) and *O. cotio* (8.01%) which were mainly influenced by water temperature and depth. Small indigenous fishes are the main and inexpensive form of indispensable vitamin and mineral in the diet of people in Bangladesh (Bogard *et al*., 2015). Therefore, market value of these fish species is increasing day by day. As a result fishermen are currently enhancing their fishing effort in the haor to catch them.

Seasonal changes in diversity of the present study was depicted by several diversity indices such as the number of species in an assemblage (Gotelli and Chao, 2013), evenness (Jost, 2010) and richness (Delang and Li, 2013). Diversity indices in the present study were found to increase significantly in post-monsoon season and decrease for the period of monsoon season. Higher diversity index during post-monsoon indicates the increase in fish species by reproducing, feeding and sheltering themselves successfully (Aziz *et al*., 2021). Similar findings were also made by Nath and Deka (2012) and Iqbal *et al*., (2015), who observed the highest diversity of fish during the post-monsoon season. However, lower species diversity during monsoon can be described by the higher water depth which reduced the effectiveness of fishing gear to catch fish. On the other hand, comparatively lower diversity indices during pre-monsoon season are possibly because of the stress caused by overfishing and scarcity of water (Aziz *et al*., 2021). Increased water temperature are also causing higher evaporation rate which reducing the water area and encourages the anthropogenic activities by local communities such as intensive rice production and irrigation which are affecting the ecological process of haor. Reduced transparency is also inhibit the light penetration, reduced primary and secondary productivity and finally declined fish diversity in the present study. However, the diversity index recorded during the present study (2.60-3.27) was within the range (2.90-3.12) reported by Iqbal *et al*., (2015), higher (1.22-1.36) than the findings of Hossain and Rabby (2020) and lower (3.76-3.81) than the findings of Aziz *et al*., (2021). According to Biligrami (1988) improved status of an aquatic habitat for fish diversity is indicated by Shannon-Wiener index of 3.0-4.5. That’s mean studied haor is light to slightly polluted during monsoon season and this might be due to the domestic discharge, poor water quality and from the uses of different insecticides and pesticides. Evenness and richness of fish species was also peak in post-monsoon season. Evenness is the degree of relative diversity which can be higher when the entire habitat supports similar density and richness is the range of relative abundance fish species. In an even population all species are assumed to be distributed identically into the habitat. As observed in the present study, decreased water level during post-monsoon season leads to more fish species caught by fishing activities causing a homogenous catches of the fishes. On the contrary, higher water depth during monsoon season causes irregular distribution of fish species and the majority of fishes were caught using selective fishing gears which have low evenness and richness indices. Similar pattern of seasonal variation of fishes are also observed in various aquatic habitat of Bangladesh (Joadder *et al*., 2015; Jewel *et al*., 2018; Akhi *et al*., 2020).

Conclusions

By 52 species, Cypriniformes was the most numerous orders in the Dingapota haor, which can be considered to be a species-rich haor. The water depth and heavy post-monsoonal fishing pressure were the main causes of the seasonal variation in fish species diversity in this area. To protect the remaining fish species, it is possible to maintain control over the perennial water regions that were produced for the period of the post-monsoon season. By designating the perennial water areas as a sanctuary for young fish in the post-monsoon season, additional steps could be made to lessen the effects of human activity on fish.

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Fecundity and gonadosomatic index of grey eel catfish, *Plotosus canius* (Hamilton, 1822) in the Mid-Southern coast of Bangladesh

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Abstract

This study was carried out from January to December 2020 to investigate reproductive biology of the Grey-eel catfish, *Plotosus canius* in Mid-southern coast of Bangladesh. The highest fecundity (3043.94) was found from a fish having total length of 84.76 cm (weight 2500.32 g) and the lowest (1594.50) in fish measuring 38.77 cm in total length (weight 373.55). The study of fecundity indicated a liner relationship with total length, body weight and gonad weight. The highest GSI values (20.45%) of female fish were found in September and the lowest (6.5%) in December and GSI increased from March onwards and reaching its peak in September followed by a gradual decrease in December. This indicated the development of gonads during March to September and spent stage in December. The findings of the present study would be very useful for proper management, conservation and development of aquaculture of this species.

Key words: Reproductive Biology, *Plotosus canius*, Mangrove estuary.

Introduction

The grey-eel catfish, *Plotosus canius* (Hamilton, 1822), belong to the family Plotosidae is one of the near threaten catfish of Bangladesh (McAllister *et al.*, 2000). This canine catfish is most commonly distributed in the estuarine region, particularly in the south west coast of the country and the mangrove areas (Islam *et al.*, 2007). It is primarily found in marine habitat but sometimes can be caught in brackish or fresh water habitats (Sarkar *et al.*, 2008). Juveniles of *Plotosus canius* are commonly found to form compact aggregates, thus resulting in very tight shoals with about 50 juvenile fish (Ambak *et al.*, 1993, Murawski *et al.*, 2001). It has been observing to live on or near the bottom of the sea and migrate between sea and fresh water (Rishi and Singh 1983). Eel catfish of the family Plotosidae are endemic to the estuaries and brackish waters of South Asia where the occurrence of *P. canius* is limited to specific locations from India to Papua New Guinea (Mohsin *et al.*, 1993). Its venomous spine and skin secretions had probably deterred research, thus only few workers have studied the species (Gimlette, 1971, Iekhsan *et al.*, 1971, Mace, 1994; Sinha, 1981; Weber and Beaufort, 1913). Canine catfish is a less common species and its population abundance shows a declining trend in Bangladesh. Although, the estimated extent of occurrence (46,947.01 km^2) and area of occupancy (10,178.31 km^2) are above the threshold values for any IUCN threatened category but the fish is impacted by some major threats, including destruction of habitat and overexploitation and poses a risk for its extinction in future, however its consider as near threatened catfish (IUCN, 2015).

Knowledge of biological properties of any species is of paramount importance, both for judicious management of its population as well as to assess its availabilities for culture purpose. *P. canius* is in serious need of attention to ensure aquaculture and conservation of the species in Bangladesh. There is need of increasing concern on reproductive biology in marine fish, as this becomes very useful to get accurate estimate of the effect of fishing on the potential of reproduction of any fish (McAllister *et al.,* 2000, Narejo *et al.*, 2002). To manage any fish species knowledge of reproduction has become necessity (Rehman 2002, Mekkawy and Hassan, 2011). Knowledge about fecundity of a fish is essential for evaluating the commercial potentialities of its stock, life history, practical culture and actual management of the fishery (Doha and Hai, 1970, Lawson *et al.,* 2011). So, to save this species from its extinction through induced breeding a complete knowledge about its biology including breeding behavior, fecundity, fertilization and hatching is also essential. Induced breeding is an effective means to save a species from its extinction as the seed production of any species is completely dependent on brood stock development. Understanding the reproductive biology of any fish species is very important for its successful culture (Le Cren, 1965). It also plays a very important role in the aquaculture practice in raising economically important fishes in aquaculture system as well as to evaluate the level of exploitation, seasonal variation and conservation of fish stock (Khan *et al.,* 2002, Gupta and Gupta 2006, Adebiyi *et al.*, 2011, Islam and Kurokura, 2012,). A few studies on its reproductive biology and feeding habit have been carried out (Sinha, 1984; Sinha 1986, Ahmed *et al.,* 2007, Islam *et al.,* 2020). However, for developing culture technologies, biological studies of this species are indispensable. Therefore, this study was carried out to identify the GSI and to estimate fecundity of *P. canius* to generate the base line information for more intensive research in the culture, management and breeding of this fish species in Bangladesh.

Materials and methods

For this study, berried females of *P. canius* were collected twice a month from January 2020 to December 2020 from the Andharmanik river (21^{0}59\`14.6546\`\`N and 90$^0$13\`50.934\`\`E) and different collectors in the coastal waters of Patuakhali district, Bangladesh on the basis of new moon and full moon with a minimum of five (5) fishes in each sampling and a total of 120 fishes during the study period. The collected fish samples were brought to the laboratory of Riverine Sub-station, Bangladesh Fisheries Research Institute (BFRI), Patuakhali, Bangladesh for detailed studies. The ovaries of each fish specimen were removed very carefully from the females and were preserved in 5% formalin with proper labeling to permit hardening of the ova (Fig. 1). The ovary was cleaned properly and each pair of the ovary was weighed separately to the nearest 0.01 mm with an electric balance. Gravimetric method was used to determine the fecundity of fishes (Lagler 1949). The preserved ovaries were weighed and samples from anterior, middle and posterior regions of each lob of each pair were weighed accurately. The number of matured and maturing eggs was then found out by actual counting. Fecundity was calculated using the formula (Baly 1981) as follows:

F= N*Gonad weight/ Sample weight
Where, F is the fecundity and N is the number of eggs in the sample.
Gonadosomatic index (GSI) of the fishes was calculated by using the formula:
GSI= Gonad weight/ Total body weight of fish*100 (Rahman 2011).

Diameter of the ova was taken under the microscope fitted with ocular micrometer and determines the maturity according to Leh and Sasekumar (1989). Diameter of about 10 ova was measured at random from the anterior, central and posterior regions of each lobe of the ovaries. Male and female fish were differentiated and data were recorded monthly basis after dissecting out the gonads of the individual fish (Parameswarn *et al.,* 1974).

(a) Male (b) Female (c) Ovary and testis

Fig. 1. External and internal sex identification of *P. canius*.

Results

Fecundity
The mean numbers of eggs were 2462.69 for a fish with a mean total length 61.61cm and a mean weight of 1305.45 g (Table 1).

The maximum fecundity (3043.94) was found from a fish having total length of 84.76 cm and weight 2500.32 g, respectively. The minimum fecundity (1594.50) was observed in fish measuring 38.77 cm in total length and weight 373.55 g. The highest no. of ova per gram weight of fish was 4.2685 and the lowest was 1.2174. The highest and lowest numbers of ova per gram weight of ovary were 73.9564 and 15.1206, respectively.

Table 1. Average fecundity counts at various lengths and weight ranges of *P. canius*

Serial No.	Length range (cm)	Mean length of fish (cm)	Mean weight of fish (g)	Mean ovary weight (g)	Fecundity	No. of ova per gram of body weight	No. of ova per gram of ovary weight
01	36.50-40.50	38.77	373.55	21.56	1594.50	4.2685	73.9564
02	40.60-44.60	42.63	465.60	46.68	1896.65	4.0735	40.6308
03	44.70-48.70	46.96	795.67	75.50	2098.40	2.6372	27.7933
04	48.80-52.80	50.47	889.34	137.75	2197.80	2.4712	15.9549
05	52.90-56.90	54.92	897.54	145.32	2367.45	2.6377	16.2912
06	57.00-61.00	58.36	1087.45	160.45	2582.22	2.3745	16.0936
07	61.10-65.10	64.30	1386.87	143.24	2387.21	1.7212	16.6658
08	65.20-69.20	68.50	1485.75	164.45	2689.31	1.8100	16.3533
09	69.30-73.30	72.45	1660.89	174.06	2798.45	1.6849	16.0775
10	73.40-77.40	76.56	2031.75	185.92	2874.98	1.4150	15.4635
11	77.50-81.50	80.65	2090.75	196.05	3021.32	1.4450	15.4109
12	81.60-85.60	84.76	2500.32	201.31	3043.94	1.2174	15.1206
	Mean	61.61	1305.45	137.69	2462.69	2.3130	23.8176

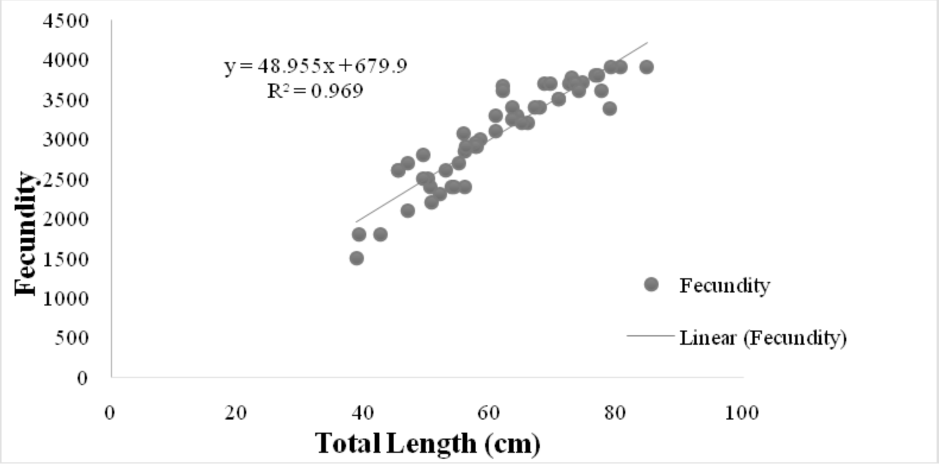

Fig. 2. Relationship between fecundity and total length of *P. canius*

Relationship between fecundity and total length, body weight and gonad weight was found statistically significant ($P<0.05$). The variation of fecundity with total length is expressed as y = 48.955x+679.9 (Fig. 2.). The fecundity and body weight relationship (Fig. 3) is illustrated by the formula y = 0.6749x + 1461.2. The relationship between fecundity and gonad weight was also calculated and illustrated by the formula y = 7.0385x + 1442.8 (Fig. 4.)

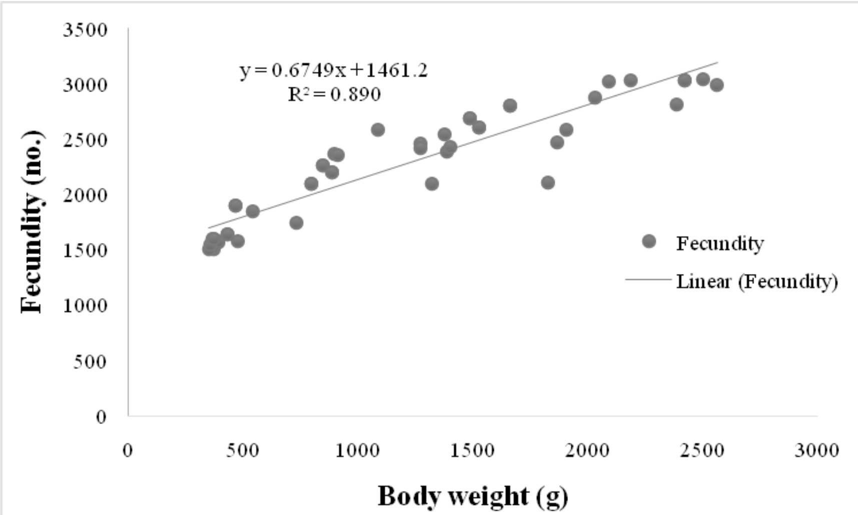

Fig. 3. Relationship between fecundity and body weight of *P. canius*

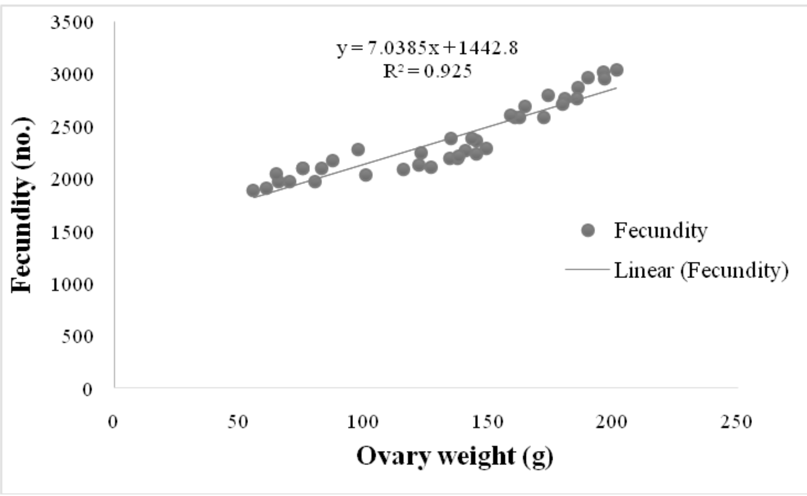

Fig. 4. Relationship between fecundity and ovary weight of *P. canius*

Gonadosomatic index (GSI %)

The gonadosomatic index is an indicator of the state of gonadal development and maturity of *P. canius*, calculated for berried female and depicted in Fig. 5. GSI increases steadily from April, dropped suddenly in June and further increases gradually to reach the peak in September. Therefore, the highest GSI value (20.45%) was found in the month of September and the lowest (6.5%) in December.

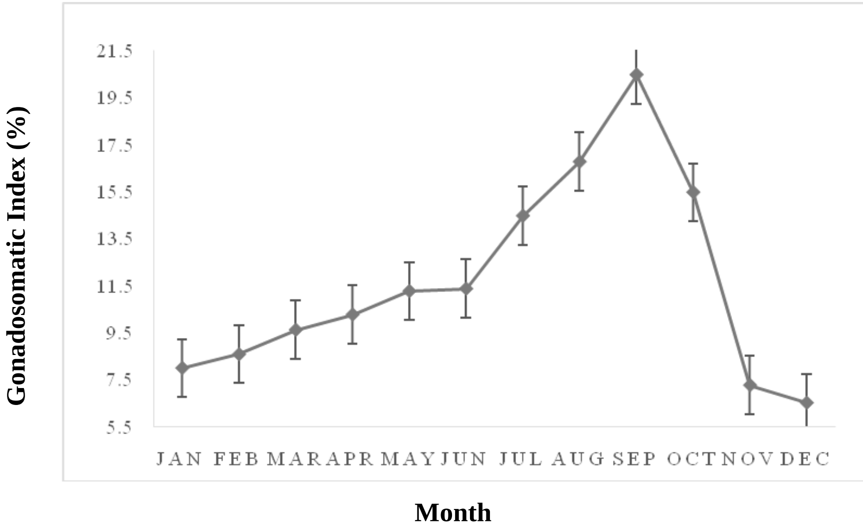

Fig. 5. Monthly variation of GSI (%) for female *P. canius*

Discussion

Fecundity is the capability of fish in terms of egg production or the number of ripening eggs in the ovaries of the female before spawning; or the number of eggs per unit length of fish in per year. Knowledge of fecundity in is very important to assess spawn production from the available stock of breeders and also to explain variation in population and to increase fish harvest (Misra, 1986). Information on fecundity is very important in assessing the commercial potentialities of fish stock (Khan *et al.,* 2002). The present study revealed that although older fish were more fecund, but the younger fish produced more ova per gram weight of body, which was the true number of ova per gram weight of ovary. There was an increase in fecundity with the increase of fish size, weight of fish and gonad weight. These results comply with the findings for catfish *Tachysuru thalassinus*, *Mystus vitatus*, *Mystus tengra*, *Mystus gulio* and *Plotosus canius* (Dan 1977; Khan *et al.,* 1992; Khan *et al.,* 2002; Islam *et al.,* 2008, Islam *et al.,* 2011). The study of fecundity indicated a liner relationship with total length, body weight and gonad weight (Fig. 2, 3 and 4). The similar findings were also observed in case of *Liza parsia*, *Plotosus canius*, *Colisa fasciata*, *Gadusia chapra*, *Puntius stigma* and *Mystus gulio*, respectively (Banu *et al.,* 1984; Islam and Hossain, 1990, Kabir *et al.,* 1998, Islam *et al.,* 2006). Gonadosomatic index (GSI) is an index used to estimate the development of gonads in fish. Breeding or spawning period can be confirmed easily after determining the stage of maturity of the gonads. The state of gonad development and maturity of *P. canius* calculated for berried female and depicted in Fig. 5. The highest GSI value (20.45%) was observed in the month of September and lowest (6.5%) was in the month of December. GSI values of female fish were found to be increased from March onwards reaching the peak in September followed by a gradual decrease up to December. Increase in GSI values indicated development of gonads during March to September and a drop in December which indicated spent stage of the fish. Similar findings were also found in the same species (Amornsakum *et al.,* 2018). It is familiar that the GSI increases with the maturation of fish, being highest during the period of peak maturity and declining abruptly thereafter (Rahman, 2011). In *P. canius*, the GSI values were highest during September, when majority of fishes were found to be matured and after then its value waned rapidly, that might be due to their spawning. Until this study, there is no proof of estimating GSI and determining the exact month of fecundity in the Bangladesh. This study will be helpful for further research on grey-eel catfish and carried the massive knowledge on reproductive and biological aspect of *P. canius.*

Conclusion

Knowledge of reproductive biology of any fish species is of paramount importance for its proper management, conservation, boosting of food security programme of any government as well as lifting the aquaculture industry of any country. Adequate and proper knowledge fish biology ensures its availability for culture purposes. *P. canius* is an economically important mangrove Canine catfish but its population abundance shows a declining trend in Bangladesh. It's considered as near threatened catfish. Increase in GSI values indicated development of gonads during March to September and a drop in December which indicated spent stage of the fish. The findings of the present study would be very useful for proper management, conservation and development of aquaculture of the species.

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Assessment of water quality parameters in relation to pollutants and contaminants in the river Halda

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Abstract
In the present study the water quality parameters of the Halda River were investigated from January to December 2019. Four sampling sites *viz.* Madarsha, Madarikhal, Katakhali and Khondokia khal of the river were selected. Twelve physico-chemical parameters viz. air and water temperature (°C), dissolved oxygen (DO), biochemical oxygen demand (BOD, B; BOD, N), chemical oxygen demand (COD), pH, alkalinity, hardness, and salinity were studied and the values of these parameters varied from 26.3-37.3 (°C), 22.3-30.0 (°C), 4.27-5.86 mg/L, 1.85-4.55 mg/L, 2.04-4.9 mg/L, 12.8-40.2 mg/L, 7.5-7.75, 51-76 mg/L, 51-489 mg/L, and 0-4.1 ppt, respectively in different seasons and locations. Cluster Analysis (CA) exhibited similarity between the different water quality parameters and individual impact on each other. The parameters belong to the same cluster with minimum cluster distance (for instance, DO, CO_2 and pH belong to cluster 1; alkalinity and hardness belong to cluster 2; BOD-B and BOD-N belong to cluster 3 and conductivity, TDS and COD belong to cluster 4) represented a strong positive association and might be influenced by the same seasonal oscillation. The water quality index (WQI) was calculated and the highest value was found in post-monsoon (1.2) followed by pre-monsoon (1.1) and monsoon (0.9). Among the planktonic assemblage, Bacillariophyceae was the dominating group over phytoplankton and Rotifer was the dominating group over zooplankton. The results revealed that anthropogenic intrusions coming to the river Halda through different discharge routes might affect the water quality and ecology of the river. This study will help us to know the present ecological status of the river Halda and to formulate guidelines to combat the anthropogenic intrusions adding to the river from difference source.

Key words: Water quality parameters, Assessment, Pollution sources, Halda River.

Introduction

The Nation's rivers and streams are an invaluable resource since they provide drinking water for a growing population, irrigation for crops, habitat for aquatic life, and myriad recreational opportunities (River Water Quality Report, 2015). Pollution from urban and agricultural areas continues to pose a threat to water quality. Assessing the current water-quality conditions of our rivers and streams and whether those conditions have improved or deteriorated exert critical information for resource managers and the public.

Halda is a meandering river which originates from the northern hilly region of Bangladesh. The river has its catchment area entirely within Bangladesh (BWDB, 1987). It originates from the hill range of Khagrachari and flows over three Upazillas of Chittagong district Fatikchari, Hathazari and Raozan before finally falling into the river Karnafuli (DoF, 1978). Halda is an important river from ecological perspective; the river is one of the most important natural carp spawning grounds in Bangladesh and has long been the major source of naturally produced carp seeds for pond culture in the country (Tsai *et al.,* 1981; Kibria *et al.,* 2009). Naturally produced carp fries from the river Halda have unique genetic diversity with faster growth and resistance to diseases (Kibria *et al.,* 2009). Spawning area of this river is extended from Garduara to Maduna Ghat where a total of 1100 egg collectors and 2000 fishermen catch fish throughout the year (Islam, 2009). Commercially important carp species, namely *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala* and some other fresh water fish species shed their eggs in the breeding ground of the Haldariver (Tsai *et al.*,1981; Patra and Azadi, 1985). Apart from fish habitats, this river also plays pivotal roles in domestic water supply, agriculture, industry and navigation.

At present, river pollution is a global concern (May *et al.*, 2006; Noori *et al.,* 2010 and Ouyang *et al.,* 2006). The rivers of Bangladesh are nothing different from this global phenomenon since they are also confronting serious problems with contaminants from different industries, domestic wastes, agrochemicals and increasing consumption of water resources (Venugopal *et al.*, 2009 and Islam *et al.*, 2015a and Islam *et al.*, 2015b). In addition to the above anthropogenic inclusions, natural processes (changes in precipitation inputs, erosion, weathering of earths crustal material) also degrade the surface waters and impair their use for drinking, industrial, agricultural, recreation or to aquatic flora and fauna (Jarvie *et al.*, 1998; Ramirez *et al.*, 2014; Kim and An, 2015; Kesalkar *et al.,* 2012). All of the constituents of river water originate from dissolution of the earth’s rocks. The dissolution of rocks in the catchment area is a major determinant of river water chemistry and this varies with geology, magnitude of inputs through the amount, type and distribution of precipitation, surrounding vegetation, catchment hydrology and land use (Hynes, 1975; Hornung *et al.*, 1990; Salmiati *et al.*, 2017). The river Halda, only tidal fed river in the country also originates in the hilly streams and subjected to be affected through the above natural and anthropogenic interventions.

Therefore, present study on the River Halda to know the level of common physico-chemical parameters and how they are conditioning and shaping the ecological harmony deserve considerable attention.

Materials and Methods

Sampling Sites

The present study was conducted to assess the water quality parameters of the Halda river.Water samples were collected from four sites of the Halda River viz. Madarsha Madarikhal, Khondokia khal and Katakhali khal marked as yellow, green, cyan and violet circle on the map of Bangladesh (Table 1 and Fig. 1).

Table 1. GPS coordinates of selected sampling sites of the river Halda.

Sampling Sites	GPS Points (Longitude and Latitude)
Madarsha	N 22º27´59´´ E 091 º51´47´´
Madari khal	N 22 º26´97´´ E 090 º51´56´´
Khondokia khal	N 22 º26´13´´ E 091 º52´44´´
Katakhali khal	N 22 º26´13´´ E 091 º52´18´´

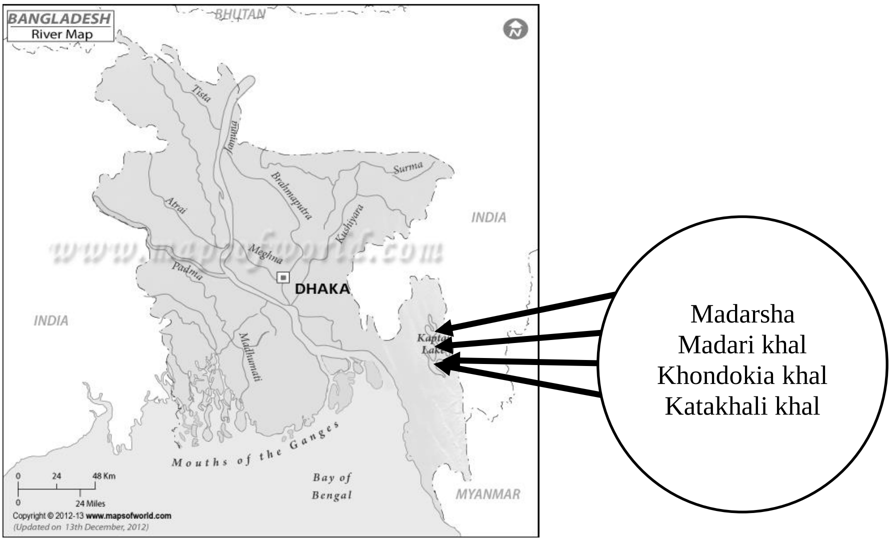

Fig. 1. Map of the study area and the location of different sampling sites.

Data Collection

After selection, water samples were collected from the four sites of the river Halda (Table 1 and Fig. 1). Sampling were performed in three phases: January to April (pre-monsoon); May to August (monsoon); and September to December (post monsoon) 2019. After selecting the sampling sites, a total of 48 sampling was completed from all the selected sampling sites.

Physical-chemical parameter such as temperature, DO (mg/L), CO_2 (mg/L), BOD (mg/L), COD (mg/L), pH, total alkalinity (mg/L), total hardness (mg/L), conductivity (μs/cm), TDS and salinity were analyzed on the same day of sampling. Temperature was measured with Celsius thermometer. Both HACH test kit (Model-FF-2, USA) and HANNA instruments (Model HI 9829) were used to measure DO (mg/L). Free CO_2 content was determined by Phenolphthalein indicator method (Welch, 1948). In this method, at first100 ml water sample was taken at first and then added 6 drops Phenolphthalein indicator and finally titrated with NaOH until pink color appeared. Bio-chemical oxygen demand (BOD) was assessed through Modified Winkler Method (1988)and COD was determined by Dichromate Reflux Method as stated by APHA (2005).The value of hydrogen-ion-concentration (pH) of water was determined by using Hanna pH meter (Model HI 9829). Total alkalinity was estimated by using Phenolphthalein and Methyl orange indicator method (Welch, 1948). In this method, at first 100 ml water sample was taken and then 6drops Phenolphthalein indicator and 6 drops Methyl orange were added. Finally, this solution titrated with 0.2 N H_2SO_4 until orange color appeared. Total hardness was determined by EDTA titrimetric method. Total dissolved solid (TDS) and conductivity was measured by HANNA instrument (Model HI 9829). Salinity was measured through handheld Refractometer (ATAGO, HHR-2N).

Planktonic biomass was collected by sieving 50 liters of habitat water through a 25 µm mesh net and finally concentrated to 50 ml. The plankton population accumulated in the jar were then moved to plastic bottles and immediately preserved in 10% formalin, labeled and transferred to the laboratory for further analysis. Each sample was stirred smoothly before microscopic observation. One ml from agitated sample was transfer to a Sedge-wick Rafter counting cell with a wide mouth graduated pipette. The abundance of plankton was estimated by counting their presence per focus of the microscopic field. Total numbers of planktons per liter of water were estimated by the following formula:

Nos. of plankton were measured by the following formula (Rahman, 1992):

$$N = \frac{\mathrm{A} \times 1000 \times \mathrm{C}}{\mathrm{V} \times \mathrm{F} \times \mathrm{L}}$$

Where,
N = Nos. of plankton units per liter of original sample;
A = Total nos. of plankton counted;
C = Volume of final concentrate of the sample in ml;
V = Volume of a field in cubic mm;
F = Nos. of fields counted; and
L = Volume of original water in liter.

The benthic macro-invertebrate samples were collected from 4 different sites of the river Halda by using an Ekman dredge (covering an area of lower mouth 225 cm). After collecting, the bottom materials were passed through a 0.2 mm mesh sieve in order to separate benthic organisms. Collected organisms were washed and preserved in 10% formalin. Finally, samples were taken to laboratory and identified according to Needham and Needham (1962) and Edmondso (1959).

Water Quality Index (WQI)is considered as an integrated approach that converts all the input parameter to single value index to classify the water quality, where any little change in concentration of any input variable can alter the WQI designation of water quality. Furthermore, WQI evades use of any theoretical ideal value or dissimilar weightages of different variables commonly practiced in some conventional indexing approaches. In the present study, WQI was computed following the method, defined by Horton, (1965) (Table 2).WQI can be applied with wide range of data sets (i.e., even when the variables are not normally distributed and skewed). Besides, use of different indices for different purposes may be lengthy and time consuming for a single study, where WQI can deliver a general idea of water quality status in context with any input parameters, and can be applicable for any designated purpose by just applying the standard guideline values for that particular use (Oni *et al.*, 2016; Wu *et al.*, 2020). The standard limit of different water quality parameters used for the calculation of WQI was accessed from Shafi *et al.*, 2013 and Kumar and Puri, 2012 (Table 3 and 4).

Table 2. Qualitative interpretation of water quality depending on the WQI values.

WQI Value	Category
<0.5	Excellent water
0.5-0.75	Good water
0.75-1	Moderately polluted water
>1	Highly polluted water

The following equation was used to calculate WQI :

$$WQI = \sum_{1}^{n} \frac{X1 + X2 + ... + Xn}{n}$$

Where, n = total number of parameters, x = ratio of observed value and maximum permissible limit of each parameter measured.

Table 3. Different water quality parameters used in WQI calculation and its standard limits (Shafi *et al.*, 2013).

Standard	Temp (°C)	DO (mg/L)	CO_2 (µg/L)	BOD (mg/L)	COD (mg/L)	pH	Alkalinity (mg/L)	Hardness (mg/L)	EC (µs/cm)	TDS (mg/L)
Drinking	25	6	10	0.2	4	7.5	200	500	700	1000
Irrigation/ livestoc	25	5	-	10	6	7.5	500	500	700	1000

Table 4. Water quality standards for river water.

Parameters	Standard (DOE, 2003)	Bangladesh Standard for Fisheries (EQS,1997)	Domestic Standards (De, 2005)	Drinking Standards (ADB, 1994)	Irrigation standard (Ayers and Westcot, 1976)
Temperature(°C)	30.5	25	-	-	-
pH	7.25	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
DO (mg/L)	6.5	4.0-6.0	4.0-6.0	-	-
BOD (mg/L)	5.0	(-) or < 2	-	-	-
Hardness (mg/L)	200-500	-	-	-	-
TDS (mg/L)	165	500	500	1000	< 450
Conductivity (mg/L)	300	800-1000	-	-	750

Data Analysis
After collection, all data were checked for homogeneity and equal variance. Thereafter, data were analyzed by using MS Excel (version 2016), Past software (version 4.0) and Graph Pad Prism (version 6.0) to find out the seasonal variation and relationship among each other. For simple statistical analysis viz. calculating mean, standard deviation MS Excel was used. On the contrary, Past software was used to complete the cluster analysis of water quality parameters and Graph Pad Prism was used to prepare the Pearson's correlation matrix.

Results and Discussion

Water is indispensable to all life forms. We must have adequate water for all our essential needs, which must be of suitable quality for the intended purpose. Increase in production and consumption patterns, land use changes, urbanization, industrial and agricultural practices, as well as impact of climate change, are increasingly affecting the quantity and quality of the river Halda.

Temperature
Temperature being one of the most important ecological factors is of great importance in streams (van Vliet *et al.*, 2011; Beechie *et al.*, 2013). Annual temperature range in temperate streams is usually between 0and 25 °C (Matthews and Zimmerman, 1990). The mean air temperature of the Halda river ranged from 26.3°C to 33.2°C at three seasons in the selected sampling sites whereas the mean water temperature ranged from 24.7°C to 30.3°C (Table 5). A positive change of water temperature was also observed with the changes of air temperature that supports the aforesaid findings. Nevertheless, wood and grassland occupy both sides of the river Halda in some areas. This might also exert vital role in demonstrating spatial and seasonal variation in temperature. The mean temperature found in the present study in different seasons and locations complies with the standard limits of river water as presented in Table 4. More or less similar findings from the Halda River were reported by Sarwar *et al.*, (2010) from the Karnafully River and Fatema *et al.*, (2018) from the Buriganga River. The standard value of water temperature is 20-30°C Santhosh and Singh (2007) and accordingly, the present result of water temperature for the three stations of Halda River was found within the permissible limit. The high positive correlation between airand water temperature in streams increasing with distance has been observed by other workers as well (Zappa *et al.*, 2000; Smith *et al.*, 2001; Uehlinger *et al.*, 2003). Streams flowing underground or man-made culverts/discharge may cool or warm the temperature according to the season, and wind or shade may also cause considerable changes. Macan (1958) reported a fall from 21.6 to 14 °C in a small stream flowing through woodland.

Dissolved gases
In the present study, the highest DO was recorded 5.86 mg/L at Madari khal during pre-monsoon and the lowest was recorded 4.27 mg/L during post monsoon at Khondokia khal (Table 5). Almost similar observations were also been recorded by Effendi *et al.*, (2015), Gasim *et al.*, (2007), Alam *et al.*, (1996), Jashimuddin and Khan (1993), Hossain and Khan (1992), Islam and Khan (1993), Hossain *et al.*, (1988), Bhuyian (1979), Khan *et al.*, (1976), and Mahmood and Bhuyian (1988). The mean level of DO found in the present study also

satisfy with the standard limits (Table 4). More than four decades ago the more or less similar result was also recorded by Patra and Azadi (1985) in the Halda River and disagreed with the results of Sarwar *et al.,* (2010) in the Karnafully River and Sharif *et al.,* (2017) in the Meghna River due to different ecological condition.Among the dissolved gases, both oxygen and carbon dioxide occur in river water in substantial amounts. The incidence of these major dissolved gases is influenced by partial pressure, temperature, salinity, respiration and photosynthesis (Allan, 1995; Wetzel and Likens, 2000; Effendi, 2003; Huq and Alam, 2005). Furthermore, carbon dioxide concentration is influenced by groundwater inflows substantially enriched with carbon dioxide (Allan and Castillo, 2007; Wetzel and Likens, 2000). Diffusion of oxygen across air–water interface tends to moderate changes in dissolved oxygen concentrations in streams (Wilcock *et al.,* 1995). The solubility of oxygen is reduced at higher elevations due to lower atmospheric pressure and also due to increase in salinity, by about 20%in normal seawater (Allan, 1995). DO concentration in water is in versely related to water temperature (Hynes, 1960). Cold water holds more oxygen than warm one (Said *et al.,* 2004). Various biological life forms are greatly influenced by the DO level (Saksena *et al.,* 2008; Wetzeland Likens, 2000; Allan and Castillo, 2007). The survival of aquatic organisms largely depends on the oxygen dissolved in water. The low DO directs high demand for oxygen by the microorganisms (Ott, 1978). In stream the oxygen content varies seasonally and from source to mouth. Hall (1955), during his lengthy study, recorded the values that ranged from 100 to 129% saturation. In large rivers, high water is accompanied by lowered oxygen concentrations, and these are brought about by the wash-in of organic matter and the decrease in photosynthesis caused by turbidity (Gessner, 1961). In the present study, the dissolved oxygen was found between (4.27-5.86) mg/L in all sampling sites (Table 5). The river Halda is located in the hilly areas where organic washout frequently comes from adjacent hill and crop lands. Additionally, tidal flash two times in a day also makes the water turbid, affects photosynthesis and DO levels. High dissolved oxygen was recorded during winter season which may be due to high photosynthetic rate of phytoplankton communities in clear water (Sharma and Rathore, 2000; Ravindra *et al.,* 2003). Higher dissolved oxygen in winter season were also recorded in many rivers of Gangetic plain (Sharma and Sharma, 2007; Sharma *et al.,* 2009).

In the present study higher levels of free carbon dioxide (free CO_2) (maximum 15.0 and minimum 7.9 mg/L) (Table 5), possibly because of groundwater influxes substantially enriched by CO_2 due to soil respiration (Mulholland, 2003). The lower free CO_2 concentrations are associated higher pH, shallow depth and clear water (Allan and Castillo, 2007). Higher level of free CO_2 during in pre-monsoon season (ranged from 13.9±2.9 to 15±3.6) (Table 5) might be attributed to increased decomposition rate under the river bed following slowdown of river water current. Gupta *et al.,* (1996) and Gupta and Mehrotra (1991) obtained maximum value of free CO_2inthe month of in pre-monsoon and minimum in monsoon that complies with the findings of present study. Free CO_2 is an important parameter of the buffer system and impacts the concentration of carbonates, bicarbonates, pH and total hardness in water. Carbon dioxide (CO_2) in river water are disposed through atmospheric diffusion, metabolism and by groundwater influxes, which are commonly enriched with CO_2due to soil respiration (Allan and Castillo, 2007). In addition to physical processes, biological processes like photosynthesis and respiration also alter the concentration of CO_2 in river water. Rivers receiving significant amount of organic load, have excess CO_2 generated by microbial respiration (Small and Sutton, 1986; Rebsdorf *et al.*, 1991).

BOD and COD

Biochemical Oxygen Demand (BOD) is the amount of oxygen used by microbes to decay carbon-based materials in water within a five-day period (APHA, 2005). In the present study, lower level of BOD during the monsoon might be attributed to rain and flashflood that dilute the river water. Kaur and Kaur (2015) also found lower BOD during the monsoon in their study. Shafi *et al.*, (2013) studied BOD values of the Ganges, Brahmaputra and confluence that ranged from 4.53 to 1.10, 4.60 to0.66 and 4.30 to 0.55 mg/L. The permissible limit for BOD for drinking water is 0.2 mg/L, for recreation 3mg/L, for fish 6 mg/L and 10 mg/L for irrigation (ECR, 1997). Therefore, the BOD values found inthe present study indicated that river water is suitable for fish culture and irrigation activities andnot suitable for drinking purpose (Table 5). This disagreed with the results of Sarwar *et al.*, (2010) in the Karnafully River and Sharif *et al*., (2017) in the lower Meghna River which might be due to different ecological conditions. The present BOD level of the four stations of Halda River was nearest the standard level. Kumar *et al.*, (2009) stated that the water without pollution has a concentration of BOD 2 mg/l or below. Low BOD in water indicates that the riverside is free from organic pollution (Saksena *et al.*, 2008) while high BOD is detrimental as it reduces the DO (Fatoki *et al.*, 2005). Paul and Meyer (2001) mentioned that, river water with a BOD rate above 10 mg/L is considered to be moderate, while above 20 mg/L is considered highly contaminated water. Bio-chemical oxygen demand (BOD) (B, bottle) and BOD (N, natural) demonstrated very minimum level of fluctuations where the highest BOD (B) was found 4.55 mg/L at Madarsha and BOD (N) 4.67 mg/L was found at Madarikhal point.

Chemical Oxygen Demand (COD) is a reliable factor for judging the pollution degree in water (Loomer and Cooke, 2011). In this study, COD exhibited similar seasonal variation (higher in pre and post-monsoon and lower in monsoon) like BOD from the minimum 12.8mg/L at Khondokia khal to maximum 40.2 mg/L at Madarsha point of the river (Table 5). The positive correlation between COD and BOD among the four sampling locations throughout the yearindicated that sources of organic material in the river Halda are similar in nature. The COD values found in the present study is similar to the results of Sikder *et al.*, (2016), Ahmed and Nizamuddin (2012) and Miah (2012). It is the amount of oxygen present in the water that is required or used in various chemical reactions (mainly oxidation) occurring in the water. Higher COD is harmful to all aquatic living organisms, which increase pollution in water bodies (Nian *et al.*, 2007). COD in pure water must be below 20 mg/L, whereas water bodies with a COD above 200 mg/L is considered contaminated (Effendi *et al.*, 2015).

pH

Low pH is one of the major problems of river ecosystems worldwide, can result from anthropogenic stresses (Herlihy *et al.*, 1990; Angelier, 2003). In the present study, the pH values were slightly alkaline (7.5 to 7.75) (Table 5) and it was within the standard limit for surface water (6.5- 8.5) (ECR, 1997)**. S**imilar results were recorded by Patra and Azadi (1985) in the Halda River and Sarwar *et al.*, (2010) in the Karnafully River.Ahmed and Rahman (2000) mentioned that in most raw water sources, pH lies within the range of 6.5- 8.5. From that consideration, the pH level of River Halda seems to be suitable. pH has been recognized as are gulating factor in aquatic systems, and the biological components are severely affected at extremes of their pH tolerance. Bio-chemical and chemical reactions are influenced by the pH (Manjare *et al.*, 2010).In aquatic ecosystems, temperature, photosynthesis and respiration often are the most important metabolic processes affecting pH. Roy (1955), Moore (1972), APHA (2005), Mahmood and Bhuyian (1988), Sarma *et al.*, (1982) and Campbell (1978) stated that industrial or municipal waste materials plays a significant role in increasing or decreasing pH of the adjacent water body, into which waste materials had been dumped. Moreover, activities like bathing, washing, and agrochemical draining along water bodies related to pH fluctuations (Effendi *et al.*, 2015). The variation in pH is due to the presence or absence of free carbon dioxide and carbonate and periphytic algal density during various months (Lashari *et al.*, 2009). During the summer, pH values are normally higher due to high photosynthetic rate, increase in carbonate and due to the decomposition of organic matter (Kim *et al.*, 2003; Kim and Kim, 2006).

Alkalinity and Hardness

The quantity of base present in water defines is known as total alkalinity. Common bases found in river water include carbonates, bicarbonates, hydroxides, phosphates and berates. Carbonates and bicarbonates are the most common and most important components of alkalinity. Alkalinity (20–200 mg/L) is common in most of the freshwater ecosystems including ponds, lakes, streams and rivers (Hem, 1985; Ishaq and Khan, 2013). Alkaline water promotes high primary productivity (Kumar and Prabhahar, 2012). Alkaline nature of water was also reported in Greater Zab River, Iraq (Ali, 2010). In the present study, alkalinity ranged from 49.0±6.7 to 54.0±5.5 mg/L in pre-monsoon, from 56.0±7.9 to 62.0±7.5 mg/L in monsoon and from 68.0±7.2 to 76.0±6.9 mg/L in post-monsoon, respectively (Table 5). The observed alkalinity in the river Halda lies within the common values of freshwater ecosystems. Nahian *et al.*, (2018) also found higher value of alkalinity in the Gowain river, Sylhet during the post-monsoon. Ravindra *et al.*, (2003) studied the seasonal variations in physico-chemical characteristics of river Yamuna in Haryana, India and found similar seasonal variations. The higher values of alkalinity during the post-monsoons indicate a greater ability of the river water to support algal growth and other aquatic life in this season.

River waters usually contain 1-2 mg/L calcium, but in lime river zones water can contain as high as 100 mg/L calcium. Calcium ion exerts great influence on aquatic organisms, enhancing metal toxicity in their gills (Florescu *et al.*, 2010).The hardness of freshwater ecosystems exhibits slightly different seasonal patterns in their behavior. In the present study, the higher values of hardness (ranged from 470.0±21.7 to 489.0±38.5 mg/L) were found during the post-monsoon compared to pre-monsoon and monsoon (Table 5). According to the DoE (DoE, 2003) standard, the permissible limit of hardness of drinking water is 200 to 500 mg/L. According to Huq and Alam (2005), the optimum hardness for aquatic organism is 123 mg/L. From that consideration, hardness contents were more or less suitable for fisheries during pre-monsoon and monsoon and little uncomfortable during the post-monsoon. However, data from a single year doesn’t reflect the long-term portrait of hardness in the river Halda. Higher values of hardness were also reported in Haraz river, Iran (Jafari *et al.*, 2011). The average hardness in Tista river water of wet and dry seasons was found 98.48 and 102.46 ppm, respectively

(Islam *et al.,* 2014). Joshi *et al.,* (2009) recorded higher hardness in the monsoon season (120.62 mg/L) and lower in the winter season (87.55 mg/L) in the river Ganga which are close to values of hardness found in pre-monsoon and monsoon in the river Halda.

Electric Conductivity

A higher conductivity reflects higher water pollution (Florescu *et al.,* 2010). Typical EC value is 300 μS/cm (De, 2007). In the present study, EC ranged between 112 to 372 μs/cm. The highest value (372 µs/cm) was found at Khondokia during monsoon, while the lowest one (112 µs/cm) was recorded at Madarsha khal during post monsoon (Table 5). Apparently, the EC values found in the river Halda were higher in during the pre-monsoon. For inland surface water EC contents 800 to 1000 μS/cm is suitable for aquatic environment (ECR, 1997) and the EC contents of Halda river was lower than that standard. The EC contents of Turag river ranged from 691 to 822, 618 to 1334 and 155 to 276 μS/cm in post monsoon, pre-monsoon and monsoon season, respectively. In the monsoon season, the flow of the river increases which may cause the dilution of the water, while in dry season, the flow of the river decreases which results in increase of EC (Meghla *et al.,* 2013). Hoque *et al.,* (2012) recorded the mean values of EC to be 452.4 μs/cm in monsoon and 901 μs/cm in winter, in the Bansi River**.** The EC higher values found in the river Halda during the pre-monsoon exhibits coherence with the above studies.

Total Dissolved Solids

In the present study, the highest TDS value was found during the monsoon in Khondokia khal (185±22.6 mg/L) and the lowest TDS value during the pre-monsoon in Madarsha (56.19±8.4 mg/L) (Table 5). During the monsoon season TDS values were significantly higher in every point as compared to the pre and post-monsoon. Monsoon rain might be associated with the increased TDS of the river Halda. The standard level of TDS for aquatic environment or fisheries is 500.00 ppm (EQS, 1997). Compared EQS standard, the TDS values of river Halda are still lower and constant level of minerals in the water is necessary for aquatic life. The obtained values of TDS in the river Halda might not only the nutrients coming from different sources, but also contains some pollutants. TDS mainly indicates the presence of various kinds of minerals like ammonia, nitrite, nitrate, phosphate, alkalis, some acids, sulphates and metallic ions etc. which are comprised both colloidal and dissolved solids in water (Shafi *et al.,* 2013). Water that contains more than 500 ppm of dissolved solids usually contain minerals that give it a distinctive taste or make it unsuitable for human consumption (Sarker *et al.,* 2015). A maximum TDS value of 400 ppm is permissible for diverse fish production (Chhatwal, 1998). . Islam *et al.,* (2014) found the mean TDS contents of the Padma river 155, 125 and 169 ppm during pre-monsoon, monsoon and post-monsoon, respectively which are close to the present study. The deviation that was found might be associated with the location difference.

Salinity

Salinity plays an important role in the growth of aquatic organisms through osmoregulation of body minerals from that of the surrounding water. Chloride is an indication of salinity in water. An excess of chloride ions in inland water is usually taken as an index of pollution. Sewage water and industrial effluents are rich in chlorine and hence the discharge of these wastes results in high chloride levels in fresh waters. In the present study, salinity was nil during pre-monsoon and monsoon, but it ranged from 3.9±0.3 to 4.1±0.2 ppt during the post-monsoon (Table 5). Ravindra *et al.,* (2003) in the Yumuna river in India and Uddin *et al.* (2016) in the Buriganga river in Bangladesh also observed similar seasonal variation of salinity.

Table 5. Seasonal variation of water quality parameters of the Halda River.

Parameters	Seasons	Sampling Sites			
		Madarsha	Madarikhal	Katakhalikhal	Khondokiakhal
Air temperature (°C)	Pre-monsoon	27.2±1.3	28.6±1.4	28.4±2.5	32.0±1.2
	Monsoon	33.2±1.2	33.0±1.0	32.3±1.3	32.5±1.0
	Post monsoon	27.6±3.1	30.7±1.2	29.8±5.3	26.3±3.5
Water Temperature (°C)	Pre-monsoon	25.3±2.2	26.7±2.5	26.7±2.4	28.8±3.6
	Monsoon	30.0±1.0	30.3±0.7	30.2±0.5	30.0±0.5
	Post monsoon	25.6±3.1	29.3±1.5	25.2±3.6	24.7±3.5
DO (mg/L)	Pre-monsoon	5.75±1.1	5.86±0.9	5.34±0.7	5.85±1.0
	Monsoon	5.76±0.8	4.42±0.5	5.31±0.8	4.96±0.68
	Post monsoon	4.75±0.6	4.72±0.43	4.65±0.4	4.27±0.7
CO_2 (mg/L)	Pre-monsoon	13.9±2.9	14±3.0	14.2±2.8	15±3.6
	Monsoon	10.6±2.5	12.4±2.8	11.1±2.1	8.5±2.0
	Post monsoon	11.1±2.3	7.88±1.8	8.9±1.9	8.43±1.5
BOD (B) (mg/L)	Pre-monsoon	4.42±1.1	4.41±0.9	4.34±0.6	3.93±0.6
	Monsoon	3.65±0.5	1.85±0.2	2.61±0.1	3.96±0.4
	Post monsoon	4.55±0.7	4.33±0.6	4.32±0.2	3.96±0.5
BOD (N) (mg/L)	Pre-monsoon	4±0.1	4.48±0.2	4.5±0.1	4.8±0.3
	Monsoon	4.9±0.2	2.49±0.1	3.6±0.5	2.04±0.21
	Post monsoon	4.67±0.5	4.5±0.3	4.49±0.1	4.02±0.1
COD (mg/L)	Pre-monsoon	40.18±8.5	32±7.6	32±7.2	36±6.9
	Monsoon	19.2±5.6	16±4.8	16±4.9	12.8±5.5
	Post monsoon	32.6±7.5	28.5±5.3	40.2±6.6	32.2±5.9
P^H	Pre-monsoon	7.56±0.4	7.56±1.1	7.5±1.4	7.56±1.3
	Monsoon	7.5±0.9	7.5±0.5	7.75±0.7	7.75±1.1
	Post monsoon	7.5±1.3	7.5±1.1	7.5±1.2	7.5±1.1
Alkalinity (mg/L)	Pre-monsoon	49±6.7	50±8.3	48±5.9	54±5.5
	Monsoon	58±7.8	60±8.1	56±7.9	62±7.5
	Post monsoon	76±6.9	74±7.7	68±7.2	71±6.4
Hardness (mg/L)	Pre-monsoon	53±4.5	51±6.7	53±4.8	54±4.0
	Monsoon	69±13.8	72±12.9	68±11.7	73±12.5
	Post monsoon	489±38.5	482±32.1	476±28.5	470±21.7
Electrical Conductivity (µS/cm)	Pre-monsoon	360±19.8	340±21.6	348±22.7	372±24.1
	Monsoon	362±23.2	345±27.5	342±20.7	370±16.6
	Post monsoon	112±14.1	120±9.7	130±8.8	132±11.2
TDS (mg/L)	Pre-monsoon	56.19±8.4	61.1±9.7	65.9±11.9	65.25±15.7
	Monsoon	181±21.3	169±19.5	172±16.8	185±22.6
	Post monsoon	63±18.5	61±14.8	66±13.9	65±12.7
Salinity (ppt)	Pre-monsoon	0	0	0	0
	Monsoon	0	0	0	0
	Post monsoon	3.9±0.3	4.0±0.1	4.0±0.1	4.1±0.2

Cluster Analysis

Cluster analysis was carried out using Bray Curtis Similarity function of the Past Software (version 4.0), to show the similarity among the parameters that enormously contribute to water pollution. From the output of the cluster analysis, four clusters were found during different seasons: Cluster 1, includes DO, CO_2 and pH; Cluster 2, includes alkalinity and hardness Cluster 3, includes BOD-N and BOD-B, Cluster 4, includes conductivity, TDS and COD (Fig. 2). Dissolved oxygen, CO_2 and pH represent a strong connection with minimum cluster distance, indicating that these parameters are influential during seasonal variation. Parameters are grouped together in less distance have higher affinity with identical behavior, during temporal variations and they also exert a probable effect on each other. Alkalinity and hardness also have strong linkage, though lesser than cluster 1. However, they contribute largely to the environmental process. BOD-N and BOD-B are under cluster 3 with minimum distance, compared to cluster 1 and cluster 2. Conductivity, TDS and COD are under the cluster 4 have strong linkage.

Correlation Matrix

Table 6. Correlation matrix of chemical parameters in the river Halda.

	DO (mg/L)	CO_2 (mg/L)	pH	Alkalinity (mg/L)	Hardness (mg/L)	BOD-N (mg/L)	BOD-B (mg/L)	Conductivity (µS/cm)	TDS (mg/L)	COD (mg/L)
DO (mg/L)	1									
CO_2 (mg/L)	-0.59	1								
P^H	0.20	-0.59	1							
Alkalinity (mg/L)	-0.77	0.62	-0.24	1						
Hardness (mg/L)	-0.70	0.77	-0.43	0.90	1					
BOD-N(mg/L)	0.38	0.34	-0.57	0.02	0.27	1				
BOD-B(mg/L)	0.23	0.45	-0.66	0.04	0.40	0.91	1			
Electrical Conductivity (µS/cm)	0.69	-0.79	0.47	-0.88	-0.99	-0.31	-0.44	1		
TDS (mg/L)	-0.03	-0.35	0.54	-0.10	-0.46	-0.62	-0.85	0.49	1	
COD (mg/L)	0.15	0.34	-0.54	-0.01	0.37	0.67	0.85	-0.39	-0.93	

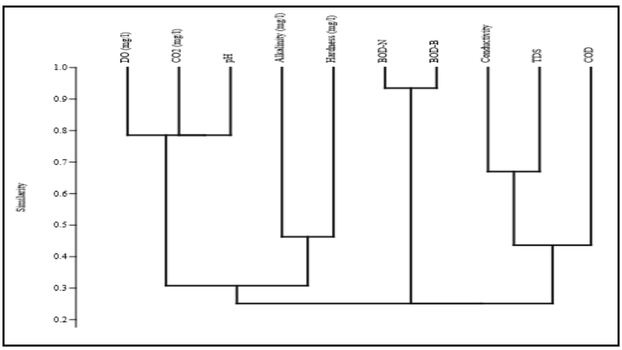

Fig. 2. Dendogram showing the percentage of similarity among water quality parameters.

In aquatic environment, the interconnection among water quality parameters conveys noteworthy information as well as trails for parameters. The Pearson's correlation matrix (prepared with the help of Graph Pad Prism software, version 9.0) between water quality parameters fully consented with those, obtained by CA, disclose some new connotations among the variables. Positive linear to very strong positive linear relation was found between pH vs DO (0.20), hardness vs CO_2 (0.77), BOD-N vs DO (0.38), BOD-N vs CO_2 (0.34), hardness vs alkalinity (0.90), BOD-B vs hardness (0.40), conductivity vs DO (0.69) and conductivity vs pH (0.47) (Table 6). Moderately strong positive correlations were recorded between Alkalinity and CO_2 (0.62) (Table 6). Positive and moderately strong correlations indicate that the parameters were originated from similar sources, particularly from industrial effluents, domestic wastes and agricultural inputs. Besides, strong negative correlations were found between CO_2 and DO (-0.59), alkalinity and DO (-0.77), hardness and DO (-0.69), BOD-B and pH (-0.66) and conductivity and CO_2 (-0.79), conductivity and hardness (-0.99) in Halda River water. Bhuyan and Baker (2017) conducted a study with Halda river and found positive and negative association between different water quality parameters. The results of the present study exhibit slightly different mode of association between water quality which might be due to the variation of sampling procedure, sampling locations as well as the number of samples.

Variation in Water Quality Index (WQI)

Water quality index (WQI) is a dimensionless number that combines multiple water qualityparameters into a single number by normalizing values to subjective score (Miller *et al.*,1986). Conventionally it has been used for evaluating the quality of water for water resources such as rivers, streams and lakes.

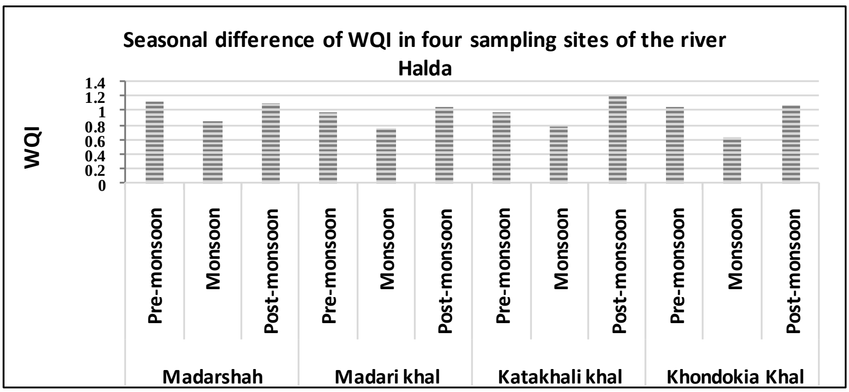

Fig. 3. WQI of the river Halda in different seasons

Parameters incorporated in WQI varies depending upon the designated water uses of the water body and local preferences. However, the present study proposes a simple modified WQI considering local environments and hydrology of the Halda river for drinking and irrigation purposes. The parameters measured in the current study have diverse ranges and expressed in different units. The WQI takes the complex scientific information of these variables and synthesizes into a single number. In this study highest WQI values were found in post-monsoon (1.2) at Katakhali khal followed by pre-monsoon (1.1) and monsoon (0.9) at Madarshah (Figure 3) indicating moderate to high pollution of the river Halda. The lower WQI found in the monsoon compared to other seasons might be connected to the dilution of water resulted in lower individual weight of each parameter. Several researchers have worked on the concept of WQI and presented examples with case scenarios (Liou *et al.*, 2004; Said *et al.*, 2004; Nasiri *et al.*, 2007, NSF, 2007). Bhuyan and Baker (2017) found similar WQI values and recommended that the river Halda is highly polluted.

Planktonic Biomass

Total abundance of planktonic biomass/liter were assessed in the present study. In terms of total plankton density Madarshah was highest followed by Khondokia khal, Madari khal and Katakhali khal (Table 7). The mean contribution of phytoplankton was more than 90% while zooplankton contributed the rest. In the river Halda, four dominating family of phytoplankton viz. Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae were identified (Figure4 and Table 8). Among the zooplankton, Rotifer was the dominating group followed by the Copepodaand Cladocera (Fig. 5). Among the benthos community three family including Mollusca, Chironomidae and Oligocheate were identified under the present study (Fig. 6).

Table 7. Abundance of plankton in the River Halda

Sampling sites	Total Plankton (No./L)	Phytoplankton (No./L)	Zooplankton (No./L)
Khondokiakhal	52×10^2	47×10^2	5×10^2
Katakhalikhal	35×10^2	31×10^2	4×10^2
Madarikhal	39×10^2	34×10^2	5×10^2
Madarsha	57×10^2	50×10^2	7×10^2

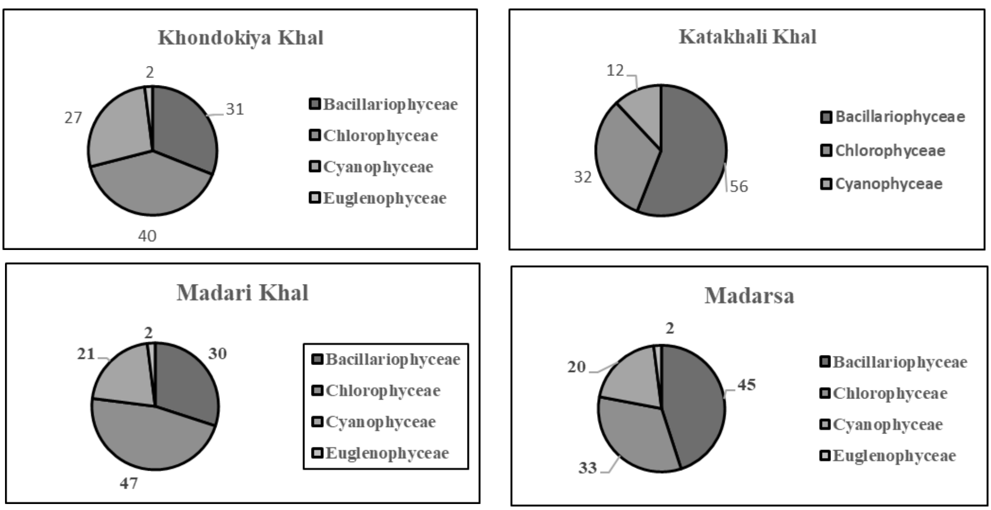

Fig. 4. Planktonic composition of the river Halda in four sampling sites

Table 8. Plankton genera observed in the River Halda

Phytoplankton (Class)	Genus
Chlorophyceae	*Pediastrum,Volvox, Scenedesmus, Acanthocystis*
Bacillariophyceae	*Navicula, Gomphonema, Asterionella, Diatoma, Frustulia, Stephanodiscus, Cyclotella, Pleurosigma*
Cyanophyceae	*Spirulina,Rivularia,Oscillatoria*
Euglenophycea	*Euglena*
Zootoplankton (Class)	Genus
Rotifera	*Brachionus, Asplancha*
Copepoda	*Cyclops sp, Diaptomus sp.*
Cladocera	*Moina*

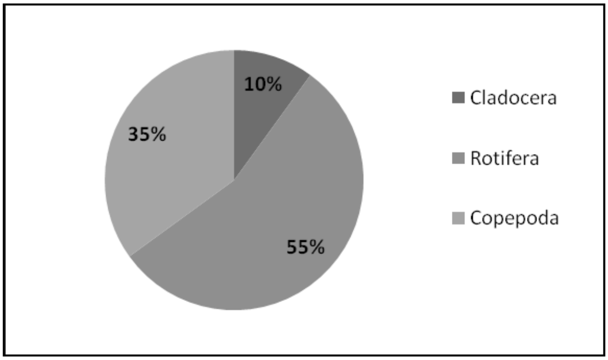

Fig. 5. Percentage of different zooplankton groups in four sampling sites of the river Halda.

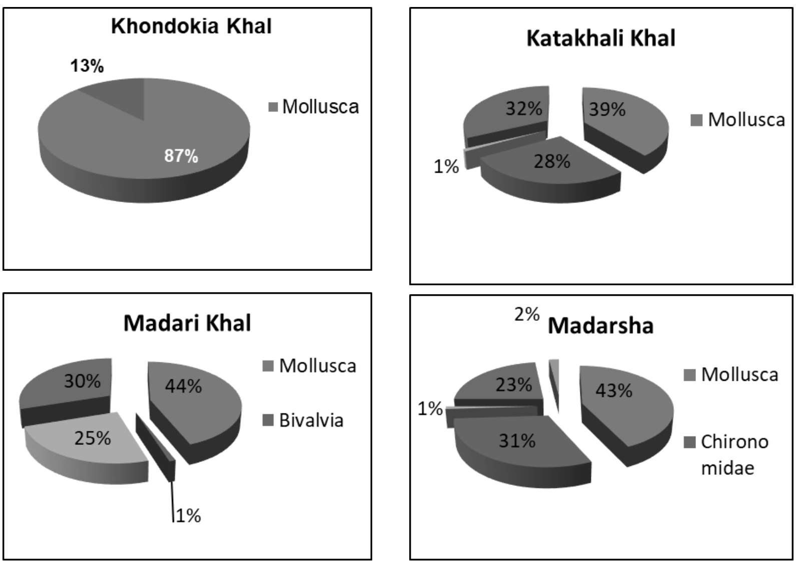

Fig. 6. Percentage of different groups of benthos in the river Halda.

The information on the planktonic and benthic community of the river Halda was inadequate and therefore; it was not possible to compare the results of the present study with the previous one. However, similar studies were conducted by different authors on other rivers of Bangladesh. Shafi *et al.*, (1978) found higher percentage of phytoplankton 76.0 to 93.6% from the Meghna river. In another study, in the river Meghna, Ahmed *et al.*, (2003) found that zooplankton contributed more than 3% of the total planktonic assemblage). In the Ganga Meghna river system, phytoplankton formed 90 per cent of the total plankton abundance (Ahsan *et al.*, 2012). In the present study, Chlorophyceae and Bacillariophyceae were dominating groups. Khan *et al.*, (2007) also found similarresults from the Mouri river of Khulna. Among the zooplankton, 3 families belonged to Rotifera, Copepod and Cladocera were dominant in the present study. Copepods were the dominanting group in the Meghna river.The study was slightly similar to the study of Ahsan *et al.*, (2012) found 19 taxa of phytoplankton belonged to three groups and 39 taxa of Zooplankton. Hossain *et al.*, (2017) recorded Chlorophyceae as most dominant phytoplankton group and Copepoda as most dominant zooplankton group. Macrobenthos are organisms that are living on orinside the bottom of a water body (Barnes and Hughes, 1999; Idowu and Ugwumba, 2005; Khan *et al.*, 2007). These organisms are the important constituents of river ecosystem and useful bio indicators in understanding the ecological health of an aquatic ecosystem., 5 different groups of macro-invertebrates were identified where Mollusca were dominating group. Khan *et al.*, (2007) studied the abundances and distribution of macro benthic organisms of the Mouri river and also identified 5 groups of macro-invertebrates during their investigation where Polychaeta were dominating group. Haque *et al.*, (2020) found 11 groups of macro benthos while studying the distribution and diversity of macro benthos in the Sangu River, Bangladesh. The variation of the results of the present investigation with the previous works might be associated with the ecological and spatial variations of the studies.

Conclusion

The river Halda plays a vital role as the important freshwater resources of Bangladesh. Water of this river is used for different purposes including irrigation, navigation, fisheries, dumping of domestic and industrial wastes and recreational purposes. The river Halda also bears this significance as the only tidal fed spawning ground of IMC. The apparent sources of pollutants in the river are anthropogenic activities like improper agricultural practices and disposal of waste effluents. The conservation of rivers has immense potentiality for its ecological, cultural and tourist value. Presently it has been declared as the Bangabandhu Fisheries Heritage. This study will disclose crucial information on the present ecological status of the river and help to aware local people and take necessary actions by the policy planners.

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Culture potentials of freshwater apple snail (*Pila globosa*) at the farmer's ponds

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Abstract
One of Bangladesh's main exports generating industries freshwater prawn (*Macrobrachium rosenbergii*) farming uses snail flesh more frequently than other types of farming. Due to over catching the country's natural supply of freshwater snails from many rivers and beels has significantly decreases. The current study focused on developing farmer-level freshwater snail (*Pila globasa*) culture system and highlighted the species potential as a fish feed. The study was carried out at ponds in Gopalgonj Sadar and Kotalipara upazilla in Gopalgonj district, Bangladesh. Over the six months of culture period from May to October 2021 had been conducted. In this work, snail collection techniques, pond management and a cost-benefit analysis of snail culture have been noted. The ponds for growing freshwater snails were rectangular in shape and had an area of 40 decimal at Kotalipara upazilla and 52 decimal at Gopalgonj Sadar upazilla. For collecting snails from ponds, four techniques were used. In one cycle, there were found 21122kg/ha of snail production. The benefit cost ratio (BCR) for snail farming was determined to be 2.29, indicating that it may be a viable crop for farmers. And it will be helpful to reduce overexploitation of snail and conserve biodiversity.

Keywords: Apple snail, *Pila globosa*, Farming, Production

Introduction

Pila globosa (Swainson, 1822) is one of the most abundant molluscs which have huge commercial value in Bangladesh. It is widely distributed and available in all types of seasonal and perennial water bodies, such as ponds, canals, ditches, beels (a large surface static water body that accumulates surface runoff water through internal drainage channel), haors (a wetland ecosystem which physically is a bowl or saucer shaped shallow depression, also known as a back swamp) and baors (closed water body equivalent to an ox-bow lake, up to several hundred hectares) (Nath *et al*., 2008). Muslim community of Bangladesh do not prefer snails (Saha, 1998). However identified 29 groups of tribal people prefer it in their diet. But, nowadays different delicious snail flesh food items are served at different hotels in tourist city of Bangladesh like Cox's Bazar, Khulna, Chattogrm. Snail flesh is more extensively used in freshwater prawn (*Macrobrachium rosenbergii*) farming in the south-western part of the country (Baby *et al*., 2010), which is one of the major exports earning sectors in Bangladesh (DoF, 2011). The average application of snail meat to prawn ponds is 66.5 kg $ha^{-1}day^{-1}$ during June to October (Ahmed *et al*., 2008). Snail meat is also utilized as a supplementary feed in indigenous catfish (*Clarius batrachus*) farms and domestic ducks throughout the year

(Banglapedia, 2006). Snail shell is also used to produce lime and animal feed additive due to its rich $CaCO_3$ content (Nath *et al*., 2008).

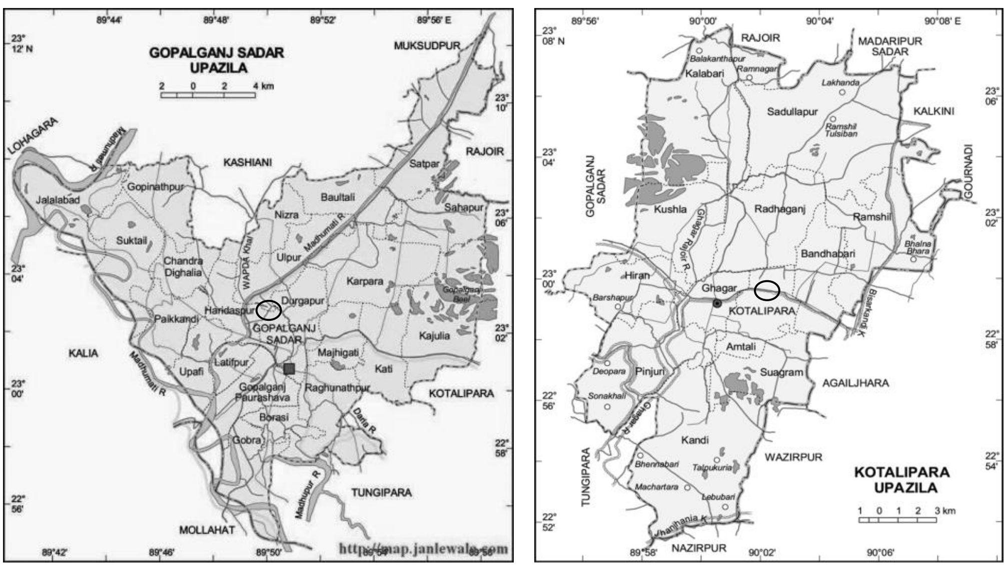
Nowadays, some innovative farmers of Bangladesh started snail culture within their fish farms to provide feed for their Prawn (*Macrobrachiam rosenbergii*), indigenous catfish (*Clarias batrachus*), duck and also as a protein supplement for preparing pellet fish feed.

The main goals of snail farming are to increase snail output and lessen the threat of the native snail population going extinct. This is due to the dearth of available literature on snail farming in Bangladesh. A freshwater or apple snail culture system has been established in this study.

Materials and method

Study area and study period

Two farmer's ponds have been selected for this research. The total area of the selected ponds were 52 decimal (2104 m^2) at Gopalgonj sadar upazilla and 40 decimal (1618m^2) at Kotalipara upazilla in Gopalgonj District, Bangladesh (Fig. 1). Rearing of snail was conducted for a period of 06 months from May to October in 2021.



(a) Gopalganj Sadar **(b)** Kotalipara

Fig. 01: Maps and view of experimental site

Fencing and sanitizing

Bamboo split, fine meshed nylon net and bamboo were used for fencing. Fencing has been given on the dike around the ponds to prevent the snail going escapement. Some aquatic vegetation was planted for ensuring proper breeding ground of snail. Dikes were prepared as snails can lay their eggs.

Pond preparation

The ponds were dried before the stocking of juvenile snail. The excessive bottom mud was removed from the ponds. Liming was done at the rate of 1-1.5 kg/decimal. Then the ponds were filled up with water up to 1 ft and then compost was spreaded throughout the ponds at the presence of sunlight. Cowdung, mustard oil cake, and urea were combined to make compost at the ratio of 1: 1: 0.5 respectively, which was employed at a density of 2.5 kg/ decimal. Compost was hand mixed and submerged in water for three days. Prepared compost was given into the water. After few days, planktons were grown in the ponds. After 3-4 days, ponds were filled up with 3-4ft water and then snails were stocked.

Selection and stocking of snail

In May, snail juveniles were collected from different rivers, canals, beels and ponds. Snails were gathered using a variety of techniques, including pulling nets, iron or plastic pipes, bamboo poles, and palm leaves. Average weight of juvenile snail was 0.82 g. Wild snails were stocked at the rate of 600/decimal. For the proper growth of snails, compost, leaves and feed were given in the ponds. It was ensured that feed were spreaded all over the pond.

Feeding & monitoring

Adequate feed supply was ensured in the ponds. For this, small cutting of various plant leaves were sprinkled in the pond. For proper growth and breeding of snails, compost was provided at fifteen days interval. Compost was created by mixing together cowdung, mustard oil cake, and urea in the ratios of 1: 1: 0.5 and it was used at a density of 2.5 kg per decimal. Hand-mixed compost was placed in water for three days and divided into three parts and sprinkled in the pond. After the application of compost, red and other earthworms were found in the soil of the pond. In addition, the use of compost has resulted in an abundance of plankton in the pond water which snails take as a feed. Commercial fish feed was given at 10% of their body weight. Continuous monitoring was given that applied feed cannot foul the water of pond. The shell of snail was checked from time to time, If the shell did not grow properly required lime was applied in the pond. Young snails prefer tender leaves and shoots while mature snails increasingly feed detritus: fallen leaves, rotten fruit and humus. Food was given at morning and evening only. Growth (weight basis) and survival of snails were estimated.

Culture pond monitoring and water quality management

Physico-chemical parameters viz., Water Temperature, Dissolved Oxygen, pH, Ammonia, Carbon Dioxide (CO_2), Hydrogen Sulfide (H_2S), and Nitrite were monitored between 8.30 to 9.30 am at 15 days interval using Celsius thermometer, portable dissolved oxygen meter (Oakton), a portable pH meter (HI 8424, Hanna Instruments, Portugal), portable moisture meter respectively. Ammonia (HI 3826, Hanna Ammonia test kit, Romania), CO_2, H_2S and Nitrite were determined using HACH Kit (HQ40d, Hach multimeter, USA).

Statistical analysis

SPSS package and Microsoft XL programme were used for data analysis.

Results & discussions

Growth performance and harvesting of snail

After 180 days of culture weight of snails was found 8.2±0.07 g and 8.1±0.28 g in ponds of Gopalganj sadar and Kotalipara, respectively (Fig. 2) and the differences in final weight among two treatments were not found any significant ($p \leq 0.05$).

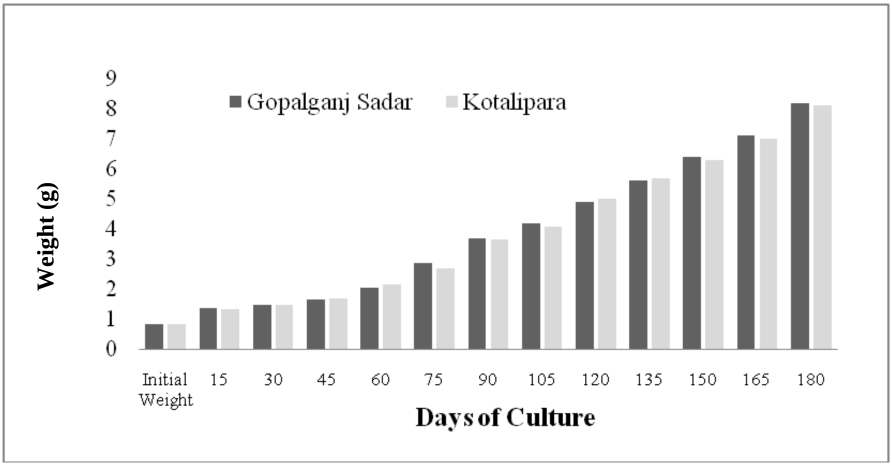


Fig. 2 : Growth of Snail

Average survival rate was found 95% in Gopalganj sadar and 93% in Kotalipara (Fig. 03). The snail was harvested in October after six months of cultivation. From Gapalganj Sadar, the highest snail production was measured at 21122kg/ha.

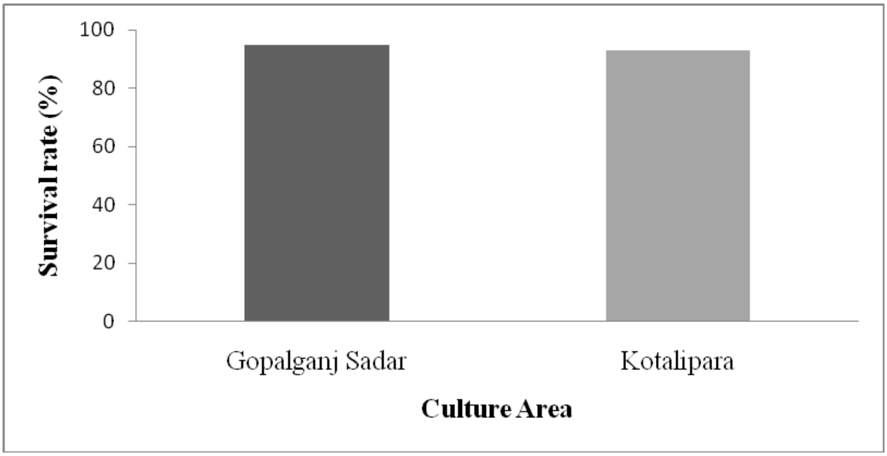


Fig. 03: Survival rate of snails in different ponds

Water quality parameters

The physico-chemical parameters of water viz. transparency, temperature, dissolved oxygen, pH, salinity, alkalinity and total ammonia etc. recorded during the study period were found within optimum range. Water temperature varied between 26 ºC and 34 ºC, pH ranged from 7.5 to 8.8 and ammonia concentrations were within 0.01 mg/l in both areas. The mean values of water quality parameters are presented in Table 1.

Table 1 : Mean value ±SD of water quality parameters of culture ponds

Parameters	**Gopalganj Sadar** (Mean value ± SD)	**Kotalipara** (Mean value ± SD)
Air Temperature (ºC)	31±1.33	30±0.92
Water Temperature (ºC)	30±1.64	29±1.22
pH	8.12±0.25	8.04±0.19
DO (mg/l)	6.21±2.05	7.18±1.05
CO_2 (mg/l)	1.9±0.17	1.4±0.12
Total Ammonia (mg/l)	0.012±0.15	0.017±0.4
Nitrite (mg/l)	0.14±0.21	0.16±0.11
Hydrogen sulfide (mg/l)	0.05±0.13	0.03±0.15

Cost benefit analysis

The whole expense from preparing the pond through harvesting was 46,000 Tk. The highest output was found to be 21122kg/ha. Snails are sold in local markets at 50 kg/sack. The cost of each sack was 250 Tk. Profit, based on this price was 59610 Tk/ha. Cost benefit analysis of snail culture in 1ha area pond is given in table 2.

Table 2 : Cost benefit analysis of Snail farming (1ha area)

Items	Cost (Tk)
Pond repair and preparation	10000
Purchase of small snail	13000
Supplementary food	8000
Others expenditure (cowdung, fertilizer, compost meterial, labor)	15000
Total Cost	46000
Total Production	21122 kg
Total Income (5tk/kg)	105610
Total Profit	59610
BCR	2.29

Discussions

Before stocking snail seeds, the pond was dried at the start of snail culture. Where repairs were required, pond dykes were restored. The pond's extra bottom mud was removed, and it was treated with lime at a rate of 1-1.5 kg/decimal or 250-375 kg/ha. The lime dose in traditional aquaculture was 1.1 kg/decimal (Siddique, 2003 & Shafiullah, 2003). Following the liming, the pond was filled with water and compost was scattered throughout the pond in the presence of snails for snail culture. Cowdung, mustard oil cake, and urea were mixed at 1.0 kg, 1.0 kg, and 0.5 kg/decimal, respectively, to make compost. Cowdung (1235 kg/ha), urea (14.82 kg/ha), and TSP (22.23 kg/ha) were used to treat ponds in conventional aquaculture systems. (Shamsuddin, 2004). Then, at a pace of 600 per decimal, snail seeds were discharged. Snail seed weighed between 0.8 to 1.1 g per. The best stocking density for juveniles weighing 0.5-49 g of gigantic african snails, *Achatina fulica* and *Achatina chatina*, in tropical environments was 100/m^2 (Leef lang, 2005). After 180 days of culture weight of snails was found 8.2±0.07g and 8.1±0.28g in ponds of Gopalganj sadar and Kotalipara, respectively. After 6 months cultivation snail production was found 21122 kg/ha. Snails were collected from the culture pond using a variety of surfaces. Palm leaf, plastic/iron tubing, bamboo pole, net, and other materials were used as substrates. The usage of those substrates was simple because they were all readily available and could be quickly thrown into the pond. Palm leaf was the most successful substrate for snail collection among the four substrates tested since it was inexpensive, readily available, and controllable. This substrate contains a large amount of algae that can efficiently attract snails. . For this reason huge numbers of snails were attached. Average survival rate was found 95% in Gopalganj sadar and 93% in Kotalipara. In the present study, at water quality parameter average temperature was found that 29-30°C. Okafor (2001) stated that temperature ranges between 23-32ºC are suitable for snails' growth and development. The prevalence and diversity of snails could be increased or decreased depending on the class of pollutants. Under natural condition, snails are exposed to several environmental factors which produce a collective effect on the snails. This is in coincidence with El-Khayat *et al*., (2009), who revealed that snails can tolerate a wide range of temperature 19 – 34°C. However, it has been showed that snails can tolerate low temperature rather than a high temperature which can lethally affect them (Mahmoud, 1994). This indicates that snail species is highly sensitive to an elevation in temperature that may cause thermal stress on snail and also reduces the dissolved oxygen content of water body (Hofkin, 1991). However, significant link was not found between snail abundance and water temperature (Kariuki *et al*., 2004). From the current work, it was found that DO range of 6.21 – 7.18 mg/L. This result was almost within the range mentioned by Njoku-Tony, 2011, who found that the desired concentration of DO for snails ranged between 2.2 – 8.5 mg/L. Water pH was found at two upazela were 8.04, 8.12. The present pH range found to be nearly similar to the observation by Ntonifor and Ajayi (2007), who found that pH range was 7.2 – 10.9 for all the sites that harbored snails.

Snail will be the profitable item for farming. In snail farming BCR was found 2.29 that indicate it can be profitable item for farmers. Farmers can be easily benefited by cultivating this snail in sallow land.

Conclusions

In the district where shrimp culture is practiced, snail will be the profitable item for farming. Farmers can easily benefited by cultivating this snail in sallow land. It will be the good alternative of fishmeal. On the other hand, snail culture reduces pressure of natural snail population from extinct.

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Physico-chemical properties, plankton composition and commercially important fish diversity of Hakaluki Haor

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Abstract

This study was conducted in three Beels namely Zalar Beel, Dudai Beel and Chatla Beel of Hakaluki Haor, Moulvibazar from December 2020 to June 2021. Water quality parameters such as water temperature, transparency, total alkalinity, hardness, pH, dissolved oxygen (DO), free CO_2, total dissolved solid (TDS) and conductivity of the Beels were measured monthly. The Secchi disc transparency was ranged from 31 - 53 cm in those Beels. The water temperature among the three Beels ranged from 19 - 32°C. TDS ranged from 15 - 50 mg/l, while the electric conductivity of water ranged from 30 - 100 μS/cm. The pH value was ranged from 6.5-8 in those study areas. The concentration of DO was ranged from 4.5 – 6.8 mg/l. In all the three studied Beels, the free CO_2 concentration was 5-16 mg/l. Total alkalinity and hardness value was moderate in all three stations (ranged within 18-41 and 10-66 mg/l, respectively). Low values of alkalinity and hardness may be due to the less nutrient enrichment of Haor Water. Otherwise, all water quality parameters were in a suitable range of fish growth. A total of 43 genera of phytoplankton and 8 genera of zooplankton were identified of which Zygnematophyceae (09 genera) Chlorophyceae (09 genera) and Cyanophyceae (9 genera) in the phytoplankton population and Branchiopoda (03 genera) in the zooplankton population were dominant. A total 24 species under 14 family of commercially important fishes were recorded from those three Beels throughout the study period, with five of them threatened. Longer-term research is required to improve Hakaluki Haor management and gain a better knowledge of the commercially significant fish population.

Keywords: Hakaluki Haor, Water quality, Plankton, Fish diversity, Conservation, Bangladesh

Introduction

Haor is an integral part of the inland open water fisheries resource of Bangladesh. There are numerous Haor laid between the Sylhet-Mymensingh Basin of Bangladesh. These Haors play a vital role in the livelihood of rural people. During winter these Haors become dried and used as a paddy field. Besides, in the rainy season, they become fulfilled with water which is blessed with fish, birds and other aquatic vertebrates. Most of the Haor is connected with nearby Rivers, which play as a source of water in Haor. This fishery is in decline, partly due to increasing fishing pressure from the ever-increasing population and partly due to loss of natural habitat as well as climate change. Climate has a major influence on water quality and consequently, the biodiversity within the water bodies (Boyd and Tucker, 1988). Good water quality in fish beel is essential for survival and adequate growth of fish. Water quality, i.e. the Physico-chemical and biological charters of water, plays a big role in plankton productivity as well as the biology of the cultured organisms and final yields. Water quality determines the species optimal for culture under different environments. Singh (1960) observed the direct influence of physicochemical conditions of water environment which is very important to culture of fish properly. The knowledge of water quality parameters of the water bodies provides an important tool for successful fish production and fisheries management. In turn, the quality of the aquatic environment depends on the abundance of plankton. In these circumstances, knowledge of plankton community structure or simply ecology of microalgae is a very important tool for managing the water of Beel for higher yields.

Phytoplankton is the basis of primary producer of all types of water bodies and is used as food by fish directly or indirectly. Phytoplankton, also called fresh-water algae which vary in shape and color, and are found in a large range of habitats, such as ponds, lakes, reservoirs, and streams. Phytoplankton is the predominant type of plant in most managed as well as non-managed water bodies. Plankton is an important component in the cycle of organic matter and inorganic nutrients in aquatic ecosystems. The composition, abundance and distribution of plankton over a while providing an index of the ecosystem. Phytoplankton is the primary producers for the entire aquatic body and comprises the major portion in the ecological pyramids (Odum, 1971). Phytoplankton is a diverse assemblage of microscopic and photosynthetic organisms that are suspended or weakly swimming in water. Some species are mobile through flagella or cilia, some species can change cell density and some move up and down in the water column and other species are immobile and move only in response to water currents or turbulences.

The major groups of phytoplankton are found in inland open water are green algae (Chlorophyta), euglenophytes (Euglenophyta), yellow-green and golden-brown algae (Crysophyta), dinoflagellates and blue-green algae (Cyanobacteria). They are a natural and essential part of the ecosystem. The phytoplankton population represents the biological wealth of a water body, constituting a vital link in the food chain. The primary productivity of a water body can easily be determined from its planktonic composition, which forms the backbone of the aquatic food chains (Ahmed and Singh, 1989). Both the qualitative and quantitative abundance of plankton in a water body is of great importance in managing the successful operations, as they vary from location to location and Beel to Beel within the same location even within similar ecological conditions (Boyd, 1982).

A total of 265 freshwater fish species are reported in Bangladesh (Rahman *et. al*., 2005). But very few are reported to be present in natural poor conditions. Many of the fishes become vulnerable, endangered, or critically endangered. However, for sustainable exploitation and proper management of resources, the fish diversity in the water must be known. Little studies on water quality, plankton composition and fish diversity status in Hakaluki Haor. By considering those, this study was taken to know the water quality, plankton composition and fish diversity status, through the period from December 2020- June 2021 in Hakaluki Haor.

Materials and methods

Site selection and Study period:

The study was conducted for a period of seven months from December 2020 to June 2021 at Zalar Beel, Dudai Beel, and Chatla Beel of Hakaluki Haor Moulovibazar, Bangladesh (Fig. 1).

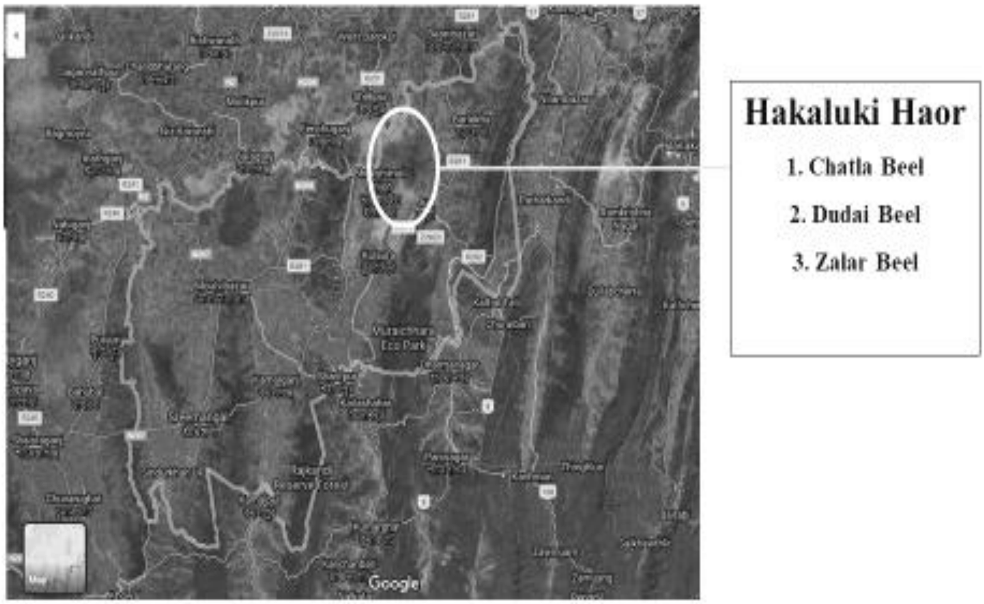

Fig. 1. Location of Hakaluki Haor, Moulvibazar, Bangladesh.

Water quality monitoring

Throughout the study period, the water quality parameters such as temperature (^{o} C), transparency (cm), dissolved oxygen (mg l^{-1}), carbon di-oxide (mg l^{-1}), pH, alkalinity, hardness, TDS and conductivity were recorded monthly.

During the study period, water temperature was recorded with a Celsius thermometer. Transparency was measured with a secchi disc of 20 cm diameter. pH of the water samples was measured by a direct reading digital pH meter (Jenway, model 3020 CORNING 445 pH meter) and dissolved oxygen was also measured by using a digital DO meter (YSI, model 58) on the spot. The concentration of carbon di-oxide was determined by HACH kit with Sodium Hydroxide. Alkalinity was also determined by the HACH kit with phenelopheline indicator, bromocresolmethyel red and sulfuric acid. The same HACH kit and buffer solution, manvar 2 and EDTA was used to determine Hardness. TDS and conductivity was measured directly by using a digital TDS meter (HACH, USA).

Plankton Sample

Plankton samples were collected monthly from Dec 2020 to June 2021. Collection of plankton was made by filtering 50 liters of habitat water from approximately 10 - 12 cm below the surface level passed through a 25 µm mesh net and finally concentrated to 25 ml. The population of plankton accumulated in the container were then transferred to other bottle and immediately preserved in 4% formalin, labeled and then transferred to laboratory for further experimentation.

Plankton Identification

Plankton identification was done as per Ward and Whipple (1959) and Presecot (1962). Each sample was stirred smoothly just before microscope examination. One ml from agitated sample was transfer to a Sedgwick Rafter counting cell with a wide mouth graduated pipette.

Plankton Composition

Plankton sample were categorized according to their order for both phytoplankton and zooplankton.

Commercial Fish specimen collection and identification

Samples of different fish species were collected from the fisherman's catch landed at the selected sampling areas. A digital camera was used to capture the photos of different fish species. The collected fish samples were identified by analyzing their morphometric and meristic characteristics following Rahman *et. al.*, 2005, Rahman *et. al.*, 1989, and Talwar, 1991. The valid scientific names of the identified fish species were ensured by checking catalogue of life Roskov *et.al.*, 2016.

Determination of conservation status

The global conservation was determined following the database of IUCN 2016 whereas the local conservation status was based on IUCN 2015.

Order wise Percentage Composition

Fishes of Hakaluki Haor were categorized according to different fish order throughout the study period.

Feeding Behavior

Fish species were grouped according to their feeding habit such as Carnivorous, Herbivore or Omnivore by analyzing their morphology.

Data analysis

Collected data was analyzed by computer software Microsoft Excel 2010.

Results and Discussion

Water quality of Hakaluki Haor

Almost all water quality parameters were within the acceptable range for fish (Fig. 2, 3 & 4) according to Bangladesh Standard (DoE 2001, EQs 1997). Some exception was observed in the case of Alkalinity and Hardness among the sampling spot. The highest value of Alkalinity was 41 mg/L and the highest value of Hardness was 66mg/L. Lower values of alkalinity and hardness among the Haor water body indicate Beel water to be less nutrient-enriched (Flura *et al.*, 2015)

The water quality parameter was more or less similar for three sampling spots of Hakaluki Haor. Physico-chemical parameters of different sampling stations for Hakaluki Haor were represented in Fig. 2-4.

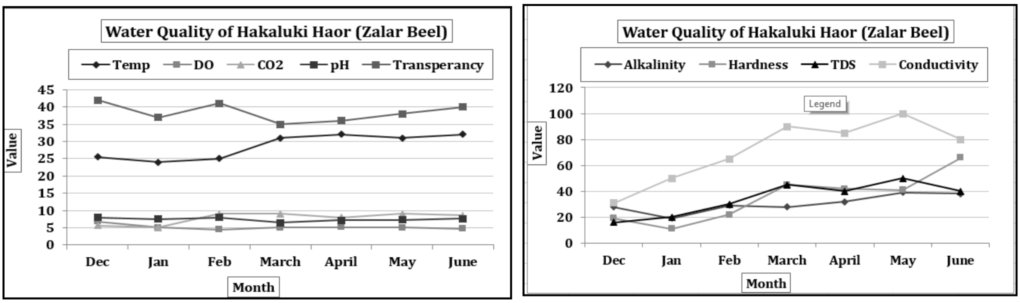

Fig. 2. Water quality parameters of Zalar Beel, Hakaluki Haor at Moulvibazar

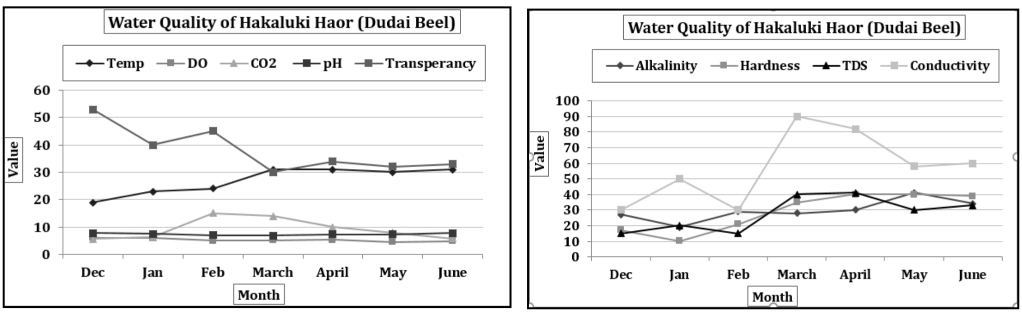

Fig. 3. Water quality parameters of Dudai Beel, Hakaluki Haor at Moulvibazar

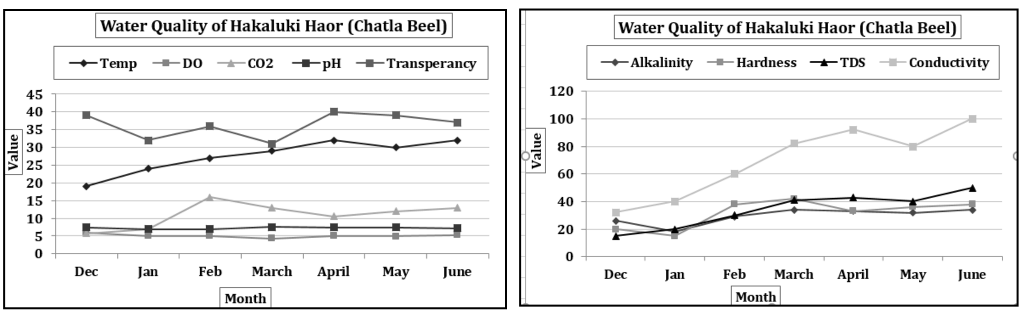

Fig. 4. Water quality parameters of Chatla Beel, Hakaluki Haor at Moulvibazar

Air temperature of all the sites was recorded slightly higher in the month of May-June according to DoE (2001). The air and water temperature in Hakaluki Haor ranged from 28.2 - 30.4°C stated by Bhuiyan *et al.*, (2021). DO value was found lower than the standard value of 6.5 (DoE, 2001). Fluctuation of dissolved oxygen concentration may be attributed to photosynthetic activity and variation in the rate of oxygen consumption by fish and other aquatic organisms (Boyd, 1982). The concentration of DO in Hakaluki Haor was recorded as very poor which ranged from 2.8-5.4 mg/l by Bhuiyan *et al.,* (2021). The free CO2 concentration was 0.096 mg/l observed in three different Beel of Hakaluki Haor by Bhuiyan *et al*., (2021) which shows a huge difference with present findings. The pH value recorded in all sampling sites was within the acceptable range (EQS, 1997). The pH of Hakaluki Haor water was also found the highest at 8.33 in the wet season while the lowest was 7.69 in the dry season described by Akter *et al.*, (2017). Transparency was found inside the acceptable range in all sampling sites. Bhuiyan *et al.*, (2021) recorded Secchi Disc Transparency was 0.74 - 1.91 m in Dudai Beel and Zalar Beel of Hakaluki Haor. Alkalinity levels indicate a medium to a higher level of productivity. Alkalinity was recorded inside the accepted range (Boyd and Tucker, 1998) although it was found to be lower in January. Hardness was also recorded inside the accepted level although it was found to fluctuate throughout the study period. Akter *et al.*, (2017) found mean hardness content in wet and dry seasons was 79.00 and 54.38 mg/l, respectively. TDS and conductivity were also recorded within a suitable range. Bhuiyan *et al.*, (2021) recorded TDS ranged from 35-42 mg/l, while the electric conductivity of water showed 40-50 μS/cm in Hakaluki Haor.

Plankton Identification

A total of 43 genera of Phytoplankton and 8 genera of Zooplankton were identified of which Zygnematophyceae (09 genera) Chlorophyceae (09 genera) and Cyanophyceae (9 genera) in the Phytoplankton population and Branchiopoda (03 genera) in the Zooplankton population were dominant.

Plankton Composition

Eight families of Phytoplankton: Zygnematophyceae (9 genera), Chlorophyceae (9 genera), Euglenophyceae (4 genera) Cyanophyceae (9 genera) Bacillariophyceae (6 genera) Coscinodiscophyceae (2 genera) Dinophyceae (3 genera) and Mediophyceae (1 genera) were found. Four groups of Zooplankton: Rotifera (2 genera) Branchiopoda (3 genera) Copepoda (2 genera) and Protozoa (1 genera) were also identified. Alam *et. al.*, 2015 enlisted 50 genera of Chlorophyceae, 1 genera of Xantheophyceae, 5 genera of Chrysophyceae, 11 genera of Bacillariophyceae, 5 genera of Dinophyceae and 23 genera of Cyanophyceae in Tanguar Haor, Sunamgonj where Chlorophyceae were dominant genera whereas, in present findings, 9 genera of Chlorophyceae, Zygnematophyceae (9 genera) and Cyanophyceae (9 genera) were dominant. Among the planktonic algae, 44 genera of Phytoplankton under 4 groups were enlisted in Hakaluki Haor which was 40 genera in case of the observation of Bhuiyan *et al*., (2021). 12 genera of Zooplankton were recorded inside the sanctuary areas of Dudai Beel by Bhuiyan *et al*., (2021) which were more or less similar to the present study where 8 genera of the different groups were identified. In the study area, the phytoplankton abundances were consistently higher than that of Zooplankton. Higher Phytoplankton concentrations in water normally indicate higher productivity.

Table 1. List of Phytoplankton genera identified from Hakaluki Haor.

Phytoplankton Group Name	Genera
Zygnematophyceae	*Closterium* sp.
	Cosmarium sp.
	Desmidium sp.
	Spirogyra sp.
	Staurastrum sp.
	Staurodesmus sp.
	Mougeotia sp.
	Arthrodesmus sp.
	Xanthidium sp.
Chlorophyceae	*Ankistrodesmus* sp.
	Eudorina sp.
	Scenedesmus sp.
	Padiastrum sp.
	Pandorina sp.
	Tetraedron sp.
	Volvox sp.
	Sphaerocystis sp.
	Chlorococcum sp.
Euglenophyceae	*Phacus* sp.
	Euglena sp.
	Trachelomonas sp.
	Lepocinclis sp.
Cyanophyceae	*Polycystis* sp.
	Anabaena sp.
	Aphanocapsa sp.
	Coelosphaerium sp.
	Lyngbia sp.
	Microcystis sp.
	Oscillatoria sp.
	Spirulina sp.
	Gloeocapsa sp.
Bacillariophyceae	*Navicula* sp.
	Amphora sp.
	Asterionella sp.
	Synedra sp.
	Nitzsehia sp.
	Fragilaria sp.
Coscinodiscophyceae	*Coscinodiscus* sp.
	Melosira sp.
Dinophyceae	*Ceratium* sp.
	Peridinium sp.
	Glenodinium sp.
Mediophyceae	*Cyclotella* sp.

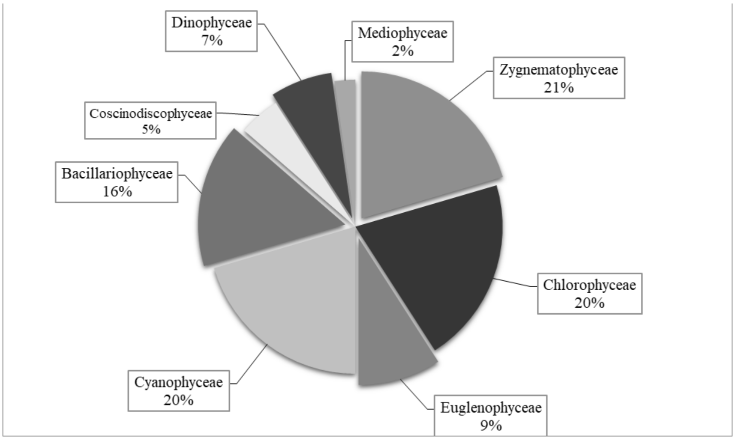

Fig. 5. Group wise phytoplankton percentage of Hakaluki Haor.

Table 2. List of Zooplankton genera identified in the studied areas during the study in Hakaluki Haor

Zooplankton Group Name	Genera
Rotifera	*Brachionus* sp.
	Lecane sp.
Branchiopoda	*Bosmina* sp.
	Daphnia sp.
	Moina sp.
Copepoda	*Cyclops* sp.
	Naplius sp.
Protozoa	*Arcella* sp.

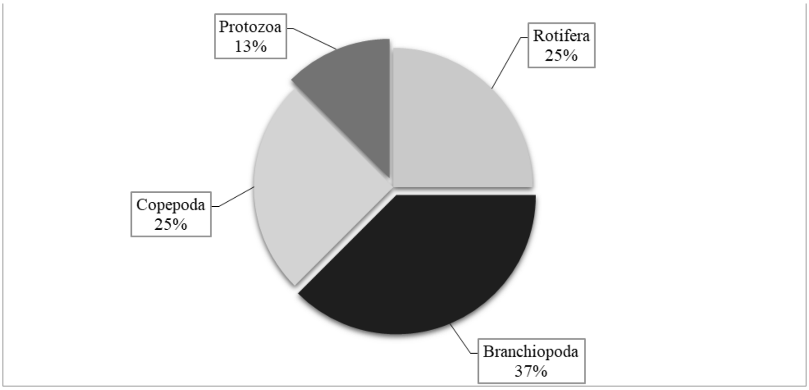

Fig. 6. Group wise zooplankton percentage of Hakaluki Haor

Fish Diversity Observation (Commercial and available fish)
A total of 24 species under 14 families of commercially important fish were recorded from 3 Beel namely Zalar Beel, Chatla Beel and Dudai Beel of Hakaluki Haor throughout the study period. List of existing fish species with their taxonomic position (family name), scientific name, local name, common group, habitat and their conservation status in Bangladesh and global aspects are presented in Table: 3 and Plate :1.

Table 3. List of commercially important fish species collected from Hakaluki haor

Order	Family	Scientific Name	Local Name	Group Name	IUCN Conservation Status (BD)	IUCN Conservation Status (GB)
Cypriniformes	Cyprinidae	*Puntius sophore*	Bhadipunti	Barb	LC	LC
		Puntius ticto	Tit punti	Barb	VU	LC
		Puntius sarana	Sarpunti	Barb	NT	LC
		Amblypharyngodon mola	Mola	Minnow	LC	LC
		Labeo calbasu	Kalibaus	Carp	LC	LC
		Labeo rohita	Rui	Carp	LC	LC
		Labeo bata	Bata	Carp	LC	LC
		Labeo gonia	Gonia	Carp	LC	LC
		Cirrhinus mrigala	Mrigal	Carp	NT	LC
	Cobitidae	*Lepidocephalus guntea*	Gutum	Loach	LC	LC
	Botiidae	*Botia dario*	Rani	Loach	EN	LC
Perciformes	Gobiidae	*Glossogobius giuris*	Baila	Mudskipper	LC	LC
	Nandidae	*Nandus nandus*	Meni	Perch	NT	LC
	Ambassidae	*Chanda nama*	Chanda	Perch	LC	LC
Siluriformes	Bagridae	*Mystus vittatus*	Tengra	Catfish	LC	LC
		Mystus bleekeri	Gulsha	Catfish	LC	LC
	Siluridae	*Wallago attu*	Boal	Catfish	VU	NT
		Ompak pabda	Pabda	Catfish	CR	NT
	Bagridae	*Sperata aor*	Ayre	Catfish	VU	LC
Channiformes	Channidae	*Channa punctata*	Taki	Snake head	LC	NE
Osteoglossiformes	Notopteridae	*Notopterus notopterus*	Foli	Feather back	VU	LC
Clupeiformes	Clupeidae	*Gudusia chapra*	Chapila	Clupeid	VU	LC
Synbranchiformes	Mastacembelidae	*Mastacebelus armatus*	Baim	Eel	EN	LC
Exotic Fish Species						
Cypriniformes	Cyprinidae	*Ctenopharyngodon idella*	Grass carp	Carp		NE

Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN),Data Deficient (DD), Critically Endangered (CR), Not extinct (NE)

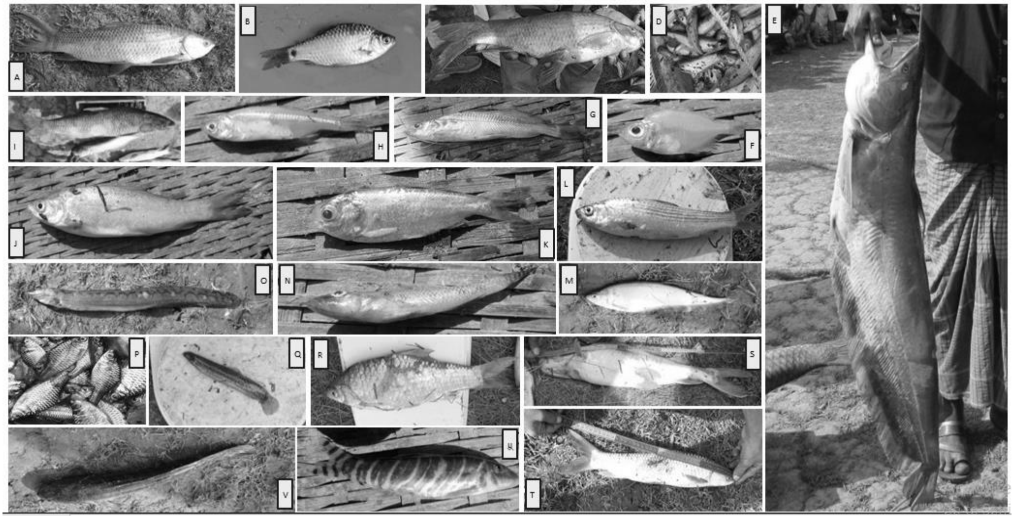

Plate: 1. Fish Species of Hakaluki Haor. A. Rui (*Labeo rohita*), B. Bhadi punti (*Puntius sophore*), C. Kalibaus (*Labeo calbasu*), D. Pabda (*Ompak pabda*) E. Boal (*Wallago attu*), F. Chanda (*Parambassis ranga*), G. Gulsha (*Mystus bleekeri*), H. Mola (*Amblypharyngodon mola*), I. Grass carp *(Ctenopharyngodon idella*), J. Gonia (*Labeo gonia*), K. Chapila (*Gudusia chapra*), L. Bata. *(Labeo bata*), M. Foli (*Notopterus notopterus*), N. Baila (*Glossogobius giuris*), O. Baim (*Mastacebelus armatus*), P. Tit Punti (*Puntius ticto*), Q. Gutum (*Lepidocephalus guntea*), R. Sar Punti (*Puntius sarana*), S. Ayre (*Sperata aor*), T. Mrigal (*Cirrhinus mrigala*), U. Rani (*Botia Dario*), V. Taki (*Channa punctate*).

Conservation Status

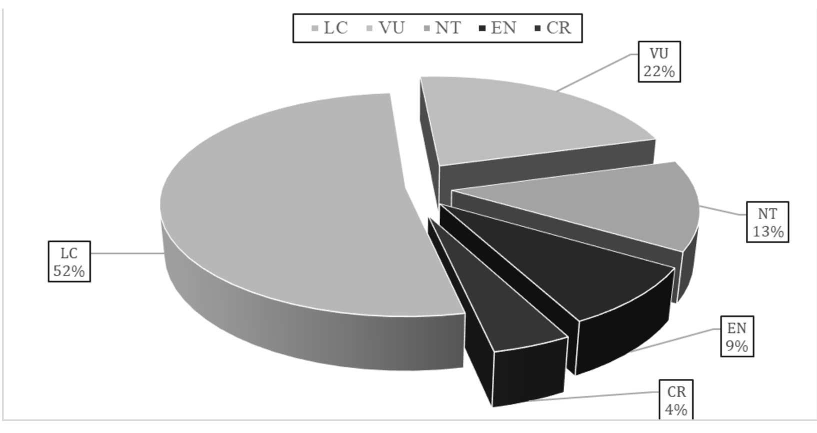

Fig.7. Local conservation status of fish speicies of Hakaluki Haor

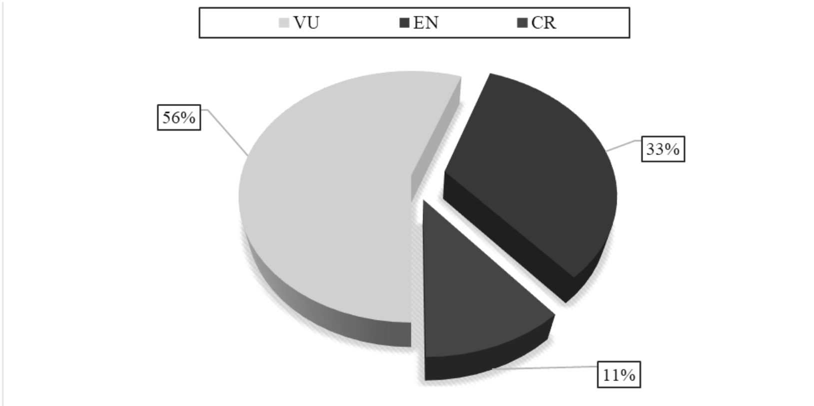

Fig. 8. Percentage of threatrened fish species of Hakaluki Haor

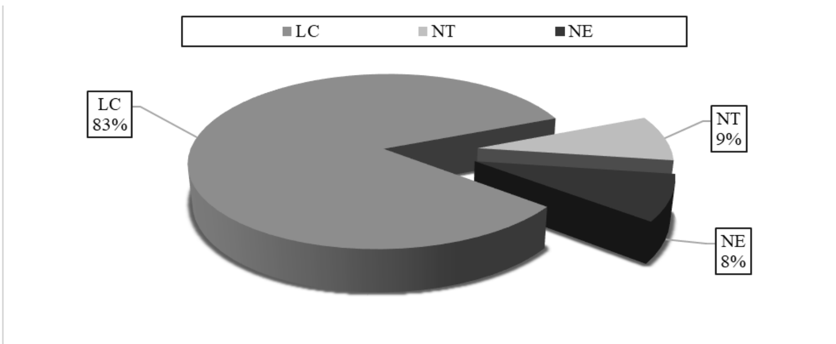

Fig. 9. Global conservation status of fish speicies of Hakaluki Haor

According to the IUCN 2015, 64 native freshwater fish species of Bangladesh have been declared as threatened species. Among them 9 fish species which are commercially available were recorded from the Hakaluki Haor. Among them 5 species (56%) were found as Vulnerable (VU), 3 species (33%) as Endangered (EN) and 1 species (11%) as Critically Endangered (CR). Local conservation status of fish species of Hakaluki Haor showed that the highest percentage was recorded as Least Concern (50%) followed by Vulnerable (23%), Near Threatened (14%), Endangered (9%) and Critically Endangered (4%). According to IUCN 2016, the highest percentage of fish species was occupied by the Least Concern category (82%) followed by Not extinct (9%), and Near Threatened (9%).

Order wise Percentage Composition

Fishes of Hakaluki Haor were categorized according to different fish order throughout the study period. Dominant fish order was Cypriniformes (38%) and followed by Siluriformes (21%).

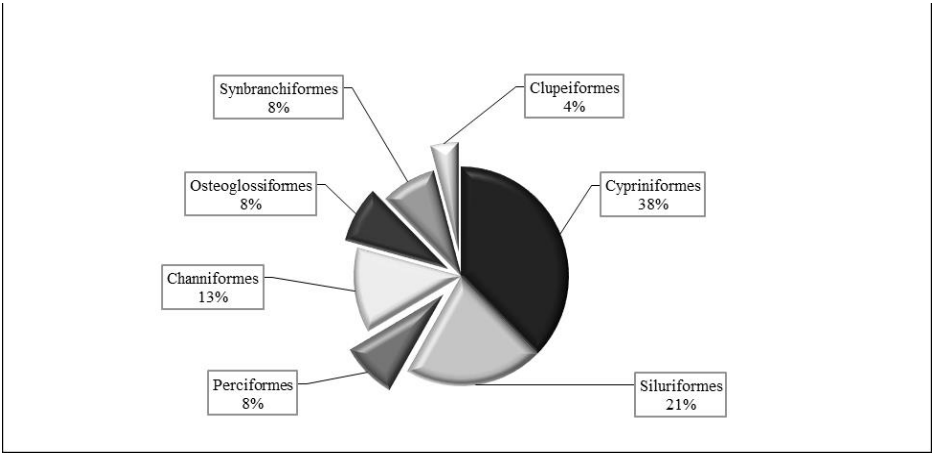

Fig. 10. Order wise Fish Percentage (%) of Hakaluki Haor

Feeding Behavior

52% of the commercially important fish species were classified as carnivores, 40% as omnivores, and 8% as herbivores (Fig.11). The existence of greater biomass of predatory fishes is clear since the percentage of carnivore fish species is higher than the others found in the current study.

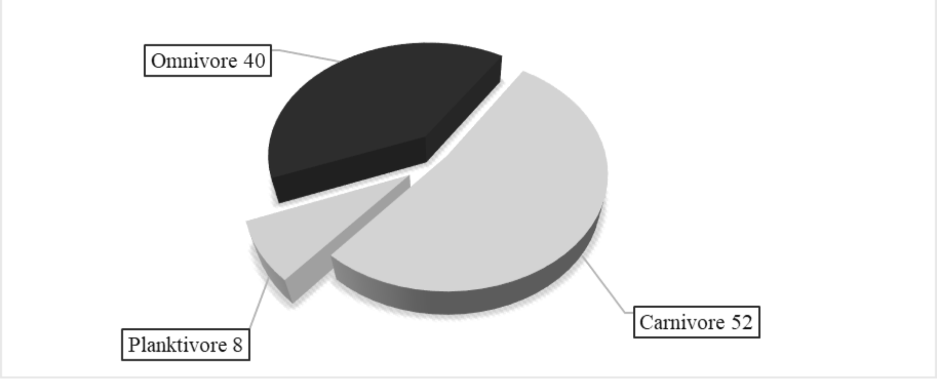

Fig. 11. Feeding habits of different fishes throughout the study period in Hakaluki Haor

Conclusion

The current research focused on documenting the biodiversity of commercially important fish species in the Hakaluki Haor, as well as their present conservation status in Bangladesh and around the world. The physico-chemical parameters of water were found to be mostly in line with Bangladesh standards, while they did differ between study sites. High nutrient concentrations are indicated by the presence of more phytoplankton groups than zooplankton groups in Hakaluki Haor. The presence of a higher percentage of carnivorous fishes indicates a higher predatory fish biomass. Longer-term research is required to improve Hakaluki Haor management and gain a better knowledge of the commercially significant fish population.

Acknowledgement

The research work was supported by Bangladesh Fisheries Research Institute (BFRI) – "Ecological assessment of inland open water fisheries population with bio-physicochemical properties to frame Ecological Based Fisheries Management approach (EBFM approach) (Comp-D)" project of BFRI and the authors are thankful to them. The authors are also thankful to the fisherman community of Hakaluki Haor as well as Upazilla Fisheries Officers (UFO), Leaf and relevant staffs for their kind cooperation to provide data and information.

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Culture Potentialities of Gura Chingri (*Macrobrachium rude*) in Pond at Different Stocking Densities

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Abstract

The experiment was conducted to assess the production performance of Gura Chingri (*Macrobrachium rude*) at different stocking densities for a period of 05 months from January to May,2021. There were three different treatments (T_1, T_2 and T_3) each with three replications. The stocking density was 400g/decimal, 800g/decimal and 1200g/decimal in T_1, T_2 and T_3, respectively. The initial average weight of *M. rude* was 0.43 ± 0.09g, 0.42 ± 0.11g and 0.43 ± 0.13g in treatments T_1, T_2 and T_3, respectively. The nursery and supplementary feed were supplied at the rate of 8% of their body weight and gradually reduced up to 3%. The highest and lowest percentage of weight gain was found in T_1 (139 ± 2.52) and T_2 (117 ± 6.01) at the end of the experiment. The highest and lowest final weight of Gura chingri was found in T_2 (0.92 ± 0.22g) and T_3 (0.90 ± 0.41g) respectively. The average highest production was found in T_3 (2780 ± 76g) whereas the initial stocking density was higher and the lowest production was found in T_1 (955 ± 27g) whereas the stocking density was lower than other treatments (T_2 and T_3). The average Feed Conversion Ratio (FCR)was lowest in T_1 (1.95) and highest in T_2 (2.30). The highest BCR was found in T_3 (1.60) and the lowest was found in T_1 (1.12) at the end of the experiment. Water quality parameters were measured on daily basis and were within the suitable range. Gura chingri breeds within a short period of time. Therefore, the production of Gura chingri was found higher where the maximum stocking density was conferred. According to the result of the experiment, farmers could be suggested to culture Gura chingri at the stocking density of 1200g/decimal to assemble superfluous production and financial benefit. Further experiment need to be carried out by taking higher stocking density than the 1200g/decimal for the optimization of stocking density to get the adequate consistency in culture system and residual circumstances.

Keywords: Gura Chingri, Growth and production, Stocking density, Feed Conversion Ratio (FCR)

Introduction

Different species of prawns are available in the water bodies of Bangladesh. Several species of genus, *Macrobrachium,* are abundant from larger too small in size and tasty to eat. Freshwater prawn has been performed as a major aquaculture species in many countries including China, Vietnam, Indonesia, India, Bangladesh and Ecuador after its domestication in 1960s (Fatema *et al.*, 2011). Eventually, Bangladesh has engrossed into the commercial prawn farming in early 1990s and has become a world player as one of the seven major export countries (Wahab, 2009). About 1.5 million people are directly related to farming of 24 prawn species and 36 shrimp species for their livelihood in the country (DoF, 2012). About twenty-four species of freshwater prawns, including 10 species of *Macrobrachium* sp. are found in Bangladesh (Ahmed *et al.*, 2008). Small prawns grow comparatively more rapidly and more frequently than larger ones, and these growth rates are usually highest during summer. Over the last two decades, prawn farming has come to farmer's attention because of its easy operation, significant export potential and lower susceptibility to diseases compared to marine shrimp.

Several factors are reported to be affecting the growth, production and survival in freshwater prawn farming (New, 1995). Stocking density also plays an important role in the balance of an aquaculture system and therefore, on the growth, production and survival of aquatic organisms (Ray and Chien, 1992). Successful aquaculture system needs not only careful selection of species, appropriate feeding and water quality management but also a great extent, the density to which the fish are stocked as compared to the food ration and extent of management (Barua, 1990). Considering popularity of small prawn's and high market price treated it as a promising cultured species in Bangladesh. Till now no research work has been carried out in Bangladesh on the culture of Gura chingri (*M. rude*). Therefore, the present study was carried out to evaluate the growth and production performance of Gura chingri at different stocking densities in pond culture system.

Materials and method

Experimental site

The experiment was carried out for a period of 5 months from January to May 2021 in earthen ponds located at Freshwater Station of BFRI, Mymensingh. The size of each pond was $400m^2$. The ponds were equal in depth, basin, configuration and pattern including water supply facilities from underground. The water depth was maintained at a maximum of 1.2m. A well-organized inlet and outlet system to maintain water level.

Experimental design

The experiment was conducted into three different treatments (T_1, T_2 and T_3) with each have three replications. The stocking density was 400g/decimal in T_1; 800g/decimal in T_2 and 1200g/decimal in T_3 (Table 1).

Table 1. Experimental layout of Gura chingri (*M. rude*) in pond

Treatment	Pond size (decimal)	Prawn species	Stocking density (g/decimal)	Culture periods (Months)
T_1	$400m^2$	*Macrobrachium rude*	400	05
T_2			800	
T_3			1200	

Pond preparation

At first all the ponds were dried properly before stocking Gurac hingri. All aquatic weeds and undesirable fishes were completely removed manually. The ponds were prepared by using lime and fertilizers. Lime was applied at the rate of 250 kg/ha. The Urea and TSP were applied at the rate of 25kg/ha and 25kg/ha respectively for plankton and algal growth. Three days after the application of fertilizer, when the water turns green, small prawn were stocked in nine ponds . Aquatic weeds (Kalmilota and Water hyacinth) were used to create shelter for small prawn and the ponds were fenced by nylon net with bamboo sticks.

Collection and stocking of Gura chingri

Small prawns in bulk were collected from the nearby Old Brahmaputra River at Mymensingh. Healthy and vigorous small prawns were collected and transported in oxy-polythene bags. The collected prawns then kept in cistern for acclimatization. After 06 hours of acclimatization, small prawns were transferred to the experimental ponds. The initial average length and weight of *M. rude* were recorded before releasing into the ponds.

Feeds and feeding

Commercial Golda Nursery Feed (32% Protein) and Homemade feed were used for the present experiment. The ingredients of homemade feed for small prawn were Rice bran, Mustard oil cake, Fish meal, vitamins and minerals etc. At the beginning of the experiment feeding was done at the rate of 8% of biomass and gradually it was readjusted to 3%. Apart from feeding, for increasing the primary productivity of water, 100g TSP and 50g urea were applied at fortnightly interval.

Water quality management

During the experimental period, the water quality parameters of the experimental ponds i.e., water temperature, transparency, pH, DO and alkalinity were monitored at fortnightly interval at 9.00 am. Samplings was done to know the consecutive growth and production performance of *M. rude* fortnightly also.

Experimental data analysis

The following parameters were used to evaluate the growth and production of small prawns
a) Mean weight gain (g)= Mean final weight (g) - Mean initial weight (g)
b) Mean length gain (cm)= Mean final length (g) - Mean initial length (g)
c) Production of small prawn
    Net production= No. of fish caught X average final weight (g)

All the data were analyzed using one-way analysis of variance (ANOVA) and level of significance was fixed at the 5%. All statistical analysis was done by using the SPSS (Statistical Product and Service Solutions) version 21.5. The graphs of water quality parameters were performed using Microsoft Excel.

Results

The experimental ponds were harvested after 05 (five) months of culture. In the present study, the stocking density revealed distinct effect on the final weight, FCR and production of Gura chingri.

Water quality parameters

Water quality parameters i.e., water temperature (◦C), pH, dissolved oxygen and total alkalinity (mg/l) of all the treatments were recorded fortnightly during experimental period. Water quality parameters (mean ± SE) measured throughout the experimental period are presented in Table (2).

Table 2. Mean (±SE) values of water quality parameters of experimental ponds under different treatments

Parameters	T_1	T_2	T_3
Temperature(◦C)	29.34±4.22^{a}	29.62±4.14^{ab}	29.87±3.21^{b}
pH	7.80±0.43^{b}	7.75±0.38^{a}	7.78±0.31^{ab}
DO (mg/L)	5.55±0.61^{b}	5.49±0.72^{a}	5.75±0.79^{c}
Total Alkalinity (mg/L)	127.8±3.49^{a}	128.7±3.65^{ab}	131.4±4.52^{b}

** Figures in the same row having the same superscripts are not significantly different ($p \geq 0.05$)

During the experimental period, water temperature of different treatments was more or less same. The mean values of water temperature were recorded 29.34 ± 4.22, 29.62 ± 4.14 and 29.87 ± 3.21◦C in T_1, T_2, and T_3, respectively. The mean values of dissolved oxygen were recorded 5.55 ± 0.61, 5.49 ± 0.72 and 5.75 ± 0.79mg/L in T_1, T_2, and T_3, respectively. The highest dissolved oxygen content was found 5.75 ± 0.79 in T_3 whereas lowest dissolved oxygen was found 5.49 ± 0.72 in T_2. Water pH of different treatments was more or less same. The mean values of water pH were recorded 7.80 ± 0.43, 7.75 ± 0.38 and 7.78 ± 0.31 in T_1, T_2, and T_3, respectively. Variation was seen in case of total alkalinity due to change in water temperature during winter, algal bloom and other factor related to water of different treatment. The mean values of total alkalinity were recorded 127.8 ± 3.49, 128.7 ± 3.65 and 131.4 ± 4.5mg/L in T_1, T_2, and T_3, respectively. The highest alkalinity content was found in T_2 whereas lowest alkalinity was found in $T_{1.}$

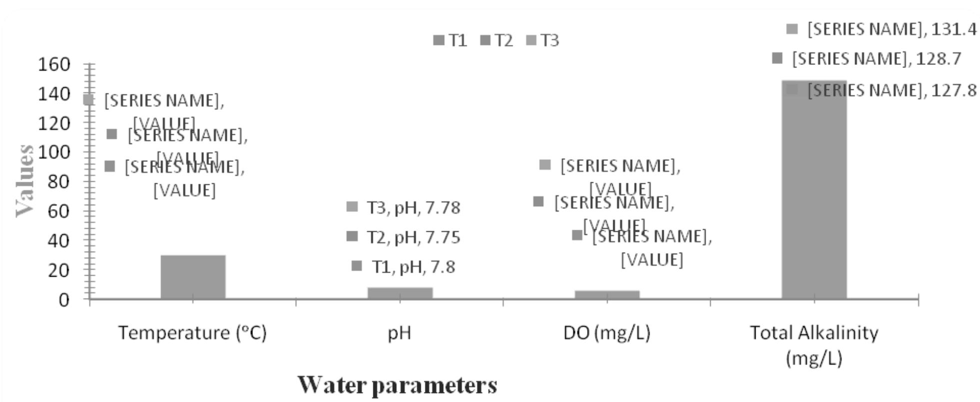

Fig. 1. Comparison of water parameters in different treatments during the experimental period.

Growth and production performance

In the present experiment, stocking densities of Gura chingri in the treatments T_1, T_2 and T_3 were 400, 800 and 1200g/decimal, respectively. At the end of the experiment, the production was 955, 1738 and 2780g/decimal inT_1, T_2 and T_3, respectively. The highest production was found in T_3 where stocking density was 1200g/decimal followed by T_1 and T_2. Gura chingri breeds every 4 months' interval found from this experiment. As for that, production was higher where the maximum stocking density was provided. The production was shown in Table 3.

Table 3. Growth and production performance (mean ± SE) of *Macrobrachium rude* in different treatments

Parameters	T_1	T_2	T_3
Mean Initial length(cm)	2.40 ± 0.41^a	2.39 ± 0.32^a	2.41 ± 0.29^a
Mean Initial weight (g)	0.43 ± 0.09^a	0.42 ± 0.11^a	0.43 ± 0.13^a
Mean Final length(cm)	3.7 ± 0.55^a	3.68 ± 0.48^a	3.69 ± 0.62^a
Mean Final weight (g)	0.89 ± 0.61^a	0.92 ± 0.22^a	0.90 ± 0.41^a
% Weight gain (g)	139 ± 2.52^b	117 ± 6.01^a	132 ± 6.11^b
FCR	1.95^a	2.30^c	2.05^b
Production	955 ± 27^a	1738 ± 51^b	2780 ± 76^c

** Figures in the same row having the same superscripts are not significantly different ($p \geq 0.05$)

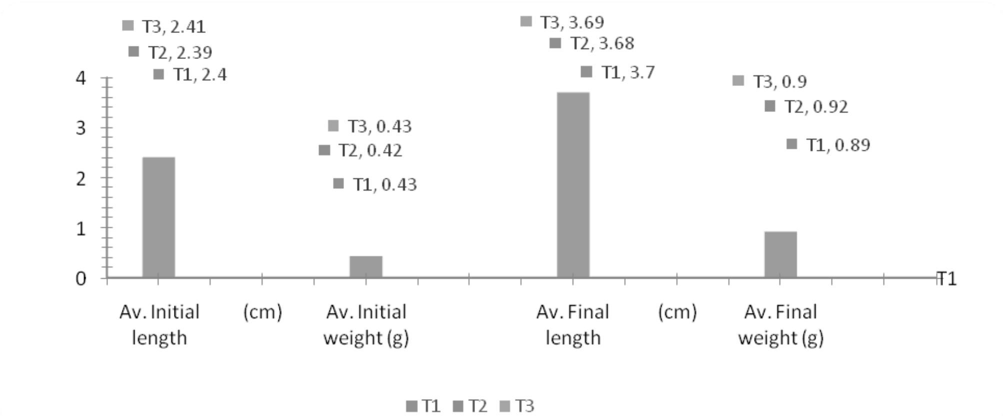

Fig. 2. Comparison of growth and production performance (mean ± SD) of Gura chingri.

Cost-benefit analysis

Total prawn seed cost in T_1, T_2 and T_3 was BDT 200, 400 and 600, respectively. Feed cost was 75, 116 and 180 BDT in T_1, T_2 and T_3, respectively. The gross cost of different treatments is shown in Table 4. Total gross income was calculated by multiplying total production and market price of small prawn. The gross income in T_1, T_2 and T_3 was BDT 600, 1038 and 1668, respectively (Table 4). The Net income was estimated by the deduction of gross cost from the gross income. The Net profit was BDT 65, 262 and 628 in T_1, T_2 and T_3, respectively (Table 4).

Table 4. Cost-benefit analysis of T_1, T_2 and T_3 culture system in the ponds at the end of the culture period

Items	T_1	T_2	T_3
Expenditure (BDT)			
Pond preparation	150	150	150
Lime	50	50	50
Fertilizer	60	60	60
Feed	75	116	180
Seeds	200	400	600
Gross cost	535	776	1040
Income			
Gross income/dec.	600	1038	1668
Net profit (BDT)	65	262	628
BCR	1.12^c	1.34^b	1.60^a

** Figures in the same row having the same superscripts are not significantly different ($p \geq 0.05$)

Discussion

The stocking density is considered one of the crucial factors for the growth and production of aquatic organisms to be cultured. Stocking density is an important parameter that directly affects growth and its production (Backiel and Lecren, 1978). The average weight gains (%) of Gura Chingri at the harvesting time were 139 ± 2.52, 117 ± 6.01 and 132 ± 6.11 in T1, T2, and T3, respectively. The highest average weight gain was found (0.92 ± 0.22) in T_2 where stocking density was 800g/decimal whereas the lowest average weight gain was found (0.89 ± 0.61) in T_1 where stocking density was 400g/decimal. The highest average length gain was found (3.7 ± 0.55) in T_1 where stocking density was 400g/decimal whereas the lowest average length gain was found (3.68 ± 0.48) in T_2 where stocking density was 800g/decimal. At higher stocking densities, the presence of abundant feed substance could produce a competitive interaction among the larvae causing a stressful situation (Houde, 1975). The growth rate of prawns considerably slowed down after a substantial culture period and also to some climatic or seasonal changes (Paul *et al.*, 2013). But survival was not affected by density and recent studies reported that survival was not affected when stocking density is increased (Kutty *et al.*, 2010). The size variation exhibited in prawns when males become matured during smaller in size but their growth rate never slow down for maturation and the growth rate of immature females was relatively high; after maturation, growth slowed considerably but did not cease (Ra'anan *et. al.*, 1991). Temperature also plays a significant role in respect of fish production. The mean values of water temperature were recorded as 29.34 ± 4.22, 29.62 ± 4.14, and 29.87 ± 3.21°C in T_1, T_2, and T_3, respectively. From an experiment, Aminul (1996) reported that water temperature 25 °C to 35 °C is suitable for fish culture and Akhteruzzaman (1988) found water temperature 25.5 °C to 30.0 °C is favorable for fish culture. During the experimental period, the mean values of dissolved oxygen were recorded 5.55 ± 0.61, 5.49 ± 0.72 and 5.75 ± 0.79mg/L in T_1, T_2, and T_3, respectively. According to Rahman (1992) dissolved oxygen

content should be 5 mg/L or more for a productive pond. pH is considered as an important factor in prawn culture and treated as the productivity index of a water body. The mean values of water pH were recorded 7.80 ± 0.43, 7.75 ± 0.38 and 7.78 ± 0.31 in T_1, T_2 and T_3, respectively. For pond fish culture, the suitable ranges of pH are 6.5 to 8.5. Higher production was obtained from T_3 which might be due to higher stocking density. As for that, production of Gura chingri was higher where the maximum stocking density was provided as it was observed that high densities did not adversely affect water quality (Kutty *et al.,* 2010).
Furthermore, ponds contain microbial, macroinvertebrate populations that are of high nutritional value to the prawns. The abundance and availability of natural food in ponds significantly increase the weight and net biomass of prawns (Correia *et al.,* 2002). In addition, as prawns are opportunistic omnivores hence they can efficiently utilize different types of natural food items in their environment which promotes growth (Tidwell *et al.*, 1997).

Moreover, the results of the present experiment revealed that water quality parameters of the treatments were suitable for the growth of Gura chingri. The highest production was found from T_3 where the higher stocking density measured and the lowest production was found in T_1 in which the lower stocking density was observed. The weight gain (%) was not significantly different between the treatments but significant variation was found between treatments $T_1$and other treatments (T_2 and T_3). The highest net income was also obtained from T_3 followed by T_1 and T_2. The benefit-cost ratio (BCR) was done after the accomplishment of the experiment. The best benefit was gained from T_3 in which BCR was 1.60 and the BCR of other two treatments were 1.34 in T_2 and 1.12 in T_1. From the above discussion it can be concluded that the culture of Gura chingri with higher stocking density may be conducted to get higher production and maximum benefit. The stocking density of 1200g/decimal is recommended for Gura chingrito acquire improve growth rate and production in Bangladesh.

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Growth performances and biometric indices of mud eel, *Monopterus cuchia* from the cultured pond of Southern Bangladesh

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Abstract
This study was conducted to evaluate the effect of culture site on growth performances and biometric indices of swamp mud eel, *Monopterus cuchia*. Treatments were selected from three different upazilas as Kalapara and Bauphal upazila of Patuakhali district and Amtoli upazila of Barguna district. The experiment was conducted in nine ponds with a water area of 40 m^2 each of pond. The initial average weight of *M. cuchia* was 44.85±3.21 g in Kalapara, 44.55 ± 2.34 g in Amtoli and 44.76 ± 2.93 g in Bauphal. After 180 days of culture, the significantly highest average final weight was found 128.07±8.38 g in Kalapara and significantly lowest 117.45 ± 7.86 g in Bauphal. The significantly highest weight gains of fish were found in Kalapara (84.52±2.84 g) followed by 73.37 ± 2.79 g in Bauphal and 62.95±2.51 g in Amtoli. The specific growth rate of *M. cuchia* in Kalapara, Amtoli and Bauphal were found 0.53 ± 0.11, 0.49±0.07 and 0.51±0.09%, respectively. The total production was significantly highest in Kalapara (1.47 ± 0.31 kg/m^2/6 months) and lowest in Bauphal (0.91±0.24 kg/m^2/6 months). Length-length relationships for the selected fish species were highly significant ($R^2 > 0.98$, $p < 0.01$). Length-weight relationships indicated isometric growth (b = 3.0197) in Amtoli and positive allometric growth in Kalapara and Bauphal (b > 3.00). The condition factor values of *M. cuchia* ranged from 0.92 to 1.13 in all the three locations. The current study provided data about growth performances and biometric indices of *M. cuchia* such data would be valuable for establishing a monitoring and management system of this species.

Keywords: Growth performance, Length-weight relationships, Length-length relationships, *Monopterus cuchia*.

Introduction

Freshwater, air-breathing, swamp mud eel *Monopterus cuchia*, locally known as Kuchia or Kuichia belongs to the family Synbranchidae of the order Synbranchiformes. It commonly occurs in the freshwaters of India, Pakistan, Burma and Bangladesh. It is commonly available throughout Bangladesh in shallow beels, mud-holes and Boro-paddy fields of Sylhet, Mymensingh and Tangail districts (Rahman, 2005). In the global market, eels have an outstanding reputation as a commodity that may be exported. The collection, transportation, management and processing of eels provide a living for the underprivileged people of Bangladesh, which helps to provide jobs that are crucial to the country's socioeconomic growth. Several industrialized nations, including Australia, Thailand, Malaysia, Japan, Korea, USA, China, Italy, Greece, Egypt, Singapore, Cambodia and Taiwan have substantial commercial eel fisheries with a sizable export market. Researchers often recommend biometric studies to conserve and manage fisheries resources because they can provide an accurate assessment of fish biomass in a particular habitat (Jisr *et al*. 2018, Hasan *et al*., 2020). Determination of length-weight relationships (LWRs) i.e., growth characteristics of fish is the most important in biometric assessment. Studies have shown that there are several advantages to estimating LWRs in open water fisheries management (Ecoutin and Albaret, 2003, Gonzalez *et al*., 2004, Baek *et al*., 2015). For example, it facilitates converting length data into weights for estimating biomass. LWRs can quickly provide the weight of stock while direct weight counting of each individual fish stock in nature is quite complicated and costlier.

Length-weight relationships (LWRs) are expressed in a formula, which allows the estimation of the fish weight (W) using a particular length (L) and can be applied to studies on gonadal development, feeding rate and maturity condition (Beyer, 1987). It must be noted, however, that LWRs differ among fish species depending on the inherited body shape and physiological factors such as maturity and spawning (Schneider *et al*. 2000). This relationship might change over seasons or even days (De Giosa *et al*., 2014). It is argued that b may change during different time periods illustrating the fullness of the stomach, general condition of appetite and gonads stages (Zaher *et al*., 2015). In addition, the growth process can differ in the same species dwelling in diverse locations, influenced by numerous biotic and abiotic factors. An additional important biometric tool is the condition factor (K) that was derived from the LWRs (Le Cren, 1951). The condition factor measures the deviation of an organism from the average weight in a given sample in order to assess the suitability of a specific water environment for the growth of fish (Yilmaz *et al*., 2012; Mensah, 2015). An overall fitness for fish species is assumed when condition factor values are equal or close to one.

Hence, the aim of this study was to calculate the growth performance, length-weight relationships, length-length relationships and condition factor of *M. cuchia* from three different locations in southern Bangladesh. This information will enhance management and conservation and allow future comparisons between populations of this species.

Materials and Methods

Experimental design

Three treatments were selected from three different upazilas as Kalapara and Bauphal upazila of Patuakhali district and Amtoli upazila of Barguna district of Bangladesh. The experiment was conducted in nine (09) ponds with a water area of 40 m^2 each of pond.

Pond preparation

The pond bottom was covered with polythene and knotless nylon net so that *M. cuchia* can't escape and then fill-up with 08-12-inch clay mud. The ponds were protected by fencing with a nylon net. The pond's soil was treated with quick lime at a rate of 2 kg per decimal. Ponds were filled-up with 0.6-0.8 m water and then dolomite at 15 ppm was applied for strengthening the buffer capacity of pond water. After three days, the pond's water was fertilized with urea, TSP and MoP at 2.5 ppm, 3.0 ppm and 1.0 ppm, respectively to accelerate primary productivity. Water hyacinth (*Eichhornia crassipes*) and PVC pipe were provided to the ponds for the suitable and safe shelter. After the water color became green which is an indicator of sufficient production of plankton, *M. cuchia* fingerlings were stocked in the experimental ponds in the month of February 2021 at the rate of 10 fingerlings/m^2. A total of 400 fingerlings were stocked at each pond. *M. cuchia* was fed with live fish (trash fish) and SIS (3% BW every 15 days) + Vermicompost 1.5% BW every day.

Growth performance

During the period of the experiment, the mud eel was sampled every 15 days interval. The growth of mud eel was recorded by measuring the length (cm) and weight (g) of the harvested eel by using a measuring tape and an electric balance, respectively.

Weight gain (W)

Weight gain (W) was calculated through the equation, Weight gain, $W = W_2 - W_1$, Where, W_1 is the initial weight and W_2 is the final weight.

Specific growth rate (SGR)

The specific growth rate of mud eel under different treatments was calculated by using the following formula:

$$\text{SGR (\%)} = \frac{LnW2 - LnW1}{T} \times 100$$

Where, InW_2-InW_1 is the difference in the logarithm of initial and final weight and T is the duration of the experiment (days).

Survival rate (SR)

The survival rate (SR) of mud eel was calculated as follow:

$$\text{SR (\%)} = \frac{Final\, total\, number\, of\;\; fish}{Initial\, total\, number\, of\;\; fish} \times 100$$

Length-length relationships (LLRs)

The length-length relationships with total length among different body lengths were determined by the method of least squares to fit a simple linear regression model as Y = a + b X where Y = various body lengths, X = total length, a= proportionality constant, b = regression coefficient.

Length-weight relationships (LWRs)

The log transformation formula of Le Cren was used to establish LWRs (Le Cren 1951). The length-weight equation $W = aL^b$ was used to estimate the relationship between the weight (g) of the fish and its total length (cm). Using the linear regression of the log-transformed equation: $\log (W) = \log (a) + b \log (L)$, the parameters a and b were calculated with ‘a’ representing the intercept and ‘b’ the slope of the relationship.

Condition factor (K)

The condition factor was determined by using the equation (Fulton, 1904; Froese 2006) as follows:

$$K = 100 \times W / L^b$$

Where, K = condition factor, W = the weight of the fish in gram (g), L = the total length of the fish in centimeters (cm), b = the value obtained from the length-weight equation.

Statistical analysis

All data were analyzed using IBM SPSS statistics 25 and Microsoft Office Excel (version 2019). To investigate the LWRs data, ANOVA was used to evaluate the statistical significance of the regression model detected when $p < 0.05$. All the statistical analyses were considered at a significance level of 5% ($p < 0.05$).

Results and Discussion

Water quality parameters

Mean levels of water quality parameters over the six months culture of *Monopterus cuchia* are presented in Table 1. The recorded temperature ranged from 29.38-30.62 ℃, transparency from 23.83-28.25 cm, pH from 7.52-7.91, DO from 4.37-5.18 ppm, NH_3-N from 0.14-0.21 ppm in the three treatments.

Table 1. Variations in water quality parameters of ponds water under different treatments of *Monopterus cuchia*.

Parameters	Treatments			P-value
	Kalapara	Amtoli	Bauphal	
Temperature (˚C)	29.38±0.81	30.62±1.36	30.19±0.92	0.011
Transparency (cm)	25.91±1.73	28.25±1.48	23.83±1.29	0.053
pH	7.84±0.61	7.52±0.72	7.91±0.91	0.009
DO (ppm)	4.83±0.97	4.37±0.85	5.18±0.91	0.017
NH_3-N (ppm)	0.14±0.31	0.21±0.42	0.19±0.38	0.027

The water temperature, transparency, pH, dissolved oxygen and NH_3-N of the experimental ponds were within the acceptable range for the culture of *M. cuchia* that agree well with the findings of Narejo *et al.*, (2003), Chakraborty *et al.*, (2010), Miah *et al.*, (2015) and Chakraborty *et al.*, (2017). Narejo *et al.*, (2003) reported that the optimum temperature was 22-31°C for increasing the growth performance of *M. cuchia*. Nasar (1997) reported that the optimum temperature for the suitable rearing of *M. cuchia* was between 20-35 °C. Chakraborty *et al.*, (2017) found that the Secchi disk transparency (22.33 cm) was suitable for *M. cuchia* culture. Chakraborty *et al.*, (2010) also found that the transparency was appropriate for *M. cuchia* culture between 14.80-20.50 cm in a rice field and 13.60-18.40 cm in ponds. Narejo *et al.*, (2003) found that the dissolved oxygen values were found between 3.7-4.15 mg/L. Chakraborty *et al.*, (2010) recorded that the pH value was 5.50-7.20 in a rice field and 5.88-7.40 in ponds. Narejo *et al.*, (2003) found that the range of pH values was 7.35-7.55.

Moreover, there are some factors that affect the growth and existence of any species such as temperature, dissolved oxygen, carbon dioxide, ammonia, pH and substrates like fine particles; autumn shed leaves, submerged wood and moss (Islam *et al.*, 2017a). In another study, Islam *et al.*, (2017b) revealed that factors to be considered include pond management, water quality and temperature, disease control, food supply, broodstock age, density and sex ratios.

Growth performance

After six-month cultivation period, the final average weight of *M. cuchia* was significantly higher at Kalapara (128.07±8.38 g) and significantly lower final average weight of *M. cuchia* was at Amtoli (106.94±6.61 g). It was also found that the significantly highest final average total length of *M. cuchia* was found at Kalapara (52.85±3.72 cm) and the lowest final average total length of *M. cuchia* was found at Amtoli (46.39±3.85 cm) (Table 2). The significantly highest and lowest body weight gain was found at Kalapara (84.52±2.84 g) and Amtoli (62.95±2.51 g), respectively. Therefore, significantly higher body length gain was found at Kalapara (27.28±1.08 cm) while significantly lower body length gain was found at Amtoli (24.18±0.97 g). The specific growth rate was significantly higher at Kalapara compared to the Amtoli. At the end of the experiment the significantly highest survival rate was observed in Kalapara (91.32±2.51%) and significantly lowest survival rate was recorded in Bauphal (79.46±4.83%).

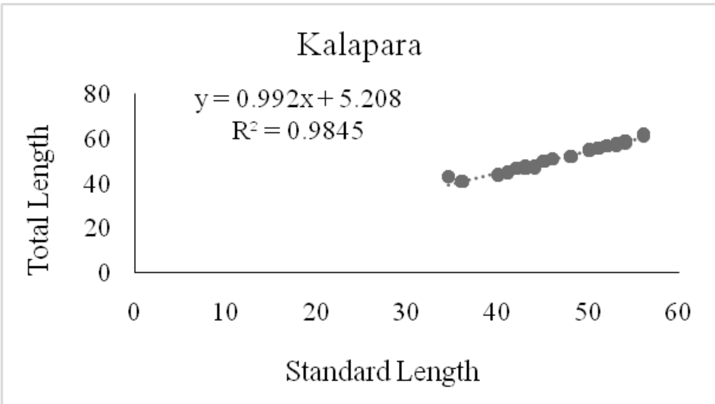
Table 2. Growth performances of *Monopterus cuchia* (mean±SD) in different treatments over the experimental period of 180 days.

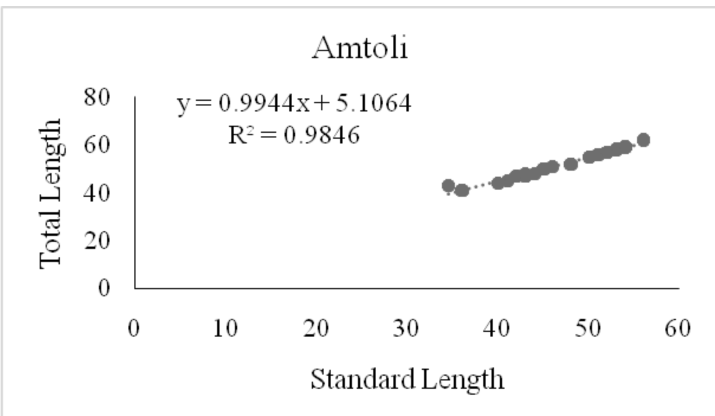
Parameters	Treatments		
	Kalapara	Amtoli	Bauphal
Initial average weight (g)	44.85±3.21	44.55±2.34	44.76±2.93
Initial average total length (cm)	25.30±2.94	24.83±1.38	25.01±1.97
Final average weight (g)	128.07±8.38^{a}	106.94±6.61^{b}	117.45±7.86^{ab}
Final average total length (cm)	52.85±3.72^{a}	46.39±3.85^{b}	49.61±3.93^{ab}
Body weight gain (g)	84.52±2.84^{a}	62.95±2.51^{c}	73.37±2.79^{b}
Body length gain (cm)	27.28±1.08^{a}	24.18±0.97^{b}	25.07±1.12^{b}
Specific growth rate (%)	0.53±0.11^{a}	0.49±0.07^{b}	0.51±0.09^{a}
Survival rate (%)	91.32±2.51^{a}	86.92±1.94^{b}	79.46±4.83^{c}
Total production (kg/m^2/6 month)	1.47±0.31^{a}	0.98±0.27^{b}	0.91±0.24^{b}

Growth performance was recorded significantly highest in Kalapara (84.52±2.84 g) in terms of weight gain and significantly lowest in Amtoli (62.95±2.51 g) might be due to variation of geographical position. Chakraborty *et al.*, (2010) recorded that the body weight gain was 214.67±0.98 g and 144.04±0.84 g where the body length gain was 16.87±0.8 cm, 17.61±1.2 cm, and 18.02±1.09 cm in three different treatments. Narejo *et al.*, (2003) recorded that body weight gain was 53.80±0.65 g in mud, 82.63±5.80 g in water hyacinth, 34±1.0 g in PVC pipes, and finally 24.93±0.89 in control at 12 months culture period. The present results might not be like the findings due to geographical location, environment, culture period, feed, stocking density etc. The specific growth was 0.53±0.11%, 0.49±0.07%, and 0.51±0.09% which was more or less similar to Chakraborty *et al.*, (2010). Chakraborty *et al.*, (2010) was found that the specific growth rate of the freshwater mud eel was 0.79±0.23% in a rice field and 0.61±0.32 in ponds, respectively. The survival rate was recorded at 91%, 86% and 79% which was near to Chakraborty *et al.*, (2017). Chakraborty *et al.*, (2017) observed that the highest survival rate was 96% and the lowest was 87%. The survival rate of the freshwater mud eel was 90% in a rice field and 87.25% in ponds according to Chakraborty *et al.*, (2010). The total production of fish ranged from 0.90±0.24 to 1.07±0.31 (kg/m^2/6 month) within 6 months of this experiment where Narejo *et al.*, (2002) found the total production of fish ranged from 0.241 to 0.624 kg/m^2/year.

Length-length relationships (LLRs)

All length-length relationships were highly significant ($p < 0.05$) and most of the coefficients of determination values were higher than 0.9845 (Fig. 1). The b value ranges from 0.9915-0.9944. Results comparisons were not possible due to an absence of available works on the length-length relationships for *M. cuchia*. Differences in length-length relationships can be due to variances in ecological conditions of animal habits, variance in animal physiology, or both (Saha *et al.*, 2019).





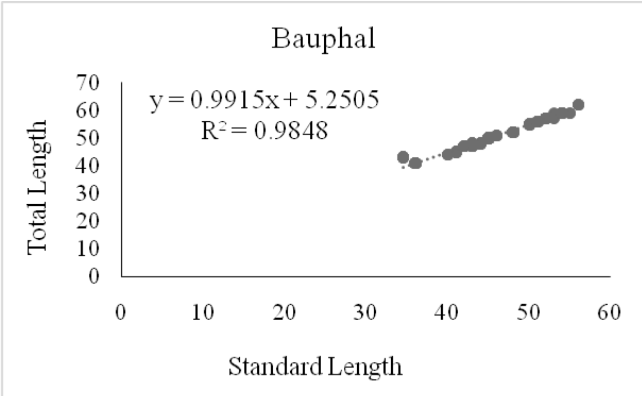
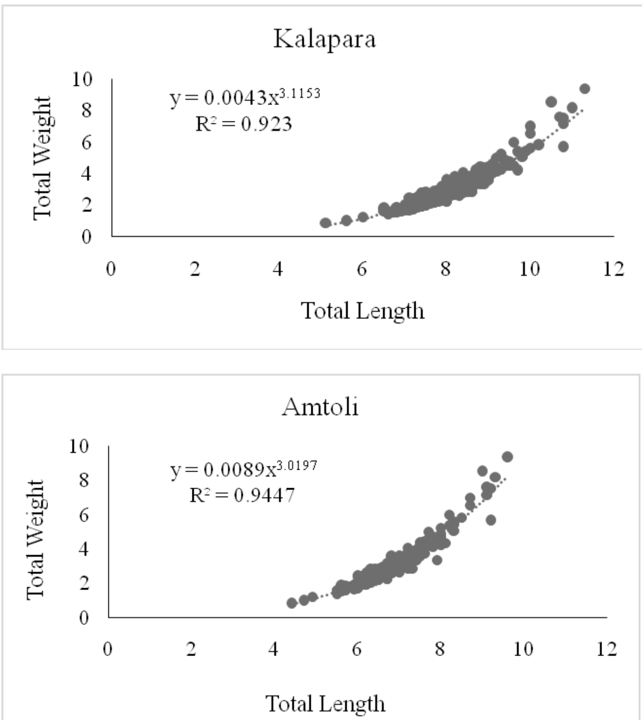


Fig. 1. Length-length relationships of *Monopterus cuchia* in different treatments.

Length-weight relationships (LWRs)

The allometric coefficient b of the LWRs was close to the isometric value (b = 3.0197) in Amtoli, although it suggested positive allometric growth in Kalapara and Bauphal (b > 3.00). All the LWRs were highly significant ($p < 0.05$) and most of the coefficients of determination values were higher than 0.925 (Fig. 2).



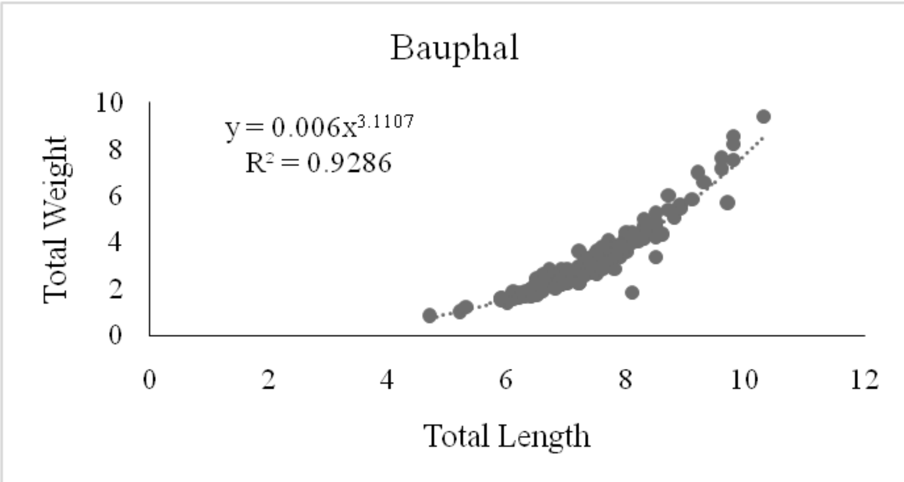


Fig. 2. Length-weight relationships of *Monopterus cuchia* in different treatments.

The length-weight relationships (LWRs) can be resulting from the length and weight measurements of the same fishes throughout their lives or from a sample of fish taken at a particular time (Wootton, 1998). The values of a and b for the *M. cuchia* in this study were within the limits reported by Froese (2006), although these parameters varied significantly among the locations. In this study, the LWRs of *Monopterus cuchia* showed isometric and positive allometric growth from all three areas. The present results are in conformity with the above findings and showed positive allometric growth for the three different places where fish specimens are collected. Similarly, Wild and Hampton (1993), Sun and Yeh (2002) also attained similar results. Chakraborty and Goswami (2016) also reported that the regression coefficient for the LWRs and relative condition factor of Peacock Eel (*Macrognathus aral*) indicates positive allometry. The positive allometry shown by the fish may be due to higher proficiency in feeding (Soni and Kathal, 1953; Kaur, 1981; Saikia *et al.,* 2011) and better environmental conditions for survival for the species. The effect of the availability of food and other associated factors are responsible for positive allometric growth (Bura-Gohain and Goswami 2013, Rahman *et al.,* 2015; Das *et al.,* 2015; Deka and Bura-Gohain, 2015). Furthermore, LWRs parameters (a and b) of the fish have been reported to be influenced by many factors such as feeding intensity, availability of food, fish size, age, sex, season, stage of maturation, the fullness of the gut, degree of muscular development, the amount of reserved fat and life history (Bagenal and Tesch, 1978; Ujjania *et al.*, 2012; Gupta and Banerjee, 2015).

Condition factor (K)

Condition factor (K) values of *M. cuchia* ranged from 0.92 to 1.13 in all three locations. The lowest average K was found in Amtoli (K = 0.92) and the highest in Kalapara (K = 1.13) (Fig. 3).

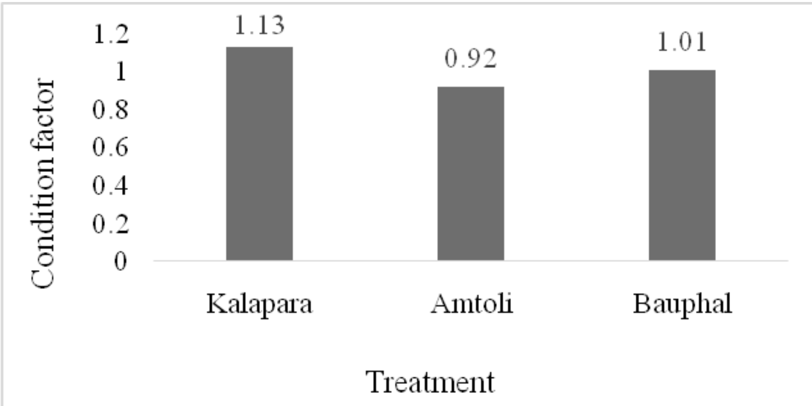


Fig. 3. Condition factors of *Monopterus cuchia* in different treatments.

The condition factor (K) value is a physiological indicator of the general well-being of any fish living in a given environment (George *et al.,* 1985, Raj Kumari *et al.,* 2006). Moreover, the condition factor is an index to monitor the feeding intensity, well-being and growth rate of the fish (Oni *et al.,* 1983). The high value of 'K' for fish is heavy for its length, while low 'K' is lighter (Bagenal and Tesch, 1978). However, the 'K' value greater than 1 (K >1) indicates the better condition of fish (Le Cren, 1951). Narejo *et al.,* (2002) also revealed that the values of 'K' showed fluctuations in all sized groups. Shendge (2005) also reported that the value of K > 1 implies that food was not limited in the rivers. Furthermore, the "K" value of the fish has been reported to be influenced by many factors such as feeding intensity, availability of food, fish size, age, sex, season, stage of maturation, the fullness of the gut, degree of muscular development, the amount of reserved fat and life history (Bagenal and Tesch 1978, Ujjania *et al.,* 2012; Gupta and Banerjee, 2015).

Conclusion

Growth performances of *Monopterus cuchia* i.e., weight gain, total length gain, specific growth rate, survival rate was found significantly highest in Kalapara upazila of Patuakhali district. All the LWRs showed isometric and positive allometric growth of *M. cuchia* which might be attributed to environmental conditions or linked to morphological characteristics. Condition factor was also close to 1 showing an overall state of wellbeing of *M. cuchia*. This study fulfilled the aims set for it and the data presented might constitute a valuable guideline for establishing future biometric studies for *M. cuchia.*

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Effect of Gear Selectivity and Diversity on Catch per Unit Effort (CPUE) of Haors and Beels of Bangladesh

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Abstract
The study was carried out to assess the fishing gears used, their diversity, selectivity and their effect on fishing and CPUE of Beels and haors of Greater Sylhet Basin, Bangladesh namely Hakaluki and Hail haor of Moulavibazar and Vailadhora beel of Brahmanbaria from December, 2020 to June 2021. A total of two groups of fishing gears i.e., net, trap consists of 18 types were found to use, among them 12 types of net, 6 types of traps were recorded during study period in 3 haors and beels of Sylhet Basin. Considering fishing nets, the highest and the lowest CPUE (kg/hr/100m net) of Hakaluki haor, Hail Haor and Vailadhora beel were 98.72 (Seine net) and 2.69 (Push net), 3.87 (Cast net) and 1.06 (Gill net), 4.19 (Seine net) and 0.15 (Gill net), respectively. Of the traps, the highest and the lowest catch per unit effort (CPUE) were 3.25 kg/hr/trap (Barrier trap) of Hakaluki haor and 0.01 kg/hr/trap (Tengra chai) Hail haor, respectively. It was observed that huge number of fishes was caught by seine net (Berjal) and cast net (Taki jal), and the rare species are damaged through these bulk catches and thus Seine net, gill net and Cast nets are the most detrimental gears compared to others. Among these Seine net contributed to the highest catch (91.09%) and push net was the lowest (1.66%).

Keywords: Fishing Gears, Fish Species, Gear Contribution, Beel, Haor, Bangladesh, CPUE, Catch, Net, Trap, selectivity, diversity

Introduction

Most inland fisheries in the developing world are heavily exploited. Consequently, Freshwater biodiversity has declined faster than both terrestrial and marine biodiversity during the past 30 years. Fisheries are important to the national economies of many developing countries, through contributions to food security and supply, employment, livelihoods, and poverty alleviation (Béné, 2009). Inland fisheries comprise a large share of the total fish production in Bangladesh, which makes this issue particularly important as most of the people depend on fishes for their nutrition. About 60% of total demand of protein is fulfilled from fishes. Wetlands, rivers, khals, and estuaries are the major sources of fishes and its highly productive environment support the livelihoods of millions of poor people (Azher *et. al.*, 2007).

Wetlands are highly productive ecosystems providing a diverse array of goods and services for nature and people. Wetlands in Bangladesh encompass a wide variety of dynamic ecosystems including mangrove forests, natural lakes, man-made reservoirs (such as the Kaptai lake), freshwater marshes, oxbow lakes (baors), beels (big depressions where water remains yearlong), river, haors (bowl-shaped large tectonic depression and aggregation of many beels, inundated during monsoon season creating a vast sheets of water) and extensive floodplains that are seasonally inundated (Ahmed *et. al.*, 2007).

Inland water bodies have been supporting rich and diversified fisheries and thus, these are critically important to the people of Bangladesh for their food security and livelihood (Hasan, 2004). The most significant area is the large central depression that is the haor area (Sylhet depression) in the Northeast region, where large amount of small indigenous species (SIS) are available (IUCN, 2003). Of particular interest are beels, which are large depressions where water remains all year. Haors are also important features of the Bangladesh wetland landscape, which are bowl-shaped large tectonic depressions resulting from aggregation of many beels that are inundated during the monsoon season and thus creating vast sheets of water (Ahmed *et al*., 2007).

Haors are the integral part of floodplains of Bangladesh and their fishery is regarded as an important source of food, income and livelihood for poor farmers and fishermen. Geo-morphologically, haors are the large saucer-shaped floodplain depressions located mostly in the north-eastern region of Bangladesh covering about 25% of the entire region. There are 411 haors comprising an area of about 8 000 km2 dispersed in the districts of Kishoreganj, Netrokona, Sunamgonj, Sylhet, Moulvibazar, Hobigonj and Brahmanbaria. During monsoon, all the haors in the Sylhet-Mymensingh basin form a single waterbody, which facilitate fish movement from one haor to another. Being a natural depression, haor is connected with rivers, canals, beels and chharas. Haor fisheries are based on the faunal diversity of the surrounding rivers. The haors are enriched with various aquatic biodiversities along with 168 species of fish (Rahman, 2005) and hence, these are considered as the “Fish Mines” of Bangladesh. About 8,000 migratory wild birds visit the haor areas annually (Siddiqui, 2007). A variety of aquatic vegetation, herbs and trees are also found in the haors.

Catch-Per-Unit-Effort (CPUE) - also called catch rate - is frequently the single most useful index for long-term monitoring of a fishery. Catch per unit effort (CPUE) is a quantitative method used to describe fisheries worldwide. CPUE is commonly used as an index to estimate relative abundance for a population. These indices are then applied within stock assessments so that fisheries managers can make justified decisions for how to manage a particular stock or fishery. Increases in CPUE may mean that a fish stock is recovering and more fishing effort can be applied. Declines in CPUE may mean that the fish population cannot support the level of harvesting. Catch rates by boat and gear categories, often combined with data on fish size at capture, permit a large number of analyses relating to gear selectivity, indices of exploitation and monitoring of economic efficiency (Appelman, 2015).

The principal categories of fishing gears that are traditionally used in Bangladesh can be categorized as the following: fishing nets, fishing traps, hooks and lines, wounding gears and fish aggregation device (Sultan, 2016). The intensity of use of any form of gear in a haor is dependent on the intensity of target fish population presumed to be available in that haor

(Chakraborty, 2006). Some of the gears are species selective, whereas other account for a number of species caught during operation giving multi-species nature of the fishing (Khan, 2011). Among them, many of these have been responsible to catch fingerlings before they grow to legal size and many of these are responsible. In fact, this study is an endeavor of giving an understanding of the existing status of gear use and CPUE of commercial fisheries of Haors & Beels and the effect of fishing gear used on CPUE that will help to frame or formulate an Ecosystem-Based Fisheries Management (EBFM) approach.

Materials and Methods

Study Areas and time frame

The research is implemented by Riverine Station, Bangladesh Fisheries Research Institute, Chandpur. The study was conducted in Haors of Greater Sylhet Basin i.e., Sylhet, Moulovibazar and Hobiganj districts mainly Hail haor (Moulovibazar), Hakaluki haor (Moulovibazar) and important beel of Brahmanbaria namely Vailadhora beel (Fig. 1).

Hail Haor

Hail Haor is one of the largest 373 haor wetland ecosystems of northeast Bangladesh (Banglapedia. 2006) (Fig. 1). It is a large, rather isolated, shallow permanent beel with extensive floating and emergent vegetation, surrounded on three sides by low hills, which differs considerably in character from most other haors (Banglapedia, 2006).

Hakaluki Haor

An intricate ecosystem of Hakalukihaor is consists of more than 238 inter-connecting Beels or Jalmahals (CWBMP-DoE-CNRS, 2005) (Fig. 1.). Hakaluki Haor is the largest single haor in Bangladesh and an important "mother fishery", and is reported to support more than 100 (one hundred) fish species (FAP 6, 1994). It is located in north-east Bangladesh in Kulaura, Juri and Borolekha Upazilas of Moulvi Bazar District and Fenchuganj and Golapganj Upazilas of Sylhet District, the Government of Bangladesh in 1999, under the provisions of the Bangladesh Environment Conservation Act, declared this haor as an "Ecologically Critical Area" (ECA) (CNRS, 2006).

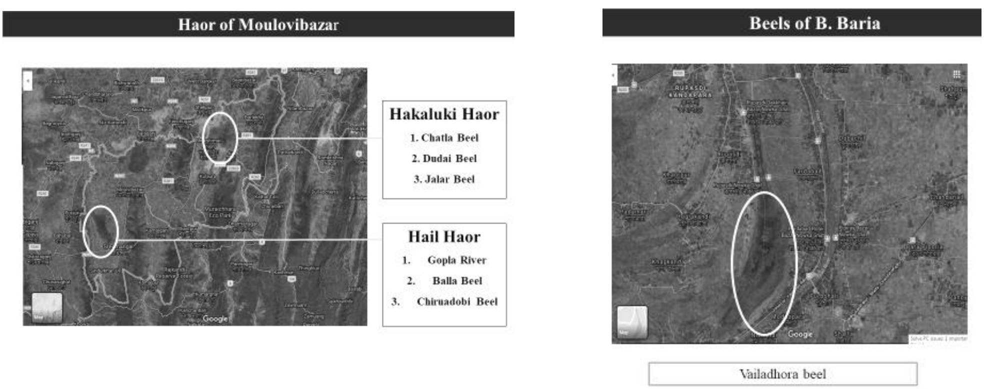


Fig. 1. Map of Study Area

Vailadhora Beel
This wetland is also known as Bamandhar beel, Bariadaha Chakbasta beel, Vailadhora, or Bailladhara beel (Fig. 1). It covers 5 Union Parishad named Khagkanda, Hoglakandi, Rupasdi, Fardabad and Jhonar Char. The beel is of kidney shape and the lower section is wider than Upper in North-West Region. The total area of the beel is about 385 acre and inundated upto about 3000 acre area in the wet season.

Study Period
The study was conducted from July 2020 to June 2021

Sampling and sampling method
The study involved direct field observations, a survey of the fish market adjacent to the Haor-Beel areas, total catch monitoring, in-situ observation of various fishing gear operation, gear selectivity monitoring, earthenware data from Haor and relevant both qualitative and quantitative data were collected through semi structured questionnaires, focus group discussion and personal observations.

Data analysis
After collecting all the relevant information, these were compiled, processed and analyzed. MS Excel and MS Word were used for data processing and analysis.

Results and Discussion

Species/gear diversity and selectivity
Various types of fishing gears/ traps were used in those study areas according to the fisherman's benefit. Seine net, cast net, gill net and Fish trap of different mesh size are most common in all study areas.

Gear characteristics, selectivity and diversity of fishing gears of Hakaluki haor
Various types of fishing gears were found to operate in the haor. Most of them were traditional and some were unique for the locality. A total of 9 types of gear under two categories i.e., 6 types of net and 3 types of traps were observed to be used by fishermen for catching fish in Hakaluki Haor (Table 1 and Figure 2). Various kinds of large and small fish species, including small prawn, *Gudusia chapra*, *Labeo rohita*, *Cirrhinus mrigala*, Catla, Kalibasu, *Ctenopharyngodon idella*, *Labeo gonia*, *Mystus vittatus*, *Puntius sophore*, *Chanda nama*, *Wallago attu, Sperata aor, Notopterus notopterus*, *Ompak pabda*, *Mystus bleekeri*, *Channa punctata*, *Amblypharyngodon mola*, *Mastacebelus armatus* etc are caught by fishing nets and traps (Table 5 & 6). Sayeed *et al.,* (2015) reported that 15 types of fishing gears were operated for fishing by fishermen in Hakaluki haor gears of five majors, Moulvibazar. Major groups of fishing gears were nets, traps, hooks and line, wounding gears and fish aggregating devices. It is always important to obtain data on the species that are targeted by different boat/gear categories and fishing methods, together with other information relating to the size of the fish being caught. These datasets are used for a wide variety of temporal (in-time) and spatial (in-space) comparisons of gear selectivity indicators (Alam *et al.,* 2015). Rahman and Akhter (2015) stated that a total of 34 different types of fishing gears were in use to catch fish

from haors. Of these seine net, gill net, lift net, push net, cast net, fish trap and hooks and lines were 12 (34%), 4 (12%), 2 (6%), 4 (12%), 1 (3%), 7 (21%) and 4 (12%), respectively. Sayeed (2010) noted that 34 different gears in six categories were recorded in Chalan beel in greater Pabna and Natore districts. Sayeed (2010) also stated that capture fishery in Chalan beel is decreasing day by day. One of the major causes was the indiscriminate killing of small fishes in the early stages by various illegal fishing gears.

Table 1. Location wise Common gears used in Haors and Beels

<table>
<tr><th>Sl. No.</th><th colspan="2">Location</th><th>Name and types of net</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Hail Haor</td><td rowspan="2">Bilash River, Gopla River and Balla Beel</td><td>Ber jal (Seine net), Jhaki jal (Cast net), Fash jal (Gill net), Current jal (Gill net)</td></tr>
<tr><td>Birti/ Poran (Fish trap), Dori (Fish trap), Bosni, (Fish trap), Taki Jal, Harroh Jal, Push Net, Fine Jal</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Hakaluki Haor</td><td rowspan="2">Zalar Beel, Chatla Beel and Gutaora Haor</td><td>Ber jal (Seine net), Ricksha net, Push net, Fashjal
(Gill net), Current jal (Gill net), Jhakijal (Cast net)</td></tr>
<tr><td>Unta/Bana (Fish trap), Ichar Chai, Kati (Fish trap)</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">Vailadhora Beel</td><td rowspan="2">Ruposhdi, Hospital ghat and Boro Beel</td><td>Ber jal (Seine net), Fash jal (Gill net), Current jal
(Gill net), Jhaki jal (Cast net)</td></tr>
<tr><td>Unta (Fish trap), Gura jal (Others)</td></tr>
</table>

It was observed that huge number of fishes was caught by seine net (Ber jal) and cast net (Jhaki jal), and the rare species are damaged through these bulk catches and both are the most detrimental gears compared to others. Among these seine net contributed to the highest catch (91.09%) and push net was the lowest (1.66%). Kati contributed to the lowest catch (1.99%) was less detrimental to the fishery (Table 2 & Fig. 5).

Table 2. Total catch and contribution of gears to catch of Hakaluki Haor (Dec-Feb 2020-21)

<table>
<tr><th>Gear Type</th><th>Total Catch/ Day (Kg)</th><th>Probable fishing time (Days)</th><th>Total Catch (3 Months) (Kg)</th><th>Contribution to total catch (%)</th></tr>
<tr><td>Seine Net</td><td>1777.00</td><td rowspan="5">90</td><td>159930.00</td><td>91.09</td></tr>
<tr><td>Cast Net</td><td>69.00</td><td>6210.00</td><td>3.54</td></tr>
<tr><td>Push Net</td><td>32.3.00</td><td>2907.00</td><td>1.66</td></tr>
<tr><td>Ricksha Net</td><td>33.5</td><td>3015.00</td><td>1.71</td></tr>
<tr><td>Kati (FT)*</td><td>39.00</td><td>3510.00</td><td>1.99</td></tr>
<tr><td colspan="3">Total</td><td>175572.00</td><td>100</td></tr>
</table>

*FT=Fish Trap

Gear characteristics, selectivity and diversity of fishing gears of VailadhoraBeel

Fishing gears and traps used in the Vailadhora Beel during the study, different gears were found to be used varying from season to season based on species selection. Various types of traps were also noticed in different areas of the studied Beel. In the study period, 5 different types of nets (Ber Jal, Fash jal, Curret jal, Jhaki jal, Gura jal and 1 type of trap (Unta) were found to be used in the beel (Table 1 & Fig. 2). All types of nets were not being used for fishing in all season. Different mesh sizes of nets were common for the different size of fishes. Various kinds of large and small fish species, including small prawn, Rui, Catla, Mrigal, Gonia, Bighead, Silver Carp, Tengra, Mola, Koi, Punti, Boicha, Chanda, Bujuri, Foli, Meni, Kholisha, Tit Punti etc. are caught by fishing nets and traps (Table 5 & 6). The fresh water fishing gears and crafts of traditional types are being used for a long time without any modification (Haque *et al.*, 1999). Rahman *et al.*, (1992) reported that fishing gear operating in the three floodplains (Chanda, BSKB and Haiti Beel) comprised four groups such as fish net (7 types, 20 sub-types), fish trap (5 types, 14 sub-types) hook and line (5 types) and spear harpoon (4 types). Traps, chiefly made of split bamboo, are extensively used for catching fish in Beels. Haque *et al.,* (1999) identified 16 types of fishing gears where 4 types of traps were recorded in Beel Kumari. Using of fishing traps was found to increase due to availability of indigenous fish species because of positive impact of fish sanctuary establishment.

It was observed that huge number of fishes was caught by seine net (Ber jal) and gill net (Jhaki jal), and the rare species are damaged through these bulk catches and both nets are the most detrimental gears compared to others. Among these seine net contributed to the highest catch (70.19%) and cast net was the lowest (9.73%). Unta contributed to the lowest catch (4.37%) was less detrimental to the fishery (Table 3 & Figure 4).

Table 3. Total catch and contribution of gears to catch of Vailadhora Beel (Dec-Jun 2020-21)

Gear Type	Total Catch/Day (kg)	Probable fishing time (Days)	Total Catch (7 Months) (Kg)	Contribution to total catch (%)
Seine Net	59.78	212	12673.36	70.19
Cast Net	8.29		1757.48	9.73
Gill Net (Fash) Net	13.38		2836.56	15.71
Unta (FT)*	3.72		788.64	4.37
Total			18056.04	100

*FT=Fish Trap

It was observed that huge number of fishes was caught by seine net (Ber jal) and cast net (Taki jal), and the rare species are damaged through these bulk catches and both nets are the most detrimental gears compared to others. Among these seine net contributed to the highest catch (43.15%) and fine Jal was the lowest (4.66%). Tengra chai contributed to the lowest catch (0.39%) was less detrimental to the fishery (Table 4 & Fig. 3).

(a) Bosni (Tapered Mouth Trap)

(b) Chai (Rectangular Basket Trap)

(c) Dori (Square Box Trap)

(d) Ichar Chai (Cylindrical trap)

(e) Birti/ Paron (Basket trap)

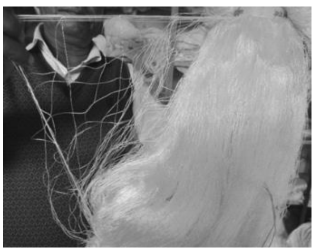
(f) Fine Jal (Fine lift net)

(g) Ber Jal (Seine net)

(h) Jhaki Jal (Cast net)

(i) Thela Jal (Push net)

(j) Current Jal
(Monofilament Gill net)



(k) Fash Jal (Gill net)

(l) Taki Jal (Set net)

Fig. 2. Different types of fishing gears operated during the study period (a-l)

Abundance and exploitation

Abundance and exploitation data were collected from the study Haors and Beels.

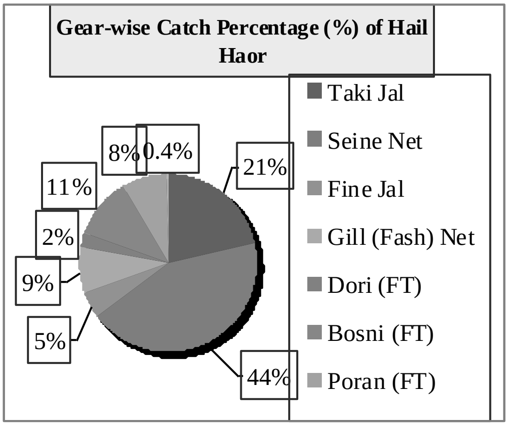


Fig. 3. Contribution of gears to catch of HailHaor

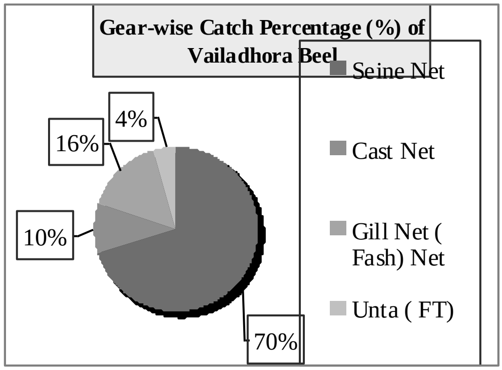


Fig. 4. Contribution of gears to catch of Vailadhora Beel

Table 4. Total catch and contribution of gears to catch of Hail Haor (Dec-Jun 2020-21)

Gear Type	Total Catch/Day (kg)	Probable fishing time (Days)	Total Catch (7 Months) (Kg)	Contribution to total catch (%)
Taki Jal	18.9	212	4006.80	21.49
Seine Net	37.95		8045.40	43.15
Fine Jal	4.1		869.20	4.66
Gill (Fash) Net	7.53		1596.36	8.56
Dori (FT) *	2.135		452.62	2.43
Bosni (FT)	9.925		2104.10	11.29
Poran (FT)	7.05		1494.60	8.02
Tengra Chai (FT)	0.35		74.20	0.39
Total			18643.28	100

*FT=Fish Trap

Gear characteristics, selectivity and diversity of fishing gears of Hail haor

Different types of fishing gears are used in the Haor. These gears which vary on size and shape are used in different seasons for fish harvesting. All the gears used in this Haor can be classified mainly into two parts- fishing traps and nets. These include a number of fishing gears, many of which are known locally by several names (Table 1 & Fig. 2). Their specification differs according to target species, fabrication, and materials available. Although most of the traps are made of bamboo sticks and plastic threads, but these are of different sizes and shapes. Cast nets, lift nets and gill nets are operated both day and night. Trap units are operated only at night time; while push nets and seine nets are operated only during the daytime. Various kinds of large and small fish species, including small prawn, Rui, Mrigal, Gonia, Tengra, Punti, Boicha, Bajuri, Foli, Meni, Kholisha, Kalbasu (Table 5) etc are caught by fishing nets and traps. The most common gears used in Hail Haor by type are shown in Table 6.

Table 5. List of available fishes in all study areas.

Order	Family	Scientific Name	Local Name	Group Name	IUCN Conservation Status (BD)	IUCN Conservation Status (GB)
Cypriniformes	Cyprinidae	*Puntius sophore*	Bhadi punti	Barbs & Minnows	LC	LC
		Puntius ticto	Tit punti	Barbs & Minnows	VU	LC
		Puntius sarana	Sarpunti	Barbs & Minnows	NT	LC
		Amblypharyngodon mola	Mola	Barbs & Minnows	LC	LC
		Labeo calbasu	Kalibaus	Carps	LC	LC
		Labeo rohita	Rui	Carps	LC	LC
		Labeo bata	Bata	Carps	LC	LC
		Labeo gonia	Gonia	Carps	LC	LC
		Cirrhinus mrigala	Mrigal	Carps	NT	LC
	Cobitidae	*Lepidocephalus guntea*	Gutum	Loach	LC	LC
	Botiidae	*Botia dario*	Rani	Loach	EN	LC
Perciformes	Gobiidae	*Glossogobius giuris*	Baila	Mudskippers	LC	LC
	Nandidae	*Nandus nandus*	Meni	Perches	NT	LC
	Ambassidae	*Chanda nama*	Chanda	Perches	LC	LC
Siluriformes	Bagridae	*Mystus vittatus*	Tengra	Catfishes	LC	LC
		Mystus bleekerii	Gulsha	Catfishes	LC	LC
	Siluridae	*Wallago attu*	Boal	Catfishes	VU	NT
		Ompak pabda	Pabda	Catfishes	CR	NT
	Bagridae	*Sperata aor*	Ayre	Catfishes	VU	LC
Channiformes	Channidae	*Channa punctata*	Taki	Snake heads	LC	NE
Osteoglossiformes	Notopteridae	*Notopterus notopterus*	Foli	Feather backs	VU	LC
Clupeiformes	Clupeidae	*Gudusia chapra*	Chapila	Clupeids	VU	LC
Synbranchiformes	Mastacembelidae	*Mastacembelus armatus*	Baim	Eels	EN	LC
Exotic Fish Species						
Cypriniformes	Cyprinidae	*Ctenopharyngodon idella*	Grass carp	Carps	-	NE

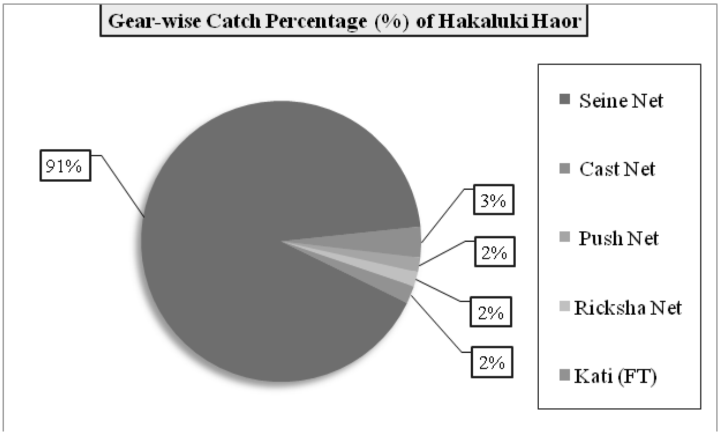


Fig. 5. Contribution of gears to catch of Hakaluki Haor

Total catch

It was observed that among all the gears used in Hakaluki Haor, the average highest daily catch-based production for Seine net was 1777 kg and the lowest for push net was 32.3 kg/day (Table 2). Among all the gears used in Vailadhora Beel, seine net contributed to the maximum average Total catch of 59.78 kg/day and cast net contributed to the minimum average Total catch of 8.29 kg/day (Table 3). Among all the gears used in Hail Haor, seine net shared the maximum average Total catch of 37.95 kg/day and fine net contributed minimum average Total catch of 4.1 kg/day (Table 4). Fishery dependent data collection mostly abundance and exploitation related data is one of the most resourceful tools available to fishery managers. Catch estimates are used to illustrate the species composition of individual fisheries, utilization rates, monitor quotas, estimate fishing mortality and calculate catch per unit effort (CPUE). These estimates include not only what is sold at the port, but also that which is discarded or used as bait, retained for personal consumption (Shatton, 1999).

Catch per Unit Effort (CPUE) of Hail Haor

The catch per unit effort (CPUE) is the average daily catch per gear type standardized per fishing unit. CPUE is influenced by several factors, primarily the type of gear used and its efficiency, how many hours it is operated for in a day, weather conditions, and location of fishing. CPUE varies between gears and years in Hail Haor. Average CPUE for all fishing gears was varied widely ranging between 3.87 and 0.01 kg/hr/gear. Seine net (small mesh) and traps (Kati) showed significantly higher CPUE than other gears. Whilst, fishing using gillnet and Trap (Tengra chai) showed low CPUE. Considering fishing nets, the highest and the lowest CPUE (kg/hr/100m net) of Hail Haor were 3.87 (Taki jal) and 1.06 (fash jal), respectively. Of the traps, the highest and the lowest catch per unit effort (CPUE) were 0.11 (Bosni) and 0.01 kg/hr/trap (Tengra chai), respectively. Gear-wise CPUE in Hail Haor is presented and gears, where CPUE increased, are highlighted in Tables 7 & 8. Catch per Unit Effort (CPUE)-also called catch rate - is frequently the single most useful index for long-term monitoring of a fishery. Declines in CPUE may mean that the fish population cannot support the level of harvesting. Increases in CPUE may mean that a fish stock is recovering and more fishing effort can be applied. CPUE can therefore be used as an index of stock abundance, where some relationship is assumed between that index and the stock size. Catch rates by boat and gear categories, often combined with data on fish size at capture, permit a large number of analyses relating to gear selectivity, indices of exploitation and monitoring of economic efficiency.

Table 7. Gear wise Average CPUE of Hail Haor [CPUE (kg)/Hour/100m Net]

Net Name	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	Jun-21	Total	Average
Taki Jal	4	4	4	4	3.5	3.7	23.2	3.87
Seine Net	1.8	1.73	1.68	1.77	1.73	1.98	10.69	1.78
Fine Jal	1.5	1.5	1.1				4.1	1.37
Gill (Fash) Net	1	1	1	1.14	1	1.2	6.34	1.06

Table 8. Gear wise Average CPUE of Hail Haor [CPUE (kg)/Hour/ trap]

Net Name	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	Jun-21	Total	Average
Dori (FT)	0.02	0.02	0.01	0.02	0.03	0.03	0.13	0.02
Bosni (FT)	0.09	0.06	0.08	0.11	0.13	0.17	0.64	0.11
Poran (FT)	0.06	0.06	0.08	0.08	0.09	0.1	0.47	0.08
Tengra Chai (FT)	0.004	0.004	0.004	0.004	0.004	0.004	0.024	0.01

*FT=Fish Trap

Catch per Unit Effort (CPUE) of Hakaluki Haor

Considering fishing nets, on average the lowest CPUE (kg/hr/100m net) of 2.69 was found in push nets which are operated typically by one fisher, on the other hand, the average highest CPUE was 98.72 kg/day for seine nets which here are operated usually by 6 to 8 fishers depending on the length of the net (Table 9 & 10). Of the traps, the highest catch per unit effort (CPUE) was 3.25 kg/hr./trap (Kati) of Hakaluki Haor. Average CPUE for all fishing gears was varied widely ranging between 98.72 and 3.25 kg/hr./gear. Seine net (small mesh) and traps (Kati) showed significantly higher CPUE than other gears. Whilst, fishing using push net and Trap (Tengra chai) showed low CPUE. The catch per unit effort (CPUE) is here calculated as the average daily catch per gear type (catch of surveyed gear units divided by the number of surveyed gear units) – here a seine net operated by multiple fishers is treated as a unit, and likewise, one or more fishers operating individually or as a team a network of several (even hundreds) of fish traps is also treated as one unit. Gears differ for example in their size, the wetland conditions they are suited to, and the species they target.

Table 9. Gear wise Average CPUE of Hakaluki Haor [CPUE (kg)/Hour/100m Net]

Net Name	Dec-20	Jan-21	Feb-21	Total	Average
Seine Net	116.5	91.5	88.17	296.17	98.72
Cast Net	3.34	3.34	4.84	11.52	3.84
Push Net	2.82	2.78	2.46	8.06	2.69
Ricksha Net	3.12	2.5	2.75	8.37	2.79

*There was not enough water in Haor during the period from March to June 2021

Table 10. Gear wise Average CPUE of Hakaluki Haor [CPUE (kg)/Hour/gear]

Net Name	Dec-20	Jan-21	Feb-21	Total	Average
Kati (FT)	3.55	3.3	2.9	9.75	3.25

*FT=Fish Trap

Catch Per Unit Effort (CPUE) of Vailadhora beel

Average CPUE for all fishing gears was varied widely ranging between 4.19 and 0.1 kg/hr./gear. Seine net (small mesh) and cast net showed significantly higher CPUE than other gears. Whilst, fishing using gill net (fash jal) and unta (trap) showed low CPUE. Considering fishing nets, In the year of monitoring of CPUE showed seine nets (small mesh and large size) with the highest CPUE and the lowest CPUE (kg/hr./100m net) was 4.19 (ber jal) and 0.15 (fash jal), respectively (Table 11). Of the traps, the lowest catch per unit effort (CPUE) was 0.10 kg/hr/trap (Unta) (Table 12). Catch per unit effort (CPUE) is the average daily catch per gear unit (calculated as the total catch by a gear type sampled over a specified period divided by the number of gear units of that type sampled). Fish catches are influenced by several factors, such as the size and efficiency of gears, populations of fish present, and weather conditions.

Table 11. Gear wise Average CPUE of Vailadhora Beel [CPUE (kg)/Hour/100m Net]

Net Name	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	Jun-21	Total	Average
Seine Net	3.45	3.68	3.58	4.65	4.4	5.43	25.19	4.19
Cast Net	0.21	0.35	0.39	0.38	0.5	0.44	2.27	0.38
Gill Net (Fash)	0.1	0.14	0.11	0.14	0.17	0.26	0.92	0.15

Table 12. Gear wise Average CPUE of Vailadhora Beel [CPUE (kg)/Hour/trap]

Net Name	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	Jun-21	Total	Average
Unta (FT)	0.08	0.073	0.07	0.12	0.08	0.19	0.613	0.10

*FT=Fish Trap

Conclusion

It was observed that huge number of fishes was caught by seine net (Ber jal) and cast net (Taki jal), and the rare species are damaged through these bulk catches and thus Seine net, gill net and Cast nets are the most detrimental gears compared to others. As, the above-discussed wetlands are widely believed to act as a fish shelter and nutrient source for fish and contribute to fish catches in the river and nearby small Beels and floodplains. However, Co-management needs to be enforced for the betterment of these wetlands. CBFM is essential and needs to encourage the fishing communities to agree on the protection of this wetlands and to agree on a closed season in pre-early monsoon when large riverine fish are migrating and spawning to protect these wetlands and its diversity as these are the major income source for the adjacent fisher folks. Protection measures and management of these wetlands will require a lead from the local fishers and CBFM and also support from the Department of Fisheries and local administration.

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Table 6. Overall description of fishing gears of Haors and Beels

SL no.	Name of Beel	Types of gears	Local name	Common name	English Name	Materials used	No of operator (Person)	Dimension (length* width)	Mesh size (mm)	Hauling time	Target species (Local name)
1.	Hail Haor	Trap	Bosni/ Fish trap	Fish trap	Tapered Mouth Trap	Bamboo sticks, Coconut fiber, metallic wire, rope	1	0.5*0.3 m	2-3	12	Punti, Chanda, Boicha, Tengra, Kholisha, Gutum, Pabda, Icha, Bujuri
			Dori/ Fish trap	Fish trap	Square Box trap	Bamboo sticks, Coconut fiber, metallic wire, rope	1	0.5*0.25m	10-15	12	Icha, Boicha, Gutum, Baim, Bajuri, Chanda
			Poran/ Fish trap	Fish trap	Basket trap	Bamboo sticks, Coconut fiber, metallic wire, rope	1	0.5*0.25m	25-35	12	Taki, Koi, Magor, Shing, Kankila, Tara Baim, Guchibaim, Pabda, Small Boal, Foli
			Tengra Chai/ Fish trap	Fish trap	Basket trap	Bamboo sticks, Coconut fiber, metallic wire, rope	1	0.4m	2-3	12	Tengra, Pabda, Icha,
		Net	Taki Jal	Set net	Fixed net	Synthetic twin, float, jute rope, sink, bamboo pole	12	23m*23m * 23 m	5-15	0.5	Rui, Catla, Boal, Kalibasu, Gonia, Ayre, Foli
			Ber jal	Seine net	Surrounding net	Synthetic twin, float, jute rope	5-8	100m*0.5 m	5-10	3	Rui, Mrigal, Gonia, Tengra, Punti, Boicha, Bajuri, Foli, Meni, Kholisha, Kalbasu
			Fine jal	Fine net	Find lift net	Synthetic twin, bamboo pole, jute rope	1	10m*10m *10 m	5-12	1	Mola, Icha, Punti, Kholisha, Boicha, Chanda

			Fash jal	Current net	Gill net	Monofilament fiber, rope, float, sink, bamboo pole	2-4	100 m	45-150	1	Punti, Kholisha, Shing, Meni, Koi, Major Carp, Foli, Taki
2	Hakaluki Haor	Net	Ber jal	Seine net	Surrounding net	Synthetic twin, jute rope, metallic weight	5-8	500m* 5 m	5-10	6	Chapila, Rui, Mrigal, Catla, Kalibasu, Grass carp, Gonia, Tengra, Punti, Chanda, Iccha, Boal, Ayre, Foli, Pabda, Gulsha, Shol, Gajar, Taki, Mola, Baim
			Jhaki jal	Cast	Falling gear	Synthetic twin, jute rope, metallic weight		3m*8 m	>10	6	Rui, Kalibasu, Katla, Mrigal, Carpio, Boal, Ayre, Chital, Foli, Shol, Gonia, Gojar
			Thela jal	Push net	Dragged gear	Synthetic twin, bamboo, jute rope	1	1m*1m*1 m	5-15	4	Icha, Chanda, Punti, Tengra, Baila, Darkina
			Ricksh aw net	Drag net	Pume Dredge	Synthetic twin, bamboo pole, jute rope	1	2m*2m*2 m	35-45	4	Ayre, Shol, Gojar
		Trap	Kati	Fixed engine	Barrier trap	Bamboo sticks, Coconut fiber, metallic wire, rope	2-4	10*2.5 m	10-35	4	Rui, Kalibasu, Mrigal, Boal, Ayre, Foli, Shol, Gonia, Gojar, Baimbaosh, Chapila, Pabda

3	Vailadhora Beel	Net	Ber jal	Seine Net	Surrounding net	Synthetic twin, float, jute rope	5-8	100m*5 m	5-10	2	Rui,Catla, Mrigal, Gonia, Bighead, Silver Carp, Tengra, Mola, Koi, Punti, Boicha, Chanda, Bujuri, Foli, Meni, Kholisha, Tit Punti
			Jhaki jal	Cast Net	Falling gear	Synthetic twin, jute rope, metallic weight	1	3m*8 m	>10	3	Puti, Koi, Shing, Foli, Tengra, Mola, Shol, Meni, Kholisha, Boicha
			Fash jal	Gill net	Fixed net	Monofilament fiber, rope, float, sink, bamboo pole	2-4	100m*0.5 m	45-150	12	Puti, Kholisha, Shing, Meni, Koi, Kalbasu, Rui, Foli, Taki, Gajar
		Trap	Unta	fish trap	Basket trap	Bamboo sticks, Coconut fiber, metallic wire, rope	1	1m*0.3 m	4-6	6	Tit puti, Icha, Chanda, Boicha, Baim, Bajuri

* (Dimension of trap = length* width* height)