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# Effects of fish cage culture on macrobenthic communities in a subtropical river

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**Abstract.** *Tania NJ, Hossain MB, Habib A, Musa N. 2020. Effects of fish cage culture on macrobenthic communities in a subtropical river. Biodiversitas 21: 3583-3589.* The present study described the impact of freshwater fish cage culture on macrobenthic faunal assemblages in the Dakatia River, Chandpur, Bangladesh. The experimental design involved the establishment of four stations in two study sites, two stations near the culture area, and two stations away from culture area. A total of 23 macrobenthic taxa belonging to annelids, molluscs, arthropods, and other minor phyla were recorded from study sites. Oligochaetes were found to be dominant at all four stations composing 42.34% of the total macrobenthos. Pollution indicator benthic organisms i.e., Naididae (30.32%), Tubificidae (20.16%), and Chironomidae (3.54%) were found most in the cage culture area. The density of benthic macrofauna was higher (28,134 inds./m²) in the cage culture site than the non-cage culture site (4,358 inds./m²) due to high abundance of certain pollution tolerant species. However, the values of diversity indices i.e., Species Richness (SR), Shannon-Wiener (S-W) diversity (*H´*), Pielou's evenness (*E*), and Margalef (*J*) were consistently higher in non-cage culture area than the cage culture area. One-way ANOVA showed no significant variation ($P > 0.05$) in diversity values between the sites. The results of the present study revealed effects of cage culture on the abundance, diversity, and composition of benthic macrofauna.

**Keywords:** Bangladesh, cage culture impact, macrobenthic communities, macrobenthos, river

## INTRODUCTION

Aquaculture production is now becoming the fastest growing food production sector globally due to high demand for fish (Habib et al. 2020; Karim et al. 2020). In addition, more than 80% of total aquaculture production contributed by Asian developing countries to the world's food system was predominated by small-scale and family-owned farming systems (Karim et al. 2020). Cage aquaculture is one of the important technologies to increase fish production (Moniruzzaman et al. 2015). The interest of cage farming has been increasing in Asia, particularly in China, Indonesia, and Malaysia (White et al. 2013). However, ecosystem destruction such as environmental impacts of effluents is one of the most important challenges facing aquaculture (Martinez-Porchas and Martinez-Cordova 2012), especially in developing countries (Jahani et al. 2012). Fish cage farms discharge large amounts of effluents such as nutrients, uneaten food, feces, pesticides, and other by-products (Jahani et al. 2012). If the environment is not able to assimilate excess nutrients quickly enough, then it tends to accumulate causing eutrophication and change to benthic biodiversity (White et al. 2013). Understanding the pattern of species biodiversity distribution is important and in recent years it has attracted the attention of ecologists (Ali et al. 2014; Yunandar et al. 2020).

Macrobenthos act as bio-indicator that can be reliably used for the classifications of coastal areas, streams, rivers, and the state of ecosystems (Gerami et al. 2016; Hatami et al. 2017). They play an important role in the decomposer food chain, which in turn affects the cycling of minerals (Rashid and Pandit 2014). Thus, the study of benthic organisms is important for specific environmental and habitat conditions (Noman et al. 2019). Cost-efficient methods for monitoring the impact of farm effluents need to be developed for sustainable aquaculture, both environmentally and economically (Hatami et al. 2017).

The Dakatia River is situated in Chandpur district, Bangladesh. The cage culture of mono-sex tilapia is successfully practiced in the Dakatia River, Chandpur (Ahmed et al. 2014). Tilapia is the most common cage culture species in Bangladesh (Mustafa 2013). Though rivers in Bangladesh have high faunal diversity, potential cage culture areas have been given least importance due to lack of sufficient research. A number of researches (Khan et al. 2007; Hossain et al. 2009; Asadujjaman et al. 2012 Abu Hena et al. 2013; Islam et al. 2013; Noman et al. 2019) have been conducted on macrobenthos of coastal and estuarine waters of Bangladesh. Information on cage culture impacts on macrobenthos community and its distribution in the Dakatia River is scant despite its importance in providing many ecological and economic services to the local people of Chandpur, Bangladesh. Therefore, the aims of the present study were to investigate the impact of cage culture on density, diversity, and distribution of macrobenthos in the Dakatia River.

## MATERIALS AND METHODS

### Study areas

The present study was conducted in the cage culture and non-cage culture areas of Dakatia River, Chandpur, Bangladesh during pre-monsoon (April-June 2016), and monsoon (July-September 2016) seasons. The farm consisted of 50 cages cultivating tilapia, *Oreochromis niloticus*.

Four sampling stations were selected, two from the cage culture area (Station 1, S1, 23º13´31.80´´ N, 90º40´58.06´´ E; Station 2, S2, 23º13´31.98´´ N, 90º40´56.77´´ E) and two from non-cage culture area (Station 3, S3, 23º13´27.88´´ N, 90º40´52.62´´ E; Station 4, S4, 23º13´29.61´´ N, 90º40´50.64´´ E), marked in Figure 1.

### Collection of sediment samples and sieving

For macrobenthos, the sediments were collected from study sites (cage and non-cage areas) during pre-monsoon (April-June 2016) and monsoon (July-September 2016) using Ekman Dredge having a mouth opening of 0.0225 $m^2$. Three replicate sediment samples were collected from each station. Sediments were taken in polyethylene bags, labeled and kept in the laboratory until analyses. The sediment samples were transferred from polyethylene bag to bucket and mixed with water, then hand-sieved through 0.5 mm mesh size screen to get the macrobenthos. The sieved organisms and residues were immediately preserved with 10% formalin solution in plastic containers and labeled until further analysis.

### Sorting, identification and preservation of macrobenthos

To increase the visibility of benthic fauna, a small amount of rose bengal (10 mL) was added to the formalin solution in the plastic containers. Benthic fauna was separated manually, and the collected organisms were kept with the other residues on a tray using magnifying glass and forceps under enough light availability. The enumerated benthic faunas were preserved in small vials for identification. For identification of the macrobenthos, the benthos samples were taken into a round transparent petri dish (diameter 15 cm and depth 2 cm) and placed on a white paper background for easy contrast of vision. Digital microscope (Yujie XSZ 21-05DN, China) and magnifying glass were used for the identification. Digital microscope was used to capture the image of benthos. The organisms were counted and calculated for mean abundance (inds./$m^2$). Identification was done under the possible taxonomic level and results were tabulated. The benthic samples were preserved in 70% ethanol for future reference.

### Data processing and analysis

The Shannon-Wiener species richness index (*H´*), Margalef's richness index (*J*), and Pielou's evenness index (*E*) were obtained from Shannon-Wiener index to determine diversity of benthic fauna. Evenness refers to the absolute distribution of relative abundance of species at a site. Statistical analysis was performed using SPSS (IBM, version 20), PAST (Paleontological statistics, version 3.10) software, and Microsoft Office Excel 2013. One-way ANOVA was performed to test the hypothesis whether means of two or more groups are equal.

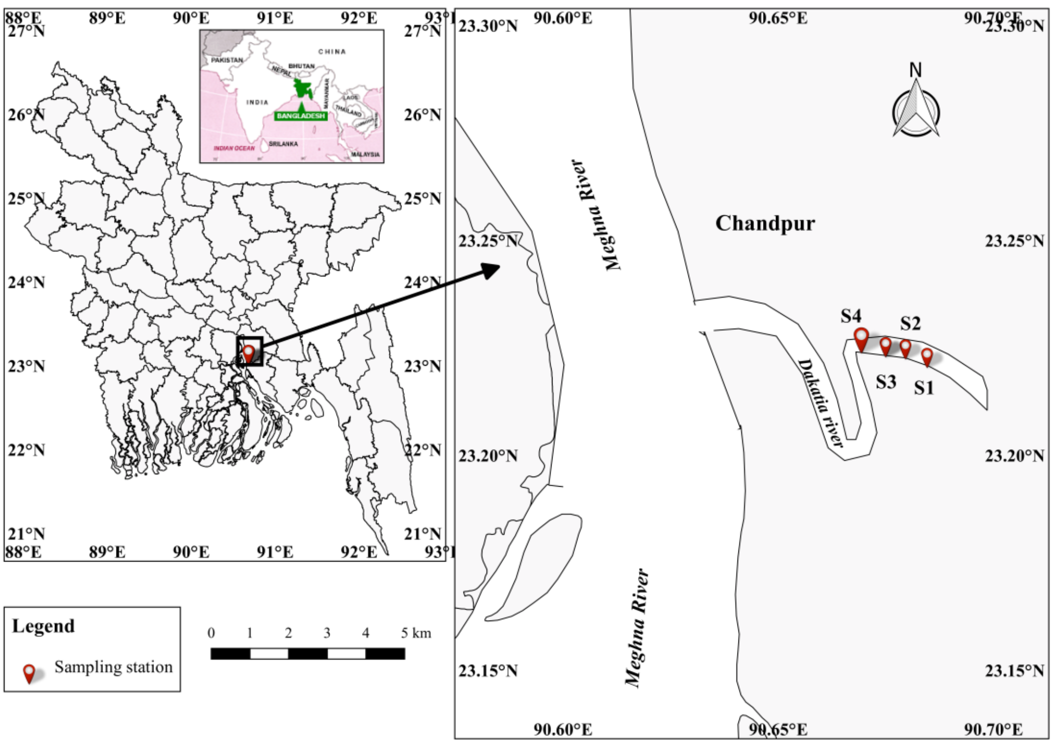


**Figure 1.** Map of the study locations in the Dakatia River, Bangladesh

## RESULTS AND DISCUSSION

### Abundance of benthic infaunal classes

The number of Gastropoda was higher in cage culture area than non-cage culture area (Tables 1 and 2). The abundance of taxonomic group from cage and non-cage culture showed in Tables 3 and 4. Abundance of Oligochaeta in cage culture site was 25333 inds./m$^2$ and 5365 inds./m$^2$ in monsoon and pre-monsoon, respectively. On the other hand Oligochaeta (16933 inds./m$^2$ in monsoon, 1438 inds./m in pre-monsoon) and Amphipoda (652 inds./m$^2$ in monsoon, 14148 inds./m$^2$ in pre-monsoon) abundance in non-cage culture area.

### Diversity indices

Diversity indices are commonly used to analyze the diversity of benthic infauna. The total number of taxa in non-cage culture area was higher but not significantly different ($P$>0.05) from cage culture area (Table 5). According to station-wise observation, the highest taxa were found in PS1, PS4, and MS4 (Figure 2). The total number of taxa in non-cage culture area was higher than cage culture area (Figure 3).

Pielou's evenness ($E$) and Margalef richness index ($J$) showed higher diversity in non-cage culture area but not significantly different ($P$>0.05) from cage culture area.

### Diversity profile

Diversity profile showed clear differences in the diversity of the present study while data are presented station-wise. Non-cage culture area showed the higher diversity value (α = 3.96) than the cage culture area (α = 0), Figure 4. The value of α for the diversity profile begins from zero (0).

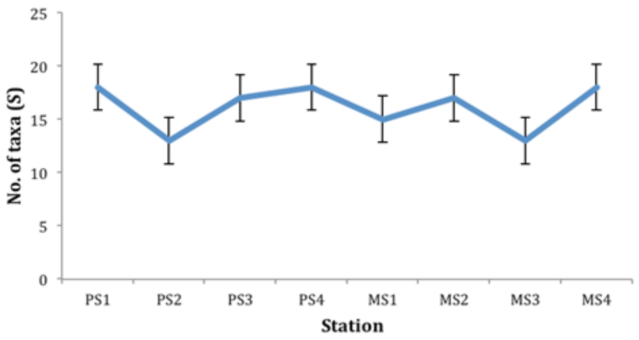


**Figure 2.** Station-wise distribution of benthic infauna (family) of the present study. Error bar indicates standard deviation (±SD)

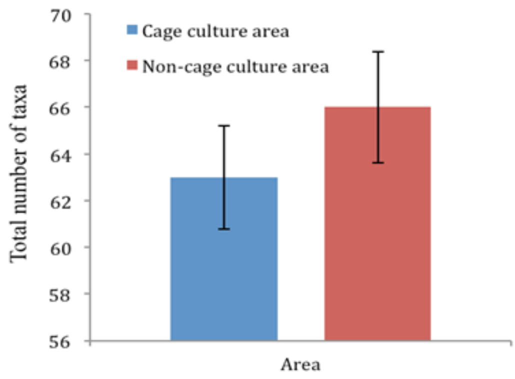


**Figure 3.** Area-wise differences of benthic infauna (family) of the present study. Error bar indicates standard deviation (±SD)

**Table 1.** Total benthic family (inds./m²) recorded in cage culture area

| Season | Pre-monsoon | | Monsoon | | | | | |
|---|---|---|---|---|---|---|---|---|
| Station | S1 | S2 | S1 | S2 | Mean±SD | Total | Percentage (%) | Rank |
| Viviparidae | 207 | 0 | 178 | 119 | 126±91.63 | 504 | 0.84 | 8 |
| Pilidae | 74 | 15 | 44 | 133 | 66.5±50.45 | 266 | 0.44 | 14 |
| Thiaridae | 148 | 0 | 30 | 0 | 44.5±70.43 | 178 | 0.30 | 15 |
| Littorinidae | 15 | 0 | 0 | 0 | 3.75±7.5 | 15 | 0.02 | 20 |
| Pachychilidae | 59 | 0 | 0 | 59 | 29.5±34.06 | 118 | 0.20 | 17 |
| Stenothyridae | 0 | 0 | 681 | 104 | 196.25±326.86 | 785 | 1.30 | 7 |
| Unionidae | 15 | 15 | 30 | 15 | 18.75±7.5 | 75 | 0.12 | 18 |
| Veneridae | 74 | 163 | 0 | 104 | 85.25±67.80 | 341 | 0.57 | 10 |
| Pholadidae | 15 | 0 | 0 | 0 | 3.75±7.5 | 15 | 0.02 | 20 |
| Tubificidae | 3556 | 667 | 5778 | 2148 | 3037.25±2174.83 | 12149 | 20.16 | 3 |
| Naididae | 341 | 519 | 1644 | 15763 | 4566.75±7486.43 | 18267 | 30.32 | 2 |
| Cirratulidae | 163 | 119 | 0 | 0 | 70.5±83.36 | 282 | 0.47 | 13 |
| Capitellidae | 1822 | 3156 | 9585 | 4326 | 4722.25±3399.41 | 18889 | 31.35 | 1 |
| Nereididae | 0 | 44 | 89 | 30 | 40.75±37.03 | 163 | 0.27 | 16 |
| Namanereididae | 133 | 30 | 133 | 15 | 77.75±64.09 | 311 | 0.52 | 11 |
| Nephtyidae | 296 | 15 | 59 | 44 | 103.5±129.63 | 414 | 0.69 | 9 |
| Ampeliscidae | 15 | 15 | 0 | 267 | 74.25±128.69 | 297 | 0.49 | 12 |
| Kamakidae | 0 | 0 | 15 | 2622 | 659.25±1308.52 | 2637 | 4.38 | 4 |
| Chironomidae | 74 | 44 | 1244 | 770 | 533±580.66 | 2132 | 3.54 | 5 |
| Hydropsychidae | 0 | 0 | 59 | 252 | 77.75±119.45 | 311 | 0.52 | 11 |
| Ceratopogonidae | 30 | 0 | 15 | 0 | 11.25±14.36 | 45 | 0.07 | 19 |
| Total | 7437 | 5098 | 19584 | 28134 | 15063.25±10781.89 | 60253 | 100 | - |
| Family found | 18 | 13 | 15 | 17 | | | | |

**Table 2.** Total benthic family (inds./m²) recorded in non-cage culture area

| Season station | Pre-monsoon S3 | Pre-monsoon S4 | Monsoon S3 | Monsoon S4 | Mean±SD | Total | Percentage (%) | Rank |
|---|---|---|---|---|---|---|---|---|
| Viviparidae | 30 | 15 | 0 | 163 | 52±75.01 | 208 | 0.37 | 13 |
| Pilidae | 0 | 74 | 15 | 30 | 29.75±31.91 | 119 | 0.21 | 15 |
| Thiaridae | 30 | 30 | 0 | 0 | 15±17.32 | 60 | 0.12 | 17 |
| Pachychilidae | 15 | 0 | 0 | 0 | 3.75±7.5 | 15 | 0.03 | 18 |
| Stenothyridae | 0 | 0 | 0 | 178 | 44.5±89 | 178 | 0.32 | 14 |
| Unionidae | 30 | 30 | 0 | 15 | 18.75±14.36 | 75 | 0.13 | 16 |
| Veneridae | 207 | 459 | 15 | 74 | 188.75±197.25 | 755 | 1.36 | 11 |
| Tubificidae | 193 | 1067 | 1007 | 4281 | 1637±1807.18 | 6548 | 11.77 | 4 |
| Naididae | 0 | 178 | 4119 | 7526 | 2955.75±3591.32 | 11823 | 21.25 | 2 |
| Capitellidae | 74 | 2593 | 1778 | 5911 | 2589±2450.76 | 10356 | 18.61 | 3 |
| Nereididae | 770 | 89 | 15 | 15 | 222.25±366.83 | 889 | 1.60 | 10 |
| Namanereididae | 667 | 74 | 59 | 163 | 240.75±287.85 | 963 | 1.73 | 9 |
| Nephtyidae | 356 | 696 | 504 | 148 | 426±231.78 | 1704 | 3.06 | 7 |
| Ampeliscidae | 89 | 1511 | 15 | 59 | 418.5±728.97 | 1674 | 3.01 | 8 |
| Kamakidae | 311 | 12237 | 193 | 385 | 3281.5±5970.86 | 13126 | 23.59 | 1 |
| Cymothoidae | 30 | 74 | 0 | 15 | 29.75±31.94 | 119 | 0.21 | 15 |
| Chironomidae | 1393 | 252 | 385 | 415 | 611.25±525.96 | 2445 | 4.39 | 6 |
| Hydropsychidae | 59 | 15 | 104 | 267 | 111.25±110.01 | 445 | 0.80 | 12 |
| Ceratopogonidae | 30 | 15 | 0 | 30 | 18.75±14.36 | 75 | 0.13 | 16 |
| Total | 4358 | 20090 | 9601 | 21586 | 13908.8±8305.05 | 55635 | 100 | - |
| Family found | 17 | 18 | 13 | 18 | | | | |

**Table 3.** Abundance of taxonomic groups (inds./m²) in the cage culture area

| Benthic group | Season Pre-monsoon | Season Monsoon | Mean±SD | Total | Percentage (%) | Rank |
|---|---|---|---|---|---|---|
| Gastropoda | 518 | 1348 | 933±586.90 | 1866 | 3.10 | 6 |
| Bivalvia | 282 | 149 | 215.5±94.05 | 431 | 0.72 | 7 |
| Oligochaeta | 5365 | 25333 | 15349±14119.51 | 30698 | 50.95 | 1 |
| Polychaeta | 5496 | 14281 | 9888.5±6211.93 | 19777 | 32.82 | 2 |
| Amphipoda | 30 | 2904 | 1467±2032.22 | 2934 | 4.87 | 3 |
| Insecta | 148 | 2340 | 1244±1549.98 | 2488 | 4.13 | 4 |

**Table 4.** Abundance of taxonomic groups (inds./m²) in the non-cage culture area

| Benthic groups | Season Pre-monsoon | Season Monsoon | Mean±SD | Total | Percentage (%) | Rank |
|---|---|---|---|---|---|---|
| Gastropoda | 194 | 386 | 290±135.76 | 580 | 1.04 | 7 |
| Bivalvia | 726 | 104 | 415±439.82 | 830 | 1.49 | 6 |
| Oligochaeta | 1438 | 16933 | 9185.5±10956.62 | 18371 | 33.02 | 1 |
| Polychaeta | 5319 | 8593 | 6956±2315.07 | 13912 | 25.01 | 3 |
| Amphipoda | 14148 | 652 | 7400±9543.11 | 14800 | 26.60 | 2 |
| Isopoda | 104 | 15 | 59.5±62.93 | 119 | 0.21 | 8 |
| Insecta | 1764 | 1201 | 1482.5±398.10 | 2965 | 5.33 | 5 |

**Table 5.** Diversity indices for cage and non-cage culture areas during study period

| Study area | Cage culture area | | | | Non-cage culture area | | | |
|---|---|---|---|---|---|---|---|---|
| Station | PS1 | PS2 | MS1 | MS2 | PS3 | PS4 | MS3 | MS4 |
| Taxa (S) | 18 | 13 | 15 | 17 | 17 | 18 | 13 | 18 |
| Density (D) | 7437 | 5098 | 19584 | 28134 | 4358 | 20090 | 9601 | 21586 |
| Shannon-Wiener (*H´*) | 1.706 | 1.339 | 1.390 | 1.490 | 2.101 | 1.453 | 1.675 | 1.676 |
| Pielou's evenness (*E*) | 0.3059 | 0.2936 | 0.2678 | 0.261 | 0.4808 | 0.2375 | 0.4106 | 0.297 |
| Margalef richness (*J*) | 1.907 | 1.406 | 1.417 | 1.562 | 1.909 | 1.716 | 1.309 | 1.703 |

Note: PS: Pre-monsoon station, MS: Monsoon station

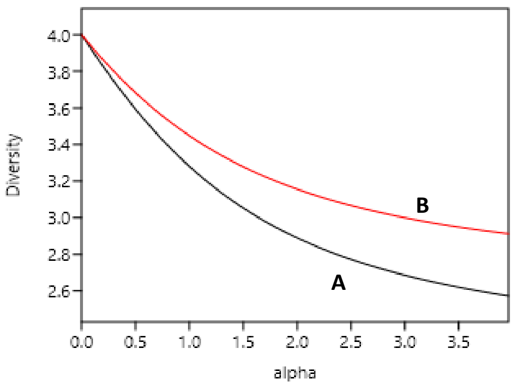


**Figure 4.** Diversity profile of the present study (A: Cage culture area and B: Non-cage culture area)

**Macrobenthic community distributions**

In the present study, macrobenthic organisms were in the sequence of Oligochaeta > Polychaeta > Amphipoda > Insecta > Gastropoda > Bivalvia, and Oligochaeta > Amphipoda > Polychaeta > Insecta > Bilvalvia > Gastropoda for cage culture area and non-cage culture area, respectively (Table 3 and Table 4). The recent study of Noman et al. (2019) identified 9 taxa namely Polychaeta, Mysida, Isopoda, Gastropoda, Amphipoda, Bivalvia, Decapoda, Tanaidacea and Echinodermata in Naf river estuary, Bangladesh. In the present study, Oligochaeta members have been found at every station. Oligochaeta was dominant among all the benthic groups comprising 50.95% and 33.02% of the total infauna in the cage culture area and non-cage culture area, respectively. This indicated that the cage culture area was an organically enriched environment. The density of Capitellidae was the highest among all the families of benthic infauna in the study area. The present results were consistent with Hossain et al. (2009) that also found higher number (53.75%) of Oligochaeta in Meghna river estuary. Oligochaeta assemblages to be important components in freshwater environments (Gorni et al. 2018); these organisms are found in almost all freshwater aquatic environments (Cesar and Henry 2017), and are the most abundant groups in freshwater ecosystems (Ragonha and Takeda 2014; Cesar and Henry 2017). Therefore, having observed more Oligochaeta in freshwater ecosystems in the present study was considered common. Polychaeta has been reported as dominant species in estuarine and mangrove ecosystems (Asadujjaman et al. 2012; Pravinkumar et al. 2013; Noman et al. 2019).

**Macrobenthic species abundance and effects on cage culture**

In the present study, the number of families found ranged from 13 to 18. The organism composition showed variations between the stations; the highest number of taxa was found at stations PS1, PS4, and MS4, and the lowest number were found at stations PS2 and MS3 (Table 5). They were less abundant during pre-monsoon in the cage areas than the control sites. It has been reported that the members of both families are tolerant of organic pollution. The results of the present study were consistent with Hatami et al. (2017) who found higher relative abundance of tolerant taxa (e.g., Tubificidae and Chironomidae) at polluted sites in Rainbow trout fish farm area. The study of Karakassis et al. (2000) and Tomassetti et al. (2009) reported that macrofaunal community was affected by up to 25 m from the edge of the cages.

**Comparison of diversity indices**

Shannon-Wiener diversity index (*H´*) in the present study showed a variation ranging from 1.339 (in pre-monsoon in cage culture site) to 2.101 (pre-monsoon in non-cage culture site). The Shannon-Wiener diversity index (*H´*) was ranging from 1.05 to 1.67 in the Naf river estuary, Bangladesh (Noman et al. 2019), which was almost similar to present study results. The study of Hossain et al. (2013) also observed Shannon-Wiener diversity index (*H´*) ranging between 1.22 to 1.49, compared with the phytoplankton diversity index of 1.97 to 3.78 observed by Meshram et al. (2018a). In another study by Meshram et al. (2018b) found Shannon-Wiener diversity index of 1.29 to 3.67 for zooplankton diversity. In the present study, Shannon-Wiener diversity index (*H´*) showed the highest diversity (1.453 to 2.101) in pre-monsoon in non-cage culture area but it was not significantly different ($F$=2.406, $P$=0.172) between groups. The findings by (Sharif et al. 2017) reported that benthic diversity in Meghna river estuary, Bangladesh not varying much during monsoon and pre-monsoon seasons which supported the findings of the present study. The Shannon-Wiener diversity index of 1.2012 to 1.2109 for Chironomidae (Arkia and Yousefi 2019) was reported in Lar river, Iran. In addition, the Shannon-Wiener diversity index of 1.29 to 3.67 indicate moderate to good levels of phytoplankton and zooplankton diversities, and low-to-medium impact of organic pollution from the anthropogenic activities (Meshram et al. 2018a). Lower values of diversity index in an area indicate pollution in the area (Das et al. 2012). Pielou's Evenness Index (*E*) showed the highest diversity in non-cage culture area in the present study but was not significantly ($F$=1.775, $P$=0.231) different between seasons. The present study results were consistent with the previous study of Noman et al. (2019) that found no significant variations between seasons. In addition, Shou et al. (2009) and Xu et al. (2016) also reported no significant variations among stations and between seasons were found. In the present study the Margalef's index (*J*) of 1.309 to 1.909 showed the highest diversity in non-cage culture area but no significant ($F$=0.252, $P$=0.634) difference between benthic groups. The Margalef's species richness was found 2.21 in the Bakkhali river estuary and 1.36 in the Meghna river estuary (Sarker et al. 2016), which were almost similar to the present study. Margalef's species richness of macrobenthos ranged between 0.86 to 1.66 in the study of Noman et al. (2019) which was partly within the range of the present study. The present study clearly demonstrated the differences in the composition and increased abundance of benthic macrofauna at the cage stations. Therefore, there is local effect of cage culture of fish of such capacity on benthic organisms within the environment, which could be reduced if more attention is given to feeding amount, types of feed, and stocking density.

In conclusion, benthic community structure can be an indicator of water pollution because organic pollutants in water affect the distribution of benthic organisms in the waterbody. The present study demonstrated the effects of cage culture practice on benthic communities. Pollution indicator benthic organisms, Tubificidae and Chironomidae were found most in the cage culture area. Thus, it can be concluded that cage culture practice has great effects on river benthic community. As this is the first research about the impacts of fish cage culture in Dakatia River, it could provide an important contribution towards strategic planning for future sustainable development of cage culture in the river.

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