



Assessment of Effectiveness of Existing Second Hilsa Sanctuary for Sustainable Production in Bangladesh

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Received: 03 February 2026

Revised: 03 May 2026

Accepted: 14 May 2026

Published: 19 June 2026

ABSTRACT

The physicochemical and biological attributes of a river ecosystem usually reveal the status of the subsistent aquatic life and affiliated species richness index of the biodiversity. The study was conducted to reassess the physical and biological condition of the 2nd Hilsa sanctuary of Bangladesh. Towards appraisal of water quality, physicochemical parameters (i.e., temperature, pH, DO, transparency and conductivity), and concentration of plankton were determined. Samples were collected from four different stations of 2nd Hilsa sanctuary areas with their special feature. The study revealed a slight spatial variation in physicochemical parameters of river water. While the parameters were found to be at acceptable levels, some measures are needed to improve the quality of water to ensure successful migration and reproduction of the Hilsa fish. The water quality parameter was found slightly alkaline (7.86 ± 0.31). The transparency was found (35.51 ± 25.32 cm) followed by water temperature (26.7 ± 3.86 °C), alkalinity (80.4 ± 15.27 mg/L), Hardness (134.33 ± 64.61 mg/L), CO₂ (11.46 ± 2.19 mg/L), DO (6.49 ± 0.79 mg/L), salinity (1.83 ± 1.48 ppt), biomass of phytoplankton, was estimated ($30 \pm 5.1 \times 10^2$ cell/L) and zooplankton ($8 \pm 2.9 \times 10^2$ cell/L). The largest quantity of plankton as a natural food (both in number and taxa) was found in the Meghna River basin compared to the other rivers. This assessment of the physical, hydrological, chemical and biological profile of the environment of the Hilsa fishery areas of the country delivers obvious evidence which is important to the apprising of the hilsa fisheries management action plan for sustainable management in future.

Keywords: Hilsa Sanctuaries, Sanctuary Assessment, Sustainable Hilsa Production, Physicochemical parameters.

1 | Introduction

An estuary is a semi-enclosed body of water with open or intermittent connections to the sea. Biophysical and chemical components in a healthy estuary persist within the limits of natural change. Meghna river estuary is an important estuary in Bangladesh for the growth rate and dominance of the estuarine phytoplankton. These form an important food item for hilsa (*Tenualosa ilisha*) which contributes to about 12% of the total fish production, 27.50% of capture fisheries production (inland and marine capture combined),

and 1.0% of national GDP. Hilsa is an important resource which immensely contributes to nutrition, livelihood and economic development of Bangladesh. It's a migratory fish which inhabits in all the three ecosystems as the rivers, estuaries and the seas. Its life cycle is complex; it lives in the sea and migrates to freshwaters in the rivers for spawning although recently it has been reported to spawn also in the coastal waters. It is noted that before implementation of Hilsa Fisheries Management Action Plan (HFMAP), the total production of hilsa in Bangladesh was only

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Bangladesh Journal of Fisheries Research, 2026; 23-25 (1-2): 41-51; <https://doi.org/10.XXXXX/XXXX.XXXXXX>

199,032 tonnes in 2002-03. Due to implementation of HFMAP, hilsa production has increased by 78% from 0.29 million tonnes in 2007-08 to 0.52 million tonnes in 2017-18. The spawning season of Hilsa is noticed during July-August to October-November in all river systems and lagoons i.e., Hoogly (De, 1980; Pillay, 1958), Ganga (Nair, 1958), Chilka (Jones and Menon, 1951), Godavari (Pillay and Rosa 1962), Padma and Meghna (Quddus, 1982; Quddus et al., 1984) but in Hooghly estuary the period of spawning is found to be prolonged and extended up to February and March. The peak spawning of Hilsa was observed from May to July in the river Brahmaputra, (Rao and Pathak, 1972). Blaber et al., (2001) reported that Hilsa spawn in rivers and estuaries. During the period from 2014 to 2020, two new (5th-2013 and 6th-2018) sanctuaries for hilsa fish have been established by BFRI. Besides, the condition of hilsa fish in major rivers of Bangladesh has been monitored including determination of hilsa catch-length variation, gillnet selectivity (Pramanik et al., 2017), assessment of hilsa breeding season and jatka fishing ban in March-April (Rahman et al., (2017). Although these parameters vary, they are strongly influenced by local weather and climate change and can be interpreted as seasonal characteristics. Due to intense fishing pressure, ecological and human activities, both recruitment and production of hilsa particularly in the upstream rivers have been declined. But 2nd Hilsa sanctuary lack of physical and biological research in depth after its

announcement during the Hilsa Fisheries Management Action Plan (HFMAP). So, there is a need to conduct continuous research on biological aspects and water quality to generate adequate information and update them on regular basis for better management of the resources for sustainable production for 2nd Hilsa sanctuary. The main purpose of the study was reassessing the previously identified spawning and nursery grounds. Therefore, studying the interaction between water quality and biological diversity of this estuarine ecosystem due to frequently changing of hydrological conditions is very important for future management of the estuarine ecosystem. The outcome of the study helps to know the potentiality of hilsa breeding and nursing for better management of the population.

1 | Materials and Methods

2.1 Sampling sites and duration

A study was conducted in the 2nd Hilsa sanctuary, the lower Meghna estuary From Char Ilisha to Char Pial of Shahbazpur Channel (90 km) of Bhola district during July 2022 to June 2023 (Fig. 1). Major water quality parameters of the study area were collected from July 2022 to June 2023 and analyzed. Plankton identification, spawning success & Spent rate of Hilsa, CPUE of Hilsa and Jatka were recorded and calculated following standard methods.

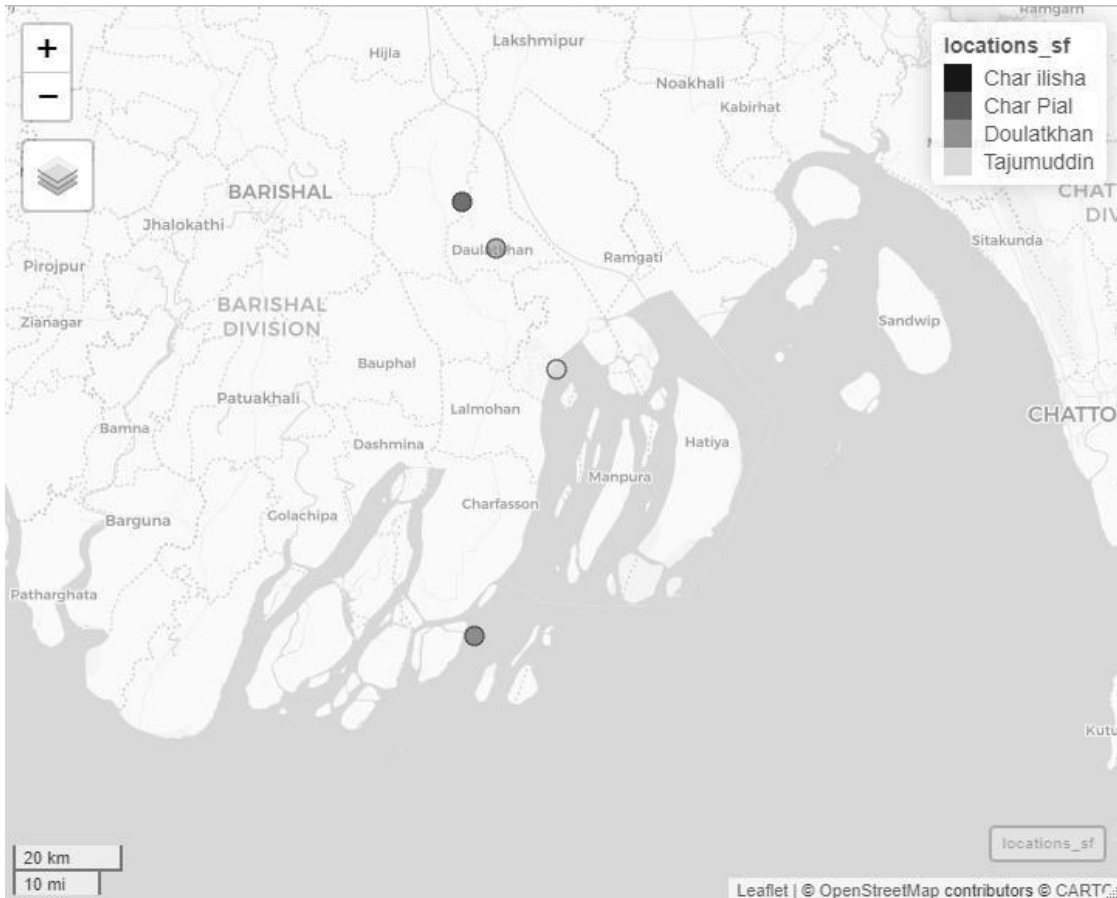


Figure 1 | Map of sampling sites

2.2 Physico-chemical parameters

Air and water temperature were recorded from sampling sites by using digital celsius thermometer (Hanna portable HI 98128 water proof Temperature meter) in the sampling point. HACH test kit (Model-FF-2, USA) was used to record alkalinity, dissolved oxygen (DO), free carbon dioxide (CO₂), pH and hardness. Transparency was measured in each places by secchi disk and measuring tape.

2.3 Plankton community composition

Plankton samples were collected by towing phytoplankton net of mesh size of 20 μm horizontally. The concentrated water samples were then transferred into 15 ml plastic vials and added 10% buffered formalin to preserve in the refrigerator. Thereafter, qualitative analysis of phytoplankton samples was accomplished under a phase-contrast microscope (Primo Star, Carl Zeiss)

for the taxonomic rank by following Ward and Whipple (1959) and Prescott (1962). For quantitative analysis, Sedgwick Rafer chamber (Wildlife, USA) was used for counting plankton cells. The number of phytoplankton (cells L⁻¹) was computed for each group using the equation defined by Snow et. al.2000. The following formula (Rahman, 1992) was used to count plankton:

$$\text{Number of plankton, } N = (A \times 1000 \times C) / (V \times F \times L)$$

where N = number of plankton cells per liter; A = total number of plankton counted; C = volume of final concentrate of samples in mL; V = volume of a field in cubic millimeter; F = number of fields counted; L = volume of original water in liter.

2.4 Species diversity indices

The species diversity of a habitat is calculated using diversity indices. Plankton diversity indices9

were calculated using the Simpson Diversity Index (D)

$$\text{Simpson index (D)} = \sum n(n - 1) / N(N - 1)$$

where N is the total number of organisms of all species in an area; n is the total number of organisms of a particular species. Simpson Index varies from 0 to 1. Zero denotes a high diversity, while 1 represents a less diverse region.

$$\text{Margalef Richness Index (d)} = (S - 1) / \ln N$$

Where S is the number of species, N is the total number of individuals in the sample. These indices were used to obtain the estimation of both Phytoplankton and zooplankton species diversity index.

$$\text{Simpson Dominance Index (D)} = \sum (n_i/n)^2$$

where n_i = number of individuals of species i, and n = total number of individuals.

2.5 Spawning success and spent rate determination

the spawning grounds (7000 square km) was estimated to reassess the spawning grounds of Hilsa by using following formulae

$$\text{TN} = \text{number of fishing boats} \times \text{fish caught per haul} \times \text{number of days}$$

$$\text{TFE} = (\text{TN} \times \text{FF} \times \text{SF} \times \text{EF}) / 1000$$

where TN = total number of fish excluded due to fishing; TFE = total fertilized egg; FF = percentage of female fishes in the study area; SF = percentage of spent/oozing fishes; EF = average egg per fish. Location-wise spent rate was determined.

2.6 Catch per unit effort

CPUE (Catch Per Unit Effort): CPUE was estimated as Kg/100m net/hour by the following formula. CPUE of fish Species was estimated (Kg/100m net/hour). Fish sampling was done in every selected sampling site to collect data of catch per unit effort (CPUE).

$$\text{CPUE} = (C \times F \times P) / M$$

where CPUE = daily catch in kg/fisherman; C = catch in kg/net/day; F = number of possible fishing days/month; P = participant fishermen/net.

1 | Results

3.1 Physico-chemical parameters

Table 1 | Identification and characterization of selected freshwater fishes based on DNA barcoding data

Parameters	Char Ilisha	Doulotkhan	Tajumuddin	Char Pial	Standard
Air Temp.	28.46 ± 3.24	26.99 ± 3.76	27.18 ± 4.22	26.85 ± 4.44	20-30 (EQS,1997)
Water Temp.	26.7 ± 3.86	25.39 ± 3.87	25.66 ± 4.37	25.71 ± 4.34	20-30 (EQS,1997)
DO	6.49 ± 0.79	6.44 ± 1.21	6.43 ± 1.16	6.39 ± 1.18	4-6 (EQS,1997)
CO ₂ (mg/L)	10.18 ± 2.04	11.46 ± 2.19	11.3 ± 2.03	11.27 ± 1.96	<6 ppm or (EQS,1997)
Alkalinity	78.33 ± 15.76	76.83 ± 16.24	79.75 ± 15.64	80.4 ± 15.27	>100 (Rahman,1992)
Hardness	96.33 ± 29.40	107.41 ± 37.61	130.16 ± 62.48	134.33 ± 64.61	40-400 ppm (Boyd,1998)
pH	7.86 ± 0.31	7.75 ± 0.25	7.77 ± 0.28	7.74 ± 0.31	6.5-8.5 (EQS,1997)
Transparency	28.43 ± 19.33	31.09 ± 17.28	35.43 ± 25.23	35.51 ± 25.32	40 or less (Rahman,1992)
Salinity(ppt)	0.75 ± 1.37	0.44 ± 1.02	0.58 ± 1.24	1.83 ± 1.48	0-10 (Rahman,1992)

Mean values and ranges of Physico-chemical parameters over the study period from July 2022 to June 2023 are presented in Table 1. Physico-chemical parameters such as air and water temperature (°C), transparency (cm), DO (mg/L), CO₂ (mg/L), pH, total hardness (mg/L), and total alkalinity (mg/L) were determined. The air and water temperature of the study areas were found to vary from 19 to 32°C and 17 to 30.5°C, respectively. Dissolved oxygen and free CO₂ ranged between 5 to 9.8 mg/L and 7.2 and 16 mg/L, respectively. pH, transparency and salinity varied from 7.5 to 8.3, 8.1 to 99 cm and 0 to 10 ppt, respectively. Saline water intrusion was observed in Shahbazpur Channel from December to March 2022 -2023 within the average ranges of 0.44-3.48 ppt. Alkalinity and hardness ranged from 54 to 99 mg/L and 62 to 270 mg/L during the study period. The results of the Physico-chemical parameters indicated that the water

quality parameters were within suitable ranges for fishes in study areas.

3.2 Study of plankton

Following the drop count method, qualitative and quantitative analysis of planktons were done (ApHA 1995). Plankton identification was made following Ward and Whipple (1959) and Prescott (1962). Ten plankton groups were identified in the qualitative study of plankton, among them seven were phytoplankton and three were zooplankton groups (Table -2). Among the seven phytoplankton groups, 22 genera were identified. Bacillariophyceae, Zygnematophyceae and Chlorophyceae were the most dominant groups in Shahbazpur Channel. But in the case of three zooplankton groups, almost six different genera were observed, including the same proportion. The quantitative study of phytoplankton observed a higher amount on the lower side of the Meghna River than on the upper side (Table 3).

Table 2 | Identified plankton groups available at Shahbazpur Channel in the Meghna River

Group	Genus
Chlorophyceae	Pediastrum, Volvox, Scenedesmus, Acanthocystis
Ulvophyceae	Ulothrix
Zygnematophyceae	Spirogyra, Nitzschia, Netrium, Staurastrum(end), Gonatozygon
Bacillariophyceae	Navicula, Gomphonema, Asterionella, Diatoma, Frustulia, Stephanodiscus, Cyclotella
Cyanophyceae	Spirulina, Rivularia, Oscillatoria
Dinophyceae	Ceratium
Euglenophyceae	Euglena
Copepoda	Cyclops, Nauplius
Rotifera	Brachionus, Keratella
Cladocera	Daphnia, Bosmina

Table 3 | Quantitative assessment of plankton (average) at Shahbazpur Channel in the Meghna River

Sampling sites	Total plankton (cells/L)	Total phytoplankton (cells/L)	Total zooplankton (cells/L)	Phytoplankton (%)	Zooplankton (%)
Char Ilisha	32±5 ×10 ²	25±2.4 ×10 ²	7±2.6 ×10 ²	78.12	21.88
Daulotkhan	34±6 ×10 ²	27±3.5 ×10 ²	7±2.5 ×10 ²	79.41	20.59
Tajumuddin	35±5 ×10 ²	26±2.7 ×10 ²	9± 2.3×10 ²	74.28	25.72
Char Pial	38±8 ×10 ²	30±5.1 ×10 ²	8±2.9 ×10 ²	78.94	21.06

Table 4 | Diversity indices of plankton of Shahbazpur Channel

Parameters	Char Ilisha	Doulatkhan	Tajumuddin	Char Pial
Taxa_S	31	31	31	31
Individuals	3267	3472	3752	3831
Dominance_D	0.04593	0.04185	0.04633	0.04659
Margalef	3.708	3.68	3.645	3.636
Simpson_1-D	0.9541	0.9582	0.9537	0.9534

Margalef Richness Index for Plankton was found to be the highest in Char Ilisha (3.70) and respectively lower to the downward areas to the estuary. The Simpson Index (D) Plankton was found to be more or less similar to the spatial distribution in Shahbazpur Channel. The Simpson Dominance Index (D) for Plankton was found to be quite similar in all the places

3.3 Spawning success

In 2022, the spawning success was recorded during and after the 22 days banning period (07-

28 October 2022). The average spawning success was 84 % across the shahbazpur channel.

3.4 Spent rate of Hilsa

In 2022, the spent rate of hilsa was recorded during and after the 22 days banning period (07-28 October 2022). The average spent rate of hilsa was 52% across the shahbazpur channel which was better than the previous years. (Fig. 2).

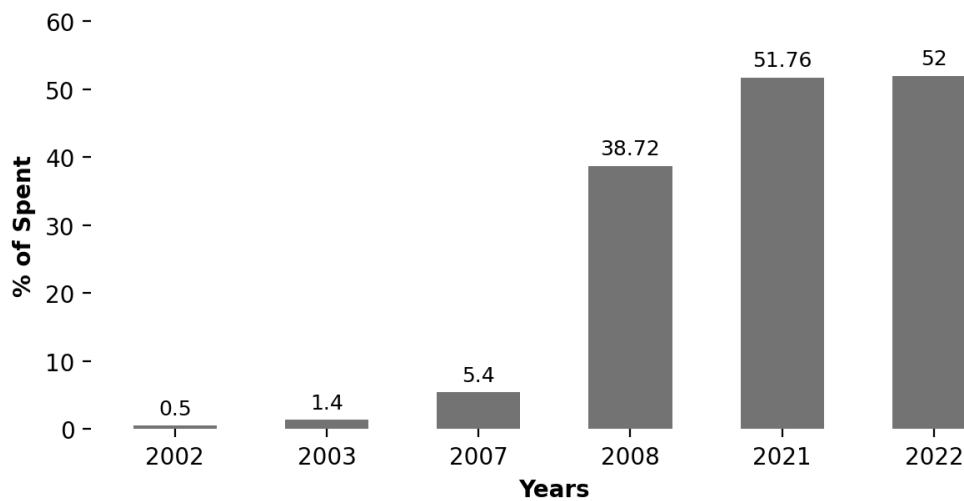


Figure 2 | Spent rate (%) of Hilsa in the Meghna River

3.5 CPUE of Hilsa at Shahbazpur Channel

Catch Per Unit Effort (CPUE) of Hilsa at Shahbazpur Channel of Meghna River was observed in higher amounts (4 -11 kg/100m

net/hour/boat) in September and October/ 2022 at Shahbazpur Channel in the lower Meghna River (Fig. 3).

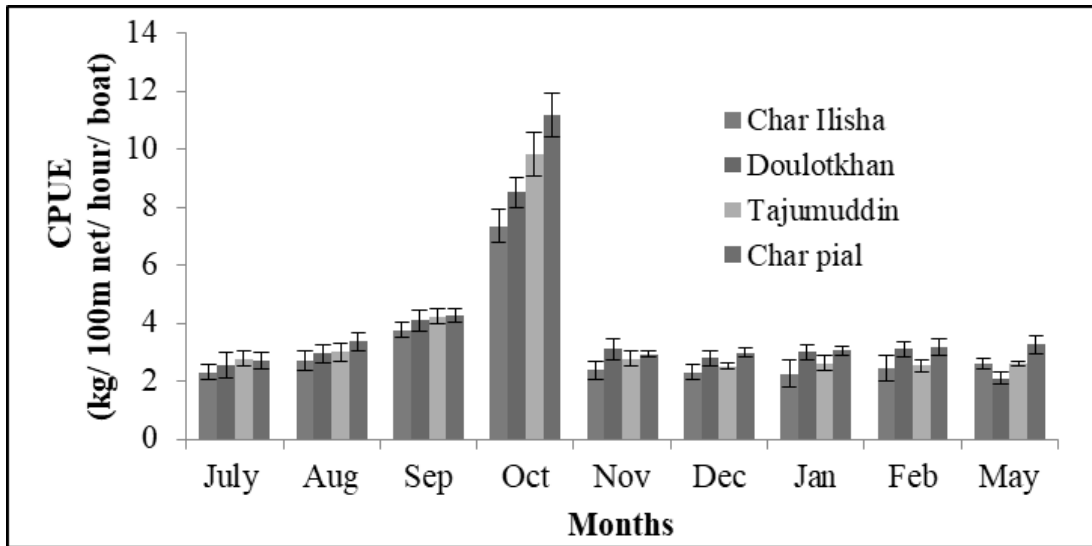


Figure 3 | Spent rate (%) of Hilsa in the Meghna River

3.6 CPUE of Jatka in the Meghna River

The highest average CPUE of Jatka was found in Doulatkhan (20.5 kg/100 m net/hour/boat) and

the lowest average CPUE was found in Char Pial (15 kg/100 m net/ hour/ boat) region of the lower Meghna River. (Fig. 4)

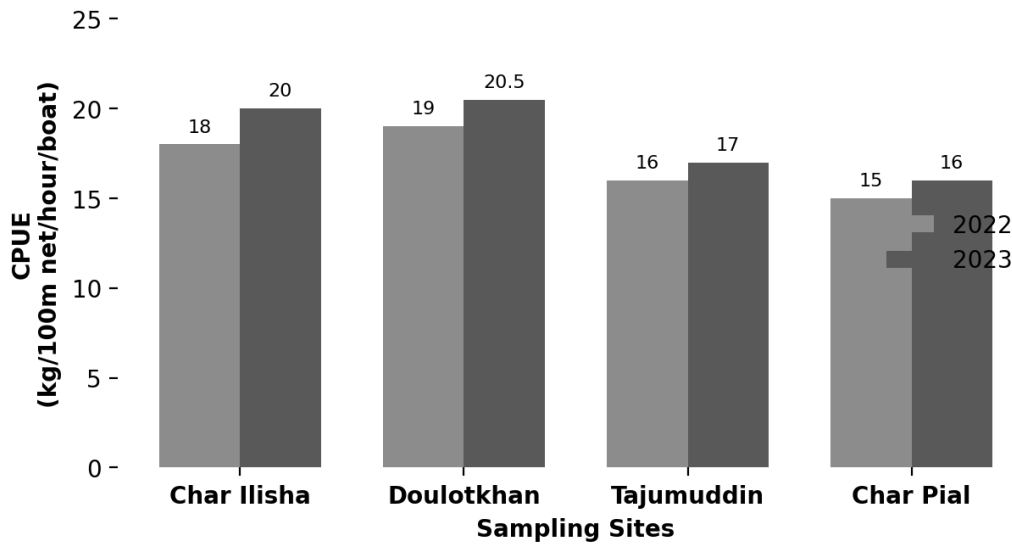


Figure 4 | CPUE of Jatka in the Meghna River

1 | Discussion

Determining the health of the estuarine ecosystem includes important biological, physical, and chemical parameters and interactions to understand the ecosystem functions (Ferreira et al., 2011). The re-assessment of Hilsa Spawning and nursery grounds and the identification of new

sanctuaries have just been completed (BFRI-RS-2018-2021). It has been seen here that Percentage of spent rate, length frequency, larvae and jatka abundance, CPUE of larvae, plankton composition and physico-chemical parameters of water were found satisfactory in Monpura, Bhola during the peak spawning period. Similar results were found in the study.

In addition, there are some scattered works on different biological aspects of the coastal estuarine system of Bangladesh (Shaha et al., 2022; Shaha et al., 2023, Hossain et al., 2012; Rahman et al., 2021; Bhuyan et al., 2017; Hasan et al., 2016; Hossain et al., 2015; Hasan et al., 2015;), none of them examined the spawning and nursery habitat assessment concerning environmental variables in the Tetulia River estuaries and Meghna River Estuaries. But all of them study the Physico-chemical variables which were mostly related to our study findings.

Shaha et al., 2023 explored that the TRE is suitable for spawning and nursery habitat (salinity <0.09 psu) for hilsa all year round because the TRE acts as a freshwater ecosystem (salinity <0.1 psu) annually. Therefore, the government should focus on protecting and conserving juvenile hilsa (jatka) and brood hilsa in the TRE year-round but seasonal fluctuation of salinity intrusion was observed in Meghna River estuary at a range of 0.1-10 in number to March which was similar to our findings.

Hasan et al. 2015 showed that there were four groups of phytoplankton comprising 25 genera and three groups of zooplankton with seven genera. Chlorophyceae was the dominant group and Ulothrix was the dominant genus among the phytoplankton, however Rotifera was the dominant group and Keratella was the dominant genus in zooplankton in in meghna river estuary which is closely related to the present findings. Ahsan et al., (2012) reported the occurrence of 58 taxa of which 19 were of phytoplankton and 39 were of zooplankton. A relatively lower abundance of plankton including 41 genera of phytoplankton and 13 genera of zooplankton were recorded (Ahmed et al., 2005).

Hasan et al., 2015 observed that the number of plankton varied from 6,096 to 96,604 cells L⁻¹, 5,925 to 97,765 cells L⁻¹, 6,023 to 85,733 cells L⁻¹, and 2,210 to 5,769 cells L⁻¹, where phytoplankton varied from 5,277 to 92,655 cells L⁻¹, 5,462 to 93,619 cells L⁻¹, 5,297 to 81,457 cells L⁻¹, 1,530 to 5,145 cells L⁻¹ and zooplankton ranged from 716

to 5,211 cells L⁻¹, 463 to 4,147 cells L⁻¹, 727 to 4,276 cells L⁻¹, 405 to 1,208 cells L⁻¹ in Meghna river Chandpur, Meghna River Doulotkhan, Tetulia River Lalmohon and Andarmanik River respectively. The mean plankton abundance were 36,996 cells L⁻¹, 35,929 cells L⁻¹, 32,556 cells L⁻¹, 4,020 cells L⁻¹, where, phytoplankton abundance were 34,795 cells L⁻¹, 34,142 cells L⁻¹, 30,612 cells L⁻¹, 3,225 cells L⁻¹, and zooplankton were 2,201 cells L⁻¹, 1,787 cells L⁻¹, 1,943 cells L⁻¹, 795 cells L⁻¹ in Chandpur, Meghna River Doulotkhan, Tetulia River Lalmohon and Andarmanik River respectively respectively. In the present study the average range of plankton observed from 3700-4600 cells L⁻¹ where phytoplankton varied from 2700-3500 and zooplankton varied from 900-1090 cells L⁻¹ in different areas of Shahbazpur Channel. The present study found that the number of plankton was quite lower than the previous study.

According to Margalef (1956), the higher diversity values reflect the suitability of habitat for the organism and have been reported to be correlated with longer food chain and complex food web of the ecosystems and also more stable community. The Margalef Richness Index has no limit value and it shows a variation depending upon the number of species. Margalef Richness Index for Plankton was found to be the highest in Char Ilisha (3.70) and respectively lower to the downward areas to the estuary.

Simpson Index (D) The Simpson Index value also ranges between 0 and 1, the greater the value, the greater the sample diversity. The Simpson Index (D) Plankton was found to be more or less similar to the spatial distribution in Shahbazpur Channel.

The Dominance Index was measured to determine whether or not particular fisheries species dominate in a particular aquatic system and can be useful index of resource monopolization by a superior competitor, particularly in communities that have been invaded by exotic species. The Simpson Dominance Index (D) for Plankton was found to quite similar in all the places.

Hilsa spawns year-round based on the full moon phase (Rahman et al., 2017). Although hilsa spawns more or less throughout the year, they have a minor spawning season during February-March and a major spawning season during September-November (Hossain et al., 2019). The spawning success and spent rate determination of Hilsa in the existing findings were higher than the previous study (Fig. 4) according to BFRI annual report 2005-2021.

Rahman et. al., 2024 enumerated 20-45 numbers of Spawn Jatka caught with experimental standard Behundi nets for monitoring Jatka (length Range: 1-3.5 cm) abundance in Meghna and Meghna tributaries at the Hizla-Mehendiganj region of Barisal by BFRI, RS Experimental Juvenile Jatka Net October-November and March –April during the period 2010-2015.

Rahman et. al., 2024 found 2.0-3.25 CPUE range of harvested Jatka (kg) caught with experimental standard BFRI, RS Experimental Juvenile Jatka Gill net (Nylon/Monofilament, Gill Mesh: 25-65 cm, Net Length: 100m) for monitoring Jatka (length Range: 10-25 cm) CPUE (100m Net/Haul/Kg) in Meghna and Meghna tributaries at the Hizla-Mehendiganj region of Barisal.

In the present findings the CPUE of Hilsa and Jatka in the Meghna River Estuaries were higher than the previous study.

1 | Conclusion

The water quality of an aquatic body largely depends on the interactions of various physicochemical factors. Variation of water quality is represented by sampling points (spatial effect) and sampling months (seasonal effect). Among water quality parameter, dissolved oxygen is an important indicator. Decreased DO levels during the rainy (wet) season are related to the amount of oxygen consuming compounds entering from nearby industrial or agricultural areas through estuary river runoff. Low salinity during the rainy (wet) season was due to the outflow of fresh water. In contrast, during the dry season, the upper region remained oligohaline and the

remaining sections become mesohaline. No significant spatial variations were observed in the water quality parameters except salinity. Considering the salinity distribution, the entire sanctuary is a suitable hilsa spawning and nursery ground during. The outcomes of the study show that water quality parameters, such as water pH, DO, alkalinity, water nutrients are within the suitable ranges for fish in all the sites. We conclude that, from the ecological view point, the hilsa sanctuaries are characterized by acceptable level of water quality. The outcome of this study opens window for further intensive study on seasonal variability of water quality parameters and chlorophyll distribution of an aquatic ecosystem.

Author Contributions:

Tayfa Ahmed: Conceptualization, data collection, data analysis, interpretation, manuscript writing and editing. Mezbabul Alam: Conceptualization, data collection, data analysis, interpretation, manuscript writing and editing. Rumana Yasmin: Conceptualization, data collection, data analysis, interpretation, manuscript writing and editing. Md. Shariful Islam: Conceptualization, data collection, data analysis, fund acquisition, manuscript writing and editing. A N M Rezvi Kaysar Bhuiyan: Conceptualization, data collection, data analysis, fund acquisition, manuscript writing and editing. Md. Monjurul Hasan: Conceptualization, data collection, data analysis, fund acquisition, manuscript writing and editing. Mehedi Hasan Pramanik: Conceptualization, data collection, data analysis, fund acquisition, manuscript writing and editing. Al-Amin & Ehsanul Karim: Conceptualization, data collection, data analysis. Md. Amirul Islam: Conceptualization, data collection, data analysis. Anuradha Bhadra: Conceptualization, data collection, data analysis, supervision, manuscript writing and editing. All authors have read and approved the final published article.

Acknowledgements:

We would like to sincerely thank the Bangladesh Fisheries Research Institute for the logistic and technical support during the study.

Funding

This study was funded by Bangladesh Fisheries Research Institute.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All data generated and analyzed during this study are included within the manuscript. No additional datasets are available.

Ethics Statement

Not applicable.

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