BANGLADESH JOURNAL OF FISHERIES RESEARCH

ORIGINAL ARTICLE OPEN ACCESS

Assessment of Efficacy of Tetulia River Ecosytems: A new hope for future Hilsa Fishery

Mezbabul Alam[2*] | Tayfa Ahmed[2] | Rumana Yasmin[1] | Kazi Belal Uddin[1] | Md. Shariful Islam[1] | A N M Rezvi Kaysar Bhuiyan[1] | Md. Monjurul Hasan[1] | Mehedi Hasan Pramanik[2] | Al-Amin[3] | Ehsanul Karim[3] | Md. Amirul Islam[1] | Anuradha Bhadra[3]

[1]Bangladesh Fisheries Research Institute, Riverine Station, Chandpur 3602, Bangladesh
[2]Bangladesh Fisheries Research Institute, Flood Plain Sub Station, Santahar,Bogura, Bangladesh
[3]Bangladesh Fisheries Research Institute, Headquarters, Mymensingh 2201, Bangladesh

Correspondence: (mbalam.bau@gmail.com)

Received: 14 January 2026 | **Revised:** 23 May 2026 | **Accepted:** 30 May 2026 | **Published:** 19 June 2026

ABSTRACT

This study presented the scientific scenary of various studies on different sites Tetulia River Hilsa sanctuary during the period of July, 2023 to June, 2024. This scientific initiative has been felt to undertake in the Tetulia (3rd sanctuary) estuaries with the view to understand their potential status as Hilsa Sanctuaries .This study explored the present status of Tetulia Riveer ecosystem (TRE), the analytical results of the Physico-chemical parameters were within suitable ranges for fishes in the study areas during the periods of July 2023 to June 2024. Among the seven phytoplankton groups, 24 genera were identified. Bacillariophyceae, Zygnematophyceae and Chlorophyceae were the most dominant groups of phytoplankton. 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 number on the lower zone of the Tetulia River than on the upper zone. Hilsa Catch Per Unit Effort (CPUE) in Tetulia River were observed higher amount in September and October, thus gradually lower in the following months. Jatka CPUE in Tetulia River were varied from a range of 4-5 kg/100 m net/ hour/ boat. 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 fishes. Tetulia River Estuary should be reassessed vigorously in future to address the potentiality of status of the 3rd Hilsa Sanctuaries.

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

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

Bangladesh Journal of Fisheries Research, 2026; 23-25 (1-2): 30-40; https://doi.org/10.XXXXX/XXXX.XXXXXX

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 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. 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. 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. 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 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 in 2013 and 6th in 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). As Tetulia River sanctuary was established before Hilsa Fisheries Management Action Plan (HFMAP) from that period the physiological and biological status of this sanctuary are not studied vigorously. The main purpose of the study was to assess the effectiveness of existing 3rd Hilsa sanctuaries for sustainable Production in Bangladesh. The outcome of the study helps to know the potentiality of hilsa breeding and nursing for better management of the population.

.

2 | Materials and Methods

2.1 Sampling sites and duration

Data was collected from the following locations of spawning and nursery grounds of 3 rd Hilsa Sanctuary i) Bheduria iii) Char Kalmi iii) Kalaiya

Figure 1 | Sampling sites in Tetulia River

2.2 Physico-chemical parameters

Physico-chemical parameters such as temperature (Air and water), transparency, DO, CO2, Ammonia, pH, total hardness, and total alkalinity were determined by Hach Kit (Model FF-2, USA).

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 Rafter chamber (Wildlife, USA) was used for counting plankton cells.The number of phytoplankton (cells L^{-1}) was computed for each group using the equation defned by Snow *et al.,* 2000.

The following formula (Rahman, 1992) was used to count plankton: Number of plankton, N = (A × 1000 × c) / (V × F × 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 the fields counted.

L = Volume of original water in liter

2.4 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).

$$\text{FCPUE} = C \times \frac{F}{M} \times P \text{ (IRBUCD, 1994)}$$

Where,

CPUE= daily catch in kg/fisherman

C= catch in kg/net/day

F= number of possible fishing days/month

P= participant fishermen/net

3 | Results

Research was conducted on the following spawning and nursery grounds: From Veduria in Bhola District to Char Rustam in Patuakhali District (about 100 km area of Tentulia River) (3 rd Hilsa Sanctuary, Tetulia River) Physico-chemical parameters 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 22 to 31°C and 22.6 to 30 oC, respectively. Dissolved oxygen and free CO2 ranged between 5 to 7 mg/l and 7.2 to 13 mg/l, respectively. The study areas pH and transparency salinity varied from 7.5 to 8, 8.1 to 29 cm respectively. No saline intrusion was observed in the study areas during the period. The results of the Physico-chemical parameters indicated that the parameters were within the suitable ranges (Environmental Quality Standard (EQS 1997), Rahamn 1992, and Boyd 1998) for fishes in study areas . Mean values and ranges of Physico-chemical parameters over the study period are presented in Table 1.

Table 1 | Physico-chemical parameters of 3rd Hilsa Sanctuary, Tetulia River Parameters Tetulia River

Parameters	Tetulia River (Mean and range)	Standard value
Air temperature (˚C)	28.06 ± 2.10 (22-31)	20-30 (Environmental Quality Standard, EQS,1997)

Water temperature (˚C)	26.41 ± 2.19 (22.6-30)	20-30 (EQS,1997)
DO (mg/l)	6.13 ± 0.52 (5-7)	4-6 (EQS,1997)
CO_2 (mg/l)	10.225 ± 1.98 (7.2-13)	6 ppm or less (EQS,1997)
pH	7.63 ± 0.15 (7.5-8)	6.5-8.5 (EQS,1997)
Transparency (cm)	16.55 ± 7.93 (8.1-29)	40 or less (Rahman,1992)
Salinity (ppt)	0.00 ± 0.00	0-10 (Rahman,1992)
Alkalinity (mg/l)	71.33 ± 15.96 (54-99)	>100 (Rahman,1992)
Hardness (mg/l)	97.58 ± 53.90 (62-270)	40-400 ppm (Boyd,1998)

3.1 Plankton identification

Ten plankton groups were identified in the qualitative study of plankton; among them seven were phytoplankton and three were zooplankton groups (Table 02). Among the seven phytoplankton groups, 24 genera were identified. Bacillariophyceae, Zygnematophyceae and Chlorophyceae were the most dominant groups of phytoplankton. But in the case of three zooplankton groups, almost six different genera were observed, including the same proportion.

Table 2: Qualitative assessment of Plankton at 3 rd Hilsa Sanctuary, Tetulia River

Group	Genus	Genus No.
Chlorophyceae	*Pediastrum, Volvox, Scenedesmus, Acanthocystis,Microspora*	05
Ulvophyceae	*Ulothrix*	01
Zygnematophyceae	*Spirogyra, Nitzschia, Netrium, Staurastrum(end), Gonatozygon*	05
Bacillariophyceae	*Navicula, Gomphonema, Asterionella, Diatoma, Frustulia, Stephanodiscus, Cyclotella*	07
Cyanophyceae	*Spirulina, Rivularia,Oscillatoria*	03
Dinophyceae	*Ceratium*	01
Euglenophyceae	*Euglena*	01
Copepoda	*Cyclops, Nauplius*	02
Rotifera	*Brachionus, Keratella*	02
Cladocera	*Daphnia, Bosmina*	02

The quantitative study of phytoplankton observed a higher number on the lower side of the Tetulia River than on the upper side (Table 3).

Table 3 | Quantitative assessment of plankton in 3rd Hilsa Sanctuary, Tetulia River

Sampling sites	Total Plankton (cells/L)	Total Phytoplankton (cells/L)	Total Zooplankton (cells/L)	Phytoplankton (%)	Zooplankton (%)
Bheduria	32×10^2	25×10^2	7×10^2	78.12	21.88
Char Kalmi	34×10^2	27×10^2	7×10^2	79.41	20.59
Kalaiya	35×10^2	26×10^2	9×10^2	74.28	25.72

3.2 CPUE of Hilsa Hilsa CPUE in Tetulia River were observed higher amount in September and October then gradually lower in the following months. (Fig. 2)

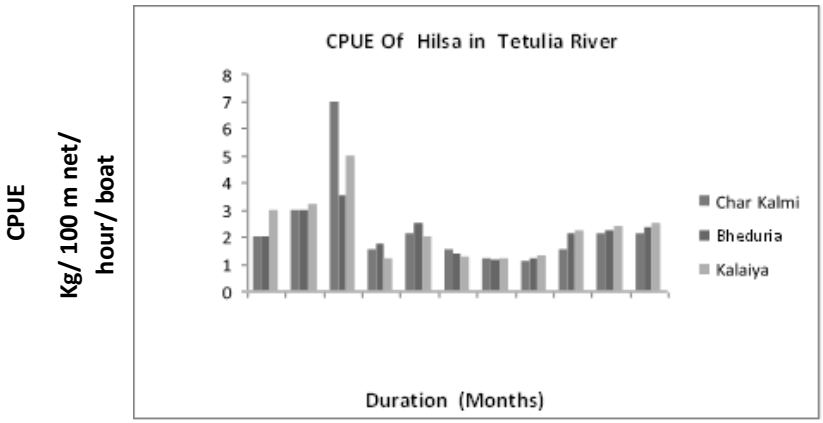

Figure 2 | CPUE of Hilsa in Tetulia River

3.3 CPUE of Jatka

Jatka CPUE in Tetulia River were varied from a range of 4-5 kg/100 m net/ hour/ boat (Fig. 3). Highest CPUE was observed in Bheduria which is adjacent to Meghna River Estuary and wide than the sampling sites.

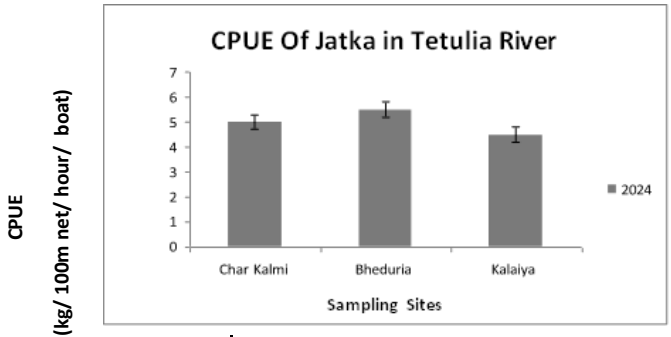

Figure 3 | CPUE of Jatka in Tetulia River

4 | 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).

In Tetulia River ecosystem, mean values and ranges of physico-chemical parameters over the study period are presented. Physico-chemical parameters such as air and water temperature (°C), transparency (cm), DO (mg/l), CO_2 (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 22 to 31°C and 22.6 to 30 °C, respectively. Dissolved oxygen and free CO_2 ranged between 5 to 7 mg/l and 7.2 to 13 mg/l, respectively. The study areas pH and transparency varied from 7.5 to 8, 8.1 to 29 cm respectively. No saline intrusion was observed in the areas during the study period. The results of the Physico-chemical parameters indicated that the parameters were within the suitable ranges for fishes in study areas. Ten plankton groups were identified in the qualitative study of plankton; among them seven were phytoplankton and three were zooplankton groups. Among the seven phytoplankton groups, 24 genera were identified. Bacillariophyceae, Zygnematophyceae and Chlorophyceae were the most dominant groups of phytoplankton. 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 number on the lower zone of the Tetulia River than on the upper zone. Hilsa CPUE in Tetulia River were observed higher amount in September and October then gradually lower in following months. Jatka CPUE in Tetulia River were varied from a range of 4-5 kg/100 m net/ hour/ boat. 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 studied the physico-chemical variables which were mostly related to the present 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 sasonal filuctuation of salinie intrusion was observed in Meghna River estuary at a range of 0.1-10 in November to March which was similar to present 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 85,733cells L^{-1}, and 2,210 to 5,769 cells L^{-1}, where phyplankton varied from 5,277 to 92,655 cells L^{-1}, 5,462 to 93,619cells 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. 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) 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.

5 | 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. Considering the salinity distribution, the entire sanctuary is a suitable hilsa spawning and nursery ground during breeding period. 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. It may be concluded that, from the ecological point of view, 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. The trend of saline intrusion in other river ecosystem is increasing which fall a threat to hilsa fishery management in case of breeding period whether saline intrusion is absent in Tetulia River ecosystem during the study period. Thus Tetulia River ecosystem opens a new hope of Hilsa fishery in the riverine system.

The study suggests the following recommendation in the studied riverine ecosystem

Saline intrusion should be more emphasis in case of future research. Tetulia River Estuaries should be reassessed in future to address the potentiality status of the 3rd Hilsa Sanctuaries.

Author Contributions

Mezbabul Alam, Tayfa Ahmed, Rumana Yasmin, Kazi Belal Uddin and Md. Shariful Islam: Conceptualization, data collection, data analysis, interpretation, manuscript writing and editing. **A N M Rezvi Kaysar Bhuiyan, Md. Monjurul Hasan, Mehedi Hasan Pramanik, Al-Amin, Ehsanul Karim:** Conceptualization, data collection, data analysis, fund acquisition, manuscript writing and editing. **Md. Amirul Islam:** Conceptualization, data collection, data analysis, supervision. **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.

References

Ahmed, K. K. U., Ahmed, S. U., Haldar, G. C., Hossain, M. R. A., & Ahmed, T. (2005). Primary production and fish yield estimation in the Meghna River system, Bangladesh. *Asian Fisheries Science*, *18*(2), 95–105. https://doi.org/10.33997/j.afs.2005.18.2.002

Ahsan, D. A., Kabir, A. N., Rahman, M. M., Mahabub, S., Yesmin, R., Faruque, M. H., & Naser, M. N. (2012). Plankton composition, abundance and diversity in hilsa (*Tenualosa ilisha*) migratory rivers of Bangladesh during spawning season. *Dhaka University Journal of Biological Sciences*, *21*(2), 177–189. https://doi.org/10.3329/dujbs.v21i2.11516

Bangladesh Fisheries Research Institute, Riverine Station (BFRI/RS). (2021). *Hilsa fisheries development and management* (Annual Report BFRI/RS 18-21). BFRI/RS.

Bangladesh Fisheries Research Institute, Riverine Station (BFRI/RS). (2023). *Hilsa fisheries development and management* (Annual Report BFRI/RS 18-23). BFRI/RS.

Bhaumik, U., & Sharma, A. P. (2011). The fishery of Indian shad (*Tenualosa ilisha*) in the Bhagirathi-Hooghly River system. *Fishing Chimes*, *31*(8), 21–27.

Bhuyan, M. S., Bakar, M. A., Akhtar, A., Hossain, M. B., & Islam, M. S. (2017). Analysis of water quality of the Meghna River using multivariate analyses and RPI. *Journal of the Asiatic Society of Bangladesh, Science*, *43*(1), 23–35.

Blaber, S. J. M., Milton, D. A., Brewer, D. T., & Salini, J. P. (2001). The shads (Genus *Tenualosa*) of tropical Asia: An overview of their biology, status and fisheries. In *Proceedings of the International Terubok Conference*. Sarawak, Malaysia.

Chatterjee, S. K., Malick, C., Banik, S. K., Bhattacharya, S., Kundu, R., Suresh, V. R., & Saikia, S. K. (2021). Do hydro-biological factors influence spawning migration: A case study of Hilsa's (*Tenualosa ilisha*) breeding habitat in Ganga River, India. *Egyptian Journal of Aquatic Biology and Fisheries*, *25*(3), 187–199.

Choudhury, S., & Panigrahy, R. (1991). Seasonal distribution and behavior of nutrients in the creek and coastal waters of Gopalpur, East coast of India. *Mahasagar-Bulletin of the National Institute of Oceanography*, *24*, 81–88.

Davies, O. A., Abowei, J. F. N., & Tawari, C. C. (2009). Phytoplankton community of Elechi Creek, Niger Delta, Nigeria-a nutrient-polluted tropical creek. *American Journal of Applied Sciences*, *6*(6), 1143–1152.

De, D. K. (1980). Maturity, fecundity and spawning of post-monsoon run of Hilsa, *Hilsa ilisha* in the upper stretches of the Hoogly estuarine system. *Journal of the Inland Fisheries Society of India*, *12*, 54–63.

De, D. K., & Sen, P. R. (1988). Observations on the embryonic and early larval development of Indian shad, *Tenualosa ilisha* (Ham.). *Journal of the Inland Fisheries Society of India*, *18*, 1–12.

Dutta, S., Abri, I. A., & Paul, S. (2021). Bioeconomic trends of Hilsa (*Tenualosa ilisha*) fishery: Perspectives of transboundary management between India and Bangladesh. *Marine Policy*, *128*, Article 104483.

Ferreira, J. C., Andersen, J. H., Borja, A., Bricker, S. B., Camp, J., Silva, M. C., Garcés, E., Heiskanen, A. S., Humborg, C., Ignatiades, L., Lancelot, C., Menesguen, A., Tett, P., Hoepffner, N., & Claussen, U. (2011). Overview of eutrophication indicators to assess environmental status within the European Marine Strategy Framework Directive. *Estuarine, Coastal and Shelf Science*, *93*(2), 117–131.

Haroon, Y. (1998). Hilsa shad: Fish for the teeming millions, new management alternatives needed for the hilsa young. *Shad Journal*, *3*(7).

Hasan, K. M. M., Wahab, M. A., Ahmed, Z. F., & Mohammed, E. Y. (2015). *The biophysical assessments of the hilsa fish (Tenualosa ilisha) habitat in lower Meghna, Bangladesh* (IIED Working Paper). International Institute for Environment and Development.

Hasan, K. M. M., Ahmed, Z. F., Wahab, M. A., & Mohammed, E. Y. (2016). *Food and feeding ecology of hilsa (Tenualosa ilisha) in Bangladesh's Meghna River basin*. International Institute for Environment and Development.

Hilaluddin, F., Yusoff, F. M., & Toda, T. (2020). Shifts in diatom dominance associated with seasonal changes in an estuarine mangrove phytoplankton community. *Journal of Marine Science and Engineering*, *8*(7), 528.

Hora, S. L. (1940). Dams and the problems of migratory fishes. *Current Science*, *9*, 406–407.

Hossain, M. S., Das, N. G., Sarker, S., & Rahaman, M. Z. (2012). Fish diversity and habitat relationship with environmental variables at the Meghna River estuary, Bangladesh. *Egyptian Journal of Aquatic Research*, *38*(3), 213–226.

Hossain, M. S., Sharifuzzaman, S. M., Rouf, M. A., Pomeroy, R. S., Hossain, M. D., Chowdhury, S. R., & AftabUddin, S. (2019). Tropical hilsa shad (*Tenualosa ilisha*): Biology, fishery, and management. *Fish and Fisheries*, *20*(1), 44–65.

Hossain, M. Y., Sayed, S. R. M., Rahman, M. M., Ali, M. M., Hossen, M. A., Elgorban, A. M., & Ohtomi, J. (2015). Length-weight relationships of nine fish species from the Tetulia River, southern Bangladesh. *Journal of Applied Ichthyology*, *31*(5), 967–969.

International Report to the Bath University Center for Development Studies (IRBUCD). (1994). *Biological assessment of the fisheries. Floodplain fisheries Project*. MRAG.

Islam, M. M., Islam, N., Sunny, A. R., Jentoft, S., Ullah, M. H., & Sharifuzzaman, S. M. (2016). Fishers' perceptions of the performance of hilsa shad (*Tenualosa ilisha*) sanctuaries in Bangladesh. *Ocean & Coastal Management*, *130*, 309–316.

Jones, S., & Menon, P. M. G. (1951). Observations on the life history of the Indian Shad, *Hilsa ilisha* (Hamilton). *Proceedings of the Indian Academy of Sciences*, *31*, 101–125.

Krishnan, A., Das, R., & Vimexen, A. (2020). Seasonal phytoplankton succession in Netravathi–Gurupura estuary, Karnataka, India: Study on a three-tier hydrographic platform. *Estuarine, Coastal and Shelf Science*, *242*, Article 106830.

Madramootoo, C. A., Johnston, W. R., & Willardson, L. S. (1997). *Management of agricultural drainage water quality*. Food and Agriculture Organization of the United Nations.

Ministry of Fisheries and Livestock (MoFL). (2014, November 27). *Sanctuary Number 1 to 5* (Bangladesh Gazette, SRO No. 269-Law/2014). MoFL.

Mozumder, M. M. H., Wahab, M. A., Sarkki, S., Schneider, P., & Islam, M. M. (2018). Enhancing social resilience of the coastal fishing communities:

A case study of hilsa (*Tenualosa ilisha*) fishery in Bangladesh. *Sustainability*, *10*(10), 3501.

Nair, P. V. (1958). Seasonal changes in the gonads of *Hilsa ilisha* (Ham.). *Philippine Journal of Science*, 255–276.

Pillay, S., & Rosa, H. (1963). Synopsis of biological data on hilsa, *Hilsa ilisha* (Ham.) 1822. *FAO Fisheries Biology Synopsis*, 25–61.

Pillay, S. R., & Rao, K. Y. (1962). Observations on the biology and fishery of the *Hilsa ilisha* (Ham.) of the river Godavari. *Proceedings of the Indo-Pacific Fisheries Council*, *10*, 37–61.

Pillay, T. V. R. (1958). Biology of the hilsa, *Hilsa ilisha* (Ham.) of the river Hoogly. *Indian Journal of Fisheries*, *5*, 201–257.

Pramanik, M. M. H., Rahman, M. A., Ahmed, T., Flura, Hasan, M. M., Khan, M. H., & Mahmud, Y. (2017). Gill net selectivity of Hilsa (*Tenualosa ilisha*) in the Meghna River estuary of Bangladesh. *Journal of Aquaculture Research & Development*, *8*(4). https://doi.org/10.4172/2155-9546.1000483

Prescott, G. W. (1962). *Algae of the western Great Lakes area* (2nd ed.). William C. Brown Company.

Quddus, M. M. A. (1982). *Two types of Hilsa ilisha and population biology from Bangladesh water* [Doctoral dissertation, The University of Tokyo].

Quddus, M. M. A., Shimizu, M., & Nose, Y. (1984). Spawning and fecundity of two types of *Hilsa ilisha* in Bangladesh waters. *Bulletin of the Japanese Society of Scientific Fisheries*, *50*, 177–181.

Rahman, M. J. (2001). *Population biology and management of the hilsa shad (Tenualosa ilisha) in Bangladesh* [Doctoral dissertation, University of Hull].

Rahman, M. J. (2006). Recent advances in the biology and management of Indian shad (*Tenualosa ilisha*). *SAARC Journal of Agriculture*, *4*, 67–90.

Rahman, M. A., Ahmed, T., Pramanik, M. M. H., Flura, Hasan, M. M., Riar, M. G. S., Hasan, K. H., Khan, M. H., & Mahmud, Y. (2017). On-board breeding trial of Hilsa (*Tenualosa ilisha*, Ham. 1822) and testing of larval rearing in Bangladesh. *Journal of Aquaculture Research & Development*, *8*(2). https://doi.org/10.4172/2155-9546.1000471

Rahman, M. A., Pramanik, M. M. H., Flura, Ahmed, T., Hasan, M. M., Khan, M. H., & Mahmud, Y. (2017). Impact assessment of twenty-two days fishing ban in the major spawning grounds of *Tenualosa ilisha* (Hamilton, 1822) on its spawning success in Bangladesh. *Journal of Aquaculture Research & Development*, *8*, 489.

Rahman, M. S. (1992). *Water quality management in aquaculture*. BRAC Prokashana.

Rahman, M. S., Ahmed, A. S. S., Rahman, M. M., Babu, S. M. O. F., Sultana, S., Sarker, S. I., Awual, R., Rahman, M. M., & Rahman, M. (2021). Temporal assessment of heavy metal concentration and surface water quality representing the public health evaluation from the Meghna River estuary, Bangladesh. *Applied Water Science*, *11*(7), 121.

Rahman, M. A., Pramanik, M. M. H., Flura, Hasan, M. M., Ahmed, T., Alam, M. A., Hasan, S. J., Rahman, B. M. S., Haidar, M. I., Rashid, M. H., Zaher, M., Khan, M. H., & Mahmud, Y. (2024). Sixth sanctuary identification research and establishment strategy for enhancing production and conservation management of Hilsa (*Tenualosa ilisha*) in Bangladesh. *International Journal of Aquatic Research and Environmental Studies*, *4*(1), 37–47.

Rao, K. Y., & Pathak, C. S. (1972). A note on the occurrence of spawning of *Hilsa ilisha* (Ham.) in the river Brahmaputra (Assam). *Proceedings of the National Academy of Sciences, India Section B*, *42*, 231–233.

Shaha, D. C., Ahmed, S., Hasan, J., Kundu, S. R., Haque, F., Rahman, M. J., Nahiduzzaman, M., & Wahab, M. A. (2022). Fish diversity in relation to

salinity gradient in the Meghna River Estuary. *Bangladesh Journal of Fisheries*, *34*(2), 145–155.

Shaha, D. C., Hasan, J., Kundu, S. R., Yusoff, F. M., Salam, M. A., Khan, M., Haque, F., Ahmed, M., Rahman, M. J., & Wahab, M. A. (2022). Dominant phytoplankton groups as the major source of polyunsaturated fatty acids for hilsa (*Tenualosa ilisha*) in the Meghna estuary Bangladesh. *Scientific Reports*, *12*(1), Article 20980.

Shaha, D. C., Hasan, J., Ahmed, S., Faysal, M. M. H., Kar, A., Haque, F., Salam, M. A., Reza, M. S., & Seba, R. N. (2023). Assessment of spawning and nursery habitats of hilsa in the Tetulia and Meghna river estuaries. *Annals of Bangladesh Agriculture*, *27*(1), 57–69.

Vajravelu, M., Martin, Y., Ayyappan, S., & Mayakrishnan, M. (2018). Seasonal influence of physico-chemical parameters on phytoplankton diversity, community structure and abundance at Parangipettai coastal waters, Bay of Bengal, South East Coast of India. *Oceanologia*, *60*(2), 114–127. https://doi.org/10.1016/j.oceano.2017.08.003

Ward, H. B., & Whipple, G. C. (1959). *Fresh-water biology* (2nd ed.). John Wiley & Sons.