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Assessment of physicochemical properties of water for the potentiality of hilsa fishes in compare to Bangladesh: A case study of the northwestern part of the bay of Bengal

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Abstract
One of the most usual and emergent tropical anadromous species is Hilsa (*Tenualosa ilisha*) in West Bengal and Bangladesh. It is very popular as well as commercial fishes in Bengali cuisine. Estuary plays a significant role to make breeding and nursery grounds for different biotic and abiotic organisms. The estuary system is very much productive when it pockets an extensive load of silt and nutrients along with massive freshwater from Ganga. A significant amount of nutrients pass into the channel inlet and its tributaries that control the whole system eminently productive during the tidal fluctuations of the estuary. The present study deals with the physical, chemical, and biological diversity of water quality in the estuary and marine water. A comparative assessment has been carried out to measure the acceptable range of physicochemical parameters of water for the potential zone of hilsa fishes of the northwestern part of the Bay of Bengal. Simultaneously, fish catch data is used to validate the potentiality of hilsa fishes of the study area. Several statistical operations have been assimilated to assume the data variability and data accuracy of water quality for the suitable environment of hilsa species and to achieve the seasonal disparity of hilsa catch in the northwestern part of Bay of Bengal.

Keywords: physicochemical parameters, hilsa catch, standard deviation, standard error, high and low tide

Introduction

Hilsa is the national fish of Bangladesh which belongs to the *Clupeidae* family under the genus, *Tenualosa,* and species *Ilish*. In these three species of Hilsa, the *Tenualosa ilisha* is captured up to 99 percent in the Bay of Bengal water (Rahman *et al*., 2012a) [25]. During the period of undivided Bengal (1947), a huge amount of fish was collected from the East Bengal and shipped to the Kolkata market, West Bengal for selling the fishes (Ali, 1991) [4]. The species not only cohesions the straddling ecosystems of Bangladesh and India but also supports the livelihood practices between the two countries. According to Rahman (2005) [24] basically, two types of *Hilsa* have resided in the Bay of Bengal region. The first one is the *Tenualosa ilisha* (Hamilton) locally known as *Ilish* termed as *Hilsa* shad and another is *Tenualosa toli* (Valenciennes) locally known as *Chandana* and Toli shad in English. Among them, *Tenualosa ilisha* ranked as a leading and commercial fish of the estuary based on their relevant characteristic. It is reported that about 50-60 percent of hilsa is globally caught from Bangladesh waters; 20-25 percent caught by Myanmar; 15–20 percent caught by India and 5-10 percent caught by the other countries (Rahman *et al*., 2010). Since the 1970 century, the hilsa fishes are progressively collapsed due to the use of small-size fishing nets, pollutions, hydrological and climatological changes, and other anthropogenic activities (Mohammed & Wahab, 2013) [22]. The fishes are extensively distributed in the riverine, marine, and estuarine environments in the Bay of Bengal for their migratory characteristics. Recently, the species is predominantly distributed in the coastal and estuarine environment of the Bay of Bengal and the tributaries and distributaries of major rivers (e.g., Ganga, Padma, Meghna and Rupsha, etc.) in the northeastern part of the country. The ongoing growth of urbanization, industry, arbitrary use of pesticides, fertilizer agrochemicals and waste material continuously contaminate the river systems as well as the water quality of the Bay of Bengal (Ahmed *et al*., 2011) [1]. Particularly, the life cycle of Hilsa is mainly influenced by the biological, hydrological, physical and chemical parameters of the water. It may, directly and indirectly, affect the circulation and fabrication of fish and other aquatic organisms (Moses, 1983; Varshney *et al*., 2004) [28]. Therefore, it is very essential to assess the water quality parameters of potential Hilsa fisheries and to improve the realization of hilsa fisheries management action plan. Although satellite-derived Potential Fishing Zone (PFZ) advisory and Catch per Unit Effort (CPUE) of PFZ are studied by Maity *et al*. (2015) [19] and Dutta *et al*. (2016) [10, 11] in the northwestern part of the Bay of Bengal.

Physical setup of the study area

The study area is covered by the estuary mouths of Hugli River, Muriganga River, Saptamukhi River and Thakurani River in the northern part of the Bay of Bengal coast within the South 24 Parganas and Purba Medinipur Districts of West Bengal, India. These are the distributary system of Ganga-Bhagirathi River system. The entire area is extended from 88°01'19.84"E to 88°27' 11.58"E and 21°18'32.74"N to 21°53'39.35"N. The area is highly influenced by the different type of coastal hazards and consequent tidal floodings (Fig. 1).

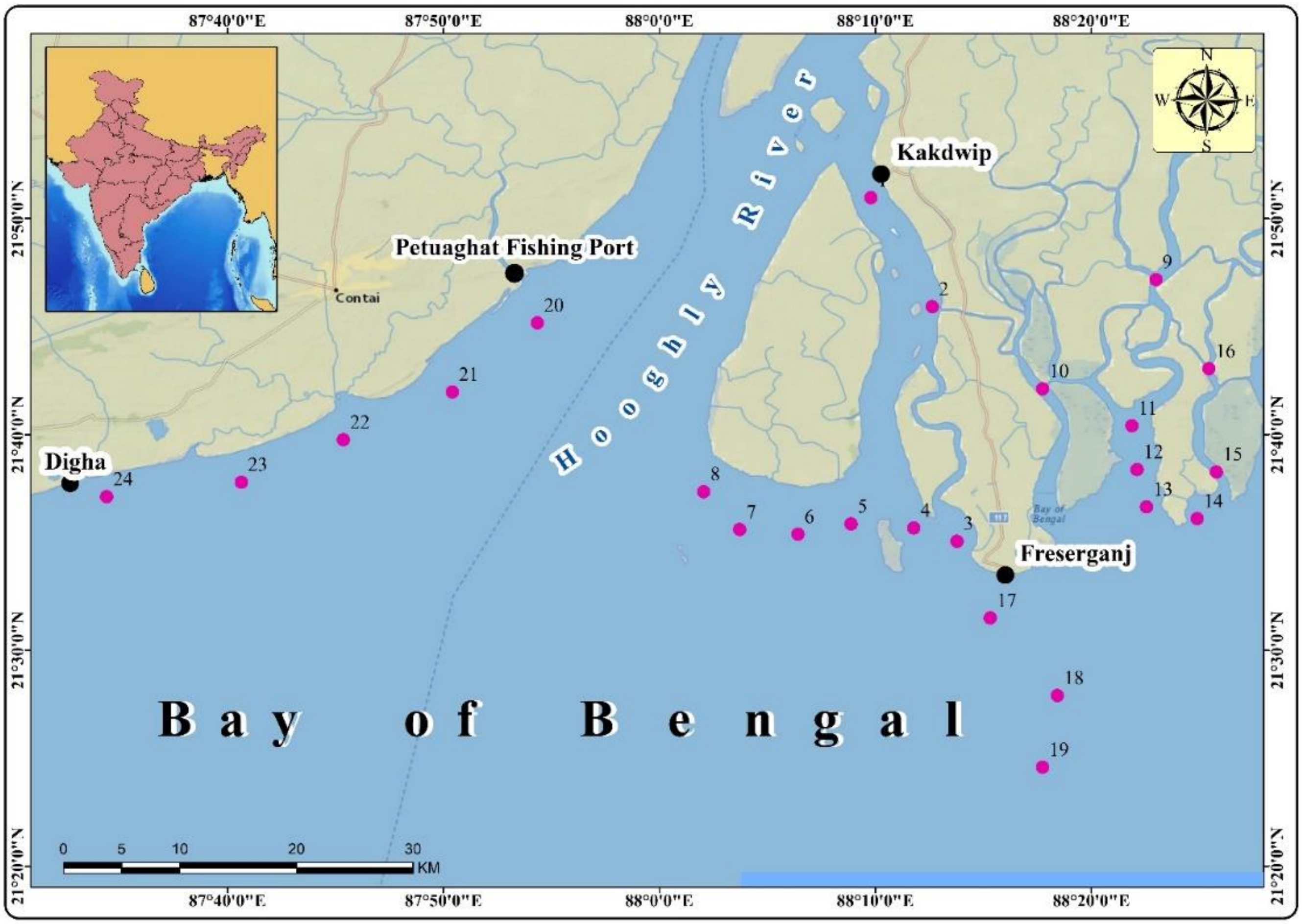

Fig 1: Location map of the sampling sites/study area.

The studied region is composed of low-lying coastal terraces coupled with extensive fluvio-marine depositional plains, deltaic islands, estuaries, interconnecting tidal creeks with intervening estuaries, mudflats and sandy beaches. The study area belongs to the tropical monsoon type of climate with seasonal reversal of wind system.

Materials and Methods

The present study combines the random sampling technique to collect the in-situ data in the estuary and marine waters through the fishing trawlers. Twenty four (24) sample sites have been selected to understand the variability of the water column for measuring the water quality parameters in different sectors of the study area. In this study, repetitive fieldwork is conducted in two temporal phases particularly post-monsoon (October to December) and winter (January to February) for sampling the physical, chemical and biological characteristics of water in High Tide (HT) and Low Tide (LT) phase. However, Water quality assessment was made by several ecologists (Zindge & Desai, 1985; Meire & Vinex, 1993; De, 1995; Gupta *et al*., 2001; Bhaumik *et al*., 2003; Borja *et al*., 2004; Rahman *et al*., 2012b) [20, 9, 26] in the different perspective of the various estuary and fishery research. Conductivity, Temperature and Depth (CTD) instrument is deployed in 0 m and 05 m depth to measure the in-situ physical characteristic of seawater as well as estuarine water. Simultaneously, Niskin Water Sampler has been used for the collection of different depths of water through cleaned Tarson bottles made of non-reactive poly-acrylic materials for measuring the nutrient changeability of waters. The awareness camp has been repeatedly conducted with the fisherman regarding the hilsa fishing in several fishing harbor stations e.g., Digha Mohana, Petuaghat, Freserganj, etc. (Fig. 8). Finally, all the datasets are assimilated and calculated by the inconsistency of several statistical deviations. Physicochemical parameters and nutrient concentrations have been normalized through a z-test of different temporal phases. Hierarchical Cluster Analysis (HCA) has been initiated to identify the cluster's shape and the diversity of variables. Based on these assessments the present study established a comparative analytical approach to evaluate and validate the acceptable range of potential hilsa fishing zone in the estuary and marine environment of the northwestern part of the Bay of Bengal (Table 1).

Table 1: Acceptable range of water quality parameters of hilsa in Bangladesh water.

	Nitrate (µmol/l)	**Nitrite (µmol/l)**	**Silicate (µmol/l)**	**Phosphate (µmol/l)**	**Ammonium (µmol/l)**
	2.89-11.06	0.65-1.28	13.01-39.30	0.22-1.81	0.22-0.88
Conductivity (s/m)	**Turbidity (NTU)**	**Chlorophyll (mg/m^3)**	**Salinity (PSU)**	**Temperature (Degree C)**	**Dissolved Oxygen (mg/l)**
0.23-1.89	20-70	0.18-0.62	13.9-25.1	26.12-30.8	4.99-6.78

Results and Discussions

The requirement of ions are classically known as nutrients and these are the key component of plant growth and fertilizer of oceans (Duxbury, 2000) [12]. Nitrate, Nitrite and Ammonia are considered a life-supporting component of inorganic substances. But phosphorus and silicates are playing a significant role in the profusion, growth rate of plankton and metabolism activities of other organisms (Raymont, 1980) [27]. The potentiality of the fertility in any coastal waters depends on the distribution of the nutrient content. So the productivity analysis is highly influenced by the exploration of nutrient content and behavior of coastal ecosystems. Based on the existing literature, the study skilled to set up the acceptable range of physicochemical parameters of water quality for nursery, breeding and migration ground of hilsa fisheries (Kannappan & Karthikeyan, 2013; Banerjee *et al*., 2013; Ali *et al*., 2014; Ahsan *et al*., 2014; Hasan *et al*., 2015; Dutta *et al*., 2016; Das *et al*., 2018; Hossain *et al*., 2019; Mitra *et al*., 2019) [18, 5, 3, 2, 16, 10, 11, 17]. The water samples are collected during the period of Post- monsoon and winter seasons of high tide and low tide phase. The data is plotted against the standard line of hilsa availability zone of Bangladesh water to assess the possibility of hilsa fishes over the northwestern part of the Bay of Bengal.

Chemical properties of water

The nitrogen cycle commonly eliminates ammonia in the water body through the conversion of toxic components of the material. A small number of ammonia damages the gills and other aquatic organisms in intensive systems. Ammonia concentration found preferable conditions at the sites-5 to site-19 in the post-monsoon season. On the other hand, there is no significant value of ammonia are found in the winter phase for the development of hilsa fishes in the marine as well as estuarine water of the study area. Nitrates are used as a building block of algae and other plants, so the surplus level of nitrates promotes the excessive growth of algae and that can create a eutrophication situation in a water body. The standby development of plants and algae produces an unbalanced amount of dissolved oxygen which makes an anxious situation for fishes and other organisms in the water body. Nitrate concentration is observed more or less the same during both seasons and it is revolving close to the acceptable range in all sites of the study area (Fig. 2).

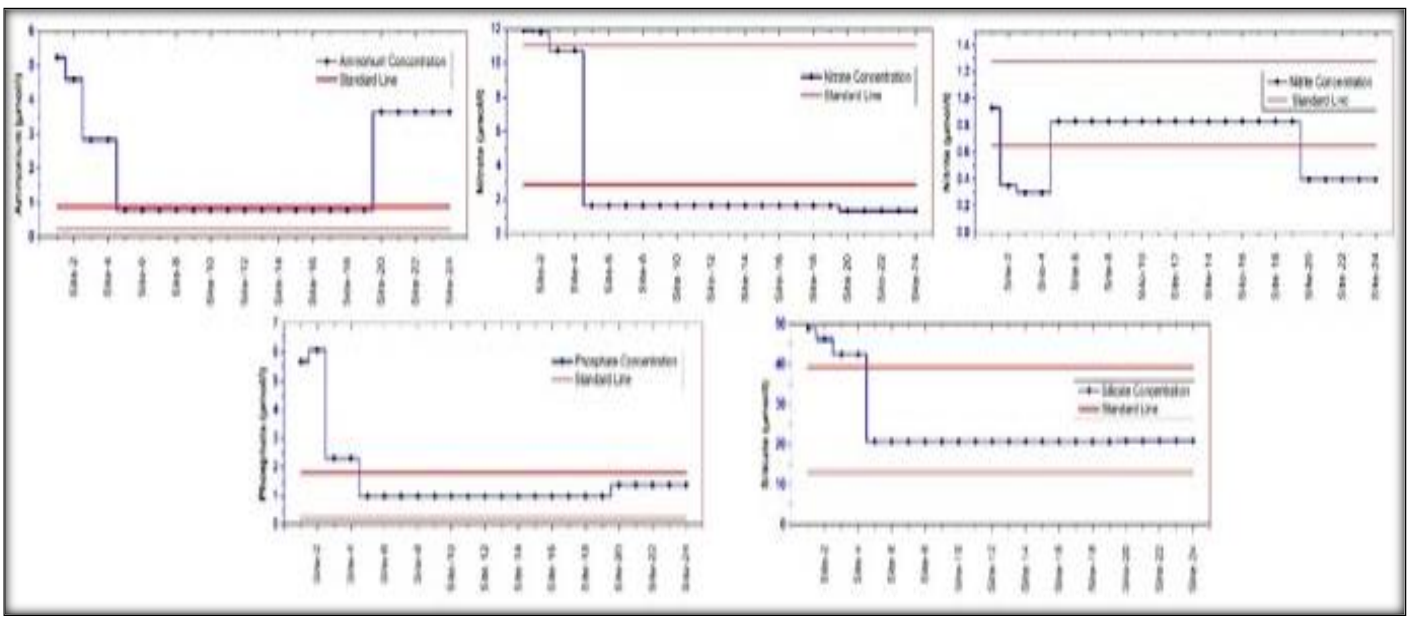

Fig 2: Distribution of chemical properties of water in the post-monsoon season.

Nitrite is considered a harmful factor for the living organism in aquatic waters because it promotes the irretrievable oxidization of hemoglobin that can trim down the oxygen transportation to blood. Being intermediate toxicity, nitrite increases the pH and interrupts the growth, resistant response and oxygen transport etc. In the post-monsoon phase, site-5 to site-19 gives significant value than other sites. But in winter, there has some inconsistent trend of nitrite in the study area. Phosphorous is very essential for aquatic species and it is a key indicator of water quality in the estuary as well as seawater. An excessive level of phosphorus acts as a pollutant in the water and it leads to going off blooms of algae that could exhaust the oxygen and makes critical conditions for aquatic animals. The phosphate concentration of all sites shows very adjacent to the acceptable range for hilsa fisheries except the range of site-1 to site-3 in the Post-Monsoon season. But in the winter season, phosphate distribution is under acceptable range for the development of hilsa community (Fig. 3).

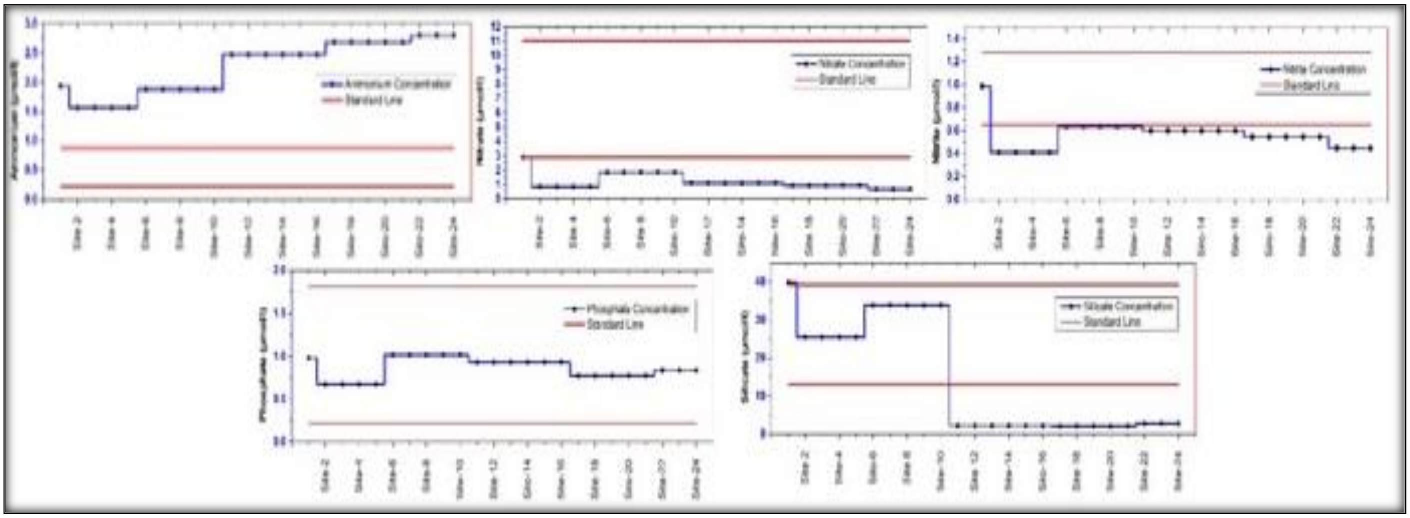

Fig 3: Distribution of chemical properties of water in the winter season.

Silicon comes in the form of dissolved silicate to the coastal and estuarine environment through the runoff process. A low concentration of silicate bears the selective control on the species composition of phytoplankton in the seawater. However, silicate concentration regulates the growth rate of algae and diatoms (Guillard *et al*., 1973; Harrison *et al*., 1976) [13, 15]. The increased rate of silicate is consuming diatoms and the consequent removal of biogenic silica. Phosphate-induced eutrophication is mainly caused by the lacking of dissolved silicates. A lower concentration of silicate is found in all sites of the study area in the Post-Monsoon phase. On the other hand, all sites are showing a very unstable trend of silicates in the winter season.

Physical properties of water

Conductivity is the measurement of the electrical flow capabilities of water and it is frankly connected to the ion concentration in the water. Dissolved salts and inorganic materials such as carbonate, chlorides, alkalis and sulfides compounds are the major sources of conductive ions in the water. The presence of a higher concentration of chloride, phosphate and nitrate ions in a body of water suddenly increased the conductivity due to their breaking nature. Chlorophyll is a living pigment in plants that absorb the light energy for processing the food to grow plants and release oxygen by the photosynthesis process. The presence of chlorophyll concentration in the water provides the message about the density of phytoplankton in the water. Phytoplankton can formulate the base of the aquatic food web in an estuary system and it is the primary production of the ecosystem which is eaten by the sequential consumers for abiding the food cycle. Dissolve oxygen is a key element in an estuary and seawater that can affect the distribution and abundance of organisms in a variety scale of habitats. Two natural processes are involved to entrance the oxygen into the water such as photosynthesis by aquatic plants and diffusion from the atmosphere. The atmospheric oxygen is dissolved or absorbed by the wind and waves with the form of surface water mixing into the water. Temperature and salinity directly influence the DO level because of the increasing rate of temperature and salinity. That can reduce the solubility and dissolves the capability of oxygen in the water. Chlorophyll concentration and conductivity range exceeds all sites and dissolve oxygen value also overstep the acceptable range of the entire region during the winter season. But dissolve oxygen plays very close to the acceptable range in Post-Monsoon season (Figs. 4, 5).

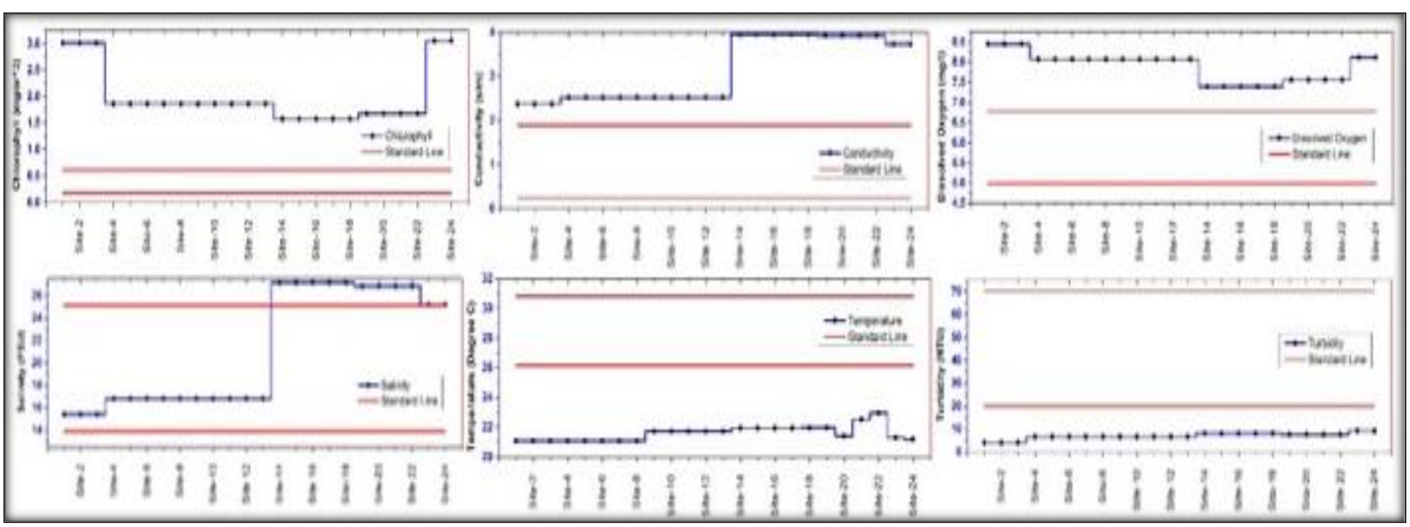

Fig 4: Distribution of physical parameters of water (0 m depth) in the winter season.

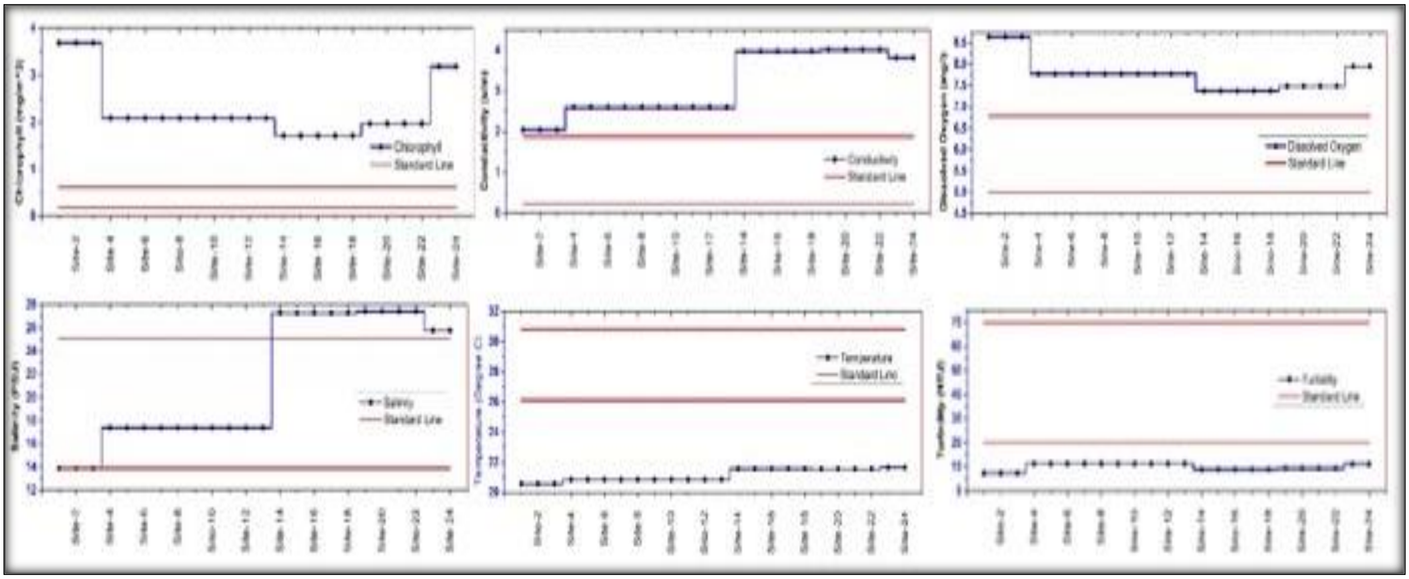

Fig 5: Distribution of physical parameters of water (05 m depth) in the winter season.

Salinity is observed higher in the river mouth where seawater and freshwater are mixing during the summer phase. The salinity level is gradually increased when higher temperature influences the rising rate of evaporation in the estuary. But salinity naturally turns down in the springtime because when the heavy rainfall increases the freshwater flow in the stream. On the other hand that can stabilize the groundwater table. The level of salinity directly affects the growth and reproduction of organisms and it also helps to change the chemical condition of water particularly dissolve oxygen in the water body. The salinity of the open ocean is remarkably constant (35 ppt) but in the estuary system salinity differs due to the volume of freshwater flow into the estuary and changes of daily tide level of the estuary. As the suspended sediments, solid waste and other dissolve materials increase in the water, the amount of light that cannot pass into the deep water. It is essential for the aquatic plants because it directly affects to carry out the photosynthesis of aquatic plants and indirectly affects the other organisms. Which are dependent on these plants for the needs of food and oxygen (Figs. 6, 7).

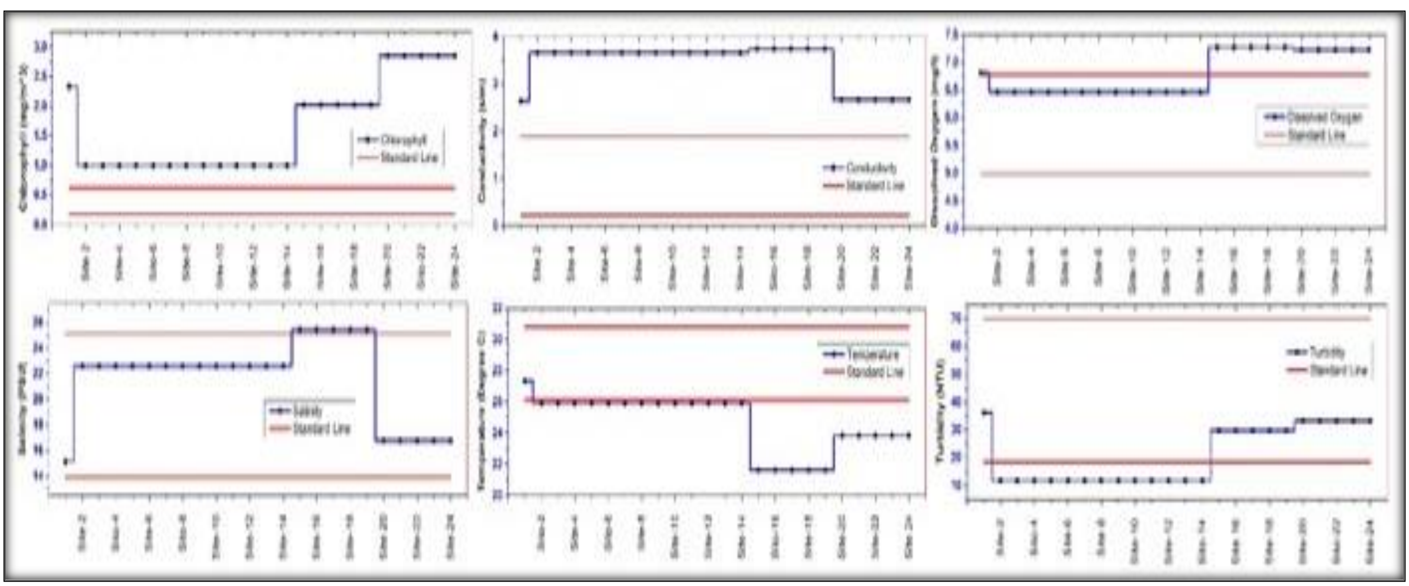

Fig 6: Distribution of Physical parameters of water (0 m depth) in the post-monsoon season.

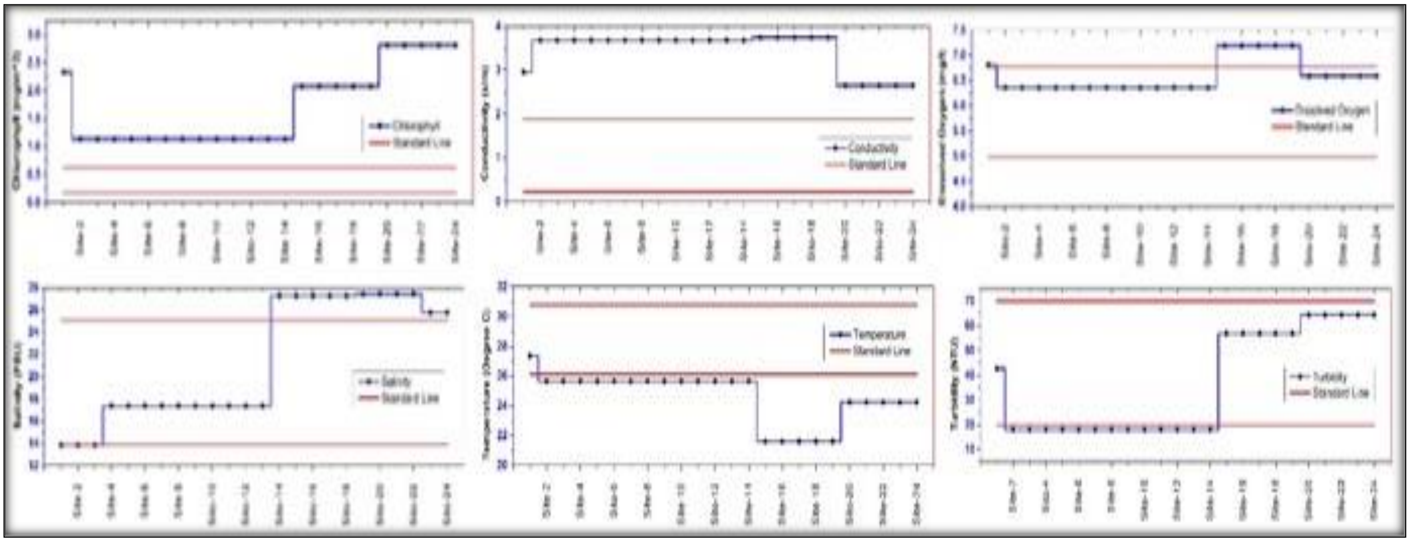

Fig 7: Distribution of physical parameters of water (05 m depth) in the post-monsoon season.

Water temperature gives an idea of dissolved oxygen concentration in the water and helps to understand the healthier condition of the ecosystem. The increasing rate of water temperature can reduce the dissolved oxygen in the water, so the seasonal fluctuation of water temperature is a good marker for assessing the habitat quality. On the other hand, water temperature reflects which type of animals and plants are surviving in a particular system. Because all types of habitat have a specific range of temperatures to sustain their life cycle.

Fig 8: (A) In-situ water quality measurement through CTD; (B) Water sample collected for chemical analysis through Niskin Sampler; (C) Chemical analysis of water sample in the Laboratory and (D) Respondent survey with the fisherman for collecting the fish catch data.

Salinity, temperature and turbidity illustrate a very significant level than other parameters of the water quality which is very close to the acceptable range in the Post-Monsoon phase for suitability of hilsa fisheries. In the winter phase, there is no significant difference is found in the water quality parameter in 0 m to 05 m depth. Salinity and dissolved oxygen are observed slightly diverse during the Post-Monsoon phase in 0 m to 05 m depth of water. All the nutrient concentrations are revealed at various levels of magnitude during spring and neap tide stages, so it can be inferred that the tidal undercurrents play a crucial role to control the short-term changeability of nutrient concentrations of the estuary (Das *et al*., 2017) [8].

Model validation

The volumetric Catch per Unit Effort (CPUE) has been calculated to validate the hilsa fishing activities for the Monsoon, Post-Monsoon, summer and winter season. The value of the CPUE concentration is higher (18.92 and 13.25) in the Monsoon and Post-Monsoon phases than in another season (Fig. 9). The present study demonstrates the physicochemical properties of water quality to understand the fevourable condition of hilsa fishes in the monsoon and Post-Monsoon phase.

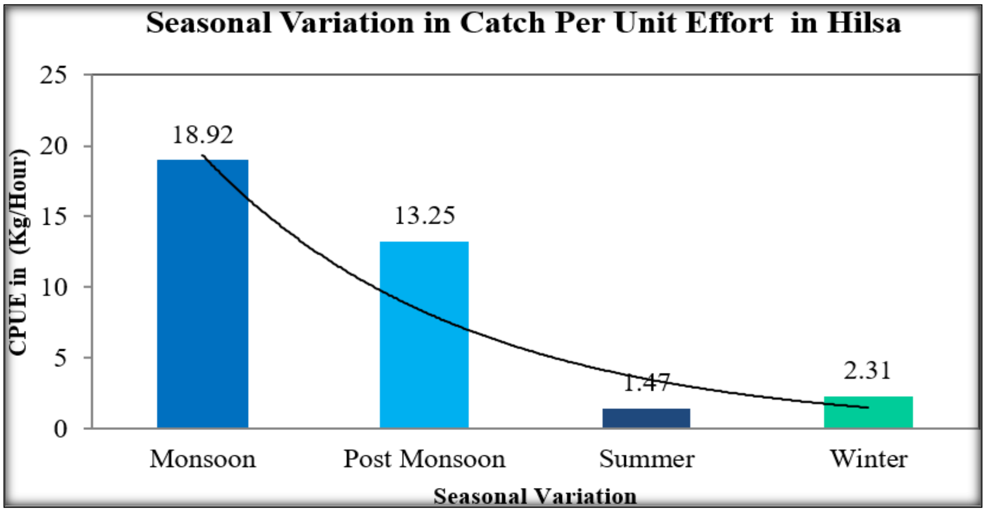

Fig 9: Seasonal variation of CPUE in Monsoon, Post-Monsoon, summer and winter.

A comparative study has been assessed to show the hilsa catch trend among the Bangladesh water and the Hugli river system (Ali *et al*., 2014) [3]. In the case of Bangladesh, hilsa catch trend is enriched from 2000 to 2011and the annual catch of hilsa has turn into highly moveable from the Hooghly-Bhagirathi river system over the years (Fig. 10). The hilsa catch trend gradually decreased from 2000 to 2010 in the Hugli river system region. But in 2011 it is suddenly increased and continued up to the present and that will be the make-believe to the researcher for assessing the reason behind the trend.

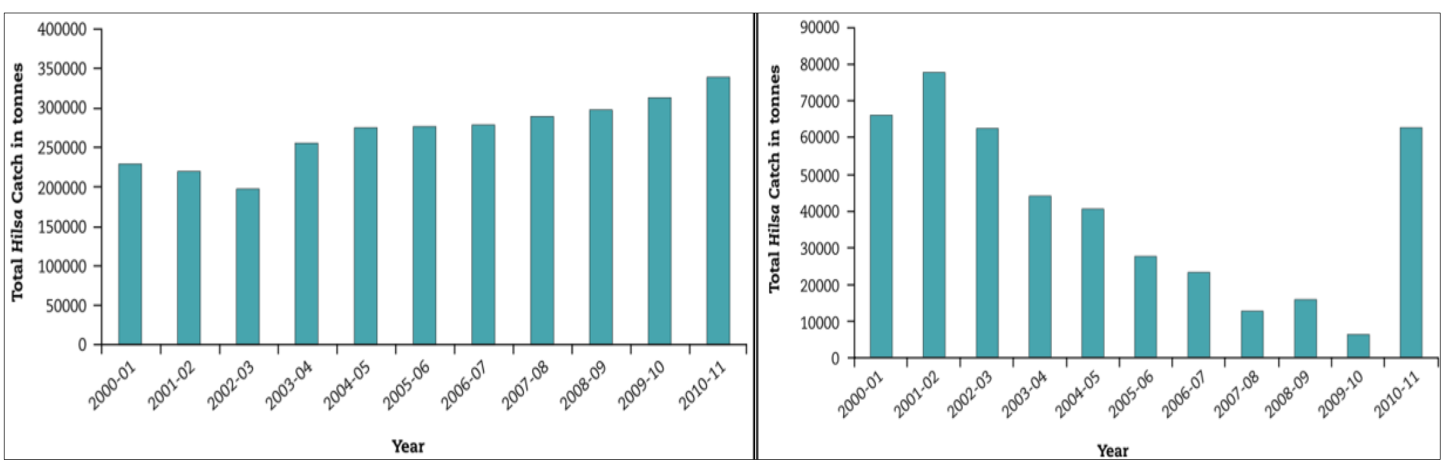

Fig 10: Hilsa catch of Bangladesh inland and marine water (left); and Hugli-Bhagirathi river system (right) from 2000 to 2010.

Standard Deviation and Standard Error

The physicochemical datasets have been assessed through the standard deviation and standard error method to validate the adequacy of data. This statistical simulation denotes the data variability and data acceptability of a data set which is very important for the analysis of water quality parameters. Because it supports to detect the nature of data. There is a substantial precision found in the dataset and the variability is not remote farthest away from the mean so, the sampling has supportive tolerability for the analysis (Tables 2, 3, 4).

Table 2: Calculation of mean, standard deviation, standard error of nutrient parameters of all sites of winter and post-monsoon season (2018-2020).

Winter Season						
	Low Tide			High Tide		
Nutrients	**Mean**	**Standard Deviation**	**Standard Error**	**Mean**	**Standard Deviation**	**Standard Error**
Nitrate	2.0402	2.2325	0.4655	2.3000	3.6788	0.6952
Nitrite	0.5661	0.2931	0.0611	0.5696	0.2380	0.0450
Silicate	13.5588	12.7165	2.6516	12.4193	11.5556	2.5618
Phosphate	0.8285	0.2803	0.0584	0.8580	0.2939	0.0555
Ammonium	2.2629	1.5006	0.3129	2.1412	1.2753	0.2410
Post-Monsoon Season						
Nitrate	1.8857	1.7659	0.3949	0.9470	1.1845	0.3166
Nitrite	0.6588	0.3419	0.0764	0.5198	0.2720	0.0727
Silicate	22.3633	4.4430	0.9935	18.7291	3.7061	0.9905
Phosphate	1.2263	0.5019	0.1122	1.1494	0.6808	0.1820
Ammonium	2.4322	2.4536	0.5486	2.0870	2.3135	0.6183

Table 3: Calculation of mean, standard deviation, standard error of physicochemical parameters of all sites of winter and post-monsoon season in 0 m depth (2018-2020).

Winter Season						
0 m Depth	Low Tide			High Tide		
Parameters	**Mean**	**Standard Deviation**	**Standard Error**	**Mean**	**Standard Deviation**	**Standard Error**
Conductivity	2.9943	0.7632	0.1799	3.3971	0.5771	0.1443
Turbidity	7.5652	2.6914	0.6344	5.9607	2.6871	0.6718
Chlorophyll	2.3484	1.0982	0.2588	1.5228	0.5605	0.1401
Salinity	20.2642	5.3316	1.2567	22.9898	4.2428	1.0607
Temperature	21.1622	0.6915	0.1630	21.5789	0.4089	0.1022
Dissolved Oxygen	8.1044	0.4850	0.1143	7.5602	0.4354	0.1088
Post-Monsoon Season						
Conductivity	3.4865	0.3127	0.0758	3.1857	0.7699	0.1815
Turbidity	17.5861	12.6277	3.0627	30.6864	29.0289	6.8422
Chlorophyll	1.3244	0.6945	0.1684	2.2523	1.5959	0.3762
Salinity	22.3820	2.5645	0.6220	20.0829	5.2804	1.2446
Temperature	24.0578	2.1222	0.5147	24.6959	2.0629	0.4862
Dissolved Oxygen	6.8651	0.7706	0.1869	6.8800	0.6944	0.1637

Table 4: Calculation of mean, standard deviation, standard error of physicochemical parameters of all sites of winter and post-monsoon season in 05 m depth (2018-2020).

Winter Season						
05 m Depth	Low Tide			High Tide		
Parameters	**Mean**	**Standard Deviation**	**Standard Error**	**Mean**	**Standard Deviation**	**Standard Error**
Conductivity	3.1294	0.8795	0.2781	3.1532	1.0349	0.2587
Turbidity	11.2391	4.4819	1.4173	8.7957	2.8767	0.7192
Chlorophyll	2.3204	0.5275	0.1668	2.2628	1.2767	0.3192
Salinity	21.2465	6.1344	1.9399	21.4318	7.2223	1.8056
Temperature	21.0290	0.7159	0.2264	21.1962	0.4462	0.1115
Dissolved Oxygen	7.7983	0.4040	0.1278	7.7251	0.6850	0.1712
Post-Monsoon Season						
Conductivity	3.5333	0.3099	0.0828	3.2435	0.7036	0.1951
Turbidity	42.2958	29.9822	8.0131	44.2777	33.5587	9.3075
Chlorophyll	1.7553	0.8809	0.2354	2.0859	1.1542	0.3201
Salinity	22.7949	2.5861	0.6912	20.6102	4.9396	1.3700
Temperature	23.8666	1.9991	0.5343	24.1891	1.9728	0.5472
Dissolved Oxygen	6.6938	0.5545	0.1482	6.6521	0.5113	0.1418

Standard deviation is frequently used to comprehend whether a particular information point is "standard" and expected or strange and startling. In these investigations, the Standard Deviation (SD) and the evaluated Standard Error of the Mean (SEM) are utilized to introduce the attributes of test information and to clarify factual examination results. SD is the scattering of information in ordinary dissemination. As the SD shows how precisely the mean speaks to test information. In any case, the importance of SEM incorporates measurable deduction dependent on the testing dissemination. A low standard deviation discloses to us that the information is firmly grouped around the mean (or normal), while an elevated expectation deviation shows that the information is scattered over a more extensive scope of qualities.

The standard error is a proportion of the factual precision of a measurement which is equivalent to the standard deviation of the hypothetical conveyance of an enormous sample of such measures. This measurement is a method to approve the precision of a sample or the truthfulness of different samples by breaking down deviation inside the methods. The SEM depicts how the mean is meticulous to the sample.

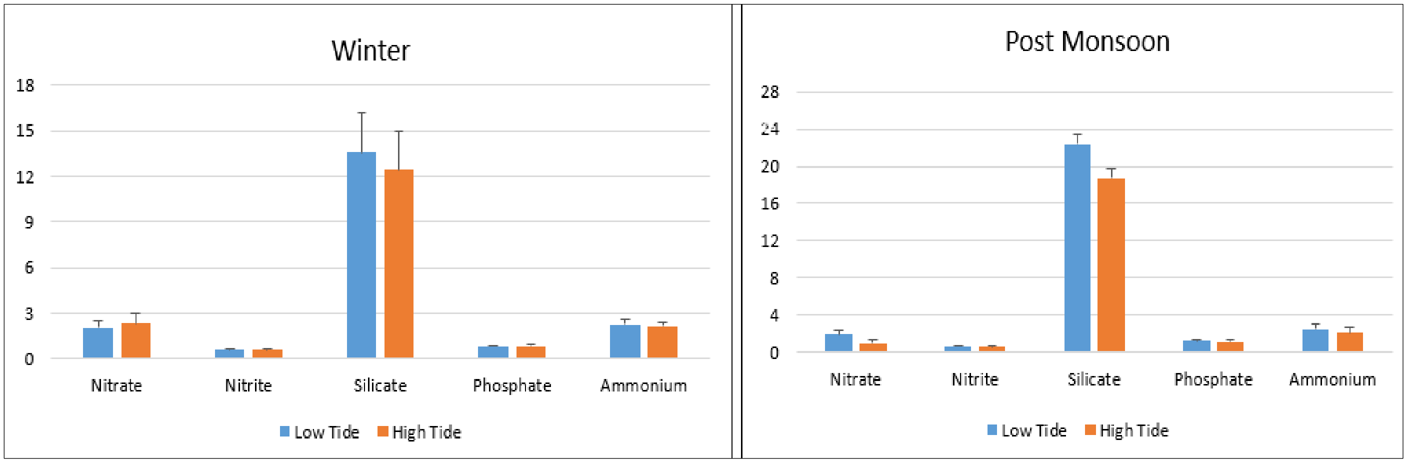

Fig 11: The error bars denote the standard deviation from the mean for the nutrient parameters during the winter and post-monsoon phase.

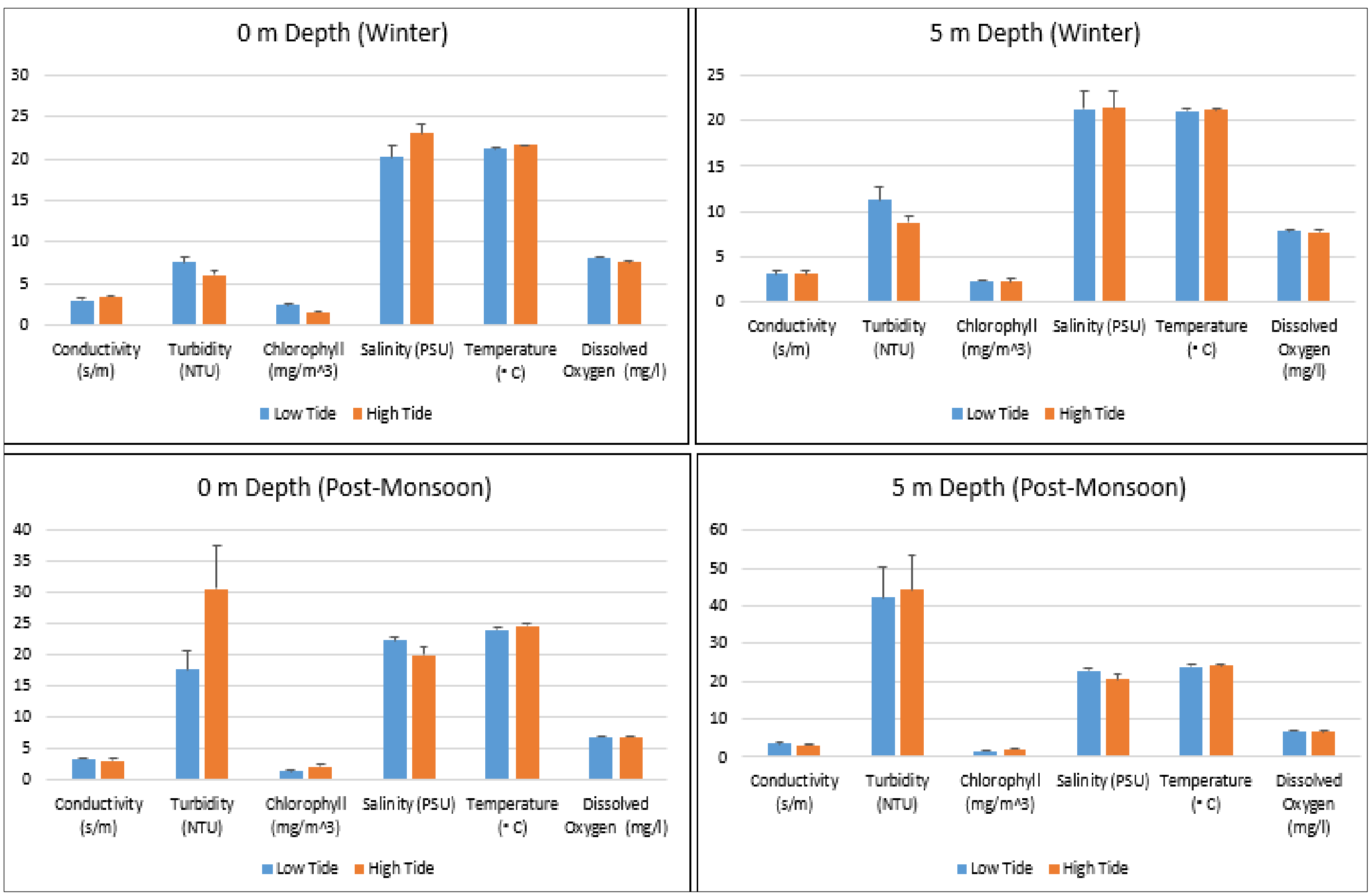

Fig 12: The error bars denote the standard deviation from the mean for the physical parameters during winter and Post-Monsoon phases.

The standard error is observed as a major aspect of informative measurements. It expresses the standard deviation of the mean inside a dataset. This fills as a proportion of variety for arbitrary factors, which gives an estimation of the spreads. The smaller the spread more precise the dataset. During the winter season, the error bar of silicate concentration is not very significant in low tide and high tide conditions. But other nutrient parameters are present in normal conditions (Fig. 11). The standard error of salinity in the 05 m depth of winter resides higher during the high tide and low tide period. On the other hand, turbidity concentration is troubled during the Post-Monsoon phase in 0 m and 05 m depth (Fig. 12).

Conclusion

In the present study, the in-situ measurement of the sample has been examined through several statistical operations. The standard deviation and standard error reveal the significant sampling strategy has been achieved in the course of the sampling period. However, the standard error of silicate, turbidity and salinity are found fluctuating trend due to the tidal pumping of the estuary. Tidal pumping is a major driving force that affects the water exchangeability between land and sea. The comparative assessment reflects the physicochemical value of water parameters are well distributed in the Post-Monsoon period for producing the suitable environment of hilsa fisheries. On the other hand, some of the parameters (e.g., ammonia, nitrate, chlorophyll, conductivity and temperature) are observed in unhinged movement in the winter season due to the lack of freshwater flow from the input channels of the estuary. But the physicochemical parameters of water are playing a significant role in the Post-Monsoon phase to keep up the favourable condition of hilsa fisheries and these have oscillated adjacent to the acceptable range of hilsa in comparison to Bangladesh.

Some acceptable range of the water quality parameters is accumulated from the high potential zone of hilsa fisheries of Bangladesh water to evaluate the comparative analysis of the present study area. Because the maximum hilsa is caught from the Bangladesh water. Accordingly, CPUE data shows a sufficient amount of hilsa caught from the entire study region based on their water quality nature. The dynamism of the physicochemical character of water is highly influenced by tidal floodings and marine influence that can act as a driving force to control the distribution pattern and dispersion of nutrients and pollutants in the estuary. Being the dynamic environment, few physicochemical parameters of water are identified as insignificant due to the movement of waves and tides in the study area. Furthermore, summer and Pre-Monsoon phases should be observed and some repetitive measurements should be incorporated in some selected sampling sites to perceive the nutrient mobility. Plankton dynamic should be assessed because it is the emergent constraint for developing the growth of, particularly hilsa fishes.

Acknowledgment

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