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DETERMINATION OF CHLOROPHYLL-A IN RELATION TO SEA SURFACE TEMPERATURE AND SHORELINE DISTANCE TO EXPLORE THE FISHERIES POTENTIALITY IN THE NORTHERN BAY OF BENGAL, BANGLADESH

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Abstract

The identification of potential fishing zones is crucial in improving the efficiency and sustainability of fishing activities. Through scientific methods like remote sensing and oceanographic data, it is possible to locate areas with high fish abundance considering favourable conditions for fish growth and reproduction. In this regard, the use of Sea Surface Temperatures (SST) and the spread of Chlorophyll-a (Chl-a) through in situ data can help to identify fishing potentiality in different areas of the Bay of Bengal (BoB). This information can guide fishing activities to the most productive areas, reducing the time and cost involved in searching for fish while avoiding overfishing in areas where fish populations is already under pressure. An attempt was made with regards to identify the fisheries potentiality in northern part of the BoB using in situ sea surface data of Chl-a in relation to SST and shoreline distance. The study aimed to determine fishing potentiality and improve the sustainability of fishing efforts and fisheries production. The study was conducted in Feb and March of 2020, 2021, and 2022, and the results showed that Chl-a concentration ranges from 3.16 mg/l to 6.15 mg/l, with SST ranging from 22.45°C to 25.88°C. Shoreline distance covered 0.0 up to 60 nm during the research. The study found that Chl-a concentration increased with the decrease of SST and shoreline distance. Sampling blocks near the shoreline were more productive than those with higher shoreline distance and SST. This productivity is may be driven by inputs of nutrients from rivers and vertical mixing due to coastal currents. Despite climate change and environmental pollution, the Chl-a concentration in the northern Bay is still higher than the minimum level of 0.3mg/l, which is considered a good water body for fish availability. Thus, the study provided valuable information on fishing potentiality in the northern Bay of Bengal, which can be used to improve the efficiency and sustainability of fishing activities.

Keywords: Marine Protected Area, Ecosystem, Conservation, Governance

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Introduction

Bangladesh has one of the largest marine ecosystems in the southern part of the country, the ‘Bay of Bengal (BoB)’. It is home to almost 475 types of fish (UNB, 2019). The BoB marine fish catch covers a big part of the foreign currency. Bangladesh earned $532 (Tk. 57853.00) by exporting fish and fishery products during the FY 2021-22 (Export Promotion Bureau Bangladesh, 2022). About 3.6 million hectares of coastal land constitute nearly 25% of the geographical area. According to the 2011 Bangladesh Population Census (BPC), about 25% of the country's total population lives in the coastal region (Peralta-Brichtova et al., 2021). The marine area, which covers almost 1,18,813 km^2, is a source of livelihood for this huge portion of the country's population (Islam, 2022). We know that among all other marine resources, marine fisheries are one of the Bangladesh's most important and popular sources of life and livelihood.

Marine fisheries cover all valuable marine living organisms, including plants and animals, with commercial importance. Marine ecosystems are the saline body of water with unique biotic (living) and abiotic (nonliving) factors. However, the marine environment changes and affects the ecosystem and its components due to different natural and artificial stressors. When living organisms are within an ecosystem, they are influenced and affected by the ecosystem's physical, chemical, and biological parameters. So, fishes are in the water; their life cycle and activities are controlled by the standard parameters of all the physical, chemical and biological factors of that body of water.

Generally, Chl-a concentration is an important issue in ocean ecosystem management and relevant research (Rehage et al., 2019). Along with this, in the aquatic ecosystem, the food web is a compulsory component where green primary producers are at the root of the food web. When the water is greenish, the green productivity indicates that the area is good for fish and other organisms as the primary food phytoplankton are available there (Singh et al., 2012). On the contrary, the temperature is a factor that determines the growth of phytoplankton and, ultimately, the Chl-a concentration within the water system. Dissolve Oxygen (DO) is also relevant to Chl-a, SST, and shoreline distance (Dworak et al., 2009). Oceanic factors supporting the parameters would explain the oceanic environment and food resource availability in an ecosystem (Patel et al., 2001). Chl-a pigment concentration is a convenient index of phytoplankton biomass (Patel et al., 2009). SST is an important factor that influences phytoplankton growth and dissolves oxygen availability (Nayak et al., 2008). In situ Chl-a and dissolved oxygen concentration provide a measure of enhanced biological production area, while SST provides information to explain oceanic environment suitability for the production of those parameters (Somvanshi et al., 2005). Using both parameters would improve our understanding of the physical and biological processes of the oceans (Snaith et al., 2001), which will finally explain the availability of fishery resources within the system (Patel et al., 2001).

Fishermen usually determine the catch zone by looking at the foam or ripples on the sea surface and the birds flying on the sea surface for food (Ritika, 2022). The abundance of fish in an area can also be predicted based on the oceanographic conditions of the waters (Muchlisin et al., 2015). The location of waters with high Chl-a content can indicate rich fish biomass as the area is rich in feeding substances (Wahyuningrum & Simbolon, 2013). Meanwhile, SST is one factor that affects the life of organisms in the ocean because the SST can affect the metabolism and reproduction of organisms in the sea. So, each type of fish has a different tolerance to SST for survival (Setiawan et al., 2022).

It is well known that climate change and pollution is the main influencer that can change or alter the standard parameters within the ocean ecosystem, and this is happening worldwide (Fenger, 2009). The oceans have taken up 93 percent of the warming created by humans since the 1970s (IUCN, 2016). Global climate change is responsible for sea-level rise, surface temperature, ocean heating, ocean acidification, coastal flooding, salinity intrusion, etc. Warming of ocean water and dumping of continuous pollution substances alter the water quality parameters like dissolved O_2, dissolved CO_2, Salinity tolerance level, pH level, and SST that, directly or indirectly affect the marine biodiversity (Alava, 2019). Many studies were conducted in the BoB either to explain Chl-a in different parts of the BoB or the relation of Chl-a with other parameters within the ecosystem. Most are done using satellite images. A study was done on the seasonal and annual variation in Chl-a in the shelf region of the northern part of the BoB using MODIS-Aqua data (Rouf et al., 2020) where Chl-a & SST were found inversely related in both annual and seasonally. Another study was carried on about the subsurface chlorophyll in the northwestern BoB (Sarma et al., 1991). The concentration of Chl-a in northern coastal BoB using Landsat-8 OLI and Sentinel-2 MSI Sensors (Poddar et al., 2019). One research study was conducted on Chlorophyll variability in the Bay of Bengal and its relation with ENSO (Annapurna et al., 2021). A scientist observed inter-annual and Decadal Variability of SST over the BoB (Rahman et al., 2011). The study showed a correlation between Phytoplankton Biomass (Chl-a) and Nutrients with the Catch Per Unit Effort in the PFZ Forecast Areas of northern

BoB during simultaneous validation of the winter fishing season (Dutta et al., 2016). The scientist has already pronounced that the coastal and marine fisheries of the BoB provide a salient feature of the available information and resource availability to identify future research and management needs (Islam, 2003). Fish are considered a dynamic aquatic and renewable resource that can be estimated and forecasted through habitat consideration. In a real scenario, the Bay of Bengal and its surrounding regions are among the least researched regions in the world, although having a significant potential for future stock growth (Islam, 2003).

No study has been made to identify a potential fishing zone in the northern BoB based on in-situ Chl-a, SST, and shoreline distance data. At the age of severe pollution and other natural calamities, the condition of BoB should be examined to draw a salient feature on the fishing potentiality. The present study, therefore, aimed to investigate the concentration of Chl-a to SST and shoreline distance to identify the fishing potentiality in the northern BoB in the present era of climate change and other environmental stressors.

Material and Method

Study Area

The BoB is a large area, and 200 nm of EEZ is under Bangladesh's jurisdiction. The research has selected the northern part of the BoB to describe fishing potentiality in that area. The area has been selected based on the priority of fisheries resources as it contains-

- Marine Reserve-South Patches Ground
- Marine Reserve-South of South Patches Ground
- Marine Reserve-Middle Ground

As still Bangladesh fishermen mostly cover up to rarely 100km distance and 80m depth, the present research has been comprised up to 112km (60nm) distance from the nearest shoreline, and a maximum of 130m depth has been covered.

The locations of this study area included the northern part of the BoB started from Latitude 22°11´N to Latitude 20°51´N and Longitude 91°50´E to Longitude 89°41´E covering most of the sea area. The total area has been classified into 10 rectangular blocks. The following latitudes and longitudes identify the blocks-

Block	North-East Corner	South-West Corner
A1	22°11′ N 91°50′ E	21°51′ N 91°28.5′ E
A2	21°51′ N 91°50′ E	21°31′ N 91°28.5′ E
A3	21°51′ N 91°50′ E	22°11′ N 91°28.5′ E
A4	20°51′ N 91°50′ E	22°11′ N 91°28.5′ E
A5	20°51′ N 91°50′ E	20°31′ N 91°28.5′ E
A6	20°51′ N 91°28.5′ E	20°31′ N 91°07′ E
A7	20°51′ N 89°41.2′ E	20°31′ N 90°03′ E
A8	20°51′ N 90°46′ E	20°31′ N 90°24′ E
A9	20°51′ N 90°24′ E	20°31′ N 90°03′ E
A10	20°51′ N 91°07′ E	20°31′ N 90°46′ E

Table 1: Locations of Different Sampling Blocks of the Study Area

Data Collection

Based on the latitudes and longitudes, the sample has been collected from 50 stations covering the study area. Then blocks were drawn as A1, A2, A3, A4, A5, A6, A7, A8, A9, A10 and each square-shaped block area covered a total of 400 sq. nm. The data of Chl-a and SST used in this study has been collected in 3 consecutive years from 2020-2022 within the same months' Feb-March consideration, and the same sampling sites were maintained. As DO is not our primary consideration, it has been collected for only 2022 of February for cross-checking of the result. The sampling months have been selected considering the weather pattern and sea conditions. For Chl-a analysis and temperature determination, sea surface (10cm depth) water sample has been used.

The Chl-a was analyzed in the laboratory using the DR6000, a direct reading spectrophotometer, at 664 nm and 750 nm wave length. For Chl-a determination, a water sample was collected from the sea, using a 20 cm diameter pot. Then the required amount of water samples was preserved in the plastic bottles in the refrigerator for further laboratory analysis. In laboratory, the collected water samples were filtered by the filter papers (Whatman 47 diameter). The filter papers were dissolved in 10 ml acetone and kept overnight, then centrifuged (Denlay centrifuge, model BS-400) for 30 minutes at 1000 rpm and made ready for the analysis of Chl-a. The DR6000, a direct reading spectrophotometer, at 664 nm and 750 nm wave length was used to determine Chl-a by following Vollenweider's equation.

Chl-a concentration/ Chl-a (μg/L) = (11.9*(A664- A750) *V*1000)/L *S

Where,

A664 = the absorbance at 664nm

A750 = the absorbance at 750nm

V = the acetone extract in ml

L = the length of cell in cm^2

S = the volume in ml of sample filtered

SST, along with DO, has been measured using a multimeter. The temperature was measured directly from the sampling area.

Data Analysis

Data of each block has been put into excel, and the average data have been counted to determine the chl-a of each block with SST and distance from the shoreline to get the productivity and suitability of each block for fish. The map (chart) used for this research is the Admiralty Chart 90. For pictorial presentation, both manual and Computer Aided Design Software were used.

Result

The determination of Chl-a, SST, and shoreline distance has been shown in Table 2.

Block	Chl-a (mg/l)	Shore Line Distance (nm)	SST (°c)
A1	6.15	00	22.45
A2	5.02	0.5	24.10
A3	4.00	01	24.10

Block	Chl-a (mg/l)	Shore Line Distance (nm)	SST (°c)
A4	3.57	12.5	24.84
A5	3.57	25	24.85
A6	3.16	46	24.90
A7	3.55	55	24.90
A8	3.55	56	24.90
A9	3.54	57	24.90
A10	3.25	60	25.88

Table 2: Chl-a, SST and Shoreline Distance of Stations Sampled in the Study Area

The result shows that Chl-a ranges from 3.16 to 6.15 mg/l, and the SST ranges from 22.45 to 25.88°C in the Feb and March sampling time frame. The sampling blocks cover the distance from 0.0 to 60 nm during this research.

The result explained that the northern part of the BoB is excellent in condition. The minimum Chl-a 3.16 mg/l indicates a productive fishing area of the northern BoB. On the contrary, maximum Chl-a 6.15mg/l does not indicate eutrophication as eutrophication may occur when the Chl-a concentration is >15mg/l in any water body. So, the above-mentioned research area ranging Chl-a concentration from 3.16 to 6.15 mg/l indicates a highly productive fishing area in the northern BoB. Relation among Chl-a, SST, and shoreline distance has been presented in Figure 1.

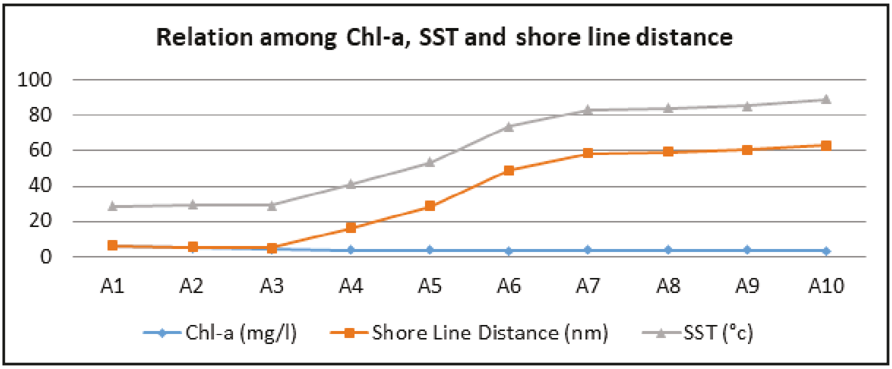

Figure 1: Relation Among Chl-a, SST, and Shoreline Distance in the Study Areas

The trend of Chl-a to SST and shoreline distance has been shown. The result projected that there is an inverse relationship between Chl-a and SST. In the case of shoreline distance, it has also shown negative relation with Chl-a concentration, which means Chl-a concentration decreases with increasing SST and shoreline distance. So, the defined blocks can be described as considering fishing potentiality, A1>A2>A3>A4>A5>A7>A8>A9>A10 (A6 is exceptional with sharply decreased low Chl-a value 3.16) and has been shown in Figure 2.

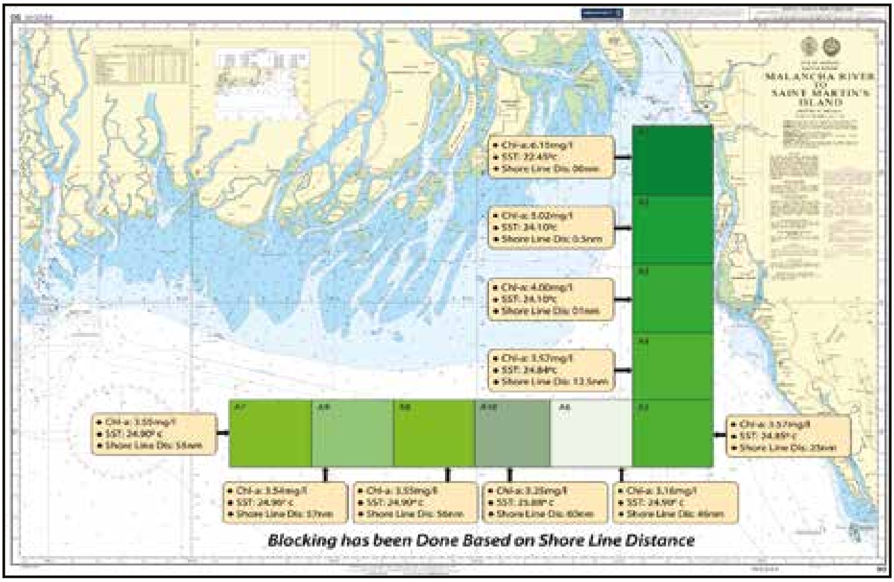

Figure 2: Fishing Potentiality in the Northern BoB

Result Validation

Relation among shoreline distance (nm), SST (°C), Chl-a (mg/l), and DO (mg/l) has been shown in Figure 3.

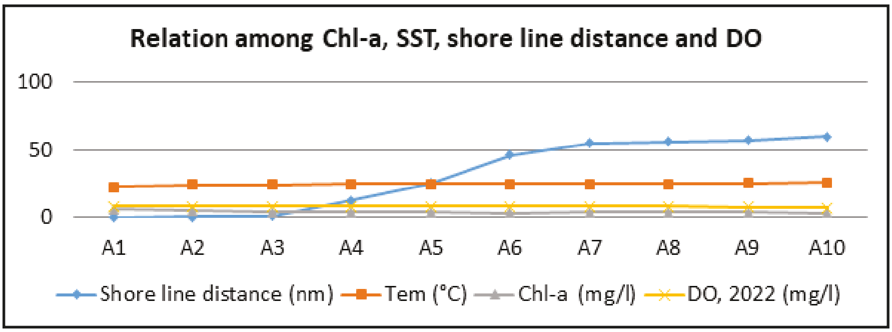

Figure 3: Relation Among Shoreline Distance (nm), SST (°C), Chl-a (mg/l), and DO (mg/l)

This DO data has been taken only for the year 2022 in April in the same sampling sites. The DO data shows that with increasing Chl-a concentration, DO has also increased. The DO has decreased with increasing shoreline distance and sea surface temperature. So, the DO concentration follows the trend of Chl-a concentration (Figure 3). The Chl-a concentration of block A6 that breakdown the sequential trend has followed the continuity of DO concentration with other blocks which can be a sampling error.

Discussion

It has been studied that SST value in the range of 29–31°C, and the range of Chl-a value 0.28-0.43 mg/L can be used as an indicator of good fishing ground (Purba, 2020). The Mackerel tuna has optimum Chl-a concentration ranging from 0.2-0.4 mg/l at 29-30.5°C (Harahap et al., 2020). Preferred range of Indian Mackerel (Rastrelliger kanagurta) was 30.75 ± 0.21°C for SST and 0.31 ± 0.10 mg/m for Chl-a (Nurdin et al., 2013). So, the present study that found Chl-a concentration ranges from 3.25-6.15mg/l indicates a good fishing potentiality in the mentioned research area at SST ranging from 22.45 to 25.88°C.

Many studies show SST, shoreline distance, and Chl-a fluctuations inversely proportional correlation. Many studies revealed low Chl-a concentrations with high SST and vice versa (Rao, 2016). Some studies found that the average Chl- a concentration is high during winter (October-December) and low in summer (June) (Narayana, 2016). Low SST (26°C) and river runoff from the major rivers are linked to the high Chl-a (Noor, 2020). In this northern region, higher river discharge was seen between July and September.

In contrast, higher Chl-a concentration was seen between September and November, demonstrating the critical effect of river discharge. In the BOB river runoff is less in winter and maximum in the monsoon. Between October and December, the BoB experiences several storms that bring nutrient-rich subterranean water to the surface, enhance blooms, and ultimately contribute to producing high Chl-a concentrations (Sarangi et al., 2008). The northern BoB shelf region with the lowest Chl-a concentration was discovered during the pre-monsoon season (March–May). It happened due to a progressive rise in SST (the specific relationship between Chl-a concentration and SST is discussed in the following section) and a fall in wind speed (Nagamani et al., 2013). It has been established that the Chl-a concentration and SST have a weakly inverse relationship. In the Northern BoB, the current study likewise discovered a negative association trend between Chl-a and SST. Chl-a has been reduced with increasing

SST, possibly due to the above-discussed phenomenal association in the northern BoB.

Various factors influence sea surface temperature (SST), such as river runoff, differential cooling and heating rates, continental air masses, near-shore ocean currents, and upwelling. Upwelling refers to the upward movement of cold, nutrient-rich water from the deep ocean layers to the surface. This process replenishes coastal waters, leading to cooler SST near the shoreline compared to offshore waters (Krezel et al., 2005).

The high upwelling activity near the shoreline promotes greater phytoplankton (Chl-a) production compared to offshore regions. Consequently, our study's findings align with this logic, as we observed a decrease in Chl-a concentration with increasing distance from the shoreline. This suggests that near the shoreline, where SST is cooler, there is higher productivity. Previous research conducted along the coasts of Washington, Oregon, and California supports this, as it revealed that due to upwelling and wind action, SST along the coast was several degrees cooler than offshore waters.

Therefore, our study's results, which demonstrate a decrease in Chl-a production with increasing shoreline distance and SST, are consistent with previous findings and support a logical relationship between these factors.

The NASA Sea-viewing Wide Field-of-View Sensor image revealed a close relationship between the physical and chemical ocean processes like temperature differences and nutrient upwelling that happens near coastlines and influences ocean plant life. Planktonic growth is higher in coastal areas than in the open ocean (NASA Earth Observatory, 2023). High chlorophyll mainly occurs near the coast, e.g., near Somalia and Oman, and their values generally decrease with offshore distance (Marinello et al., 2022). However, it has been proved that during summer months the chlorophyll variations could be explained mainly by the frequent upwelling events, whereas during winter months, high chlorophyll concentration near the coast depends on river discharges (Dias et al., 2013). Following the above perceptions may be the supporting logic of the present study that found Chl-a concentration near the coast and that SST has increased with increasing shoreline distance.

Conclusions

BoB is a large marine area with highly valuable commercially important marine species. However, the fisher has very little knowledge of the overall productivity of productive marine areas as there is very few research yet on BoB fisheries' potentiality. The present research has been designed to identify the fishing potentiality of the Northern BoB, considering the most important factors Chl-a, SST, and shoreline distance. The research found that the northern part of the BoB is highly productive. Nevertheless, the considered factors indicate that the most important biological components are yet within the optimum level that supports a highly productive water area. The level of Chl-a >0.3mg/l indicates that the Northern BoB supports very good commercially important marine fisheries. But the further intensive study with more parameters and covering the whole water area is needed to suggest the commercial fishing zone in the BoB as a whole and the study can develop finally a fishing apps on the live fishery data on the fishing potentiality of the target fishing area in the BoB.

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