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ORIGINAL RESEARCH ARTICLE

Monitoring the Seasonal Distribution and Variation of Sea Surface Temperature and Chlorophyll Concentration in Bay of Bengal using MODIS Satellite Images

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Using MODIS Global Satellite products from 2016 to 2020, the variance in sea surface temperature (SST) and chlorophyll concentrations in the waters of the Bay of Bengal (BoB) is investigated during this study. Seasonal maps prepared from the monthly average of SST are compared to observe the change throughout the timeframes of spring, summer, autumn, and winter. The annual cycle of SST depicts the phases of cooling in winter, heating in summer, and warming in spring. It has been found that the presence of heated pools (SST > 30°C) prolongs the summer endurance within the Bay in summer. The SST variations are also strongly linked to regional-scale climate variations from late winter to early spring. Anomalies in chlorophyll are often considered early indicators and drivers of changes in marine resources. However, there has been little assessment of the abnormality in this component in coastal waters of the BoB. The measured chlorophyll distribution during the study reveals anomalies consistent in magnitude having a prominent north-south gradient, where the greater concentrations lie in the northern part. In addition, the fluvial input provided in the central part of the Bay by the Ganges-Brahmaputra-Meghna River system during monsoon contributes additional credence to this assertion.

Keywords: Bay of Bengal, Chlorophyll, Sea-surface temperature, Remote sensing, Bangladesh.

The Bay of Bengal (BoB) is a geographical area bordered on the west by the Indian peninsula and the east by the Bengal-Myanmar lands. It is one of the world's most distinctive geographical regions. This region is considered regardsed as one of the most productive globally since it accounts for a considerable portion of global marine output, earning it the designation. Consequently, since 1954, the seasonal dynamics of the thermal field and coastal upwelling have been thoroughly documented in a number of scholarly articles. (1-3).
Anomalies in sea surface temperature (SST) are often both leading indications and significant causes of changes in marine resource availability (4). Additionally, it is often regarded as a significant variable in the formation of deep atmospheric convection over coastal seas and a regulating factor for marine water resources. Thus, skilled interpretation of ocean temperature anomalies has the potential to be very beneficial in dynamic marine resource management.

On a seasonal basis, the phytoplankton supply and output in the northern Bay of Bengal is very varied. Monsoon flows from the Ganges-Brahmaputra River system cause significant stratification in the top layers due to the Bengal shelf's shallow freshwater layers (5). Chlorophyll concentrations in adjacent seas may be influenced by these phenomena, which affects micro-zooplankton upwelling and down-flow.

The purpose of this research is to examine the fluctuation in chlorophyll distribution (a proxy for plankton biomass) and SST in the BoB from 2016 to 2020 in order to better understand and identify the experimental parameters that vary throughout seasons.

DATA AND STUDY AREA

The study region is a foreland bay surrounded on the north by the Bengal Lands, on the west by the Indian subcontinent, and on the east by Myanmar (Figure 1). The region is divided into two parts: the top portion is the Bengal coastal shelf, which has shallow water depths of up to 250 meters, while the bottom part is the Bay of Bengal's deep waters.

MODIS Global, 4 km Day Time SST, and Chlorophyll OCX products with dates ranging from 2016 to 2020 were used for this investigation. The seasonal averages for spring, summer, autumn, and winter are included in this package. However, since average data for winter 2020 was not available throughout the time-frame, the winter 2020 study was omitted.

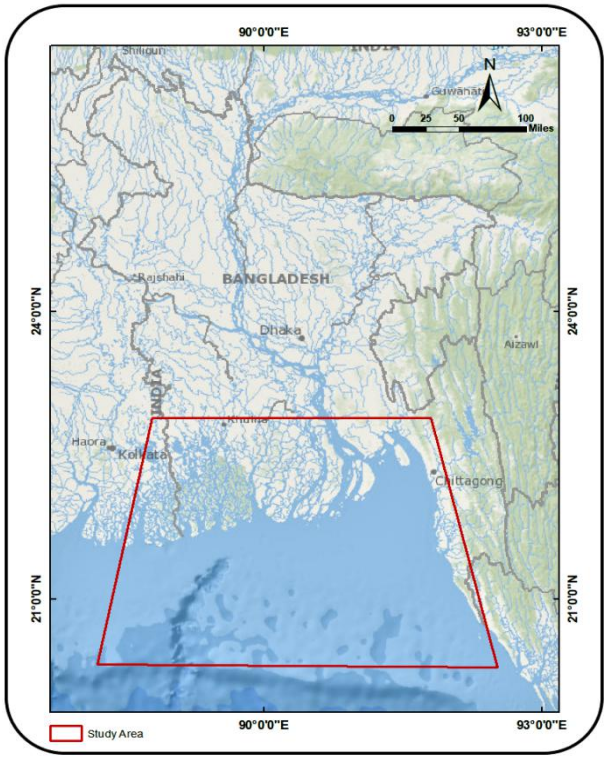


Fig.1 Location of the study area.

METHODOLOGY

Since the majority of the data in this research were Level 2 products, no critical information processing techniques were applied. Instead, basic geoprocessing operations (Figure 2) for analysis and map preparation are carried out using ArcGIS Pro 2.8 software. SST and Chlorophyll images were resampled to a resolution of 30*30 m using the nearest neighbor method for more comprehensive visualizations. The monthly readings were then converted to a seasonal average and afterward categorized into a broad numeric range; visual observations of thermal fronts and chlorophyll hotspots were used to identify and later define these features using numeric value standards.

RESULTS

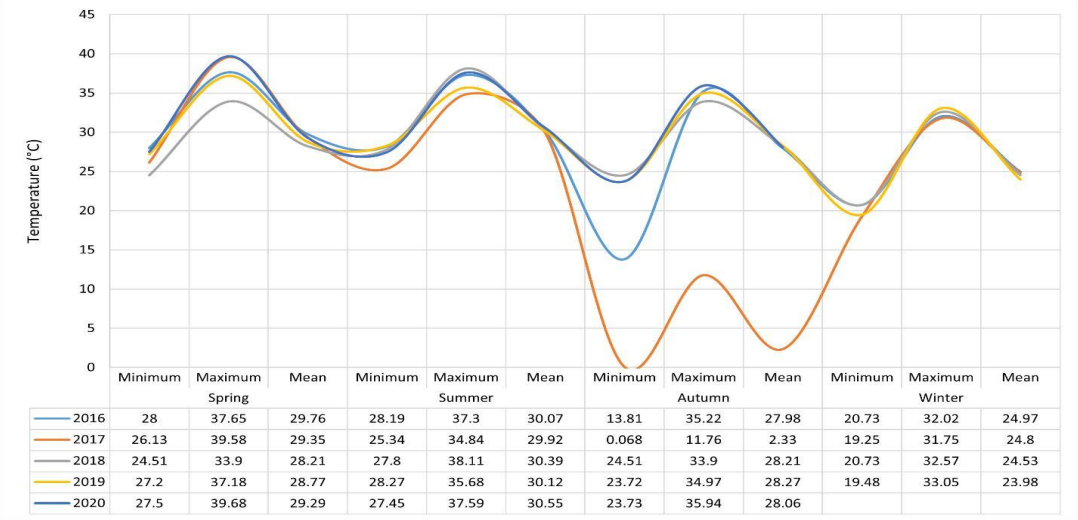
Sea Surface Temperature Analysis

Among all the seasons, maximum temperatures have constantly been observed in the summer, where the lowest boundary lies within 25.34 - 28.27 °C (Fig.3) and the highest is within 34.84 – 38.11 °C. However, the highest ever average temperature recorded was 39.68 °C in spring 2020. As expected, the temperature seems to fall in winter and reaches a value of around 19 °C. The lowest ever temperature was 0.068 °C, which is impossible in the BoB atmosphere. This value may result from an image processing error or false retrieval due to dense cloud cover over the region. The thermal fronts are more or less constant in all the seasons except for the summer. In summer, the temperatures are distributed unevenly across the entire area, making the front detection much harder and the scenario more complex for making absolute interpretation. The waters on the coastal shelves tend to be warmer compared to the deep sea-areas.

Chlorophyll Concentration Analysis

The chlorophyll concentrations obtained show three major zones; the southern low chlorophyll zone, where values are consistently less than 0.2 mg/m3 (Fig.8), the moderate location in the shelf area with values ranging from 5 - 10 mg/m3, and the high-value zone also be considered as the hotspots. Hotspots are areas that are often high in production due to coastal upwelling. These sites reached a value up to 34.73 mg/m3 in the last five years. However, the hotspots are not fixed in one place and tend to migrate within the northeastern part of the Bay of Bengal near Bangladesh's small island districts. Chlorophyll maximum is a water column characteristic representing the plankton biomass's physiological circumstances and is a well-known phenomenon. The standard value chart suggests that these zones are suitable for fisheries and other marine lifeforms.

Fig.2. Work-flow diagram of the study.



	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
	Spring			Summer			Autumn			Winter		
2016	28	37.65	29.76	28.19	37.3	30.07	13.81	35.22	27.98	20.73	32.02	24.97
2017	26.13	39.58	29.35	25.34	34.84	29.92	0.068	11.76	2.33	19.25	31.75	24.8
2018	24.51	33.9	28.21	27.8	38.11	30.39	24.51	33.9	28.21	20.73	32.57	24.53
2019	27.2	37.18	28.77	28.27	35.68	30.12	23.72	34.97	28.27	19.48	33.05	23.98
2020	27.5	39.68	29.29	27.45	37.59	30.55	23.73	35.94	28.06			

Fig.3. Seasonal temperature variation.

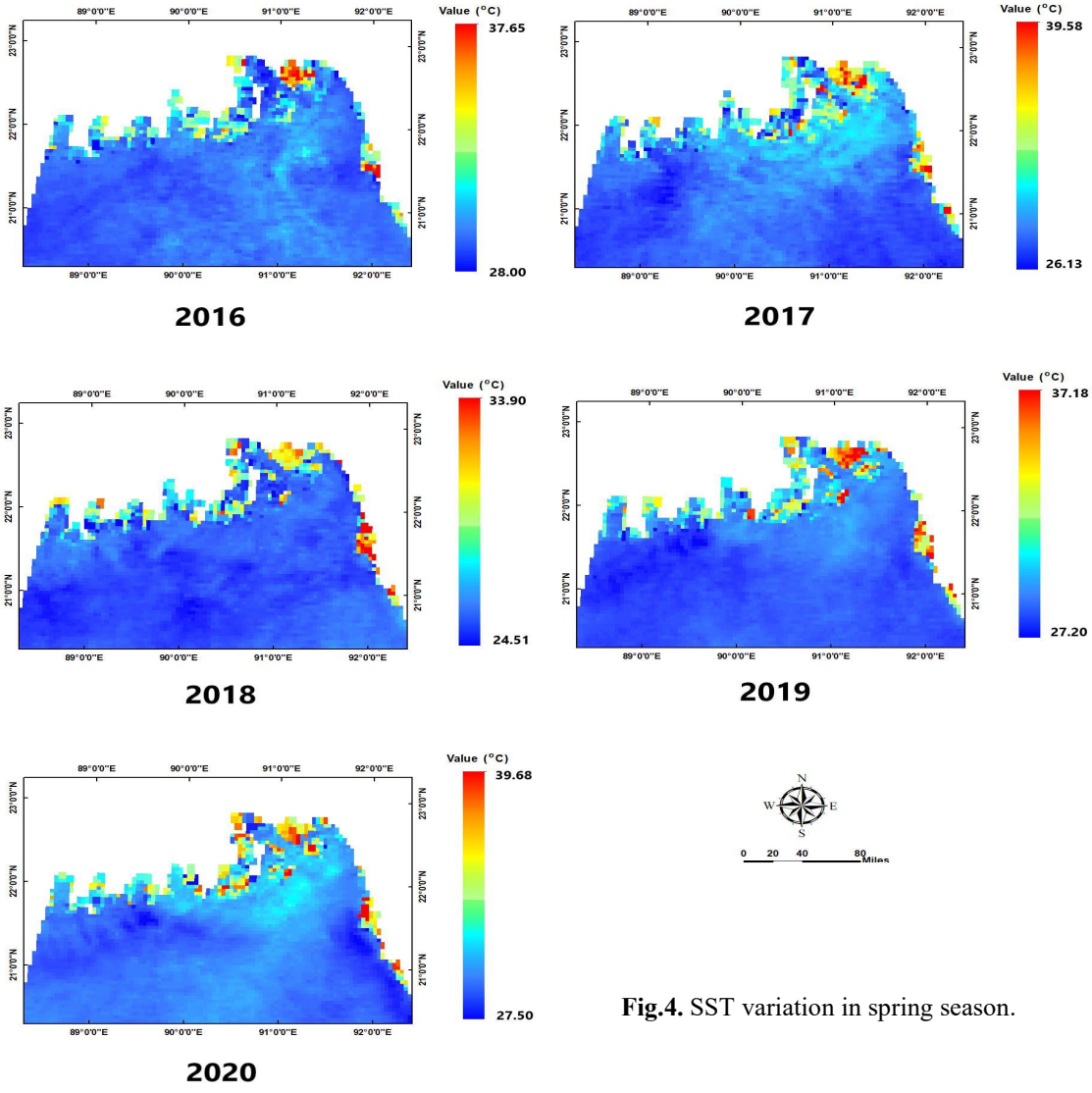


Fig.4. SST variation in spring season.

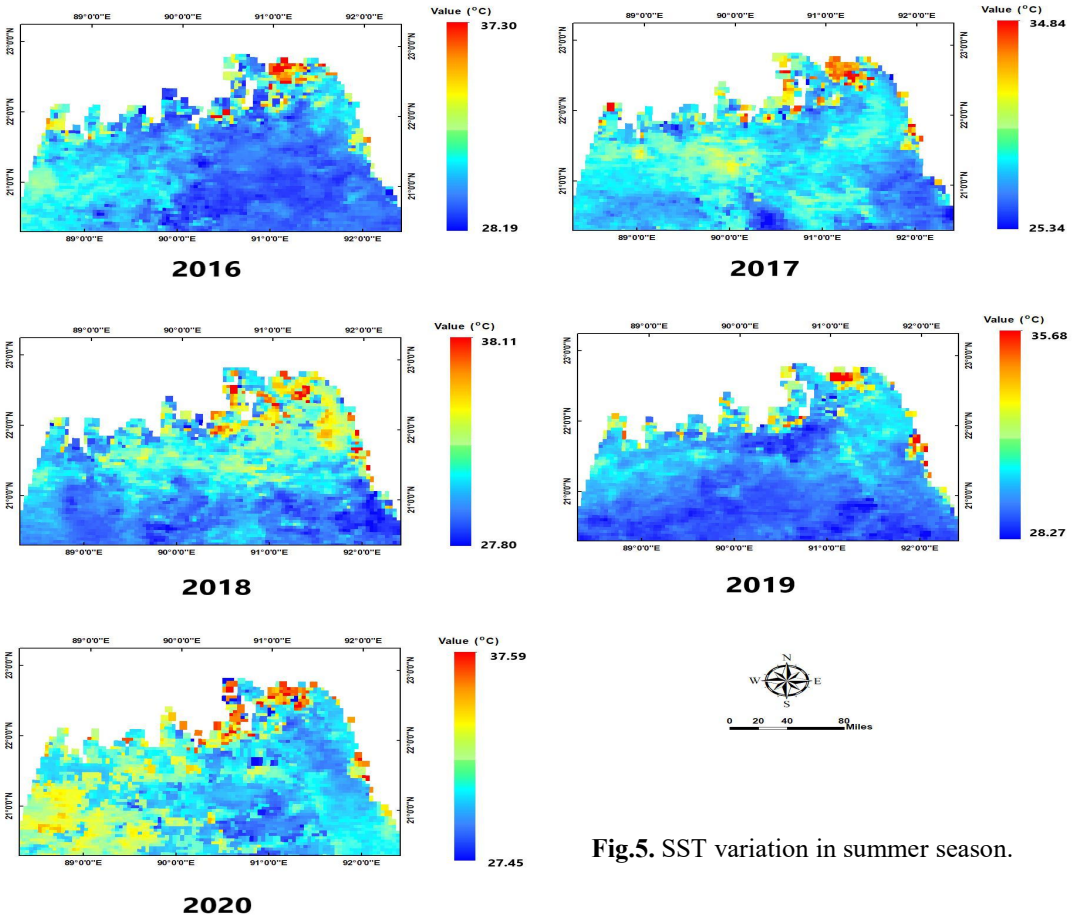


Fig.5. SST variation in summer season.

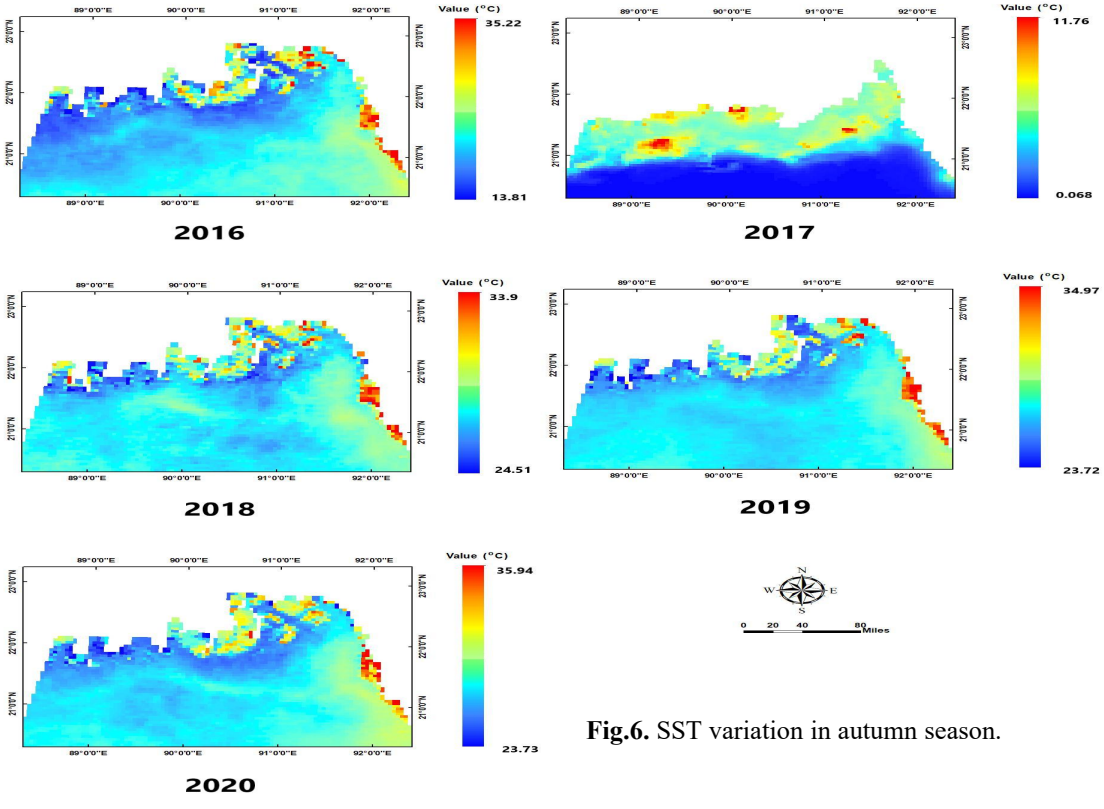


Fig.6. SST variation in autumn season.

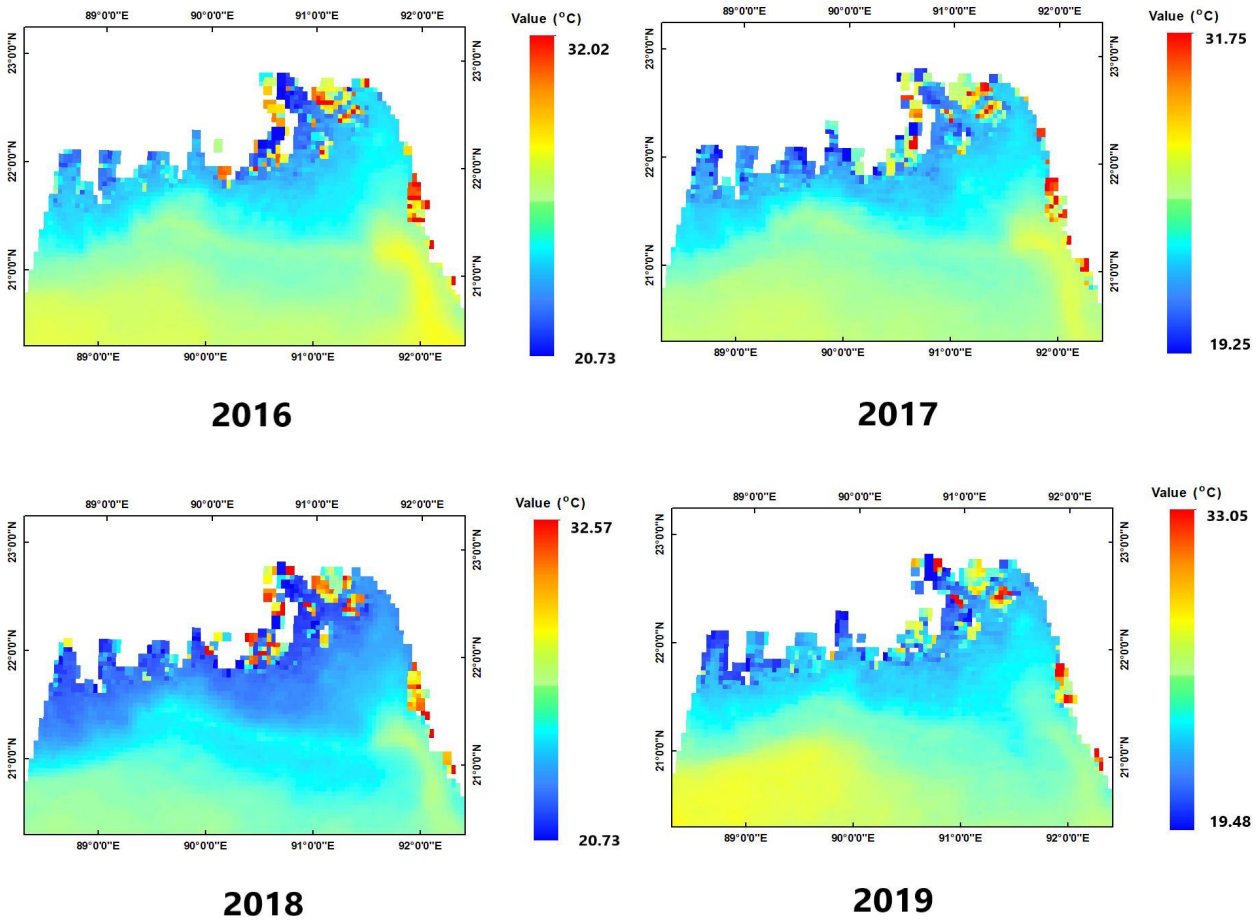
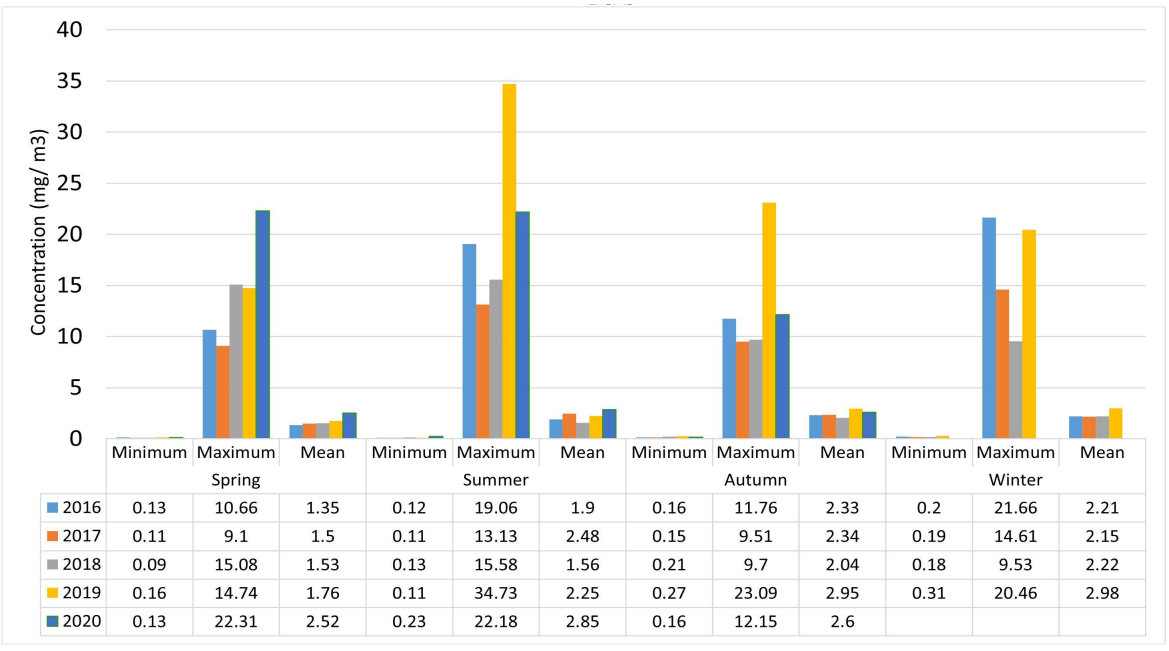


Fig.7. SST variation in winter season. Navigation is same as fig.6.



	Spring			Summer			Autumn			Winter		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
2016	0.13	10.66	1.35	0.12	19.06	1.9	0.16	11.76	2.33	0.2	21.66	2.21
2017	0.11	9.1	1.5	0.11	13.13	2.48	0.15	9.51	2.34	0.19	14.61	2.15
2018	0.09	15.08	1.53	0.13	15.58	1.56	0.21	9.7	2.04	0.18	9.53	2.22
2019	0.16	14.74	1.76	0.11	34.73	2.25	0.27	23.09	2.95	0.31	20.46	2.98
2020	0.13	22.31	2.52	0.23	22.18	2.85	0.16	12.15	2.6			

Fig.8. Seasonal chlorophyll concentration variation.

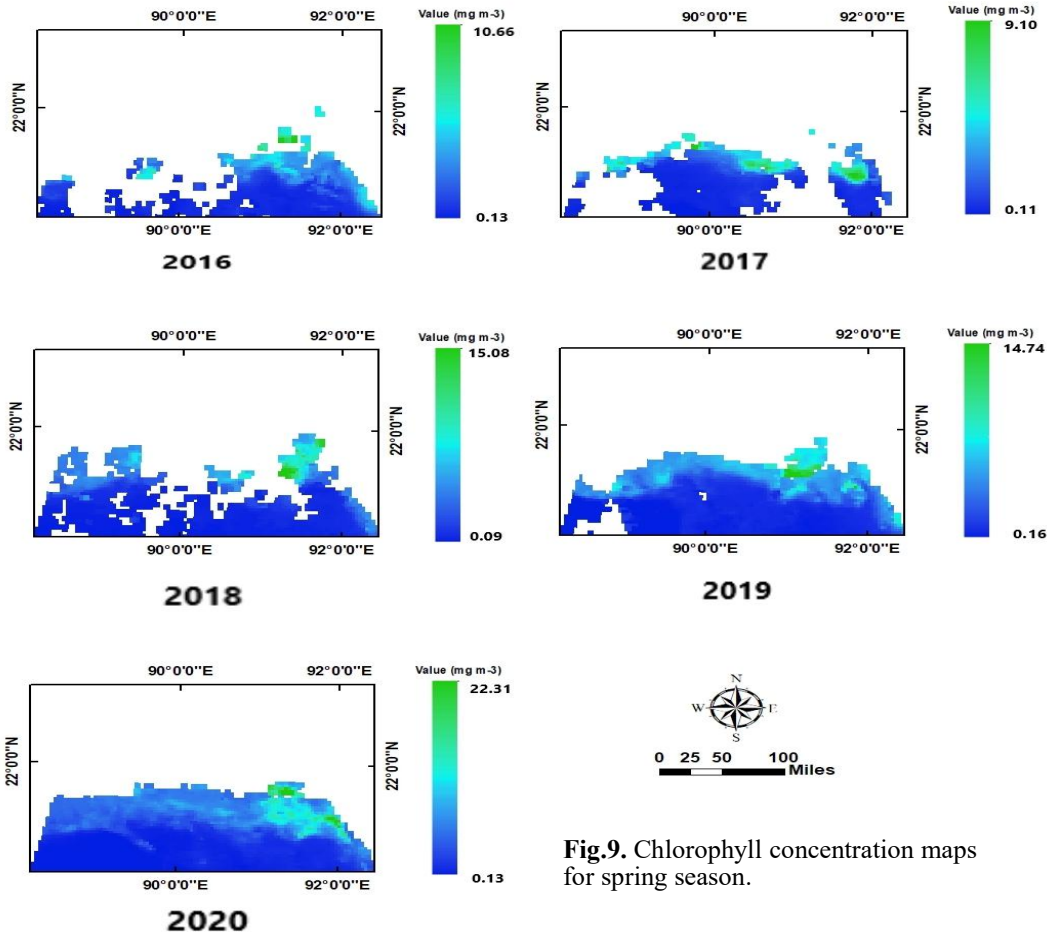


Fig.9. Chlorophyll concentration maps for spring season.

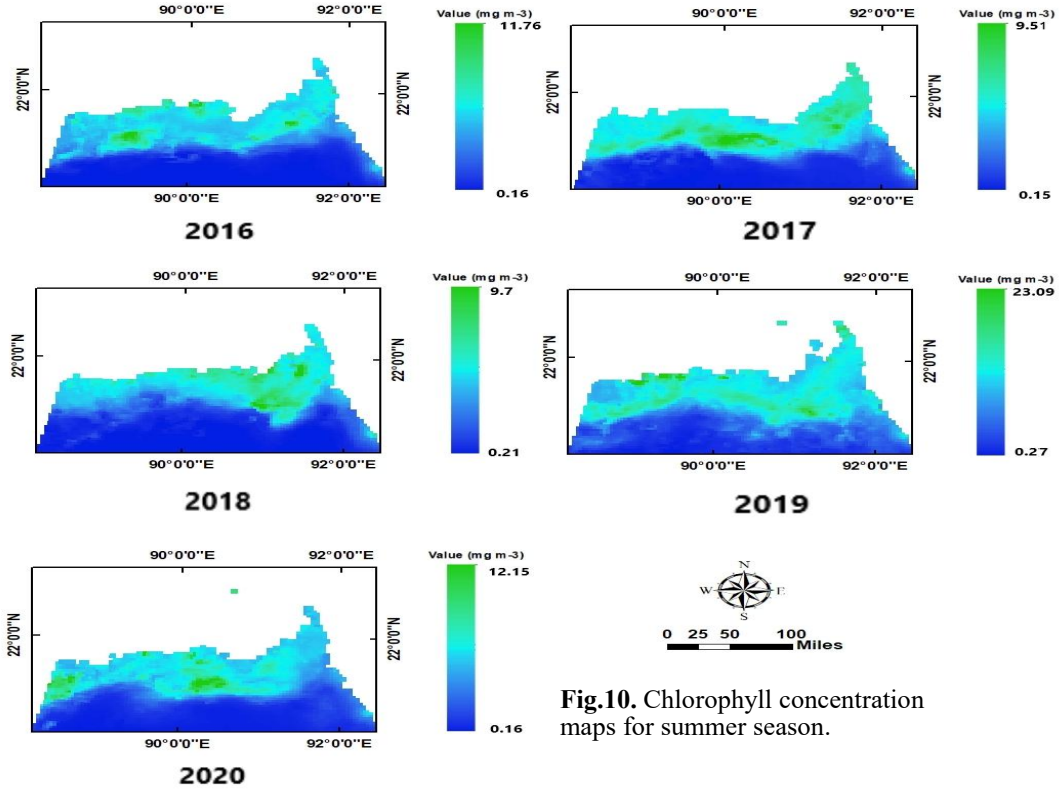


Fig.10. Chlorophyll concentration maps for summer season.

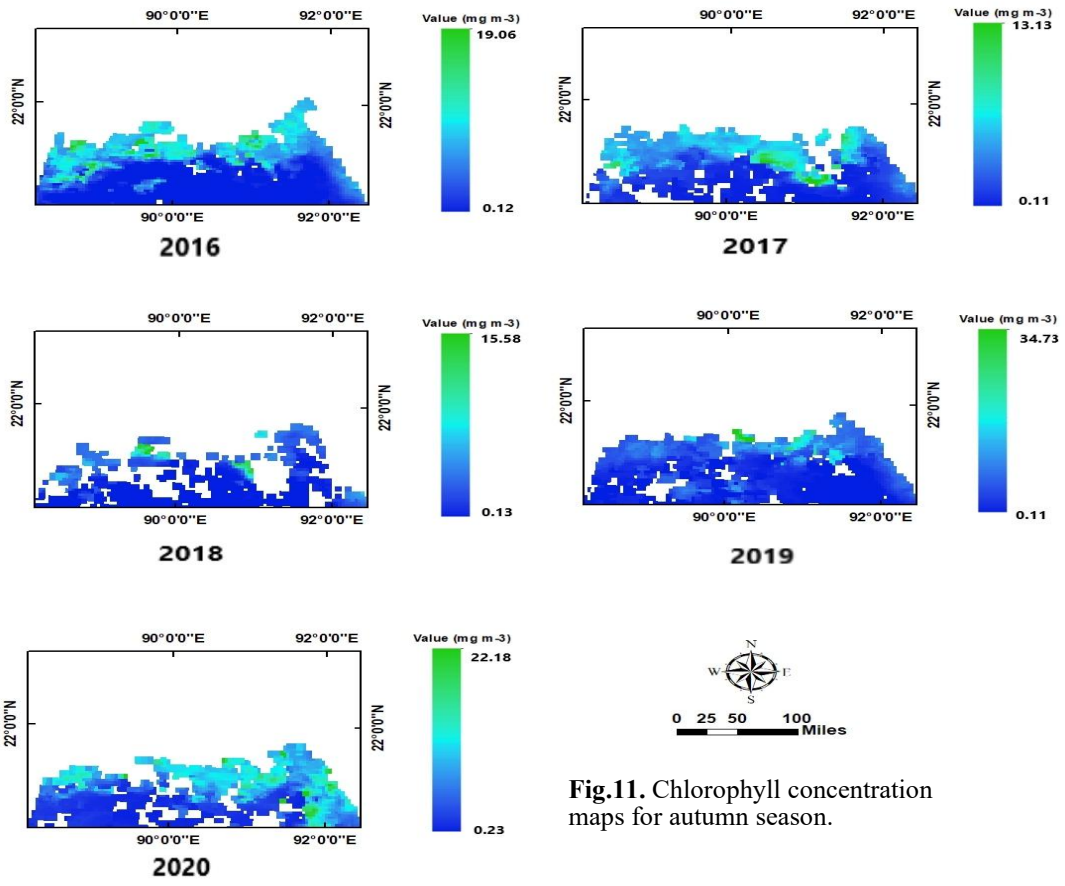


Fig.11. Chlorophyll concentration maps for autumn season.

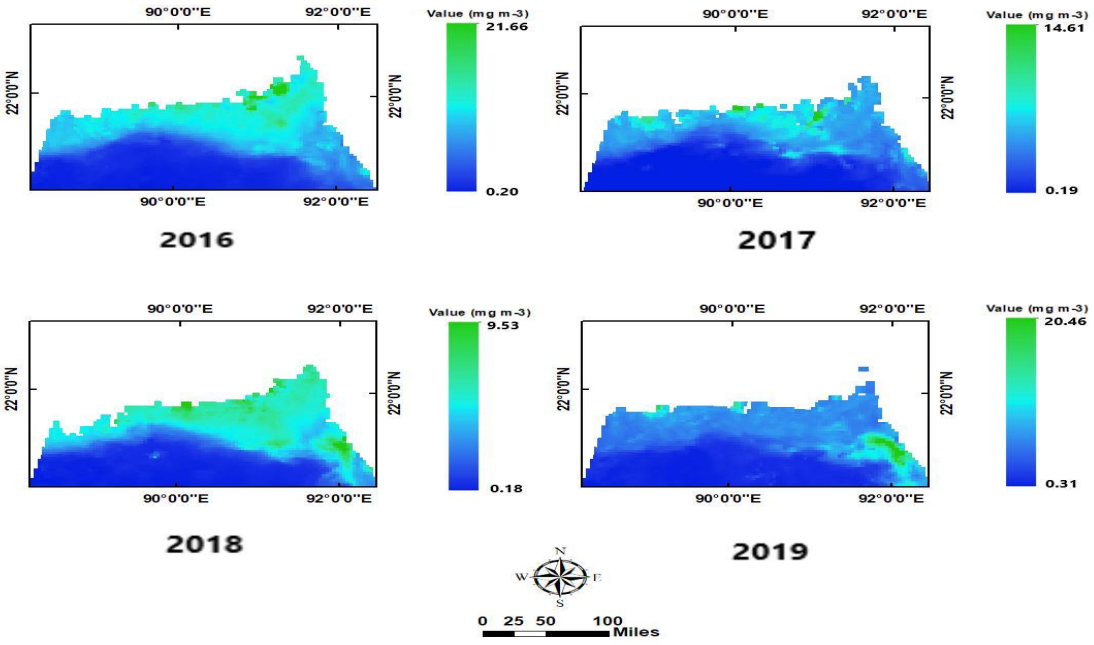


Fig. 12. Variation of Cholorophyll in Winter Season

DISCUSSION

The observed SST distribution reveals that the warm pool resides on the coastal shelf area throughout the spring and fall. In summer, the distribution is more equal throughout the whole bay. Nevertheless, once the northern bay's winter cooling process commences, the warm pool moves toward the southern bay.

There is a significant gradient in chlorophyll distribution in surface waters along the whole study region in the Bay of Bengal, with consistently higher concentrations in the northern portion of the bay compared to the southern section. Because the bay receives a significant amount of fertilizer input from the GBM rivers and their tributaries, the high chlorophyll concentrations in the bay's northernmost region may be attributed to this fact.

The seasonal changes reinforce the notion that BoB is not a stable bay, in contrast to the majority of other bays. The shallow water system in this area is very dynamic and complicated; massive river flow increases the frequency with which organic components alter and, as a result of the changing water density, has a considerable impact on the temperature range. It is thus necessary to monitor SST and chlorophyll concentrations to identify how species in the marine ecosystem, particularly fisheries, are responding to changes in the environment.

CONCLUSION

The Bay of Bengal is indeed an important region for marine biodiversity. All the islands of southern Bangladesh are the habitat of fishermen communities directly dependent on the marine fisheries. Therefore, monitoring the region's lands and water is vital for marine resource conservation. Additionally, the coasts are our most prominent tourist attractions and contribute significantly to the economy, so they need to be managed sustainably. As both SST and chlorophyll concentrations are nature-dependent factors, there is not much to do other than monitor them regularly and look for changes. Remote sensing can play a vital role in this regard. It makes it possible to analyze these critical changes in SST and chlorophyll concentration factors. Still, most importantly, it ensures continuous monitoring at a minimum time and with fewer resources.

CONFLICT OF INTEREST

Author declared no conflict of interest.

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AUTHOR CONTRIBUTION

The work plan, design, data analysis and the manuscript preparation, everything is done by the author solely.

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