CHAPTER 5

Chemical Oceanography Division

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Chemical oceanography encompasses the study of the chemical components of the oceans, their reactions, and their pathways of transformation. We study both organic and inorganic compounds, particulate and dissolved material, and the ocean sediments. The pathways that compounds follow affect the global cycling of elements such as carbon and nitrogen, and are often intimately related to biological activity. We undertake our research in environments such as mangroves and saline lakes, salt marshes, and deep ocean sediments. We combine field observations, laboratory experiments, and computer models to understand factors affecting chemical compositions and how they vary in time and space.

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Phytoplankton Assemblages in the South Eastern Coastal area of the Bay of Bengal, Bangladesh with Special Reference to Environmental Variables

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ABSTRACT

Phytoplankton assemblages in the south eastern coastal area of the Bay of Bengal, Bangladesh was studied from surface water for a period of 12 months (July 2020 to June 2021) in relation to environmental variables like, water temperature, pH, dissolved oxygen, salinity, conductivity, transparency, rainfall, TDS and nutrient contents-including nitrate, nitrite, phosphate and silicate. A total of 137 phytoplankton species were identified whereas, 115 species of diatoms from 44 genera, 15 species of dinoflagellates from 8 genera, 2 species of green algae from 2 genera, 4 species of cyanobacteria from 3 genera and 1 species of silicoflagellate were identified. The highest phytoplankton abundance was found at Shaplapurabout 12245 cells/l and the lowest at Saint Martin's Islandabout 1250 cells/l. Phytoplankton showed complete dominance of diatom genera namely *Asterionella japonica* & *Thalassionema nitzschiodes* in post-monsoon and *Odontella rhombus* in pre-monsoon. Other frequently occurring diatoms were *Coscinodiscus perforatus*, *Actinocyclus normanii*, *Thalassiothrix fraunfeldii*, *Ditylum brightwelli*, *Rhizosolenia alata*, *Chaetoceros affinis*, *Thalassionema nitzschoides* etc. respectively. Species diversity was observed to be maximum in post-monsoon (67 species) followed by pre-monsoon (42 species) and monsoon season(28 species). The average annual environmental variables values among the stations were salinity (27.09±2.27 PSU); water temperature (27.22±0.40 ℃); DO (4.78±0.15 mg/l); TDS (21.33±1.93 g/l); Conductivity (41.40±3.49 mS/cm); Transparency (3.09±2.02 ft); Rainfall (87±0.00 mm); NO_3-N (0.38±0.07 mg/l); PO_4-P (0.07±0.01 mg/l); SiO_4 (0.06±0.01 mg/l) respectively. Correlation studies of phytoplankton composition to physicochemical variables indicated significant negative relation with water temperature, salinity and pH but positive relation with nitrate, nitrite, silicate and phosphate of the water body. Nitrate was found to be the limiting factors for phytoplankton growth during pre-monsoon periods whereas, the role of silicate and phosphate remained insignificant in these perspectives.

Keywords: Phytoplankton Assemblages, Environmental Variables, Nutrients, Coastal Area.

INTRODUCTION

The base of the marine food web is phytoplankton which are transferring energy from one trophic level to higher trophic level. Phytoplankton are playing an important role in regulating energy export in marine ecosystems. The abundance, distribution, diversity and growth of plankton composition depend on the availability of inorganic nutrients (Nitrate, Nitrite, Silicate, Phosphate) and hydrological factors of the coastal waters. Comparing to other marine regions, phytoplankton are considerably understudied in the Bay of Bengal [19]. The availability of nutrient & phytoplankton diversity in the marine has a great influence for the functioning of oceanic ecosystem through cycling of nutrient, productivity & carbon export [23].The potential fertility of coastal waters is depending on availability of nutrients and this nutrient enhances the species composition, abundance and richness rates of primary production [26].

Phytoplankton are contributing about ninety percent of the total marine primary production [49]. The hydrological process is directly influencing the primary productivity and determining the phytoplankton's distribution [12]. Inorganic nutrients are taking part a leading role in phytoplankton abundance, diversity & growth performance [45, 18]. The species composition and abundance of phytoplankton determine the zooplankton diversity which are directly affects the fish production [48]. The variability in primary production influenced the fishery production which has a strong link between phytoplankton and fisheries variability [3,8]. There are several previous studies which indicated that nitrogen-limitation is a widespread phenomenon in tropical coastal waters of Bay of Bengal [47,22,34].

Phytoplankton dynamics has a complex interrelationship among physical, chemical and biological processes [9]. Over the last few decades different authors are interested to study the influencing factors of phytoplankton communities with special relation to physico-chemical parameters [36,21,16]. Nutrient relationship engaged with the successional pattern of phytoplankton communities which are helps to understand ecosystem functioning [33,4]. Different authors have been done their studies about the nutrient dynamics of the Bay of Bengal coastal waters such as [40,17]. Diatom bloom formation has been recorded along the Orissa coast [52].To understand the ecosystem dynamics, need the knowledge of primary production, nutrientconcentration level with community structure of phytoplankton [5]. Nutrient concentrations in the coastal water column are comingfrom rivers, industrial & municipal effluents plant, sediment regenerations and atmospheric deposition [50]. N:P ratio always used to predict the species composition, abundance and assemblages of phytoplankton which also helps to understand the fishery productivity and health of the coastal ecosystem [29]. Nitrate or phosphate or both are primary nutrients controlling phytoplankton production. Nitrate is the principal nutrient in limiting phytoplankton growth in South Pacific subtropical realm [14], South China Sea [10], however, phosphorus limited growth occurs in the northwest Mediterranean [60] and East China Sea [68]. Nitrogen and phosphorus may control phytoplankton production in Daya Bay [65], Taiwan Strait [66], and specific areas in the Yellow and East China Sea [32]. Nutrient functionality significantly assessing the diversity of phytoplankton. Proper attention is needed in every aspect of exploration & exploitation of marine plankton as well as fishery production. According to the ecologically important for fishery and other marine product harvesting, extensive research on phytoplankton assemblages in relation to nutrient dynamics are still lacking. Considering these, the present study will be conducted to understand the role of available inorganic nutrients in controlling the abundance and structure of plankton populations as well as for availability of fishery resources along the south eastern coast of Bangladesh. Compared to the other parts of Bay of Bengal the south eastern coast of Bangladesh is comparatively less studied from this perspective.

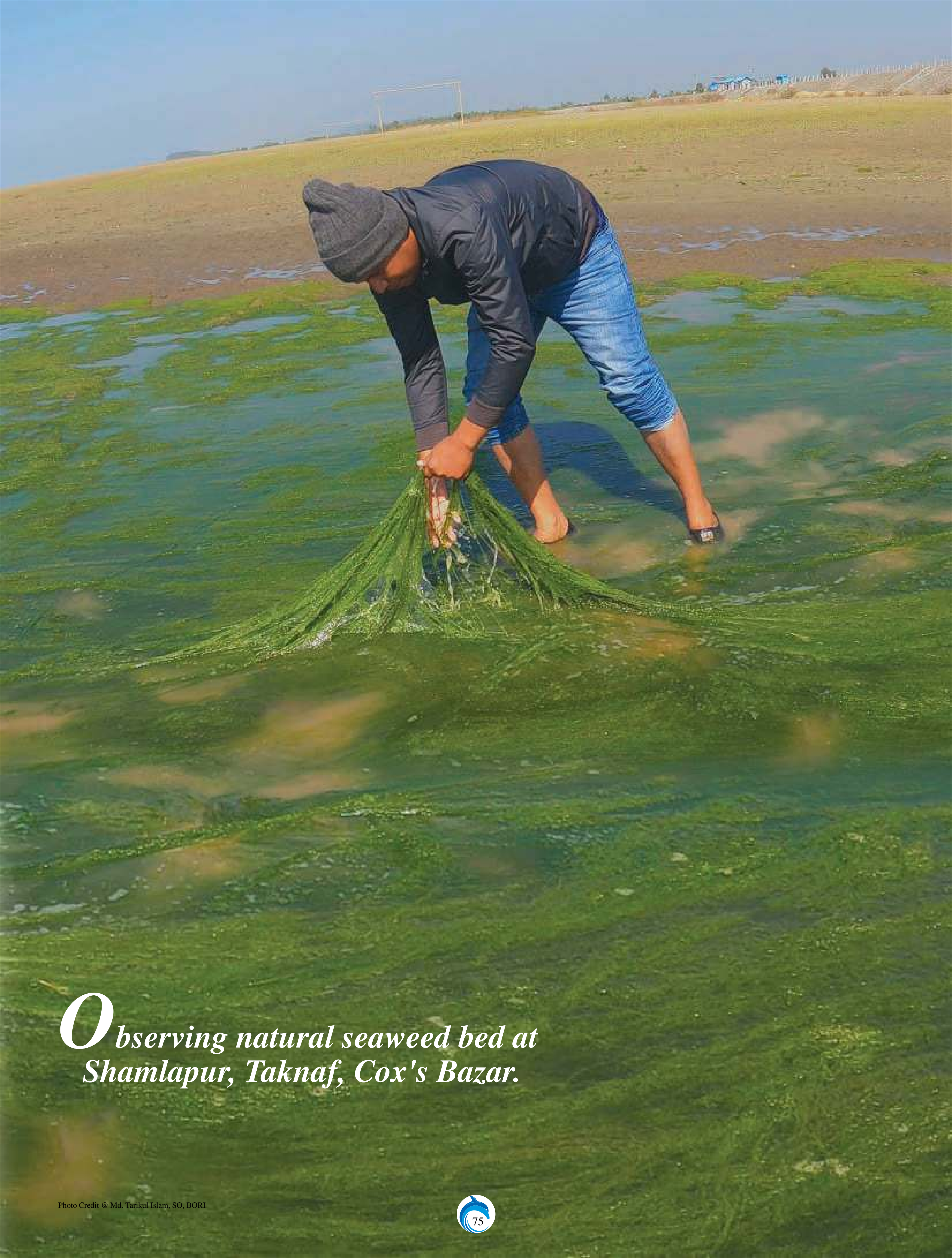
OBJECTIVES

- To determine the environmental variables (Salinity, P^H, DO, Conductivity, Transparency, TDS, Temperature, PO_4-P, NO_3-N, NO_2-N & SiO_3-Si) concentration of the study area.
- To identify phytoplankton composition of the study area.
- To assess the influence of environmental variables on phytoplankton composition of the study area

MATERIALS & METHODS

Study Area

South eastern coastal area is a unique marine environment, rich in biodiversity and is rightly referred as biologist's paradise which is elongated from Teknaf peninsula to Cox's Bazar.The coast of Cox's Bazar has freshwater influx primarily from the Bakkhali, Matamuhuri, Naf river and other hilly areas mainstream systems, but many other sources also significantly contribute carbon and nutrient to the coast and influence the coastal water quality. There are 10 sampling transects selected namely Saint Martin's Island, Naf River,



Observing natural seaweed bed at Shamlapur, Taknaf, Cox's Bazar.

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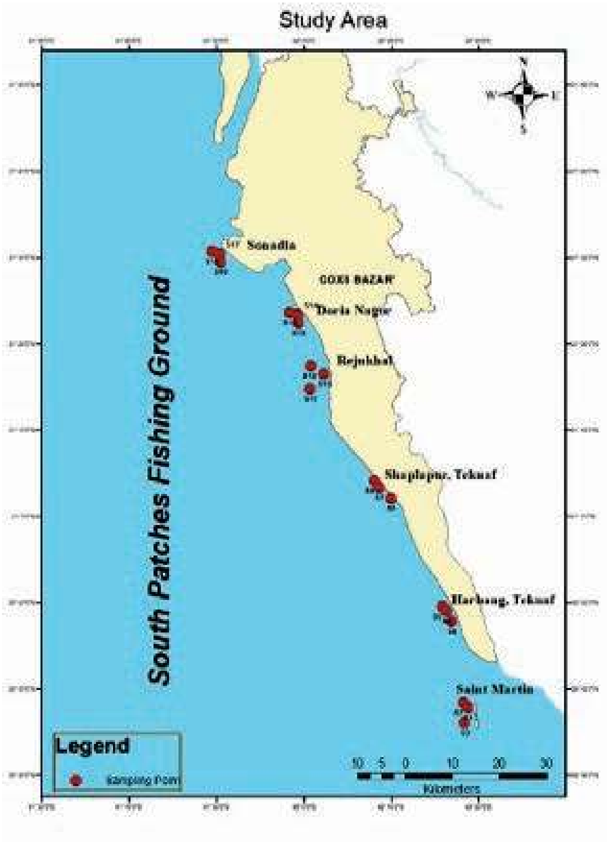
Teknaf, Shaplapur, Rezukhal, Himsori, Cox's Bazar, Sonadia, Maheshkhali&Bakkhali coastal area (A, B, C, D, E, F, G, H, I, J) for determination of environmental variables&phytoplankton sampling respectively. Three seasons viz: i. monsoon (June- September), ii. post-monsoon (October- January) and iii. Pre-monsoon (February - May) are observed in this area. As much as about 80% of total rainfall occurs during monsoon period.



Estimation of Water Analysis

Water samples were collected every month from the Ten stations for a period of one year during July, 2020 to June, 2021. Surface water samples were collected with a sterilized plastic bottle and immediately keep in an ice box and transport to the laboratory for determining the physical and chemical parameters. Water temperature were measured by using Hanna HI98194 multimeter. Salinity was measured by using a hand-held refractometer (Atago hand refractometer, Japan) and YSI ProDSS portable multimeter. Water Transparency was measuredinsitu condition by using Secchi Disk. Total dissolved solids, Salinity, pH and electrical conductivity were analyzed by using Hanna HI98194 multimeter and YSI portable multimeter and dissolved oxygen (DO) was estimated by the modified Winkler's method [54]

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Nutrients Estimation Method:

To determine the abundance and distribution of inorganic nutrients of the south eastern coastal area, surface seawater samples were collected in 1 L pre cleaned polythene bottles at monthly for 1 year. Samples were collected at early morning of the day between 6 a.m. and 9 a.m. 1.5 L capacity based Niskin water sampler was used to collect the water sample and then transferred to the pre cleaned polythene bottles to estimate the nutrients. Collected water samples was immediately keep in icebox and transfer to the testing room for the additional scrutinized. The water samples were filtered applying a Millipore filtering system along whatman membrane filter paper of 0.45 µ porosity. The quantity of the dissolved nutrients of Nitrite-N, Nitrate-N, Phosphate-P, Silicate-Si present in the filter water samples were determined following the standard methods as described by [54] through Shimadzoo-1800 Double Beam Spectrophotometer.

Enumeration of Phytoplankton

For qualitative analysis of phytoplankton, 1 litre of surface (0.5m depth) seawater samples were taken in transparent bottle and fixed with 2% Lugol's iodine solution. For the quantitative analysis, followed the settling method as detailed [57]. Phytoplankton samples were also taken by towing plankton net which 0.30m open diameter making of bolting silk about 45µm. These samples were preserved in 4 % neutralized formalin and used for qualitative analysis and species level identification. For microscopic investigation, samples were concentrated 5 to10 ml by siphoning out the top layer with a silicon tube enclose with a 10 µm Nytex filter. The required sample concentrates were transferred to a 1 ml capacity Sedgwick-Rafter counter and counted using an Olympus Research Grade Microscope (Model: BX-53) at 100× magnification. Taxonomic identification of the micro phytoplankton was done using appropriate monographs [64,11,55,56,67,62,15,1, 43,59, 63, 38,61].

The total number of phytoplankton present in 1Lwater sample was calculated using the formula-

$$N = (n \times v) / V$$

where N = total number of phytoplankton cells in 1 L water (cells/l); n = average number of phytoplankton cells in 1 ml plankton sample; v = volume of plankton concentrates (ml); & V = volume of total water filtered (L).

The Shannon and Weaver [58] formula was used for calculating the species diversity index (H). For calculating the species richness (SR) was followed Gleason [24] method. The evenness index (J') was used the formula of Pielou [41]. The Mc Naughton [35] formula was used for calculating the dominance index. For statistical analysis as like as clustering and principal component analysis (PCA) along with simple correlation were accomplished by applying XLSTAT software.

RESULTS

South eastern coastal area of the Bay of Bengal, Bangladesh is eutrophication prone area which directly influence on phytoplankton abundance, distribution and community structure. In dry season due to lower rainfall, high temperature, nutrients availability and high radiation of sun light phytoplankton bloom are occurring frequently in these regions which are concern for coastal aquatic ecosystem. Moreover, the monsoon rain causes major changes in salinity level for 4 months (June–September). The sandy coast along with rough waves resulted in turbid water, therefore reducing phytoplankton growth. The study on environmental variablesincluding inorganic nutrients and plankton assemblages were exhibited clear seasonal trend as influenced by prevailing monsoonal system along the study area. It can be inferred that fish aggregation is mostly influenced by availability of phytoplankton in the south eastern coast of Bangladesh.

Physico-chemical Parameter Analysis

Status of Sea Surface Salinity (SSS)

The seasonal variation of observed salinity values (‰) were 31±4.63 (Saint Martin), 24.47±7.02 (Naf River), 28.47±5.97 (Teknaf), 28.69±6.02 (Shamplapur), 26.35±8.41 (Rezukhal), 28.50±6.14 (Himsori), 28.36±6.24 (Cox's Bazar), 26.88±7.09 (Sonadia), 24.73±8.34 (Maheshkhali); 23.35±9.62 (Bakkhali) respectively (Table-2). The maximum salinity was recorded in Saint Martin's Island 35.01±0.44‰ during Pre-monsoon season and the minimum was recorded in Bakkhali 10.16±6.05‰ during Monsoon season.

Status of Sea Surface Temperature (SST)

The seasonal variation of the coastal water temperature (°C) values were 27.49±1.01 (Saint Martin), 26.22±1.63 (Naf River), 27.30±1.27 (Teknaf), 27.40±0.87 (Shaplapur), 27.06±1.51 (Rezukhal), 27.07±1.60 (Himsori), 26.97±1.53 (Cox's Bazar), 27.56±1.24 (Sonadia), 27.63±1.29 (Maheshkhali); 27.47± 1.47 (Bakkhali) respectively (Table-2). The maximum temperature (28.53°C±2.32°C) was recorded in Rezukhal during pre-monsoon and minimum 24.83°C±2.63°C was recorded atHimsori during post monsoon season.

Status of Water pH

The seasonal variation of observed pH values was 8.02± 0.14 (Saint Martin), 7.93± 0.11 (Naf River), 7.90± 0.14 (Teknaf), 8.01± 0.13 (Shaplapur), 7.87± 0.20 (Rezukhal), 7.96± 0.14 (Himsori), 7.94± 0.12 (Cox's Bazar), 7.95± 0.08 (Sonadia), 7.88± 0.08 (Maheshkhali)&7.81±0.21 (Bakkhali) respectively (Table-2). The maximum pH was recorded in Saint Martin's Island 8.13±0.01 during Pre-monsoon season and the minimum was recorded in Bakkhali 7.51±0.06 during Monsoon season.

Status of Dissolved Oxygen (DO)

The seasonal variation of observed Dissolved Oxygen (mg/l) values were 5.02±0.19 (Saint Martin); 4.67±0.16 (Naf River); 4.51±0.13 (Teknaf); 4.80±0.18 (Shaplapur); 4.57±0.16 (Rezukhal); 4.78±0.06 (Himsori); 4.81±0.11 (Cox's Bazar); 5.00±0.12 (Sonadia); 4.80±0.11 (Maheshkhali)&4.71±0.26 (Bakkhali) respectively (Table-2). The maximum Dissolved Oxygen was recorded in Saint Martin Island 5.24±0.23 mg/l during post-monsoon season and the minimum was recorded in Rezukhal 4.35±0.27 mg/l during Monsoon season.

Status of Electric Conductivity

The seasonal variation of observed electric conductivity (mS/cm) values were 48.20± 6.84 (Saint Martin); 37.67±11.61(Naf River); 43.02±9.76 (Teknaf); 43.87±9.31 (Shaplapur); 39.99±12.95 (Rezukhal); 43.66±9.02 (Himsori); 43.25±9.27 (Cox's Bazar); 40.61± 11.07 (Sonadia); 37.66±12.76 (Maheshkhali)& 36.11±14.91 (Bakkhali) respectively (Table-2). The maximum EC was recorded in Saint Martin Island 54.11± 0.40 mS/cm during Pre-monsoon season and the minimum was recorded in Bakkhali 15.42±9.16 mS/cm during Monsoon season.

Status of Total Dissolved Solids (TDS)

The investigated coastal water TDS (g/l) values were 24.86±2.91 (Saint Martin), 19.78±5.15 (Naf River); 22.49±3.76 (Teknaf); 22.74±3.97 (Shaplapur); 20.38±5.72 (Rezukhal); 22.58±3.57 (Himsori); 22.20±3.65 (Cox's Bazar); 21.13±4.51 (Sonadia); 19.17±5.89 (Maheshkhali)&18.00±7.28 (Bakkhali) respectively (Table-2). The maximum TDS 27.47±0.25 (g/l) was recorded in Teknafduring pre- monsoon and minimum 7.90±6.02 (g/l) recorded in Bakkhali during monsoon season.

Status of Water Transparency

The seasonal variation of observed transparency values(ft) was 9.01±3.57 (Saint Martin); 3.55±0.72 (Naf River), 1.85±0.34 (Teknaf); 1.84±0.32 (Shaplapur); 2.62±0.89 (Rezukhal); 2.57±0.85 (Himsori), 2.54±0.82 (Cox's Bazar), 2.40±0.80 (Sonadia); 2.29±0.73 (Maheshkhali)& 2.27±0.77 (Bakkhali) respectively (Table-2). The maximum Transparency was recorded in Saint Martin 13.48±1.30 ft during post-monsoon seasonand the minimum was recorded in Bakkhali 1.21± 0.52 ft during Monsoon season.

Status of Rainfall

The seasonal variation of observed rainfall (mm) value was 87.58±94.02 (Table-2). The maximum rainfall was recorded in Teknaf 220.50±77.86 mm during monsoon season and the minimum was recorded in Bakkhali 18.04±19.30 mm during Pre-Monsoon season.

Nutrients Analysis

Nutrients (NO_3-N, NO_2-N, PO_4-P: SiO_4) are the necessary parameters within the coastal waters that influence the growth, reproduction and metabolic activities of biotic components like phytoplankton.

Status of NO_3-N

The seasonal variation of observed NO_3-N (mg/l) values were 0.19±0.03 (Saint Martin); 0.41±0.05 (Naf River); 0.37±0.03 (Teknaf); 0.40±0.05 (Shaplapur); 0.41±0.04 (Rezukhal); 0.39±0.03 (Himsori); 0.37±0.03 (Cox's Bazar); 0.38±0.03 (Sonadia); 0.46±0.04 (Maheshkhali)&0.45±0.05 (Bakkhali) respectively (Table-2). The maximum NO_3-N was recorded in Rezukhal coastal area 0.51± 0.03 mg/l during post-monsoon season and the minimum was recorded in Saint Martin's Island 0.16±0.01 mg/l during pre-monsoon season.

Status of NO_2-N

The seasonal variation of observed NO_2-N (mg/l) values were 0.06±0.01 (Saint Martin); 0.09±0.03 (Naf River); 0.07±0.01 (Teknaf); 0.08±0.02 (Shaplapur); 0.09±0.02 (Rezukhal); 0.08±0.02 (Himsori); 0.08±0.01 (Cox's Bazar); 0.08±0.01 (Sonadia); 0.09±0.02 (Maheshkhali)&0.09±0.02 (Bakkhali) respectively (Table-2). The maximum NO_2-N was recorded in Rezukhal coastal area 0.09± 0.03 mg/l during Monsoon season and the minimum was recorded in Saint Martin's Island 0.06±0.01 mg/l during pre-monsoon season.

Status of PO_4-P

The seasonal variation of observed PO_4-P (mg/l) values were 0.05±0.01 (Saint Martin); 0.08±0.02 (Naf River); 0.06±0.01 (Teknaf); 0.08±0.03 (Shaplapur); 0.08±0.02 (Rezukhal); 0.08±0.02 (Himsori); 0.06±0.01 (Cox's Bazar); 0.07±0.02 (Sonadia); 0.08±0.02 (Maheshkhali)&0.08±0.01 (Bakkhali) respectively (Table-2). The maximum PO_4-P was recorded in Rezukhal coastal area 0.11± 0.01 mg/l during Monsoon season and the minimum was recorded in Saint Martin's Island 0.03±0.01 mg/l during pre-monsoon season.

Status of SiO_4

The seasonal variation of observed SiO_4 (mg/l) values were 0.03±0.01 (Saint Martin); 0.06±0.02 (Naf River); 0.06±0.02 (Teknaf); 0.06±0.01 (Shaplapur); 0.07±0.01 (Rezukhal); 0.06±0.01 (Himsori); 0.06±0.01 (Cox's Bazar); 0.06±0.01 (Sonadia); 0.08±0.02 (Maheshkhali)& 0.07±0.02 (Bakkhali) respectively (Table-2). The maximum $SiO_4$was recorded in NafRiver 0.09± 0.02 mg/l during Monsoon season and the minimum 0.03± 0.01 mg/l in Saint Martin's Island.

Phytoplankton Composition

A total of 137 phytoplankton species were identified whereas, 115 species of diatoms from 44 genera, 15 species of dinoflagellates from 8 genera, 2 species of green algae from 2 genera, 4 species of cyanobacteria from 3 genera and 1 species of silicoflagellate were identified (Table-1). The present study revealed that phytoplankton communities were found to vary from stations to stations and season to season due to the influence of environmental variables. The highest phytoplankton abundance was found at Shaplapur, about 12245 cells/l and the lowest at Saint Martin's Island about 1250 cells/l. Phytoplankton showed complete dominance of diatom genera namely *Asterionella japonica* & *Thalassionema nitzschiodesin* post-monsoon and Odontella rhombus in pre-monsoon. Other frequently occurring diatoms were *Coscinodiscus perforatus*, *Actinocyclus normanii*, *Thalassiothrix fraunfeldii*, *Ditylum brightwelli*, *Rhizosolenia alata*, *Chaetoceros affinis*, *Thalassionema nitzschoides* etc. respectively.Species diversity was observed to be maximum in post-monsoon (67 species) followed by pre-monsoon (42 species) and monsoon season (28 species). Abundance of bloom forming species Asterionellopsisglacialis & Thalassionemanitzschiodes was observed at Shaplapurand Rezukhalcoastal area during the study period. Suitable environmental conditions in post monsoon contributed towards increasing the number of phytoplankton with reported diversity of 65 species compared to the monsoon season (28 species). High density of diatom species, i.e., *Pseduonitzschia pungens* and *Thalassiothrix frauenfeldii* in post monsoon and *Thalassionema nitzschioides*, *Asterionellopsis glacialis* and *Chaetoceros* sp. in pre-monsoon could be the reason for low silicate concentration due to increase in the uptake rate by diatoms.

DISCUSSION

Salinity acts as a vital factor among environmental parameters in distribution of living organisms to the earnest coastal water. Fluctuations in salinity affect fauna of the coastal areas and determine the succession of species and it has a high influence on the marine environment of the Bay of Bengal.The ascertained higher values might be attributed to the low quantity of rainfall, higher rate of evaporation and additionally as a result of neritic water dominance [6]. Observations just like to present study were reported earlier by Palpandi[44] in Vellar estuary. The variability of salinity indicates the upright mixing of the water column due to

Observing Phytoplankton bloom at Shamlapur, Taknaf, Cox's Bazar.

Photo Credit @ Md. Tarikul Islam, SO, BORI

the nature of the sea-tide seasonally. Salinity demonstrates the negative liaison with phytoplankton biota, whereas Dissolved Oxygen (DO) indicates the symmetry between respiration and photosynthesis and exposed a positive liaison [7]. Salinity acts as a limiting factor in the distribution of living organisms, and its variation caused by dilution and evaporation is most likely to influence the fauna in the intertidal zone [19].

The water temperature is important for its effects on the chemistry and biological activities of organisms in water.Generally, surface water temperature is influenced by the intensity of solar radiation, evaporation, freshwater influx and cooling and mix up with ebb and flow from adjoining neritic waters. Less solar radiations with misty sky and moderate rainfall during the Monsoon season may greatly reduce the water temperature [30]. Higher temperature values recorded in the dry season may be because of heat raising temperature of surface water. Low temperature in post monsoon season was due to winter [13].

The pH value depends upon the salinity and temperature of the water and the climatic conditionspresent in that area. The chemical and biological condition of water also places a role in the control of pH concentrations.The lower pH observed during the month of June to September due to the influence of fresh water, dilution of seawater, low temperature and organic matter decomposition assuggested by Ganesan [20]. Generally, fluctuations in pH values during different seasons of the year is attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of seawater by freshwater influx, low primary productivity, reduction of salinity and temperature and decomposition of organic materials as stated by Rajasegar [46]. High pH values may cause sea water deprivation & high-density phytoplankton effect [42]
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Dissolved oxygen (DO) is one of the most important indicators of water quality. Dissolved oxygen is necessary to many forms of life including fish, invertebrates, bacteria and plants. Salty water holds less oxygen than fresh water.Anitha[2] has also made similar observations in Thengapattanam estuary and Tamil Selvan et al., 2016 has also made similar observations in Adayar estuary.

The conductivity of water is affected by the suspended impurities and also depends up on the number of ions in the water. The present study agrees with earlier reported by Surana [51]. High conductivity during post monsoon might be attributed to low mixing of fresh water input from river. Low value during monsoon season was due to rain and mixing of more fresh water from river. The conductivity values decreased with an increase in rainfall. In the rainy season, the increased volume of water remarkably diluted the water [28].

Total dissolved solids (TDS) include all of the disassociated electrolytes that make up salinity concentrations, as well as other compounds such as dissolved organic matter. The amount of total dissolved solids in sea water was increased by the influence of activities on the land.TDS can be influenced by changes in pH. Changes in the pH will cause some of the solutes to precipitate or will affect the solubility of the suspended matter. TDS value was higher during pre-monsoon and lower during monsoon. The mean values for the total dissolved solids (TDS) were higher in dry season than in the rainy season. The lower values of this parameter suggest that the runoff water only contributes to its dilution in the rainy season [28]. Water with a high total dissolved solids indicated more ionic concentration, which is of inferior palatability and can induce an unfavorable physicochemical reaction in the consumers. Kataria[31] reported that increase in value of TDS indicated organic loading by extraneous sources.

Water transparency is a key factor in ocean ecology as the sun is source of energy for all biological phenomena. Transparency reduction is due to the presence of particles in the water. When light attenuates, it alters or limits the capacity of life of some of the biological communities that live in the sea. Water transparency is approached by Secchi depth.Water transparency serves as an index for the trophic state of a water body. It reflects eutrophication through changes in the phytoplankton abundance; increase in the ambient nutrient status in the water leads to higher phytoplankton biomass that diminishes the propagation of light in the water.The rainfall in Bangladesh varies, depending upon season and location. Rainfall has an important effect on the chemistry and biological activities of organisms in the coastal water.

Distribution of nutrients is principally supported season, tidal conditions, fresh water influx and land runoff, chemical effluents and flushing of chemical employed in the agricultural fields. The most explanation for eutrophication involves the enrichment of water by excess nutrients. This study revealed that the minimum concentrations of nutrients observed during pre-monsoon and maximum concentrations of nutrients observed during post-monsoon. Nitrate is one of the great indicators for determination of water quality which shows the topmost oxidized form of nitrogen. Its plays a vital role in strengthening the aquatic life in coastal ecosystem.The low nitrate content encountered may be due to the less usage of nitrogen fertilizers and less disposal of wastes around these stations. The present study agrees earlier reported by HariMuraleedharan [25] in Thondicoastal water.

Nitrite is also one of the great indicators for determination of water quality. Its plays a vital role in strengthening phytoplankton in marine ecosystem.The nitrite content was fluctuated among the Transects as well as the months. The low nitrite content encountered may be due to the less usage of nitrogen fertilizers and less disposal of wastes around these stations. The present study agrees earlier reported by Hari Muraleedharan [25] in Thondi coastal water.

Phosphate concentration is helpful index of eutrophication within the coastal water. The phosphate content was fluctuated among the Transects as well as change with season. The low phosphate content encountered may be due to the less usage of nitrogen fertilizers and less disposal of wastes around these stations. The present study agrees earlier reported by HariMuraleedharan [25]in Thondi coastal water.The discovered high Monsoonal phosphate value might be due to the regeneration and release of total phosphorus from bottom mud in to the water column by turbulence and mixing [56]. Similarly, maximum value in Monsoon and minimum value in Pre-Monsoon season were also document from Tranquebar - Nagappattinam coast [53] in Vellar estuary.

Silicon in sea water may be present in suspension, in particles of clay or sand, as a constituent of diatoms, etc., or in solution. Some silicon in solution occurs in the form of silicate. Silicate minerals rapidly release silica to sea water. Biogenic silica is produced by siliceous organisms in the photic layer.Maximum value recorded in Monsoon season due to significant flow of monsoonal fresh water derived from land drainage carrying silicate leached out from rocks and sediment have been exchanged with superimposed water within the coastal environment [34]. The low value of silicate recorded during post-monsoonal season could be attributed to uptake of silicates by phytoplankton for their biological activity [40].Similar maximum value in Monsoon and minimum in summer season were additionally recorded by Nair [37] in Ashtamudi estuary.

The knowledge of phytoplankton spatial variations of primary production, nutrient concentration and community structure is fundamental for the understanding of ecosystem dynamics.Nutrients play an important role in phytoplankton growth and distribution.Nitrogen availability increased phytoplankton number and growth during post monsoon at Shaplapur&Teknaf coastal water. On the other hand, the result reflects silicate limitation in Cox's Bazar coastal water. High water transparency, moderate salinity, availability of nitrate and comparatively high N: Si: P ratio resulted in high phytoplankton density and diversity during post monsoon season. High dissolved oxygen level indicates high productivity, and in the present study maximum photosynthetic activity was observed in Post monsoon season with increase in dissolved oxygen concentration. In this study, however, phytoplankton population differed quite significantly with the seasons and there was a drastic decrease of the population in monsoon due to water turbidity. Low phytoplankton cell count in monsoon season could be attributed to rough sea conditions leading to upwelling caused conditions of the Bangladesh coastby cyclonic weather. Single species abundance of *Asterionella japonica* & *Asterionellopsis glacialis* were observed from very beginning of post monsoon with a maximum growth rate and create phytoplankton blooming condition consequently. Odontella sp. and *Coscinodiscus* sp. appeared as the most abundant species in monsoon season with a maximum growth rate of the total population. Among the other genera sudden appearance of *Skeletonema costatum* was remarkable in the pre monsoon contributing a handsome rate of total population, whereas *Thalassionema nitzschiodes* appeared as 78% of the flora in the month of March 2021.


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Table-1: Phytoplankton Composition along the Study Area.

SI	Name of Phytoplankton with Taxon
	CLASS: BACILLARIOPHYCEAE (DIATOM)
1	*Asterionella japonica* Cleve in Cleve & Moller 1882
2	*Asterionellopsis glacialis* (Castracane) Round,1990
3	*Actinocyclus normanii* (Juhl.-Dannf.) Hust 1957
4	*Actinocyclus octonarius* Ehrenberg 1837
5	*Asterolampra marylandica Ehrenberg 1844*
6	*Amphiprora gigantea* var. sulcate (O'Meara) cleve 1894
7	*Biddulphia alternans* (Bailey) Van Heurck 1885
8	*Bacteriastrum shadbolt 1854*
9	*Bacteriastrum hyalinum Lauder 1864*
10	*Bacillaria paxillifer* (O. F. Muller) T.Marsson1901
11	*Cylindrotheca closterium* Reimann & Lewin 1964
12	*Coscinodiscus gigas* Ehrenberg 1841
13	*Coscinodiscus centralis* Ehrenberg 1844
14	*Coscinodiscus eccentricus* Ehrenberg 1841
15	*Coscinodiscus perforatus* Ehrenberg 1844
16	*Coscinodiscus marginatus* Ehrenberg 1843
17	*Coscinodiscus wailesii* Gran et 1937
18	*Coscinodiscus oculus* Ehrenberg 1840
19	*Coscinodiscus radiatus* Ehrenberg 1840
20	*Coscinodiscus sp.* Ehrenberg,1839
21	*Coscinodiscus granii* Gough 1905
22	*Coscinodiscus alchetron* Ehrenberg 1841
23	*Cerataulina pelagica* (Cleve) Hendey,1937
24	*Chaetoceros aequatorialis* Cleve 1901
25	*Chaetoceros wighamii* Brightwell 1856
26	*Chaetoceros curvisetus* Cleve1889
27	*Chaetoceros danicus* Cleve 1889
28	*Chaetoceros decipiens* Cleve 1873
29	*Chaetoceros didymus* Gran & yendo, 1914
30	*Chaetoceros similis* Cleve 1896
31	*Chaetoceros diversus* Cleve 1873
32	*Chaetoceros affinis* Lauder 1864
33	*Chaetoceros brevis* F. Schütt 1895
34	*Chaetoceros eibenii* Grunow 1882
35	*Chaetoceros lauderi* Ralfs ex Lauder 1864
36	*Chaetoceros socialis* H.S. Lauder, 1864
37	*Chaetoceros denticulatus* H.S. Lauder 1864
38	*Chaetoceros lorenzianus* Grunow 1863
39	*Chaeteceros diadema* (Ehrenberg) Gran 1897
40	*Ditylum brightwellii* Grunow in Van Heurck 1885
41	*Diploneis interrupta* (Kutzing) Cleve 1894
42	*Diploneis elliptica* (Kutzing) Cleve 1894
43	*Diploneis ovalis* (Hilse) Cleve 1891
44	*Diploneis sp.* Ehrenberg ex Cleve, 1894
45	*Diploneis weissiflogii* (A.W.F. Schmidt) Cleve 1894
46	*Eucampia zoodiacus* Ehrenberg 1839
47	*Eucampia cornuta* (Cleve) Grunow 1883
48	*Fragilariopsis oceanica* (Cleve) Hasle 1965
49	*Fragilariopsis doliolus* (Wallich) Medlin & PA Sims 1993
50	*Fragilariopsis islandica* Grunow 1880
51	*Gyrosigma acuminatum* (Kutzing) Rabenhorst 1853
52	*Gyrosigma balticum* (Ehrenberg) Rabenhorst 1853
53	*Gyrosigma fasciola* (Ehrenberg) J.W. Griffith & Henfrey 1839
54	*Guinardia delicatula* (Cleve) Hasle 1997
55	*Guinardia flaccida* (Castracane) H. Peragallo 1892
56	*Guinardia striata* (Stolterfoth) Hasle 1996
57	*Hemidiscus hardmannianus* (Greville) Mann, 1907
58	*Hemidiscus cuneiformis* Wallich 1860
59	*Hemiaulus sinensis* Greville, 1865
60	*Hyadolodiscus alchetron*
61	*Lauderia annulata* Cleve 1873
62	*Lauderia pumila* Castracane 1886
63	*Leptocylindrus danicus* Cleve 1889
64	*Leptocylindrus minimus* Gran 1915
65	*Licmophora abbreviata* C. Agardh 1831
66	*Melosira sulcate* (Ehrenberg) Kutzing 1844
67	*Mediopyxis helysia* Kuhn, Hargreaves & Halliger 2006
68	*Merismopedia sp.* Meyen, 1839
69	*Nitzschia sigma* (Kutzing) w. Smith, 1853
70	*Nitzschia seriata* Cleve 1883
71	*Nitzschia lorenziana* Grunow in Cleve & Moller 1879
72	*Nitzschia sigmoidea* (Nitzsch) W.Smith 1853
73	*Nitzschia longissimi* (Brebisson) Ralfs 1861
74	*Navicula clavata* Gregory 1856
75	*Odontella mobiliensis* (Bailey) Grunow 1884
76	*Odontella sinensis* (Greville) Grunow 1884
77	*Odontella regia* (M. Schultze) Simonsen 1974
78	*Odontella alchetron*
79	*Odontella rhombus* (Ehrenberg) Kutzing 1849
80	*Odontella aurita* (Lyngbye) C. Agardh 1832
81	*Pleurosigma angulatum* Smith, 1852
82	*Pleurosigma diversestriatum* F.Meister 1934
83	*Pleurosigma elongatum* W. Smith 1852
84	*Pleurosigma directum* Grunow in Grunow & Cleve 1880
85	*Pleurosigma normanii* Ralfs in Pritchard 1861
86	*Paralia sulcata* (Ehrenberg) Cleve 1873
87	*Proboscia alata* (Brightwell) Sundstrom 1986
88	*Proboscia indica* (H. Peragallo) Hernandez-Becerril 1995
89	*Podosira glacialis* (Grunow) Cleve 1896
90	*Podosira stelligera* (Bailey) A. Mann 1907
91	*Planktoniella sol* (Wallich) Schütt 1892
92	*Pseduonitzschia pungens* Hasle 1993
93	*Rhizosolenia curvata* Zacharias 1905
94	*Rhizosolenia robusta* G. Norman ex Ralfs 1861
95	*Rhizosolenia setigera* Brightwell 1858
96	*Rhizosolenia alata* Brightwell 1858
97	*Rhizosolenia bergonii* H. Peragallo 1892
98	*Rhizosolenia formosa* H. Peragallo 1888
99	*Rhizosolenia imbricata* Brightwell 1858
100	*Rhizosolenia* styliformis T. Brightwell 1858
101	*Stephanopyxis palmeriana* (Greville) Grunow 1884
102	*Synedra Formosa* Hantzsch 1863
103	*Skeletonema costatum* (Greville) Cleve 1873
104	*Thalassionema nitzschioides* Mereschkowsky, 1902
105	*Triceratium favus* Ehrenberg 1839
106	*Triceratium robertsianum* Greville 1863
107	*Triceratium formosum* Brightwell 1856
108	*Thalassiosira decipiens* (Grunow ex Van Heurck) Jorgensen 1905
109	*Thalassiosira pseudonana* Hasle & Heimdal 1970
110	*Thalassiosira lacustris* (Grunow)Hasle, 1977
111	*Thalassiosira sp.*
112	*Thalassiosira eccentrica* (Ehrenberg) Cleve 1904
113	*Thalassiosira rotula* Meunier, 1910
114	*Thalassiothrix frauenfeldii* (Grunow) Jorgensen 1900
115	*Thalassiothrix longissima* Cleve & Grunow 1880
	CLASS: DIYANOPYCEAE
116	*Ceratium azoricum* Cleve, 1900
117	*Ceratium furca* (Ehrenberg) Lachmann 1858
118	*Ceratium macroceros* (Ehrenberg) Vanhoffen 1897
119	*Ceratium tripos* (O.F. muller) Nitzsch, 1817
120	*Dynophysis caudate* Saville-Kent 1881
121	*Noctiluca miliaris* Suriray 1816
122	*Noctiluca scntillans* Kofoid & Swezy, 1921
123	*Ornithocercus steinii* Schutt 1900
124	*Procentrum gracile* Schutt, 1895
125	*Procentrum micans* Ehrenberg 1834
126	*Pyrocystis lunula* (F.Schutt) F. Schutt in Engler & Prantl 1896
127	*Pyrocystis fusiformis* CW Thomson1876
128	*Pyrophacus steinii* Schiller 1935
	GREEN ALGAE
129	*Chlorella marina* Butcher 1952
130	*Pediastrum* sp.Meyen, 1829
	CYANOBACTERIA (BGA)
131	*Microcystis* sp. Lemmermann 1907
132	*Trichodesmium erythraeum* Ehrenberg 1830
133	*Oscillatoria princeps* Vaucher ex Gomont, 1822
	SILICOFLAGELLATES
134	*Dictyocha* sp. Ehrenberg 1837

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Table-2: Seasonal variation of Physico-chemical Parameters of the Study Area (2020-2021 FY)

Transect	Monsoon Salinity	Post monsoon Salinity	Pre-monsoon Salinity	Avg.	STD	Monsoon Temp.	Post monsoon Temp.	Pre monsoon Temp.	Avg.	STD	Monsoon DO	Post monsoon DO	Pre monsoon DO	Avg.	STD	Monsoon P^H	Post monsoon P^H	Pre monsoon P^H	Avg.	STD
A	24.64	33.77	35.01	31.14	4.63	28.45	26.10	27.92	27.49	1.01	4.77	5.05	5.24	5.02	0.19	7.83	8.11	8.13	8.02	0.14
B	16.46	23.46	33.51	24.47	7.00	24.70	25.48	28.48	26.22	1.63	4.56	4.89	4.55	4.67	0.16	7.78	7.96	8.05	7.93	0.11
C	20.10	31.69	33.63	28.47	5.97	28.00	25.52	28.37	27.30	1.27	4.40	4.69	4.44	4.51	0.13	7.89	7.74	8.08	7.90	0.14
D	20.23	32.15	33.7	28.69	6.02	27.77	26.20	28.245	27.40	0.87	4.57	5.00	4.825	4.80	0.18	7.81	8.11	8.06	8.00	0.13
E	14.46	31.92	32.67	26.35	8.41	27.65	24.99	28.53	27.06	1.51	4.35	4.65	4.73	4.57	0.16	7.59	8.07	7.95	7.87	0.20
F	19.90	31.75	33.86	28.50	6.14	28.03	24.82	28.37	27.07	1.60	4.71	4.80	4.84	4.78	0.06	7.76	8.07	8.04	7.96	0.14
G	19.63	31.58	33.86	28.36	6.24	27.81	24.83	28.27	26.97	1.53	4.65	4.86	4.90	4.81	0.11	7.77	8.06	7.98	7.94	0.12
H	16.97	30.52	33.13	26.88	7.09	28.65	25.84	28.20	27.56	1.24	4.83	5.09	5.08	5.00	0.12	7.84	7.98	8.03	7.95	0.08
I	13.30	27.93	32.96	24.73	8.34	28.73	25.82	28.34	27.63	1.29	4.65	4.89	4.85	4.80	0.11	7.78	7.88	7.98	7.88	0.08
J	10.16	27.02	32.86	23.35	9.62	28.63	25.40	28.37	27.47	1.47	4.43	4.95	4.98	4.79	0.26	7.51	7.95	7.97	7.81	0.21

Table 2: Cont…

Trnascet	Monsoon TDS	Post monsoon TDS	Pre monsoon TDS	avg	STD	Monsoon Conductivity	Post monsoon Conductivity	Pre monsoon Conductivity	avg	STD	Monsoon Transparency	Post monsoon Transparency	Pre monsoon Transparency	avg	STD	Monsoon Rainfall	Post monsoon Rainfall	Pre monsoon Rainfall	avg	STD
A	20.80	26.31	27.47	24.86	2.91	38.62	51.89	54.105	48.20	6.84	4.73	13.48	8.82	9.01	3.57	220.50	24.25	18	87.58	94.02
B	13.96	18.91	26.48	19.78	5.15	24.02	36.62	52.39	37.67	11.61	4.38	3.63	2.63	3.55	0.72	220.50	24.25	18	87.58	94.02
C	17.37	23.81	26.29	22.49	3.76	29.37	48.05	51.62	43.02	9.76	1.44	2.28	1.81	1.85	0.34	220.50	24.25	18	87.58	94.02
D	17.27	24.37	26.58	22.74	3.97	30.90	48.38	52.33	43.87	9.31	1.45	2.24	1.84	1.84	0.32	220.50	24.25	18	87.58	94.02
E	12.29	24.38	24.48	20.38	5.72	21.68	48.79	49.50	39.99	12.95	1.45	3.61	2.80	2.62	0.89	220.50	24.25	18	87.58	94.02
F	17.57	24.50	25.67	22.58	3.57	30.95	49.15	50.89	43.66	9.02	1.39	3.37	2.94	2.57	0.85	220.50	24.25	18	87.58	94.02
G	17.16	23.76	25.69	22.20	3.65	30.20	48.73	50.83	43.25	9.27	1.42	3.36	2.85	2.54	0.82	220.50	24.25	18	87.58	94.02
H	14.81	23.58	25.01	21.13	4.51	25.00	47.40	49.43	40.61	11.07	1.30	3.17	2.73	2.40	0.80	220.50	24.25	18	87.58	94.02
I	11.09	21.44	24.98	19.17	5.89	20.00	43.24	49.73	37.66	12.76	1.29	3.02	2.57	2.29	0.73	220.50	24.25	18	87.58	94.02
J	7.91	21.29	24.81	18.00	7.28	15.40	43.03	49.90	36.11	14.91	1.21	2.98	2.63	2.27	0.77	220.50	24.25	18	87.58	94.02

N.B: Transect-A (Saint Martin's Island); Transect- B (Naf River); Transect-C (Teknaf); Transect-D (Shamplapur); Transect-E (Rezukhal) Transect-F (Himsori); Transect-G (Cox's Bazar), Transect-H (Sonadia); Transect-I (Maheshkhali); Transect-J (Bakkhali)

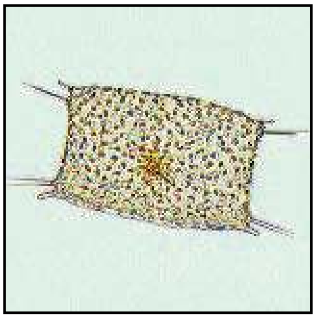
Table 2: Cont…

Trnascet	Monsoon NO_3-N	Post monsoon NO_3-N	Pre monsoon NO_3-N	avg	STD	Monsoon NO_2-N	Post monsoon NO_2-N	Pre monsoon NO_2-N	avg	STD	Monsoon PO_4-P	Post monsoon PO_4-P	Pre monsoon PO_4-P	avg	STD	Monsoon SiO_4	Post monsoon SiO_4	Pre monsoon SiO_4	avg	STD
A	0.18	0.23	0.16	0.19	0.03	0.07	0.06	0.04	0.06	0.01	0.06	0.04	0.03	0.05	0.01	0.04	0.03	0.04	0.03	0.01
B	0.42	0.47	0.34	0.41	0.05	0.12	0.08	0.05	0.09	0.03	0.11	0.08	0.06	0.08	0.02	0.09	0.06	0.050833	0.06	0.02
C	0.34	0.41	0.35	0.37	0.03	0.09	0.07	0.059	0.07	0.01	0.08	0.06	0.05	0.06	0.01	0.06	0.04	0.08	0.06	0.02
D	0.34	0.45	0.39	0.40	0.05	0.10	0.08	0.065	0.08	0.02	0.09	0.11	0.049	0.08	0.03	0.06	0.04	0.08	0.06	0.01
E	0.42	0.45	0.35	0.41	0.04	0.12	0.09	0.07	0.09	0.02	0.10	0.08	0.06	0.08	0.02	0.08	0.05	0.08	0.07	0.01
F	0.38	0.44	0.36	0.39	0.03	0.11	0.07	0.07	0.08	0.02	0.10	0.08	0.05	0.08	0.02	0.07	0.05	0.08	0.06	0.01
G	0.34	0.40	0.36	0.37	0.03	0.09	0.08	0.06	0.08	0.01	0.08	0.06	0.05	0.06	0.01	0.06	0.04	0.075833	0.06	0.01
H	0.36	0.42	0.35	0.38	0.03	0.09	0.08	0.06	0.08	0.01	0.09	0.07	0.06	0.07	0.02	0.06	0.04	0.08	0.06	0.01
I	0.44	0.51	0.43	0.46	0.04	0.11	0.09	0.07	0.09	0.02	0.11	0.06	0.06	0.08	0.02	0.08	0.05	0.09	0.08	0.02
J	0.44	0.52	0.3975	0.45	0.05	0.12	0.09	0.07	0.09	0.02	0.10	0.08	0.06	0.08	0.01	0.08	0.05	0.08	0.07	0.02

Table 3: Annual average environmental variables value (2020-2021 FY)

SI	Parameter	Unit	Transects Data										Avg.	SD
			A	B	C	D	E	F	G	H	I	J		
1	Salinity	PSU	31.14	24.47	28.47	28.69	26.35	28.5	28.36	26.88	24.73	23.35	27.09	2.27
2	Temperature	°C	27.49	26.22	27.3	27.4	27.06	27.07	26.97	27.56	27.63	27.47	27.22	0.40
3	DO	mg/l	5.02	4.67	4.51	4.8	4.57	4.78	4.81	5	4.8	4.79	4.775	0.15
4	PH	-	8.02	7.93	7.9	8	7.87	7.96	7.94	7.95	7.88	7.81	7.926	0.06
5	TDS	g/l	24.86	19.78	22.49	22.74	20.38	22.58	22.2	21.13	19.17	18	21.333	1.93
6	Conductivity	mS/cm	48.2	37.67	43.02	43.87	39.99	43.66	43.25	40.61	37.66	36.11	41.40	3.49
7	Transparency	Ft	9.01	3.55	1.85	1.84	2.62	2.57	2.54	2.4	2.29	2.27	3.094	2.02
8	Rainfall	Mm	87.58	87.58	87.58	87.58	87.58	87.58	87.58	87.58	87.58	87.58	87.58	0.00
9	NO_3-N	mg/l	0.19	0.41	0.37	0.4	0.41	0.39	0.37	0.38	0.46	0.45	0.38	0.07
10	NO_2-N	mg/l	0.06	0.09	0.07	0.08	0.09	0.08	0.08	0.08	0.09	0.09	0.081	0.01
11	PO_4-P	mg/l	0.05	0.08	0.06	0.08	0.08	0.08	0.06	0.07	0.08	0.08	0.072	0.01
12	SiO_4	mg/l	0.03	0.06	0.06	0.06	0.07	0.06	0.06	0.06	0.08	0.07	0.061	0.01

N.B: Transect-A (Saint Martin's Island); Transect- B (Naf River); Transect-C (Teknaf); Transect-D (Shamplapur); Transect-E (Rezukhal) Transect-F (Himsori); Transect-G (Cox's Bazar), Transect-H (Sonadia); Transect-I (Maheshkhali); Transect-J (Bakkhali)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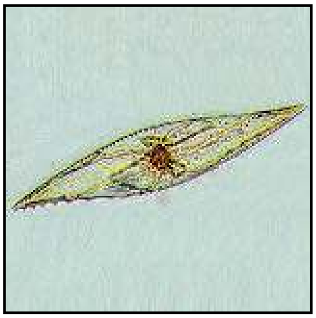
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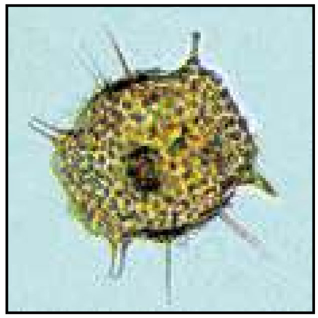
Podosira stilligera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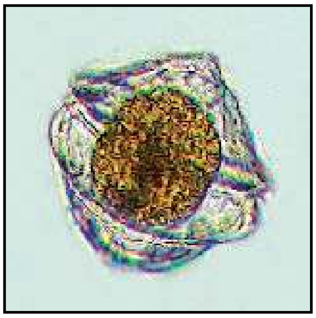
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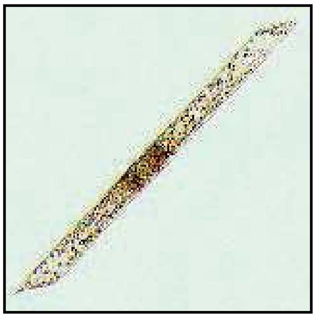
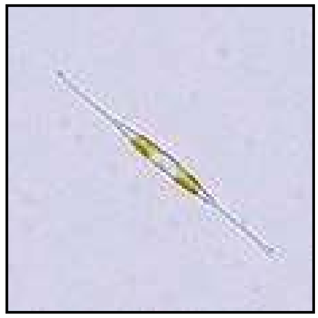
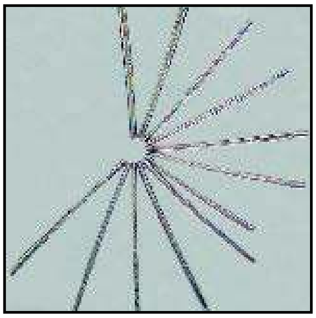

proboscia indica


Rhizosolonia sp


Nitzschia longissimi

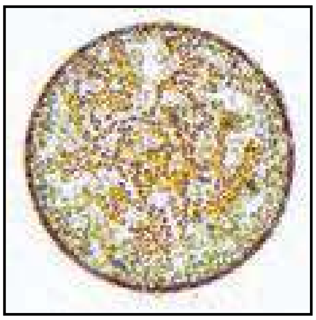

Thalassionema sp

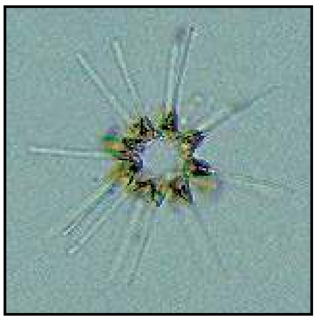

Podosira stelligera


Fragilaria islandica


Protoperidinium conicum


Pyrophacus horologium


Actinocyclus sp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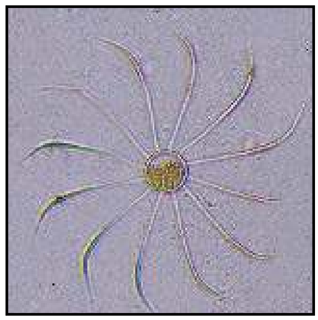
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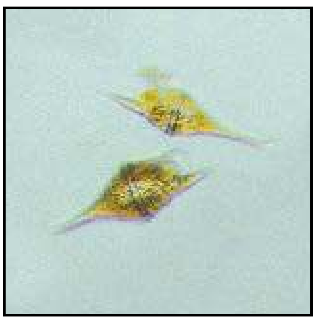
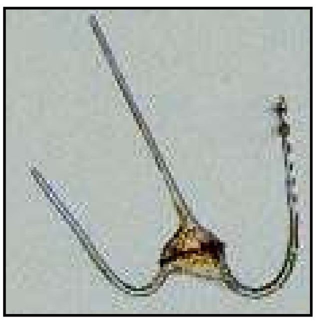
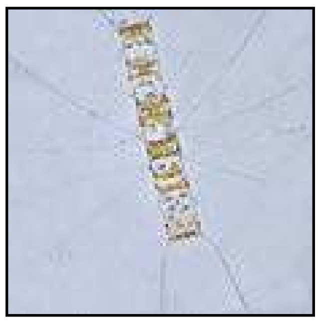

Ceratium furca

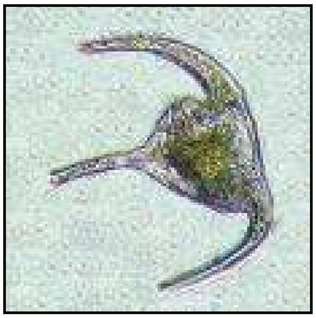

Ceratium macroceros


Chaetoceros sp


Chaetoceros brevis

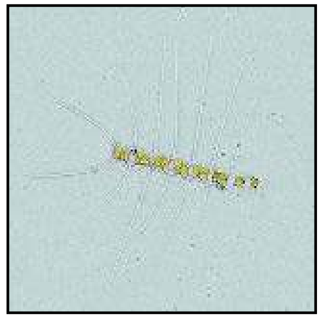
Please Note: The above images were taken under a microscope in Chemical Oceanography Laboratory of BORI. Photo Credit @ Md. Tarikul Islam, SO, BORI

Image of Marine Phytoplankton


Ceratium tripos


Chaetoceros pelagica


Chaetoceros sp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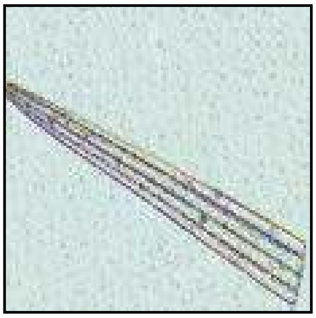
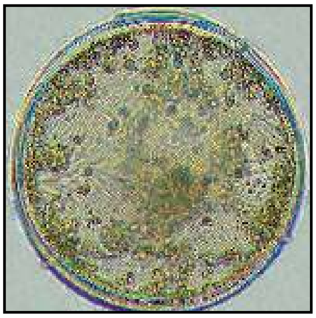
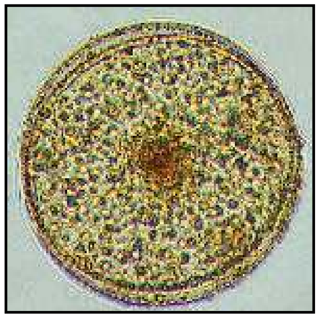
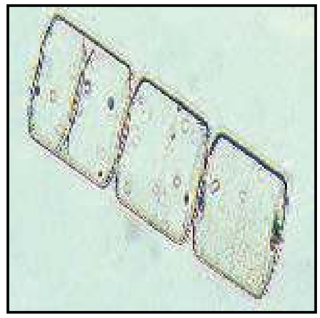
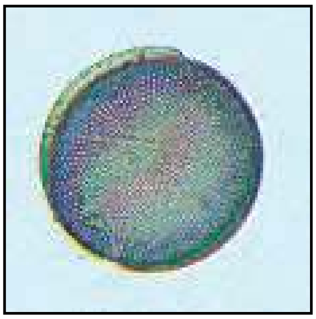

Climacosphenia moniligera


Coscinidiscus granii


Coscinpdiscus radiatus


Dinococcus sp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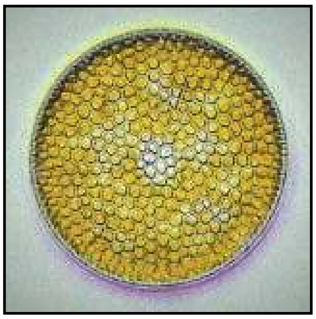
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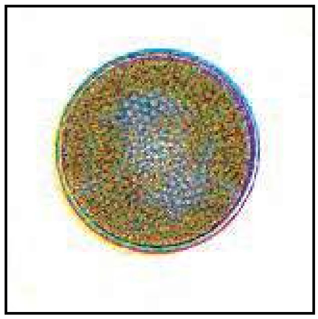
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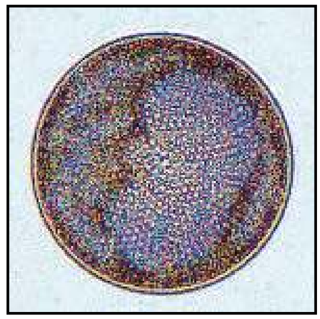
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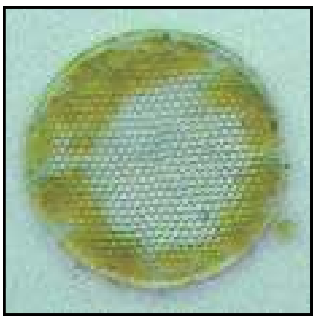
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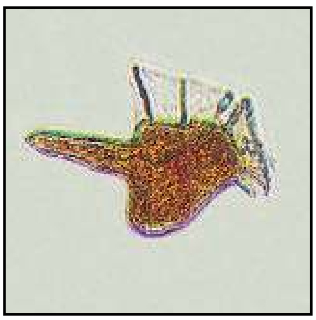
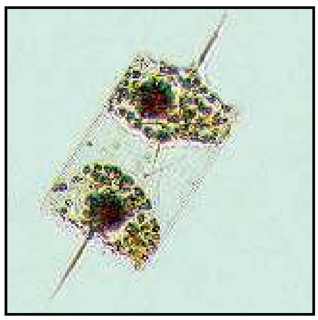
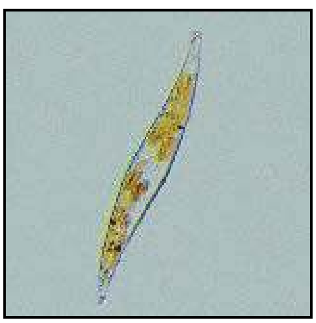
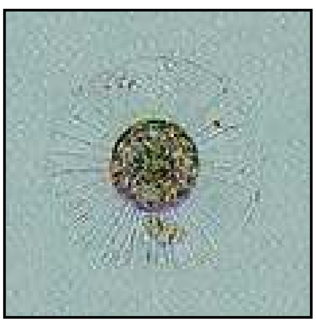
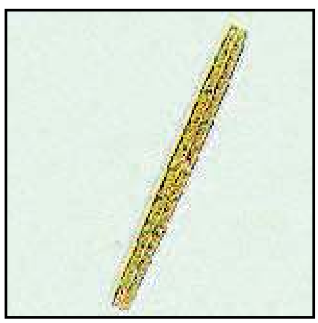

Dinophysis caudata


Ditylum brightwellii


Hemiaulus sinensis


Gyrosigma sp

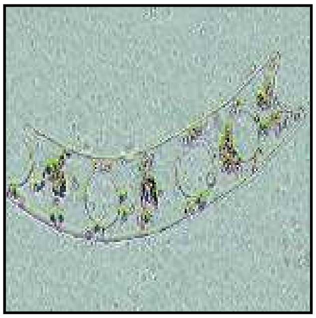

Planktoniella sol

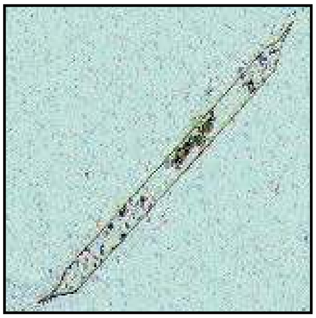

Nitzschia reversa

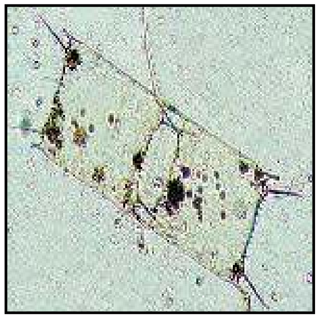

Eucampia cornuta

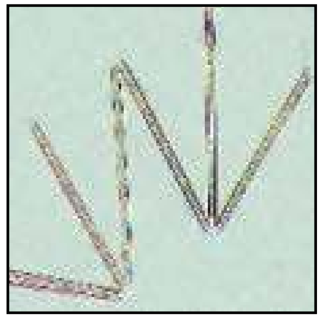
Please Note: The above images were taken under a microscope in Chemical Oceanography Laboratory of BORI. Photo Credit @ Md. Tarikul Islam, SO, BORI

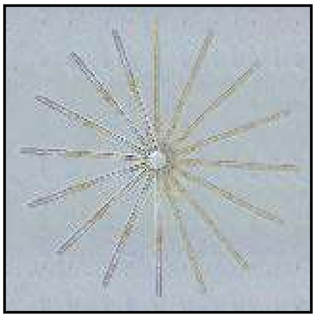
Image of Marine Phytoplankton


Eucampia zoodiacus

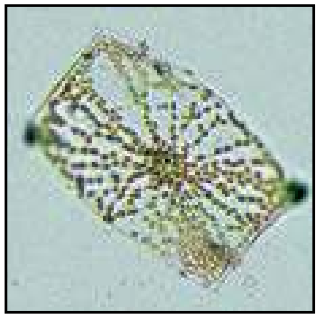

Proboscia alata


Biddulphia sinensis

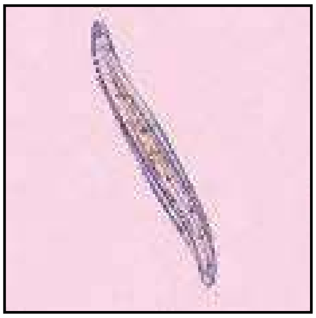

Thalassionema sp

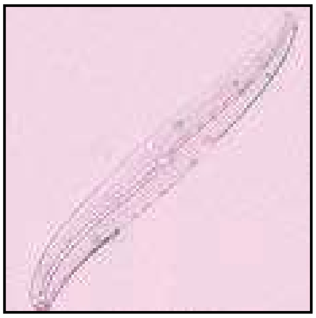

Thalassionema sp


Odontella sp


Odontella sp

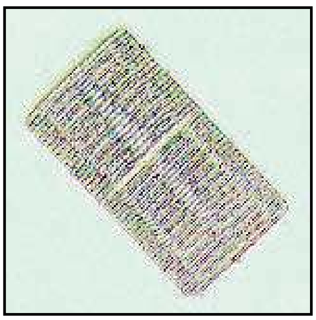

Nitzschia sp

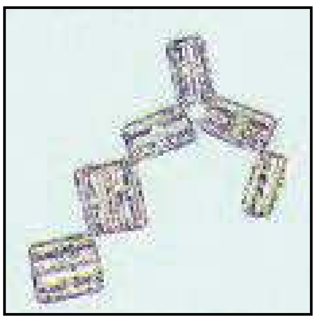

Gyrosigma sp

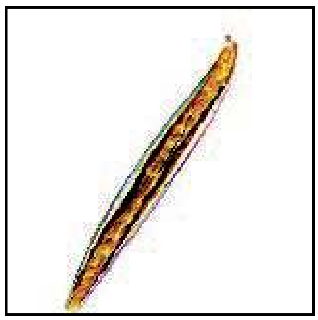

Gyrosigma sp

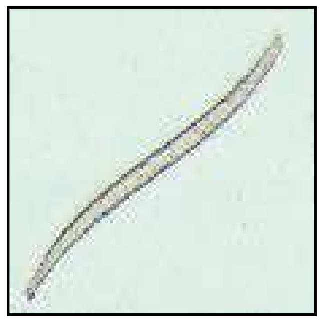

Skeletonema sp

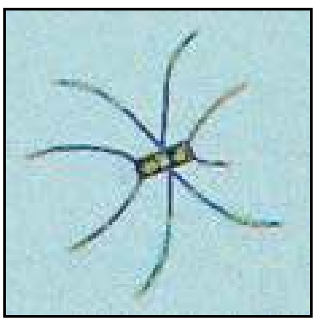

Pleurosigma sp

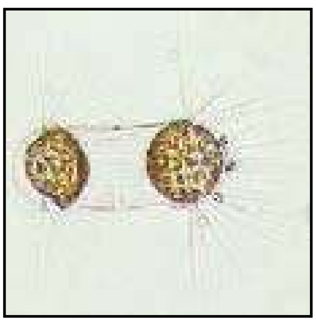

Fragilaria sp

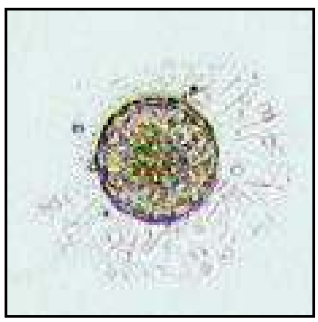

Grammatophora marina


Gyrosigma sp


Nitzschia sp


Chaetoceros sp


Corethron criophilum


Meringia sp


Coscinodiscus sp

Please Note: The above images were taken under a microscope in Chemical Oceanography Laboratory of BORI. Photo Credit @ Md. Tarikul Islam, SO, BORI

Image of Marine Phytoplankton

During Snorkeling at Saint Martin's Island

Plankton Culture Unit

Making Plankton Net

Observing Phytoplankton Bloom

Measuring Mussel Length

Collecting Phytoplankton Bloom Sample

During Sapling at Sonadia Island

During Sampling by Local Boat

In-situ Parameter Reading

Observing Dead Dolphin at Sonadia Island

Green Mussel Culture at BORI

Green Mussel Culture at BORI

Observing Barnacle at Saint Martin's Island

Observing Parrot fish

Observing Oyster at Sonadia Island

Seminar on Blue Economy

Seaweed Drying at BORI Campus

Seaweed at Saint Martin's Island

Seaweed Culture at Rezukhal

Cage Culture Visit at Maheshkhali Channel

Sampling Photography

CONCLUSION

The phytoplankton assemblages in the south eastern coastal ecosystem of the Bay of Bengal, Bangladesh werecharacterized by high species richness and abundance. The community was dominated by diatoms during the post monsoon season. Freshwater discharge makes the coastal water turbid, light limited, and less productive during certain period. Nutrient stoichiometry played an important role in the distribution of planktonic population spatially and temporally. A distinct seasonal nutrient limitation on phytoplankton growth was evident. However, sufficient attention has been given to the Cox's Bazar coast with regard to water quality analysis and its relationship with the density and diversity of phytoplankton. Hence, the present study will provide a baseline information on hydrology, photosynthetic efficiency and phytoplankton community distribution along the coast;further investigation on phytoplankton dynamics can provide clear insight about the specific type of food chain and a plankton model can be developed for future reference.

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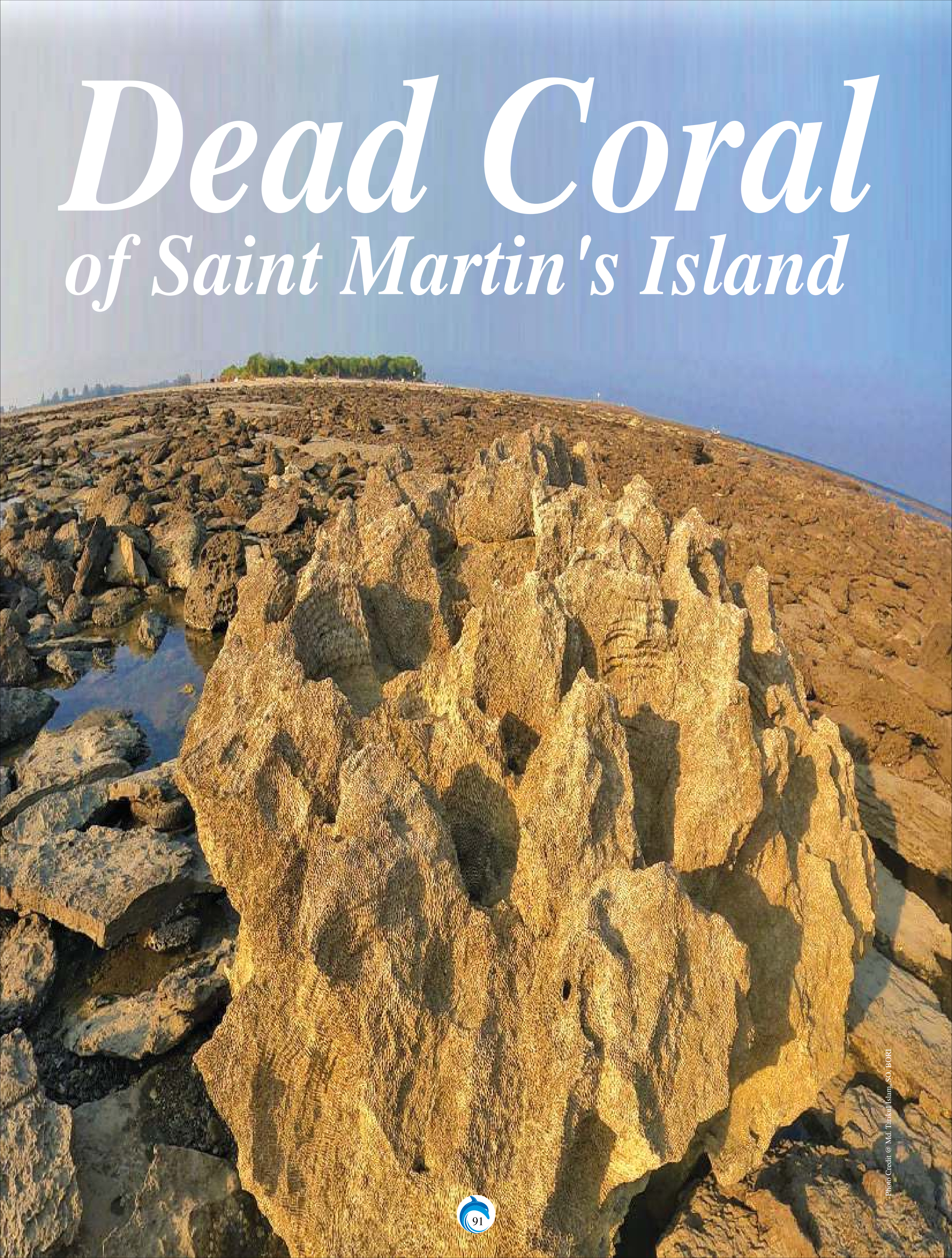
Dead Coral
of Saint Martin's Island



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EDUCATION

B.Sc. & M.S
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Dhaka University
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SKILLS

Marine Multimeter,
Primer,
SPSS,
Spectrophotometer,
PCR etc

PROJECTS

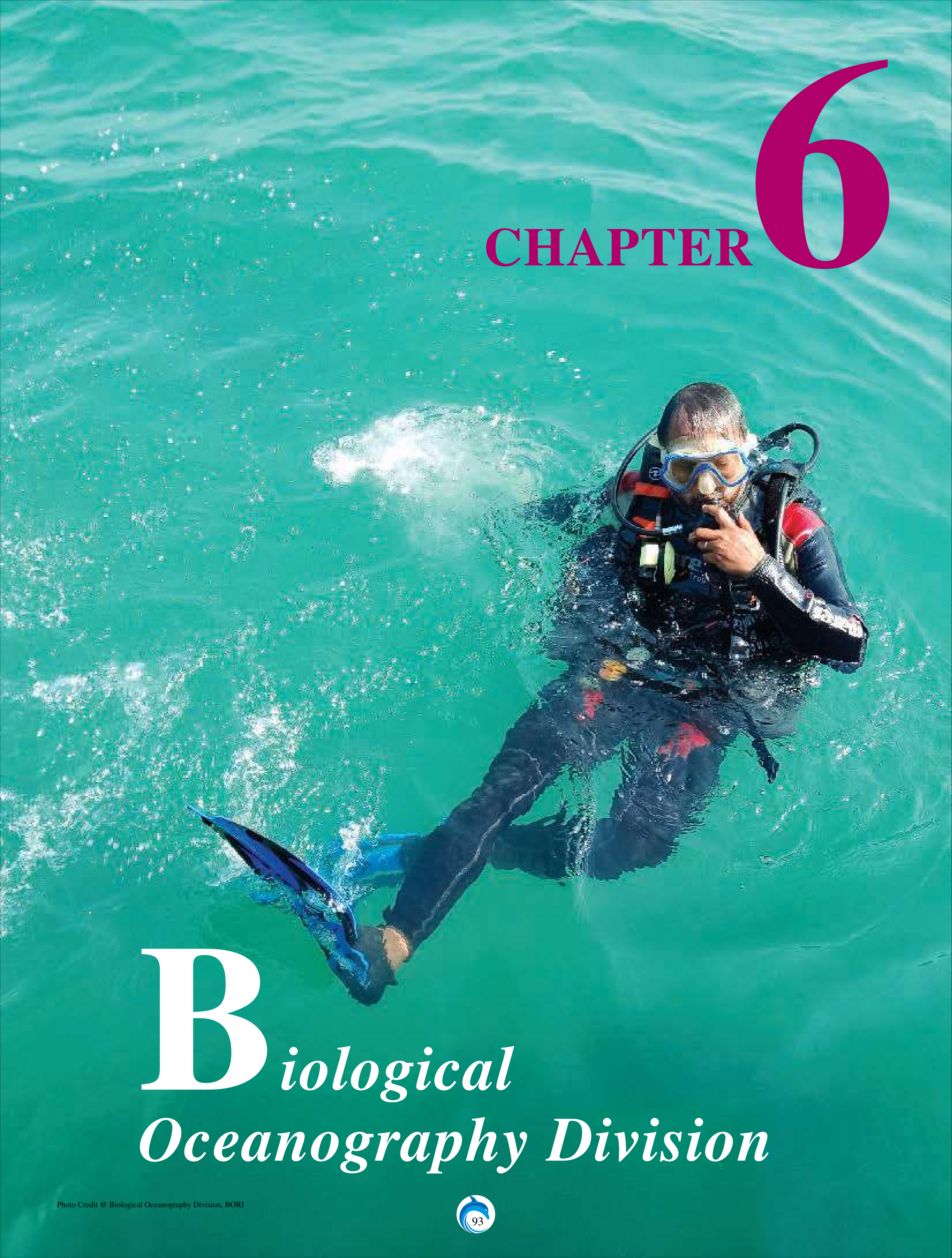
- Influence of Physico-chemical Parameters on Abundance and Distribution of Plankton Composition along the East Coast of Bay of Bengal.
- Phytoplankton assemblages in the south patches fishing ground of the Bay of Bengal with reference to the seasonal variability of nutrient abundance.
- A study on Nutritional status and culture of Green Mussel (Perna viridis) at Coastal area of Cox’s Bazar, Bangladesh.

RESEARCH INTEREST

Ocean Acidification, Marine Coastal Pollution, Nutrient Dynamics, Marine Ecology, Mariculture, Marine Planktonology & Marine Carbon Chemistry.

TRAINING

- Assessing pollution in Rivers, Estuaries and Coastal Waters -FAO, BOBLME.
- Application of Oceanography tools at NIO, GOA.
- Mariculture (Crab, Mussel & Shrimp), Marine Planktonology, Ocean Nutrient dynamics etc.



CHAPTER 6

Biological Oceanography Division

Photo Credit @ Biological Oceanography Division, BORI

Biological Oceanography Division is engaged in exploring biological resources of the Bay of Bengal as a part of baseline study through Research and Development (R&D) projects. The division is working to find potential commercial seaweeds around the Saint Martin's Island; evaluating occurrence, distribution and diversity of phytoplankton & zooplankton in the Bay of Bengal; monitoring water & bottom sediment physic-chemical quality and heavy metal contamination around the Island. It also provided technical and laboratory assistance to MSc thesis students in their research. BOD extended research collaboration with universities and research institutions etc. Beside the research activities BOD provided technical support for seaweed identification to different organizations.

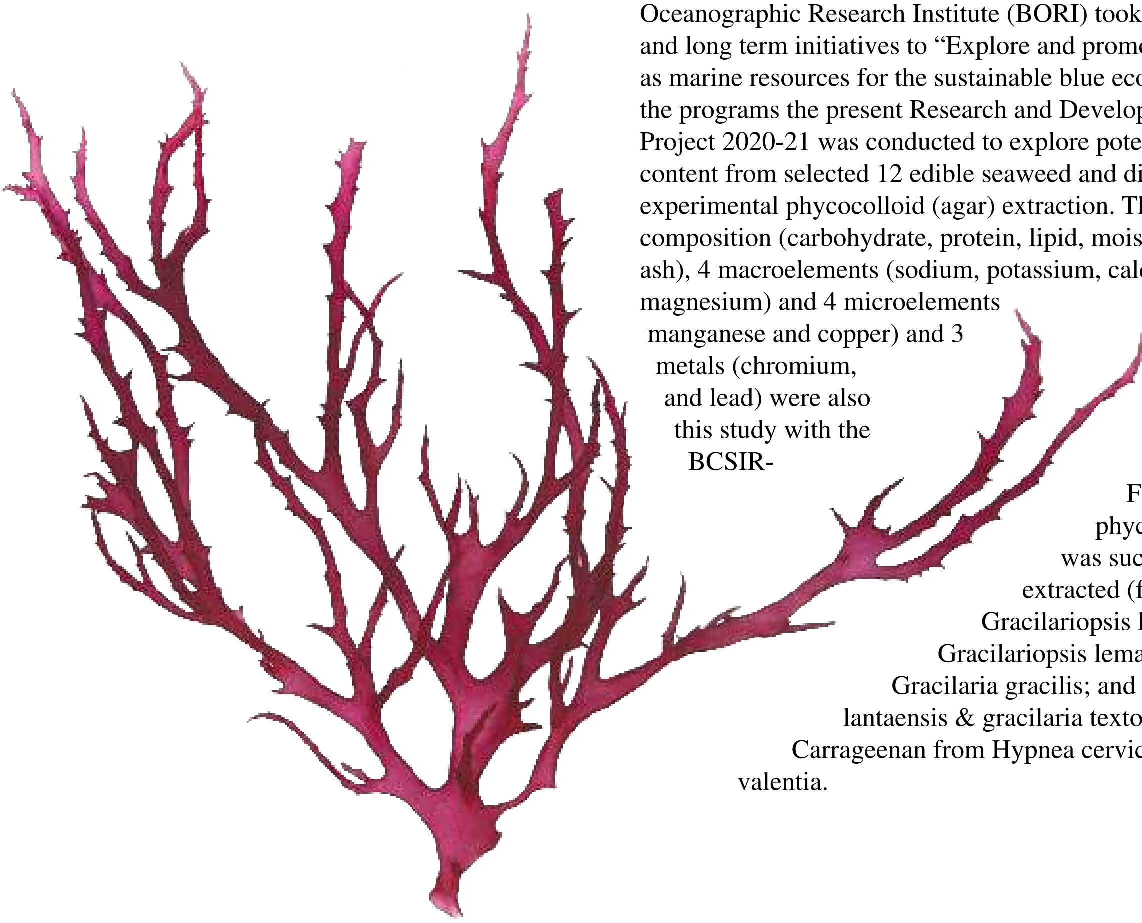
Photo Credit @ Biological Oceanography Division, BORI

Quantification of potential nutritional value from 10 seaweeds & Experimental extraction of Phycocolloids from 3-5 seaweeds available around St. Martin's island and continuation of taxonomic base line study

Abu Sayeed Muhammad Sharif
Senior Scientific Officer (SSO)

Abstract

The Biological Oceanography Division of Bangladesh Oceanographic Research Institute (BORI) took some short mid and long term initiatives to "Explore and promotion of seaweed as marine resources for the sustainable blue economy". Under the programs the present Research and Development (R&D) Project 2020-21 was conducted to explore potential nutrition content from selected 12 edible seaweed and did a trial on experimental phycocolloid (agar) extraction. The proximate composition (carbohydrate, protein, lipid, moisture, fiber and ash), 4 macroelements (sodium, potassium, calcium, magnesium) and 4 microelements (iron, zinc, manganese and copper) and 3 heavy metals (chromium, cadmium and lead) were also examined in this study with the support of BCSIR-Chittagong. Furthermore, phycocolloid agar was successfully extracted (from Gracilariopsis lemaneiformis; Gracilariopsis lemaneiformis; Gracilaria gracilis; and Gracilaria lantaensis & gracilaria textorii) whereas Carrageenan from Hypnea cervicornis, Hypnea valentia.



Halymenia floresii

Photo Credit @ Abu Sayeed Muhammad Sharif, SSO, BORI

Introduction

The Biological Oceanography Division (BOD) of Bangladesh Oceanographic Research Institute (BORI) is working on seaweed to address some short, mid and long term vision for the Sustainable Development Goals (SDG's), emerging blue economy, dynamic socio-economic development and election manifesto in a goal. The BOD Seaweed Research Team (SRT) started the journey in 2018 to achieve the goals of "Explore and promotion of seaweed as marine resources for the sustainable blue economy" (Figure 1). As part of this goal, the team took the initiative to discover phycocolloid specimens and investigate edible seaweed nutritional value around Saint Martin Island. The proposal was designed to collect the samples with the assistance of professional divers who have unique underwater exploring experiences around Saint Martin's island. Anyhow, the Bangladesh Navy Diving special force was engaged for sampling and underwater sample imaging.

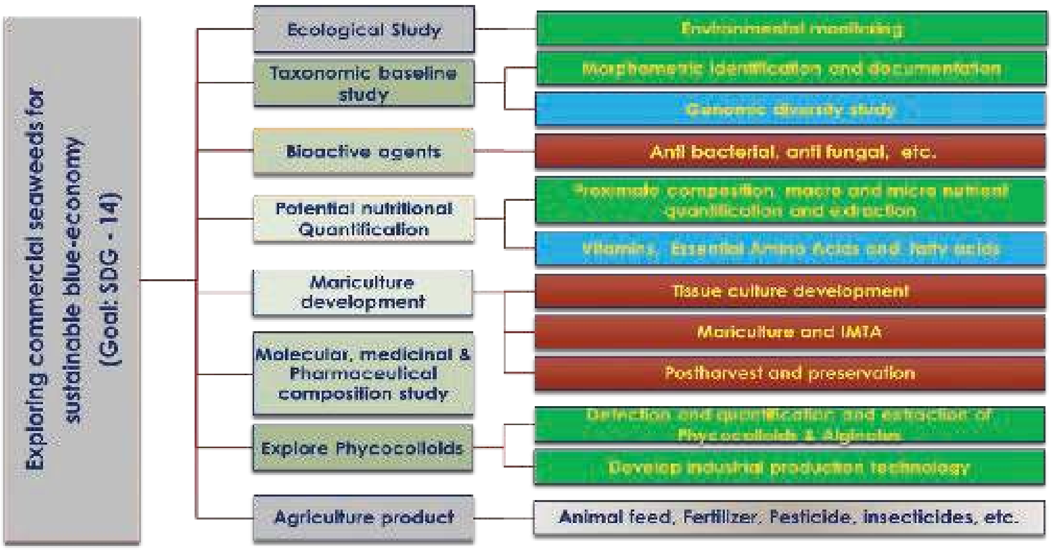


Figure 1: The short to long term programs of BORI to Explore and promotion of seaweed as marine resources for sustainable blue economy

Seaweeds are thousands of macroscopic, multicellular, marine, and macroalgae species which appear like terrestrial plants. Seaweeds are not classified as true plants because they do not have an organized vascular system to absorb nutrients. The whole plant remains in contact with the water and they can take up nutrients and exchange gases directly. The root system is called the holdfast, the stem is the stripe and the leaf is known as blade or frond. Seaweed can be reproduced by three different methods, (1) Vegetative reproduction through fragmentation or division (2) Asexual reproduction through fission, budding, spore formation, regeneration, and vegetative propagation and, (3) Sexual reproduction. Seaweeds are classified based on their major pigmentation into Rhodophyta (red), Phaeophyta (brown) and Chlorophyta (green). They are widely distributed in the coastal littoral to subtidal and neritic zone, mostly on the rocky bottom; attached by holdfast to substrates such as sand, mud, rocks, shells, coral inter alia, shells and other plant bodies (mostly mangroves).

Seaweeds play a significant role in maintaining ecological sustainability providing many ecosystem services. They play a vital role in different phases compared to other aquatic resources. The ecosystem services of seaweed are offered in many ways; they provide food and shelter for much other flora and fauna thus enriching habitat and diversity; balance ecosystem by protecting economically valuable species of fish and crustacean to maintain biodiversity; absorb nutrients & reduce blooming; act as a waste trap; host for parasites and pathogen; produce oxygen and Provide energy; support in reef-building and marine habitat; acts bio-indicator of marine habitat and play a significant role in CO2 sink. On the other hand, many seaweeds are imperative for human life as a source of food. They are nutritionally valuable as fresh or dried vegetables, salad, and other prepared food- because of their food value, flavour, colour, and texture appearance. Different species of protein-rich seaweeds are used as human food in different countries all over the world (Thomsen and McGlathery, 2007). Certain edible seaweeds contain significant types of protein, lipids, minerals and vitamins (Fujiwara-Arasaki et al., 1984). The nutrient content of seaweeds may vary with species, geographical location, season, humidity and temperature

(Hwang et al., 2008) and its environment. Some of them are good sources of iodine, potassium, magnesium, calcium. Sodium, iron, and, zinc. Industrially many important items, such as agar-agar, alginates and gelatine are used for bacteriological culture, soups, desserts, shoe polishes. Cosmetics, shaving cream and laxatives are obtained from seaweeds (Thomsen and McGlathery, 2007). Many seaweed contains potential pharmaceuticals and medicinal bioactive compounds for antibacterial, anti-fungal, anti-oxidant and anti-Viral activities/ properties, anti-obesity, anti-cancer, anti-obesity, pesticides, insecticides agents and properties. They are also a good source of animal feed and bio-fertilizer.

The present study is initiated to fulfil the gap of seaweed-based biochemical composition extraction especially hydrocolloid. A successful outcome of the study will play a significant role in the socio-economic development of the coastal community through mariculture and its industrial development will contribute to the national GDP in different ways.

Objectives

Bangladesh is blessed with a resourceful marine coastline with more than 170 (Aziz, et al., 2015), seaweed species found in Saint Martin's Island. The environment and climate are very suitable for seaweed culture and farming. However, the ongoing projects in seaweeds in Bangladesh are very inadequate in number. In this scenario, this study aims to explore the potential of seaweeds in the perspective of the blue economy of Bangladesh with the specific goals outlined below:

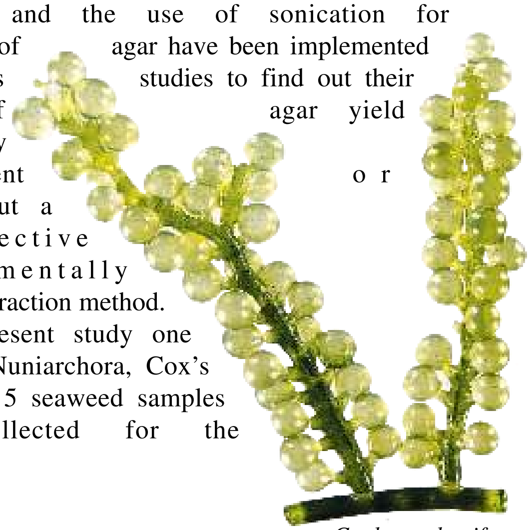
- Screening phycocolloid content from seaweed
- Developing local capacity for phycocolloid extraction assay and understanding the parameters to improve the agar yield from seaweeds
- Proximate analysis from edible seaweed to assess the nutrition value.

Literature review

The scientific investigation on seaweed in Bangladesh was first reported by Dr Nurul Islam, former National Professor, Dr A K M Nurul Islam, who is regarded as the 'Father of Phycology and Limnology in Bangladesh'. He conducted a massive study from 1970 to 1978 & published "Contribution to the study of marine algae of Bangladesh" in 1978. Following Dr Nurul Islam his devoted disciple, Dr A Aziz, professor, Department of Botany, University of Dhaka continued a lot in exploring seaweed and still enriching the taxonomic checklist. Dr Md. Zafar, Professor, Institute of Marine Science, explored Hypnea and Caulerpa cultivation in 2005 and 2007. The Asiatic Society of Bangladesh compiled all the seaweed and algae (both fresh and marine) and published "Encyclopaedia of flora and fauna of Bangladesh" vol. 3 in 2008 & vol. 4 in 2009. The Bangladesh Fisheries Research Institute (BFRI) and Dr Sheikh Aftab Uddin and his team from the Institute of Marine Science, Chittagong University published taxonomic catalogues in 2019 and 2020 respectively. Besides this, the Department of fisheries, DOF, BFRI, BARI, the COAST Trust & IDF and Falcon International are working a lot in seaweed cultivation through field extension programs and activities. Besides these in recent years a good number of experiments conducted by different university students for taxonomic study, nutrition content, biochemical composition, culture process, ecological monitoring, and bioactive composition. This is also important to mention that Jahanara Agro, a local entrepreneur in Cox's Bazar is working on seaweed product base development.

A few reports about the seaweed of Bangladesh have been stated so far. Aziz et al., 2015, reported 202 seaweeds of 77 genera in which 95 were red, 47 green and 60 brown seaweed; IMSCU reported 150 seaweeds of which 78 were red, 29 green and 43 brown seaweed; BFRI reported 132 seaweeds of 55 genera belonging 28 green, 35 brown and 69 red seaweed. So far, there are very few reports on phycocolloid seaweed for Bangladesh. Hydrocolloid from seaweed can be extracted from aqueous extraction which generally involves heat treatment at boiling point in water (Rejeki et al., 2018). However, various other ways such as enzyme-assisted extraction, microwave-assisted extraction, and the use of sonication for extraction of agar have been implemented in various studies to find out their effect of agar yield and quality improvement or to find out a cost-effective environmentally friendly extraction method.

In this present study one from the Nuniarchora, Cox's Bazar and 5 seaweed samples were collected for the



Caulerpa. lentifera

Photo Credit @ Abu Sayeed Muhammad Sharif, SSO, BORI

Materials and Methods

Sampling and sites

Seaweed samples were collected from 8 sites by diving 4 sites by snorkelling and 6 intertidal sites by selection and collection. The sampling sites are shown in (Figure 2). The Bangladesh Navy Diving experts was involved in diving, while snorkelling and intertidal shore collection was conducted by the BORI seaweed research team. The present study was designed to collect samples from January/February to April/May, but due to COVID alert, the Navy divers had some limitations to participate in sampling and could not participate from April. So sampling was conducted from February to April where diving was conducted only in February and March.

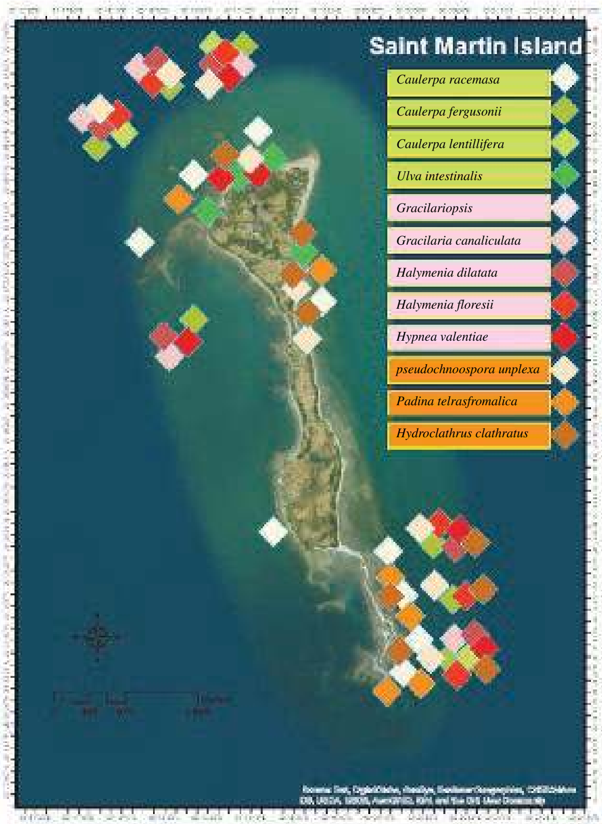


Figure 2: Map showing sampling sites of different seaweed around Saint Martin's Island

Sampling and methodology

Seaweed sampling

Diving: Transect or circular block sampling for seaweed was conducted by the Bangladesh Navy divers and about ±50sqm area was covered from each site, at a depth of 2-12m depth on the rock bed.

Snorkelling: BORI seaweed research team conducted snorkelling from 4 sites during low tide and covered about ±150sqm along subtidal zone at a depth of 1-2m depth.

Intertidal shoreline sampling: BORI seaweed research team conducted Intertidal shoreline sampling from 6 sites around the island. About 300m long intertidal area was covered while sampling.

Sample processing and preservation

All the collected samples were sorted initially in the field, on-board while diving; onshore while snorkelling and intertidal sampling. Sorted samples were kept in seawater in separate Ziploc and were pot in a transportation box filled with seawater and brought to the hotel for further processing. Reaching the hotel, the samples were further sorted, cleaned and washed carefully. In the next some part of the sample was preserved in 6-7% formalin for morphological identification, some were 95-98% alcohol for histological study; some small parts of the specimen were placed in silica gel for genetic identification, and the rest samples were put on the dryer and placed in the shed for drying. Some representative samples of every site were also separately kept for detailed imaging for documentation. All samples of each date were levelled with sampling site reference.

Imaging for documentation

Sample imaging is essential for documentation. Due to some technical limitations with the navy cable connected underwater camera was not useful to capture images due to bottom rocks and continuous surges. So Insitu sample images were not captured but the scaled laboratory image was captured in the field and at BORI.

Morphometric identification: The collected seaweed samples morphometric identification was followed by the algaebase.org, marinespecies.org, Macroalgal Herbarium Consortium Portal, high impact journal articles and identification manuals and corresponding scientists around the globe.

Experimental Phycocolloid (agar and carrageenan) extraction

Agar and carrageenan extraction was followed after (Armisen & Galatas, 1987- FAO) & (Stanley, 1990) respectively-

Method: [Hot Water Extraction Method] / [Boiling Method].Optimization experiments extended for the highest quantity with the best quality at different conditions.

Quantification of nutritional value from seaweeds: 12 seaweed samples were selected for the quantification of nutritional value. All the samples were analysed at the BCSIR Chittagong laboratory following respective standard methods by Atomic Absorption Spectrophotometer.

Proximate analysis

a) Total Carbohydrate Content Determined after Phenol-Sulphuric Acid Method (Dubois et al., 1956)
b) Protein Content Determined by Lowry's Method (Lowry, et al, 1951)
c) Crude Lipid Content by Bligh and Dyer method (Bligh and Dyer, 1959)
d) Crude Fiber Content determination method (hydrolysis with dry 100°C/105°C AOAC 978.10- 2000 method)
e) Moisture Content determination method (Drying at 95°–100°C, AOAC 934.01- 2000 method)
f) Ash Content determination method (550°C overnight; AOAC, 930.05-2000 Method)

Macrominerals, micro minerals and heavy metals

Macrominerals, micro minerals and heavy metals were determined by Atomic Absorption Spectrophotometer (AOAC-2000 standard methods)

Water and bottom sediment sampling

Surface water, bottom water samples and the bottom sediment samples were collected from 8 diving sites with the assistance of navy divers. The samples were immediately analysed on board to observe seaweed growth parameters in the physicochemical environment to understand seaweed habitat and ecology.

Physico-chemical environmental parameter

The Surface and bottom water Salinity, temperature, pH, DO, and FNU was determined by YSI Pro-DSS Multiparameter Digital Water Quality Meter and the NO3, NO2, PO4, SiO3, NH4 was determined by means of Hach DR900 Colorimeter and corresponding kit following working protocol.

Results and Discussion

Physicochemical environmental status of Saint Martin's Coast:

Some of the important environmental physicochemical parameters for seaweed growth were investigated to understand their ecology and habitat. The maximum and minimum range of the parameters (Table 1) gave an understanding of suitable growth for seaweed. This will help to find a suitable site for seaweed cultivation (mariculture) and extension in other parts of the coastal area around the Bangladesh coast.

Table 1: Environmental physico-chemical parameters ranged around Saint Martin's Island.

Parameter/ Sampling month	February, 2021		March, 2021	
	Max	Min	Max	Min
Depth (m)	6	2.5	5	3
Secchi depth (m)	6.4	2	4	2
Temperature (C)	25.9	22.4	29.9	27
Sainity (‰)	34.8	27	34.8	34
pH	8.7	7.2	8.6	7.8
DO (mg/l)	6.42	4.78	6.34	4.82
FNU	12.5	2.1	18.2	2.9
Seawater PO4-P (mg/l)	3.34	0.02	0.03	0.03
Seawater NO3-N (mg/l)	0.03	BDL	0.04	0.001
Seawater NO2-N (mg/l)	0.024	BDL	0.7	0.002
Seawater SiO3 (mg/l)	1.49	BDL	1.55	0.15
Seawater NH4+N (mg/l)	1.89	0.23	0.41	0.02
Bottom Sediment Temp C	22	22	28	27
Bottom Sediment pH	6.8	5.4	6.8	5.4
*BDL is "Bellow the Detection Level"				

Seaweeds in the study

During the cruise, a total of – seaweed were sampled. It was interesting to observe that the seaweed availability was very poor than that of the last three years in January and February. It is important to mention that the water and bottom sediment properties were almost similar in the previous years. A total of 26 seaweeds were recorded of which 15 and 22 seaweed specimen were sampled in February and March respectively. Whereas, these were 23, 29, and 11 during 2018; 34, 38 and 12 during 2019; and was 14, 14 and 15 during 20120 for the months of January, February and March respectively. Among the species, Chlorophyta was more dominating than that the others in the present study. The available seaweeds recorded in the present study are tabulated (Table 2) below.

Padina tetrastromatica

Photo Credit @ Abu Sayeed Muhammad Sharif, SSO, BORI

Table 2: Occurrence of seaweed in the study

Sl.	Name of the Seaweed	Month and specimen occurrence	
		February	March
	Chlorophyta		
1	*Caulerpa chemnitzia (Esper) J.V.Lamouroux, 1809*	A	O
2	*Caulerpa fergusonii G.Murray, 1891*	O	R
3	*Caulerpa racemosa (Forsskål) J.Agardh, 1873*	F	F
4	*Halimeda discoidea Decaisne, 1842*	O	R
5	*Enteromorpha sp.*	R	O
	Rhodophyta		
6	*Amphiroa rigida J.V.Lamouroux, 1816*	A	O
7	*Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon, 1845*	R	F
8	*Gracilaria canaliculata Sonder, 1871*	A	R
9	*Halymenia dilatata Zanardini, 1851*	R	O
10	*Halymenia durvillei Bory de Saint-Vincent, 1828*	A	O
11	*Halymenia floresii (Clemente) C.Agardh, 1817*	A	O
12	*Hypnea cervicornis J.Agardh, 1851*	O	O
13	*Hypnea valentiae (Turner) Montagne, 1841*	O	O
14	*Lobophora variegata (J.V.Lamouroux) Womersley ex E.C.Oliveira, 1977*	R	F
15	*Tricleocarpa cylindrica (J.Ellis & Solander) Huisman & Borowitzka, 1990*	O	F
16	*Neurymenia fraxinifolia (Mertens ex Turner) J.Agardh, 1863*	O	A
17	*Scinaia interrupta (A.P.de Candolle) M.J.Wynne, 1989*	A	O
	Phaeophyta		
18	*Dictyota dichotoma (Hudson) J.V.Lamouroux, 1809*	A	O
19	*Dictyota friabilis Setchell, 1926*	A	O
20	*Padina tetrastromatica Hauck, 1887*	O	O
21	*Padina pavonica (Linnaeus) Thivy, 1960*	O	F
22	*Pseudochnoospora implexa (J.Agardh) Santiañez, G.Y.Cho & Kogame, 2018*	A	F
23	*Rosenvingea intricata (J.Agardh) Børgesen, 1914*	A	O
24	*Sargassum aquifolium (Turner) C.Agardh, 1820*	O	A
25	*Sargassum ilicifolium (Turner) C.Agardh, 1820*	O	A
26	*Spatoglossum asperum J.Agardh, 1894*	A	O

Legends: *"F"= Frequently Available; "O"=Occasionally Available; Rarely Available= "R": Absent= "A"*

It was a huge challenge to reach the target while navy diving assistance was discontinued in April due to the COVID pandemic and Lockdown alert. From the previous experiences, April-May is the peak for seaweed availability. So, the SRT team visited Saint Martin and had to work hard to collect target samples for hydrocolloid extraction and edible seaweed nutrition content study. But it was very difficult to collect samples in a sufficient quantity without diving. Among the specimen for edible seaweed for nutrition content experiments C. racemosa, C. implexa, G. canaliculata, H. floresii, P. tetrastromatica, and H. clathrus were in sufficiently available which were collected during 2019 but the rest C. fergusonii, G. lemaneiformis, H. dilatata, C. lentifera, Hypnea sp., and U. intestinalis were challenging to get (Table 3). On the other hand, the team had to struggle to collect the target samples for hydrocolloid study as they are quite rarely occurring. Gracilaria gracilis, Gracilaria textorii and but Gracilaria lantaensis was sampled with a little short and were insufficient. Whereas Gracilariopsis lemaneiformis were previously stored in the lab collected during 2019 from Nuniar-Chara, Cox's Bazar and again fresh samples were collected again this year. Anyway, to find the agar and carrageenan, a set of trials was conducted in the BORI laboratory.

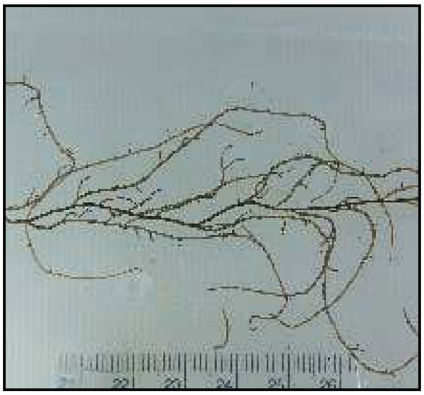

Photo Credit @ Biological Oceanography Division, BORI

Table 3: Seaweed samples studied for nutrition content

Caulerpa racemosa

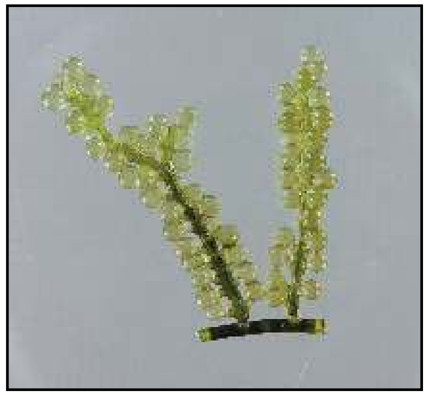
Caulerpa fergusonii

Gracilaria canaliculata



Gracilariopsis lemaneiformi

Halymenia dilatata



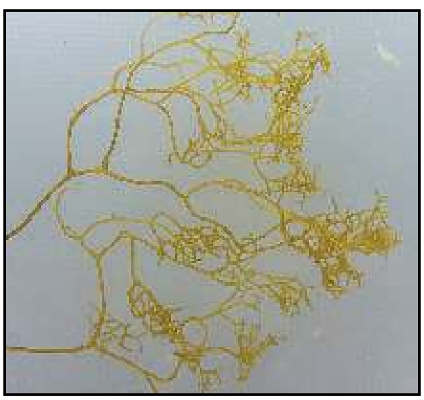
Caulerpa. lentifera

Halymenia floresii

Hypnea valentiae

Padina tetrastromatica

Ulva intestinalis



Chnoospora implexa

Hydroclathrus clathratus

Experimental phycocolloid extraction

The extraction steps for agar and carrageenan is shown in the flowchart (Figure 3) and (Figure 4). There are different methods of agar and carrageenan extraction of which Hot Water Extraction (Martínez-Sanz & LG Gómez-Mascaraque, 2019), Alkali Extraction (Bixler & Porse, 2011), Enzyme Extraction (Alencar et al., 2019) and Ultrasound-Assisted Extraction (Martínez-Sanz & Gómez-Mascaraque, 2019) are most recognized and well accepted. Among them, the Hot Water Extraction method is applied in the present study for both types of hydrocolloid extraction.

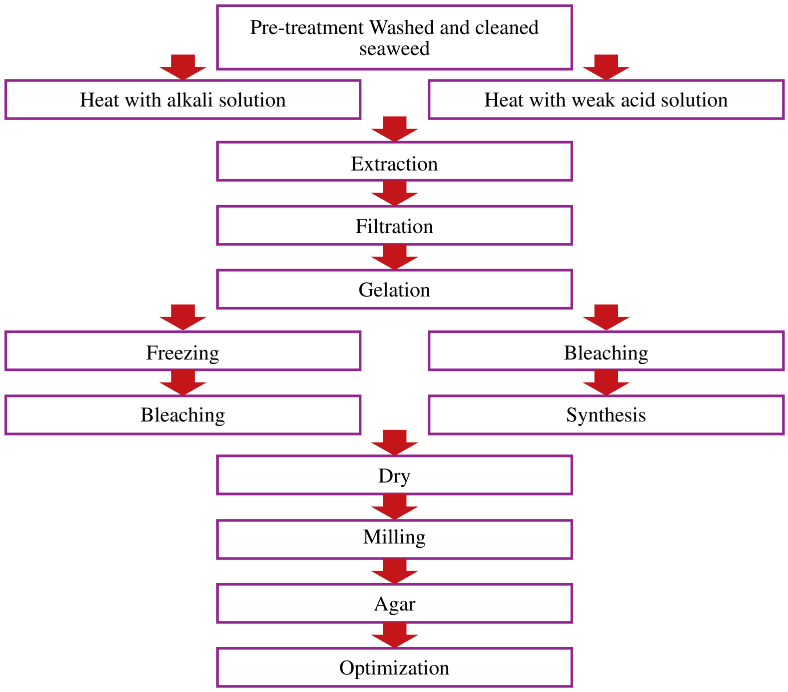


Figure 3: Agar extraction flowchart followed in laboratory.

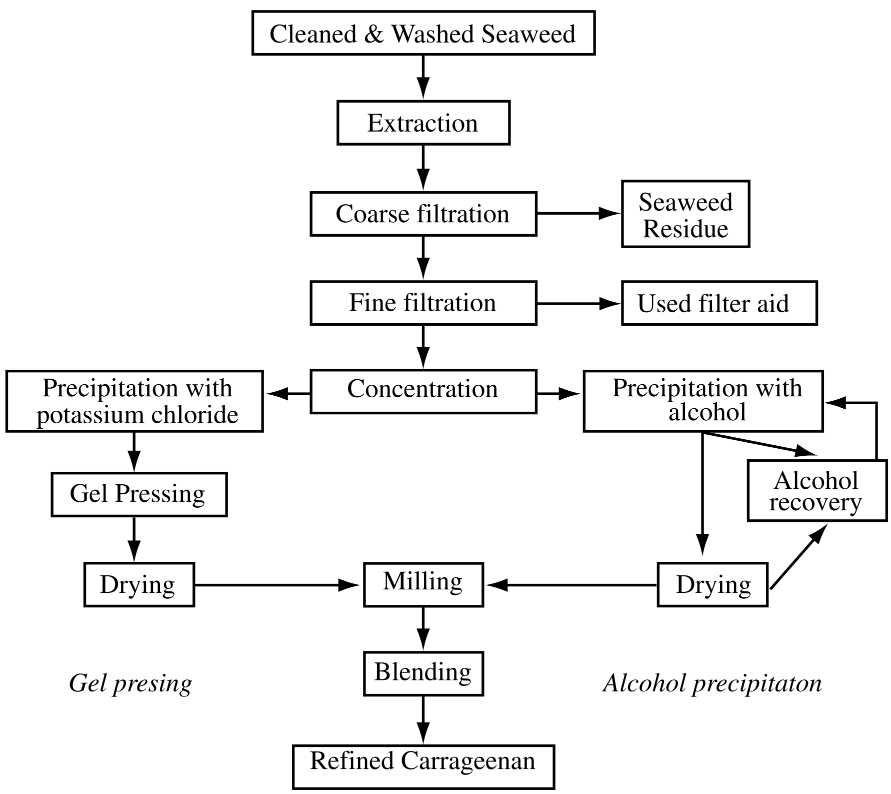


Figure 4: Carrageenan extraction flowchart followed in laboratory

The use of hydrocolloids and their dimension depends on its quality and properties of gel Formation (cooling retention and strength), viscosity (thickening and strength), Melting Point of Gel (between melting point and gelling point), Gelling temperature (at which gel forms), Gel Strength (gel solubility), and Syneresis of Gel (water retention) etc. Again, the yield percentage and quality of hydrocolloid from the same species can be exaggerated by different factors like geographic location (Freile-Pelegrín et al., 1995), seasonality (Freile-Pelegrín et al., 1995; Marinho-Soriano & Bourret, 2003; Marinho-Soriano et al., 2001; Price & Bielig, 1992; Vergara-Rodarte et al., 2010; Freile-Pelegrín et al., 1995), hydrodynamics (Price & Bielig, 1992), cultivation practice (Marinho-Soriano et al., 2001), osmoregulatory activity (Freile-Pelegrín et al., 1996; Givernaud et al., 1999; Luhan, 1992; Nil et al., 2016) etc. it is also reported that Time, temperature, and the amount of water during the agar extraction process have very important roles in hydrocolloid yield and quality for same seaweed, Kumar et al. (2009). Extraction control parameters such as alkali and acid pretreatment have an influence on yield and quality, González-Leijaus et al. (2008) showed that alkali treatment had a positive effect on significantly increased gel strength and decreases sulfate content. On the contrary, Xiao et al. (2019) showed that in comparison to enzyme-assisted extraction, the gel strength along with sulphate content may be increased but cost-effectiveness is an issue.

The present study was conducted to find suitable seaweed containing hydrocolloids especially agar and carrageenan. As a part of this experiment different samples were tested in trials in different conditions. Finally, the team was able to extract colloid extraction from some of the targeted seaweeds. From the different experimental conditions, the yield varied. The highest yield percentage of agar and carrageenan is tabulated (Table 4). It is important to mention that Gracilariopsis lemaneiformis, Hypnea cervicornis and Hypnea valentia samples were available to continue the test in different conditions. Whereas Gracilaria gracilis, Gracilaria lantaensis and Gracilaria textorii were not that sufficient to conduct extraction tests in all different conditions. Now it is important to optimize the highest yield condition considering industrial development. In the next, the cultivation methodology needs to review for a community-level extension.

Table 4: Experimental phycocolloid extraction and maximum yield

Species for agar extraction and sample collection year	**Highest Agar Yield (%db)**
Gracilariopsis lemaneiformis (collected 2019)	35.05 ± 0.15
Gracilariopsis lemaneiformis (collected 2021)	47.57 ± 0.23
Gracilaria gracilis (collected 2020)	48.47 ± 0.19
Gracilaria lantaensis and gracilaria textorii (2021)	63.43 ± 0.26
Species for Carrageenan extraction	Carrageenan **Yield (%db)**
Hypnea cervicornis (2021)	42.68 ± 0.40
Hypnea valentia (2021)	38.24 ± 0.31

Nutrition evaluation in edible seaweed

There is a good number of seaweed which are most popular in the South East and East Asian countries from an ancient time as food. The nutrition value and health benefits made them popular to the peoples of many European, South American and Asian coastal countries. The geographical location, water quality, and overall climate factor make some variations in nutrition content and qualities. Again industrial discharges, agricultural pesticide use, and urbanization may form toxic contamination in seaweed. To understand the nutrition value in selected edible seaweed including Macronutrient, Macro-minerals, Micro-minerals, heavy metal status was studied in this experiment (Figure 5). All the experiments were conducted at BCSIR Chittagong following three replicate trials.

In the present study on 12 seaweeds, the estimated maximum and minimum contents of nutrition including some macro and micro minerals and a few important heavy metal content are shown in Table 1 below.

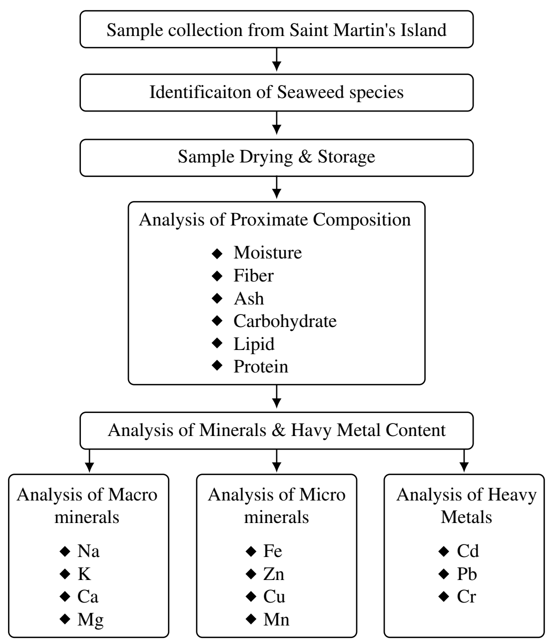


Figure 5: Potential nutrition and elements analysed studied in the present experiment

Table 5: The Maximum and minimum contents of nutrition including some macro and micro minerals and few important heavy metal content of studied samples

Nutritional value and heavy metal in different samples				
Maximum and minimum (%) of Macronutrients and Heavy metal content in different edible seaweed				
Name of the properties	**Species containing maximum concentration**	**Minimum value recorded**	**Species containing minimum concentration**	**Minimum value recorded**
Carbohydrate %	*Hypnea sp.*	76.0± 0.35	*G. canaliculata*	24± 0.56
Protein %	*Gracilariopsis lemaneiformis*	**19.2± 0.34**	*Hypnea sp.*	**5.2± 0.07**
Crude lipid %	*Padina tetrastromatica*	3.62±0.03	*Gracilariopsis lemaneiformis*	0.35± 0.04
Crude fibres %	*Gracilaria canaliculata*	17.5	*Halymenia floresii*	2.8
Ash %	*C. implexa*	85.8	*Gracilariopsis lemaneiformis*	8.8
Moisture %	*Padina tetrastromatica*	87.8	*C. implexa*	19.5
Maximum and minimum (%)of Macrominerals in seaweed				
Na mg/g	*Halymenia dilatata*	6.1	*C. implexa*	0.3
K mg/g	*Chnoospora implexa*	1.2	*Caulerpa fergusonii*	0.6
Ca mg/g	*Padina tetrastromatica*	29.9	*Gracilariopsis lemaneiformis*	6.3
Mg mg/g	*Halymenia dilatata*	13.7	*Gracilariopsis lemaneiformis*	3.2
Maximum and minimum (%)of Microminerals in seaweed				
Zn mg/g	*Chnoospora implexa*	0.63	*Halymenia dilatata*	0.02
Fe mg/g	*Gracilaria canaliculata*	3.52	*Halymenia dilatata*	0.02
Mn mg/g	*Padina tetrastromatica*	0.23	*Halymenia floresii*	0.03
Cu mg/g	*Chnoospora implexa*	0.015	*Caulerpa fergusonii*	0.002
Maximum and minimum (%)of Heavy Metals in seaweed				
Cr mg/g	*Hydroclathrus clathrus*	0.007	*Caulerpa fergusonii*	0.002
Pb mg/g	*Padina tetrastromatica*	0.006	*Hydroclathrus clathrus*	0.002
Cd mg/g	*Halymenia dilatata*	0.008	*Padina tetrastromatica*	0.003
Note: Cr, Pb, CD content was Below Detection Level (BLD) in *C. racemosa, C. fergusonii, C. implexa, G. canaliculata, G. lemaneiformis, H. dilatata, C. lentifera, H. floresii, Hypnea sp.Samples*				

Proximate composition of seaweeds: Proximate composition is the term usually used in the field of feed/food and means the components of moisture, crude protein, ether extract, crude fibre, crude ash and nitrogen-free extracts, which are expressed as the content (%) in the sample, respectively. Seaweed contains 80–98 % water. Their dry weight basis nutrition contents were studied in the present experiment.

Total carbohydrate content: Determination of carbohydrate content was followed by the Phenol-Sulphuric Acid method (Figure 6). Carbohydrate was the major component of proximate composition for all samples which ranged from 26% to 76% of dry weight (Figure 7). It was lesser G. canaliculata (26±1.85)% and (27±0.45)% in P. implexa, whereas, the higher were recorded (76±1.16)% in Hypnea sp., (73±2.69)% in H. floresii and 72±0.67)% in U. intestinalis.

(A) (B)

Figure 6: Determination of carbohydrate content by Phenol-Sulphuric Acid method. In the presence of H2SO4, simple sugars oxidize to furfural that reacts with phenol, results in the formation of yellow-brown coloured complex. (A) Standard solutions; (B) Test samples

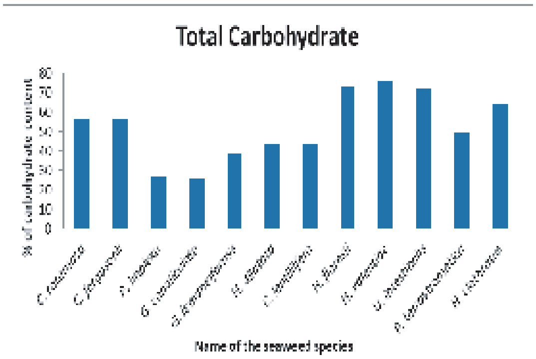


Figure 7: Proximate composition of seaweeds, Total carbohydrate content

Total protein content: the total protein was determined by Lowry's method in the BCSIR laboratory (Figure 8). A moderate amount of protein was in these samples ranging from 5.2% to 19.2% of dry weight (Figure 9). It was maximum in G. lemaneiformis (19.2±2.25) % and minimum in (5.2±0.46) % in Hypnea sp.

(A) (B)

Figure 8: Determination of protein content by Lowry's method. Under alkaline condition, peptide nitrogen reacts with copper (II) ions and causes subsequent reduction of folin-ciocalteu reagent to blue coloured complex. (A) Standard solutions; (B) Test samples

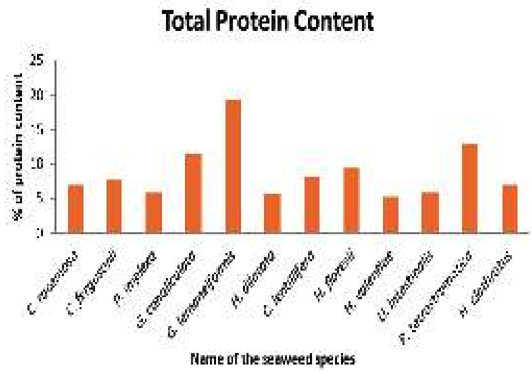


Figure 9: Proximate composition of seaweeds Total protein content in different seaweed

Crude lipid content: the crude lipid was determined following Bligh and Dyer method (Figure 10). The samples contain a relatively lower amount of lipids. The crude lipid content ranged from 0.58% to 3.62% of dry weight (Figure 11) and it was maximum in P tetrastromatica (3.62±0.03) % and the minimum was in G. lemaneiformis (0.58±0.07) %.

(A) (B)

Figure 10: Determination of crude lipid content by Bligh and Dyer method. Foil trays containing lipid residues.

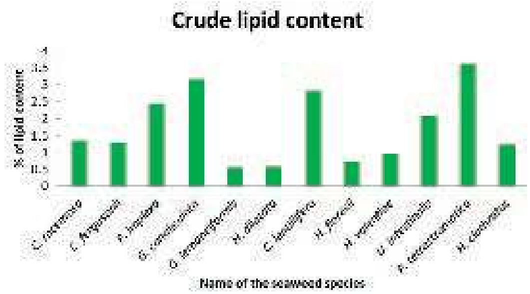


Figure 11: Proximate composition of seaweeds Crude lipid content

Ash content: Generally, ash content represents the total mineral content. In this study, the ash content of the seaweed samples was found from 8.85% to 31.28% of dry weight (Figure 12) and it was a maximum 31.28% in H. clathratus and a minimum 8.85% in G. lemaneiformis.

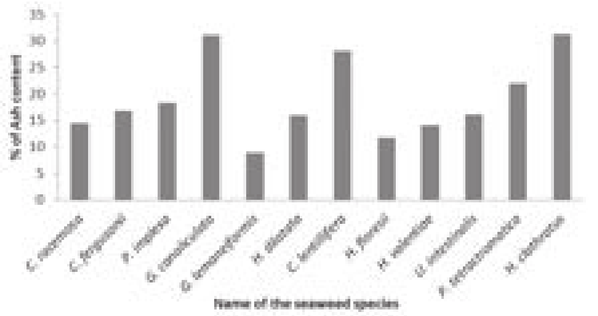


Figure 12: Proximate composition of seaweeds; Ash content

Moisture content: Moisture content is an important factor in determining the shelf-life and quality of processed seaweed food items as high moisture content may increase the risk of microbial growth. In the present study, the percentage of moisture content ranged from 58.33% to 87.88% of dry weight (Figure 13) seaweed samples. The maximum moisture content was in P tetrastromatica 88.87% and the minimum was in C. implexa 58.33%

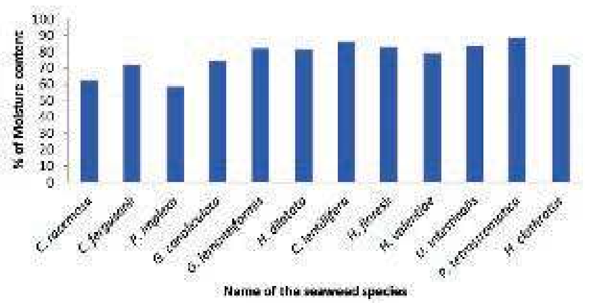


Figure 13: Proximate composition of seaweeds; Moisture content

Crude fibre content: Also known as Weende cellulose, crude fibre is the insoluble residue of acid hydrolysis followed by an alkaline one. This residue contains true cellulose and insoluble lignin. It is an essential component of the diet for good health. Seaweed dietary fibre also performs important functional activities e.g. anti-oxidant, anti-tumour, anti-coagulant and anti-mutagenic activity and play a crucial role in lipid metabolism (Sithranga & kathiresan, 2010). In the study samples, crude fibre ranged from 2.86% to 17.53% of dry weight. It was maximum 17.53% in G. canaliculata and the minimum 2.86% in H. floresii (Figure 14 and Figure 15).

Figure 14: Crude fiber content of the different seaweeds samples

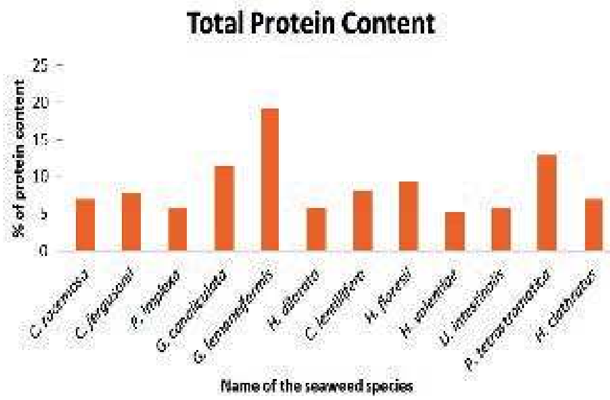


Figure 15: Proximate composition of seaweeds Crude fiber content

Macrominerals of Seaweeds

Macro minerals: Minerals that required a larger amount in our diet are the macro minerals (e.g. calcium, sodium, potassium, magnesium, phosphorus, chlorine, sulfur, etc). These elements are essential for many physiological processes such as bone formation, enzymatic regulation, blood pressure regulation, energy conservation and so on. However, seaweeds contain a high amount of macro minerals which had to process minerals content determination by the Atomic Absorption Spectroscopy (AAS) method (Figure 16).

(A) (B)

Figure 16: Sample preparation for minerals content determination by Atomic Absorption Spectroscopy (AAS). (A) Oven-dried seaweed samples before burning in the muffle furnace; (B) Ash content of the samples after burning in the muffle furnace

Photo Credit @ Biological Oceanography Division, BORI

Sodium (Na): The Na concentration was observed from 124.35 mg/100g to 612.41 mg/100g (Figure 17) dry sample. It was recorded maximum in H. dilatata 612.41 mg/100g and the minimum was in P. implexa 124.35 mg/100g

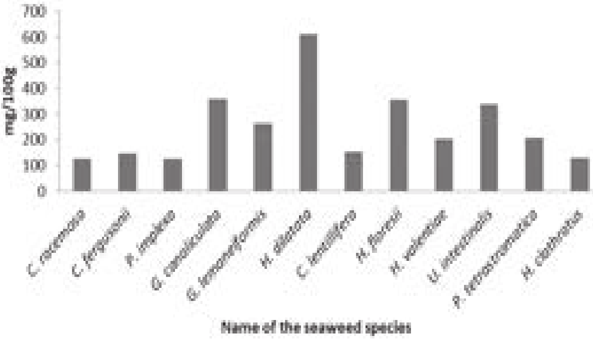


Figure 17: Macro mineral content of seaweeds; Sodium content

Potassium (K): The concentration of K ranged from 67.4 mg/100g to 462.86 mg/ 100g (Figure 18). It was found maximum in H. dilatata 462.86 mg/100g and minimum in C. fergusonii 67.40 mg/100g.

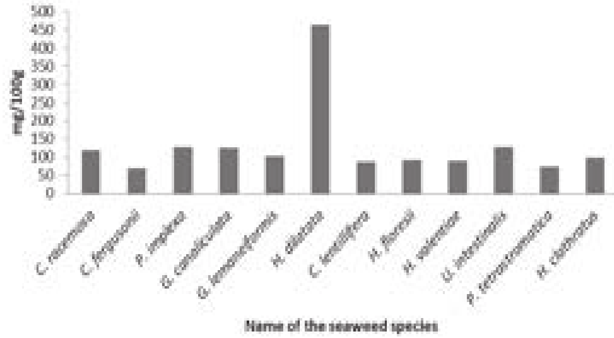


Figure 18: Macro mineral content of seaweeds; Potassium content

Calcium (Ca): In the present study Ca content ranged from 632.78 mg/100g to 2993.87 mg/100g in sample seaweeds. It was a maximum of 2993.87 mg/100g in P. tetrastromatica minimum of 632.78 mg/100g in G. lemaneiformis (Figure 19).

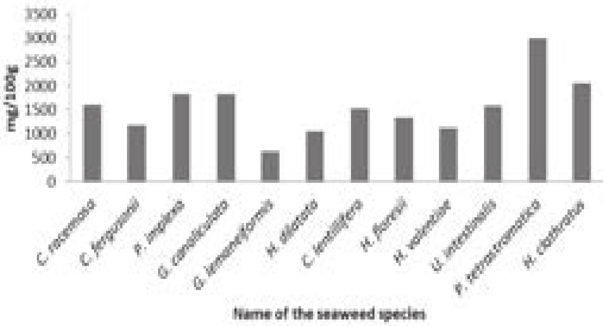


Figure 19: Macro mineral content of seaweeds; Calcium content

Magnesium (Mg): The Mg content ranged from 318.6 mg/100g to 1375.86 mg/100g and it was found highest amount in H. dilatata 1375.86 mg/100g and the lowest in G. lemaneiformis 318.6 mg/100g (Figure 20).

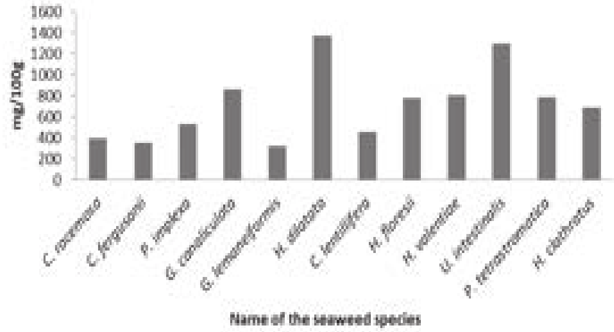


Figure 20: Macro mineral content of seaweeds; Magnesium content

Micro minerals: Minerals that are required in smaller amounts in the diet are called micro minerals or trace elements e.g. zinc, iron, iodine, cobalt, copper, selenium, manganese, molybdenum, fluorine etc. These elements also play an important role in physiological processes by involving blood cell formation, hormonal regulation, wound healing process, acting as co-factor for different enzymes and so on. Seaweeds contain a good amount of micro minerals too.

Zinc (Zn): In this study, Zn was found 11.96 mg/100g to 63.29 mg/100g. It was maximum 63.29 mg/100g in P. implexa and minimum 11.96 mg/100g in H. dilatata (Figure 21).

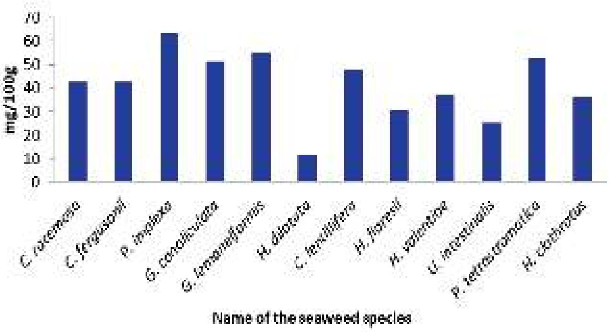


Figure 21: Micro mineral content of seaweeds; Zinc content

Iron (Fe): Fe content was found from 15.38 mg/100g to 352.29 mg/100g in sample seaweeds. It was maximum 352.29 mg/100g in G. canaliculata minimum 15.38 mg/100g in H. floresii (Figure 22).

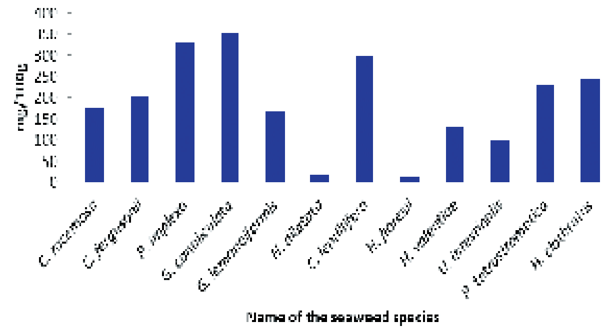


Figure 22: Micro mineral content of seaweeds; Iron content

Manganese (Mn): The Mn content was observed 3.34 mg/100g to 30.82 mg/100g in sample seaweeds. Mn was maximum in 30.82 mg/100g in G. canaliculata and minimum 3.34 mg/100g in H. floresii (Figure 23).

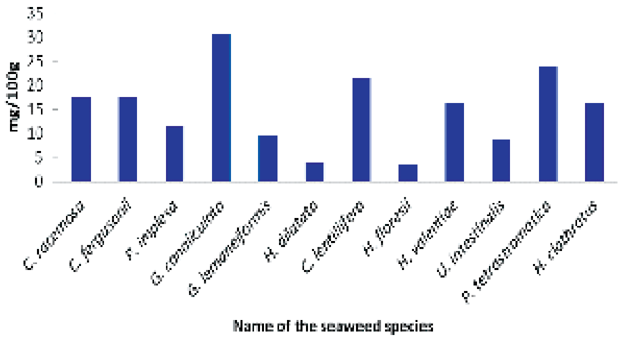


Figure 23: Micro mineral content of seaweeds; Manganese content

Copper (Cu): The concentration of Cu ranged from 0.56 mg/100g to 1.58 mg/100g and it was a maximum of 1.58 mg/100g in P. implexa and a minimum of 0.56 mg/100g in H. dilatata (Figure 24).

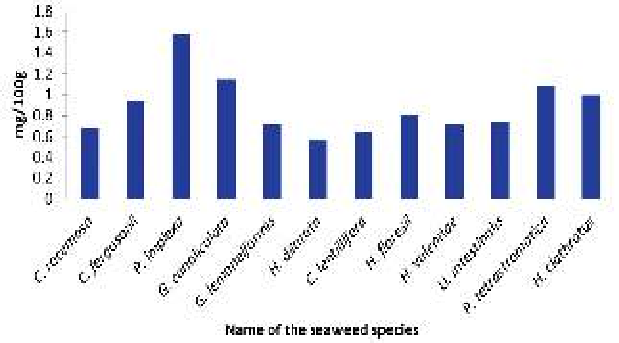


Figure 24: Micro mineral content of seaweeds; Copper content

Presence of Heavy Metals in Seaweeds

Heavy metals are usually present in trace amounts in natural waters but many of them are toxic even at very low concentrations. Several acute and chronic toxic effects of heavy metals affect different body organs. Gastrointestinal and kidney dysfunction, nervous system disorders, skin lesions, vascular damage, immune system dysfunction, birth defects, and cancer are examples of the complications of heavy metals toxic effects. The main mechanism of heavy metal toxicity includes the generation of free radicals to cause oxidative stress, damage of biological molecules such as enzymes, proteins, lipids, and nucleic acids, damage of DNA which is key to carcinogenesis as well as neurotoxicity. Seaweeds can rapidly accumulate elevated concentrations of metals, such as Cd, Hg, and Pb which can be toxic even at trace levels and biologically essential elements might cause toxic effects at elevated concentrations. Considering the contamination and high toxic effect the Cd, Pb, Cr concentrations in locally available edible seaweed were examined (Figure 25).

(A)

(B)

Figure 25: Sample processing for estimating heavy metals by AAS. (A) Seaweed ashes after nitric acid digestion; (B) Sample solutions had been prepared for metal detection

Cadmium (Cd): In the present study Cd was Below Detection Level (BLD) in most species except P. tetrastromatica, H. dilatata and the content was 0.32 mg/100 and 0.82 mg/100g respectively (Figure 26).

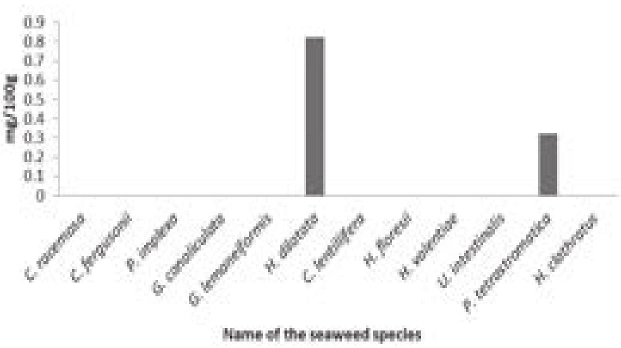


Figure 26: Heavy metals in seaweeds; presence of Cadmium content

Lead (Pb): Concentration of Pb was Below the Detection Level (BLD) whereas 0.22 mg/100g was found in H. clathratus, 0.32 mg/100g was in C. fergusonii & 0.62 mg/100g was in P. tetrastromatica respectively (Fig. 27).

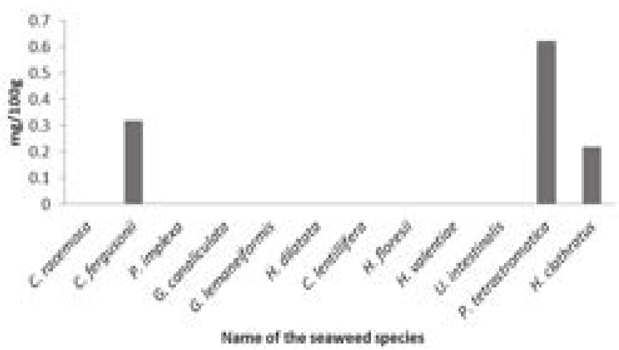


Figure 27: Heavy metals in seaweeds; presence of lead content

Under water sampling

"Seaweed sample collection & processing in the project area"

Photo Credit @ Biological Oceanography Division, BORI

Chromium (Cr): In the case of Cr, it was found 0.17 mg/100g in C. fergusonii, 0.27 mg/100g in P. tetrastromatica, 0.57 mg/100g in P. implexa and 0.76 mg/100g in H. clathratus respectively (Figure 28).

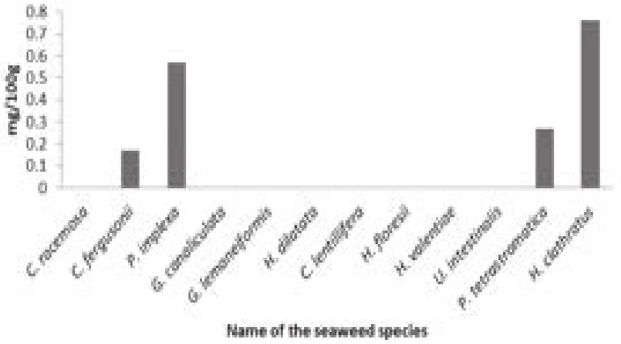


Figure 28: Heavy metals in seaweeds; presence of chromium content

Conclusion

The present investigation was carried out to exploration commercial seaweeds considering phycocolloid content and the nutrition value of edible seaweed. It was observed that Gracilariopsis lemaneiformis, Gracilaria gracilis, Gracilaria lantaensis & gracilaria textorii contain good amount of agar whereas, Hypnea for carrageenan. Now it is important to optimise the extraction in different control parameters. In the case of nutrition content C. lentifera, G. lemaneiformis, C. racemosa, U. intestinalis and Hypnea sp showed a good amount of food value. In the next, these species need to be promoted for culture extension in the local seaweed farmers after a feasibility study and trial farming along the Cox's Bazar coast initially.

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PROJECTS

- A Preliminary taxonomic checklist of marine algae (Phytoplankton & Sea Weeds) around St. Martin Island and Inani Coast, Bangladesh.
- Study on seaweed Biochemical composition with references to physico-chemical parameters of water and bottom sediment and continuation of taxonomic identification, around St. Martin Island, Bangladesh.
- Potential Nutritional Evaluation of 20 seaweeds, experimental extraction of phycocolloids from 6 seaweeds available around St. Martin's island and continuation of taxonomic base line study.

RESEARCH INTEREST

Marine Ecology, Planktology, Phycology, Mariculture, Genetics and Molecular Biology.

TRAINING

- Advance Training on Bio-Technology-NIB

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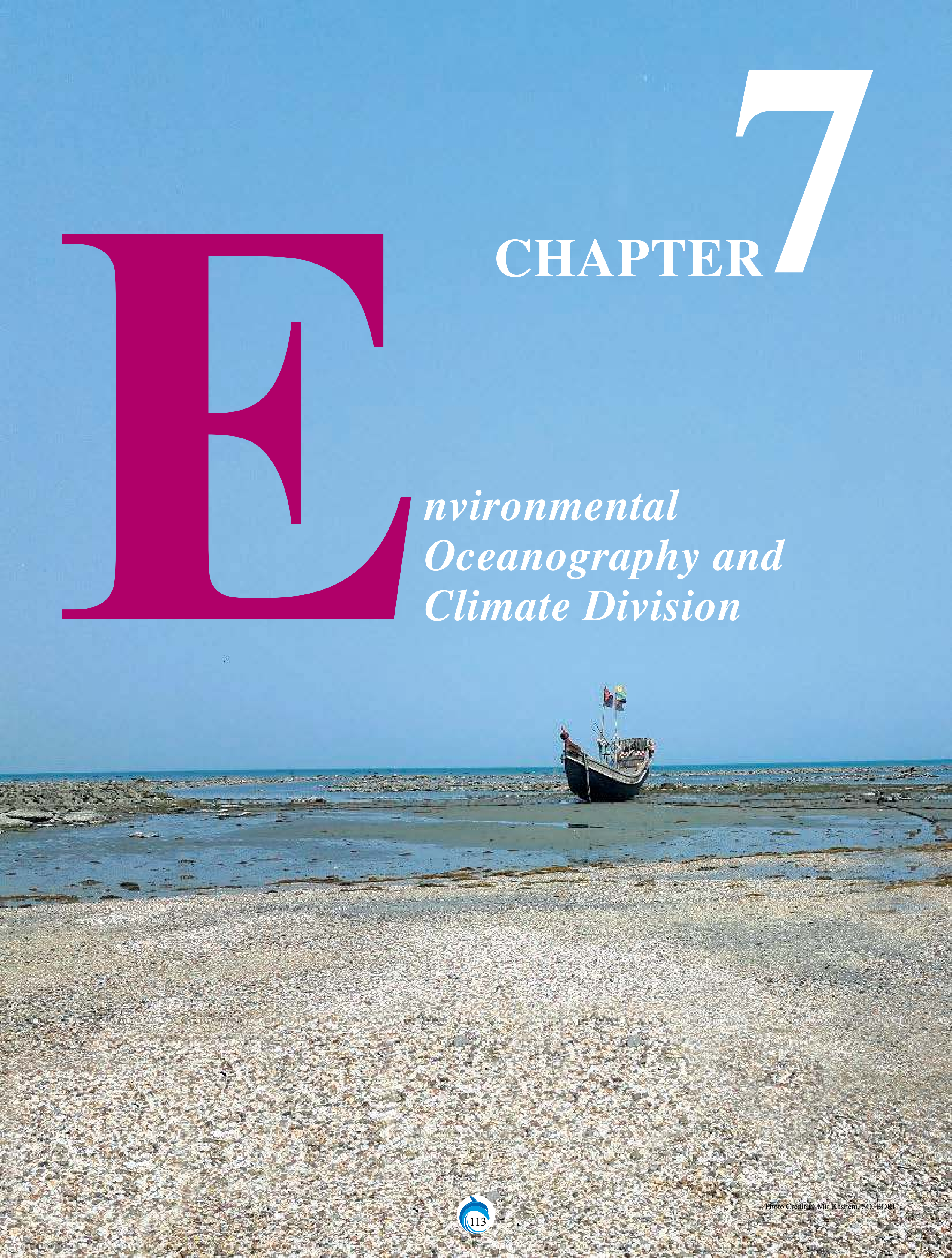
CHAPTER 7

Environmental Oceanography and Climate Division



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Marine Environment

covers not only the ocean, but estuaries (e.g., bays), which are coastal areas where the sea water is diluted with freshwater coming from rivers and streams, or sometimes groundwater.

-Judith S. Weis

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Biogeochemical Process of the Moheshkhali Channel: Physical, Biochemical and Primary Productivity Characteristics of the Channel

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ABSTRACT

Moheshkhali Channel is not only the navigation roots for the Moheshkhali Island, Kutubdia Island, and its surroundings but also economic areas through the indigenous aquaculture and other economic activities. Matamuhuri River is situated upstream of the Channel. The river is the source of fresh water for the Channel. Reliable data on biological characteristics from the Moheshkhali Channel, Cox's Bazar are elusive. The present study attempted to assess the biogeochemical process especially water quality parameters for the feasibility study of the aquaculture in two seasons e.g., end of winter (February 2021) and spring (April 2021) during high and low tide conditions from Matamuhuri River and upstream to downstream of the channel. Sample water collected from the surface layer (0 to 50 cm) at eight locations e.g. station 01 from the Matamuhuri River and remain seven stations (02 to 08) from the Moheshkhali Channel during high and low tides was analysed for the physical parameters (temperature, salinity, total dissolved solids (TDS), total suspended solids (TSS) and transparency) biochemical properties (pH, dissolved oxygen (DO)), and ecological parameters (nitrate (NO3-), ammonia (NH3), phosphate (PO43-) and chlorophyll-a) of the channel and river water. For the primary productivity, the water samples were collected from 30cm to 50cm depth from the Channel in the selective sample stations (St. 01, St. 02, St. 04, St. 06, and St.08) where St.01 is the Matamuhuri River and remain four stations (St. 02, St. 04, St. 06 and St.08) were in the Moheshkhali Channel. The study revealed that physical, biochemical, and ecological parameters were influenced by seasonal changes. Mean of the following parameters during winter and spring seasons, respectively, were in the following ranges: water temperature (24.6-27.84 and 29.1–30.4 0C); salinity (27–33 and 30 -32.1 ppt); pH (7.56 – 8.23 and 7.53 – 8.06); DO (4 – 4.6 and 4.8 -5 mg/L); TDS (33.8 – 34.7 and 42.1 – 42.7 mg/L); TSS (0.07 – 0.10 and 0.09 – 0.11); ammonia (0.36–0.41, and 0.56–0.61 mg/L); nitrite (0.04 -0.11 and 0.14 – 0.22 mg/L); nitrate (0.29 – 0.71 and 1.6 – 2.5 mg/L); phosphate (2.4 – 2.6 and 1.18 – 1.36 mg/L) and chlorophyll-a (3.74 – 5.36 and 4.85 – 6.38 mg/m3). The highest chlorophyll a was found in the Matamuhuri River (18 ± 1.3 mg/m3) and the second-highest chlorophyll a was found in St. 07 (6.5 ± 1.3 mg/m3) in the Channel due to the existence of quality amount water nutrients such as ammonia, phosphate, nitrite, and nitrate. The maximum primary productivity e.g., GPP at St. 08 (Mouth of the Moheshkhali Channel) during February 2021 due to the low surface water temperature, high water transparency and clear & bright sunny weather condition existed and the minimum GPP was obtained at St. 01 (Matamuhuri River) during April 2021 due to the high-water temperature, low water transparency and mild sunny weather condition were triggered the lowest GPP.

Introduction

Bangladesh is a low-lying riverine country located in South Asian with a largely marshy jungle coastline of 710 Km (441 miles) on the northern littoral of the Bay of Bengal. Sprawling estuaries, salt marsh, mangroves and few islands characterized the coastline of Bangladesh. These estuarine coastal ecosystems like channel, brackish water rivers, mangroves, salt marsh and seagrass habitats are referred to as being nutrient traps, which eventually maintaining food chain functions (Abu Hena et al., 2016). These nutrients support high primary productivity later on, which in turn promote high levels of secondary production i.e., zooplankton (Nixon et al., 1986) as a part of ecosystem functions.

It is well known that the richest fisheries of the world are closely related to the plankton production because the fish organisms are directly or indirectly dependent upon plankton for their nourishment. Hence, for the development and estimation of potential fishery resources, the knowledge on plankton is essential. Thus, variations in their composition are a key indication of ecological succession, breeding periodicity as well as environmental condition. The relation between total number of phytoplankton, zooplankton and the observed physio-chemical parameters (water temperature, salinity, TDS, TSS, turbidity, transparency, pH), ecological parameters (DO, nitrate (NO_3^-), ammonia (NH_3), phosphate (PO_4^{3-}), silicate, chlorophyll-a and primary productivity) directly related seasonal influences (Zafar, 2007). All consumer levels such as fisheries depend on zooplanktons for food during their larval phases, and some fishes continue to eat zooplankton in their entire lives (Martin et al. 2001). In Bangladesh, the peak abundance of copepods is normally observed during winter and pre-monsoon season when the water transparency range between 66cm to 77.5cm. On the other hand, relatively the lower abundance is observed during the monsoon period, when the water transparency ranges between 17.5cm and 38 cm. From the economical and geographical view of point, Moheshkhali channel is found to have great contribution as nursery grounds, providing abundant food and relative safety to many commercially important species.

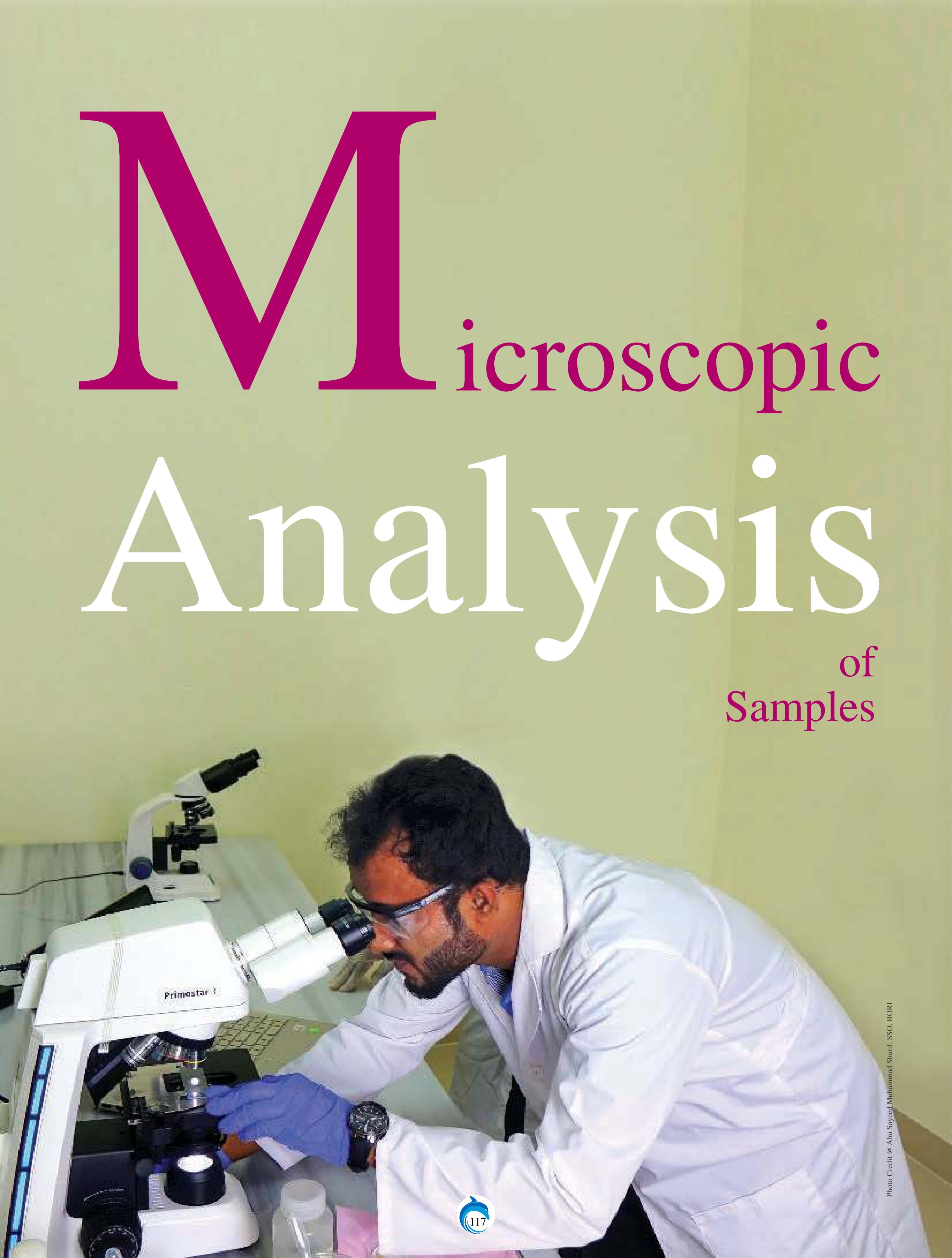
Estuaries are the transitional zones between the land and the sea which are important for both the economic and ecological perspectives. The inflows of marine and freshwater provide high levels of nutrients both in the water column and in the sediment in the estuary (McLusky and Elliott, 2004; Valle-Levinson, 2010). Estuaries occupy less than 10% of the ocean's surface only but play an important role in the global biogeochemical cycles such as carbon cycle, nitrogen cycle, and nutrient cycles (Lisitsyn, 1995; Gebhardt et al., 2005).

Physico-chemical properties of an estuary is influenced by different natural and man-made processes such as precipitation rate, weathering, soil erosion, urban development, industrial and agricultural activities, and human exploitation of water resources (Pejman et al., 2009; Yang et al., 2012; Barboza et al., 2014).Factors such as the morphological characteristics of the estuary, water residence time, tidal regime, and rainfall also determine the ecological status and nutrient input to the estuary (Pamplona et al., 2013). Dissolved inorganic nutrients such as nitrite, nitrate, ammonium, and phosphate are the major essential nutrients for the phytoplankton growth (Dyer, 1986). In an aquatic ecosystem, dissolved inorganic nitrogenous (DIN=$NH_4^+ + NO_3 + NO_2$) species are therefore very much dependent on biological uptake and regeneration (Flynn and Butler, 1986). Among the DIN species, the ammonia nitrogen is preferentially used by plants and produced by bacterial breakdown of organic matter and animal excretion (Rahaman et al., 2014). Lower concentrations of ammonia nitrogen and nitrite are found in unpolluted marine waters, and high concentrations of DIN in polluted waters which can be toxic to the aquatic organisms (Camargo and Alonso, 2006) demonstrated the increase of inorganic nitrogen after heavy rains or tidal inundation of the forest floor. In contrast, dissolved orthophosphate is another important nutrient source for phytoplankton.

Objectives

- To determine the physical parameters (temperature, salinity, conductivity, TDS, TSS, and transparency) biochemical properties (pH, DO), and ecological parameters (nitrate (NO_3^-), ammonia (NH_3), phosphate (PO_4^{3-}) and chlorophyll-a) of the channel water for feasibility study of aquaculture
- To determine the primary productivity of surface water of the Channel

Microscopic Analysis of Samples



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Materials and Methods

Study Area

Moheshkhali Channel in Cox's Bazar district is located geographically 21° 44' 41.78"N to 21° 27' 54.11" N and 91° 56' 20.88" E to 91° 55' 51.4" E in the southeastern part of Bangladesh. The Source of the Moheshkhali channel lies in the mouth of the Bay of Bengal on the south side and on the north side different net-type flow channels of the Matamuhuri River and flow over the north western part of Moheshkhali Thana and then finally it flows over the Bay of Bengal. The starting part of the channel near Kariardiar is adjacent to the Baradkhali Union. It also separated the mainland Moheshkhali Island and Cox's Bazar Sadar and represented as a Maritime open channel for transportation of the community of Cox's Bazar and Moheshkhali.

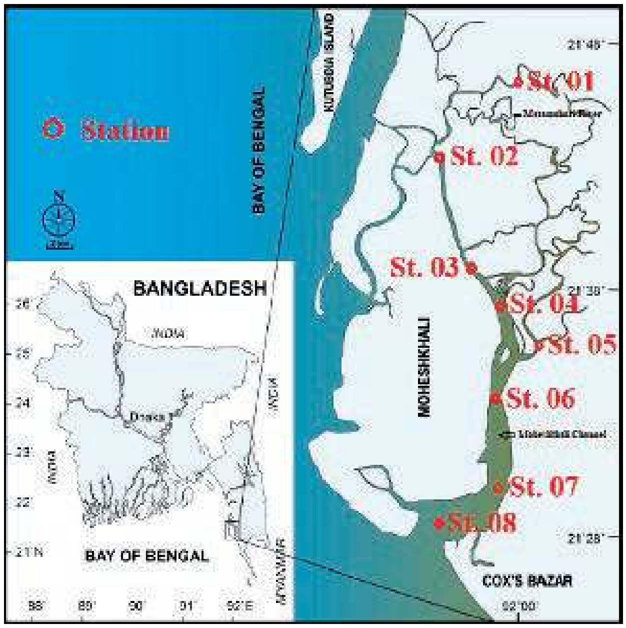


Figure 1: Water sample collecting stations in Moheshkhali Channel

Methods

Channel water samples were collected in systematic ways. The Channel surface water samples were collected from7 sites within Moheshkhali Channel and another sample of water was collected from the Matamuhuri River near the Chakaria Upazila. At the same time, sediment samples were collected from Channel. All water samples were collected by Niskin Water Sampler and Bottom sediment was collected by Ekman Grabber. Samples were collected from the Channel during 2021 for two seasons namely winter (February 2021) and spring (April 2021).

The air temperature and wind speed were measured by the digital anemometer (Handheld Wind Speed Meter). The physical and biochemical properties of the surface water (0-0.5m) samples were collected by Niskin water sampler and analyzed directly in the field at each sampling site are temperature, salinity, and pH, by using a YSI Professional Series (water quality analyser, made in the USA), digital Refractometer and transparency of seawater were measured by Secchi Disk. When doing the measurements, the probe was submerged fully into the water at least around 30 cm from the coastal water surface and collecting seawater samples. From each sampling site, 1 L of water was collected by PVC water sample bottles. Before sampling, the bottles will be cleaned and washed with detergent solution and rinsed 3 to 4 times with the water to be sampled. Hydrochloric acid was used as preservative in these sample bottles and containing samples are sealed immediately to avoid exposure to air and placed in a safe place. A total of three replicates was taken for each parameter at every sampling station. The sample bottles were screwed carefully and marked with the respective identification number. Surface water (0-0.5m) samples were collected for analysis of biological oxygen demand (BOD) and nutrients analysis. Three replicates of samples for each sampling station were collected. The samples were filtered through what man No. 1 filter papers and they will be preserved ($pH<2.0$) with a few drops of concentrated HCl for each replicate. Water samples were kept in acid-washed polyethylene pillboxes and later put into an icebox to prevent sample deterioration during transportation to the laboratory. In the laboratory, the water samples were stored at 4ºC until metal analysis. Dissolved Oxygen (DO) concentration was analyzed by the Winkler method and also analyzed by in-situ DO meter (Figure 2) in on boat period.Total dissolved solids (TDS) and total suspended solids (TSS) were analyzed by the gravity method.

Water nutrients such as ammonia concentration (NH3-H), nitrite (NO2-), nitrate (NO3-), and phosphate (PO4-) were analyzed in the onboard sampling periods by using Hanna Ammonia Test Kit for Seawater (HI3826). The HI3826 is a colorimetric chemical test kit that determines the ammonia concentration in seawater within a 0.0 to 2.5 mg/L (ppm) range as NH3-N. Nitrite concentration was analyzed by using HI-3873 Nitrite test kit (range: 0.0-1.0 mg/L (ppm)); nitrate concentration was analyzed by using HI-3874 Nitrate test kit (range: 0-5 mg/L (ppm)); and phosphate concentration was analyzed by using HI-3833 Phosphate test kit (range: 0-5 mg/L (ppm)). Water samples for Chlorophyll a (hereinafter Chl a) were obtained by filtering a known volume of surface water on glass fiber filters (0.7 mm, Whatman GF/F) and then stored at -200C. Pigments were extracted for approximately 12 hours in 15 mL of 90% acetone at 40 C and analyzed with a Photolab Spectrophotometer 7600. The accuracy of the Chl-a analysis is estimated ±4%.

Figure 2. (a) Multi-water analyzer (YSI Professional Series-626909-4, Made in the USA); (b) In-Situ DO meter (SmarTROLL RDO CA30, made in the USA); (c) Seawater Refractometer (HANNA: HI 96822); (d) Niskin Water Sampler (Hydrobius, Made in Germany); (e) pH Meter (HANNA: HI 8424) and (f) Secchi Disk

The water samples for primary production were collected from 30cm to 50cm depth from the Channel in the selective sample stations (St. 01, St. 02, St. 04, St. 06 and St.08) where St.01 is the Matamuhuri River and remain four stations (St. 02, St. 04, St. 06 and St.08) were in the Moheshkhali Channel. The observation of water samples was made in the first week of the month for a period of two seasons such as winter and spring season (February and April 2021) between 09 am to 04 pm. There are different techniques for the estimation of primary productivity such as Radioactive Carbon (C14), Chlorophyll Method and oxygen method by light and dark bottle (Gaarder and Gran, 1927). Relatively oxygen method by light and dark bottle technique is simple and does not require extensive equipments and therefore, it was used during the present study. The following calculation were used in this method.

Data Processing and Analysis

The relevant data are processed and analyzed through manually and for computer-based analysis MS Excel of Office 2019 version is used. For graphical and data displaying, Arc GIS, R programing, Matlab, Surfer and Grapher are used.

Sampling and Data Collection

Figure 3: (a) Sample collection equipments and materials, (b) Sample storage ice box, (c) Calibrating the water analyser and (d) On boat dissolved oxygen (DO) analysing by using Hanna DO kit (Winkler method)

Figure 4: (a) Channel Bank soil sample collection, (b) Preparing black and white BOD bottle for analysing the primary productivity of the Channel water, (c) Installing the black and white BOD bottle for analysing the primary productivity & (d) Preparing and installing the phytoplankton net and zooplankton net

Result and Discussion

The Channel water properties at the 7 sampling stations in the Moheshkhali Channel and 1 sampling station in the Matamuhuri River are summarized in Table 2.

Water temperature is a physical property expressing how hot or cold water is. Temperature recorded in the coastal seawater reflects that it changed with time and dates. The mean water temperature of February and April 2021 in high & low tide were 25.52 ± 0.51 ^{O}C & 25.51 ± 0.28 ^{O}C and 29.52 ± 0.36 ^{O}C & 29.70 ± 0.15 ^{O}C respectively (Table 1). From the observation of the water temperature data, comparatively water temperatures of the Channel were high in low tide in April 2021 (spring season) than the high tide in February 2021 (winter season). The minimum salinity was observed during February 2021 at station St-1 (0.13 ppt) & St-2 (27) in low tide and the maximum was registered during February 2021 at station St-8 in high tide condition.

The minimum pH was observed during April 2021 at station St-6 and the maximum was registered during February 2021 at station St-7 in high tide condition (Fig 8). The abnormal highest pH (pH= 8.40 ± 0.12) was observed in Matamuhuri river due to water pollution and others reasons (It should need more research and observation). In Australia, the reference values of pH for aquaculture in marine water: 6.0 to 9.0 (ANZECC, 2000) and in India, recommended values of pH are 6.5 to 8.5 for aquaculture in marine water (Table 01).

The DO concentration of February and April 2021 were fluctuated over the study period due to the abnormal north-east wind activity and rainfall in spring season. The high DO concentration was found in high tide at St. 03 & 04 during April 2021. The highest DO concentration (6.5 mg/L) was observed in Matamuhuri River. The mean DO concentration of February and April 2021 in high & low tide condition were 4.6 ± 0.36 & 3.91 ± 0.37 mg/L and 4.88 ± 0.26 & 4.947± 0.14 mg/L respectively (Table 2).

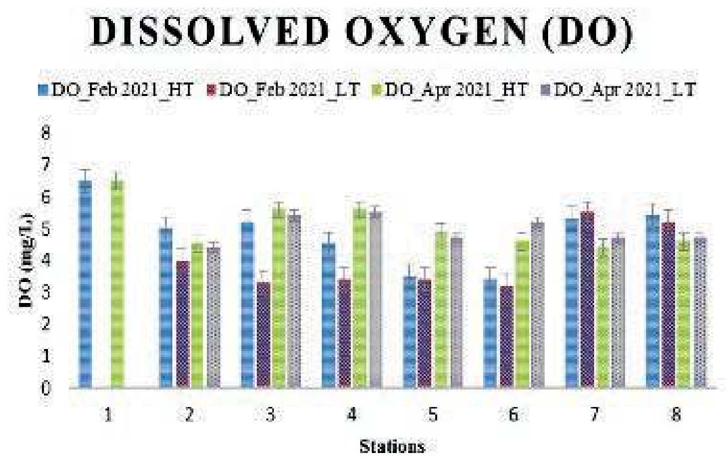


Figure 5: Seasonal variation (winter and spring) of DO concentration in the Moheshkhali Channel and Matamuhuri River

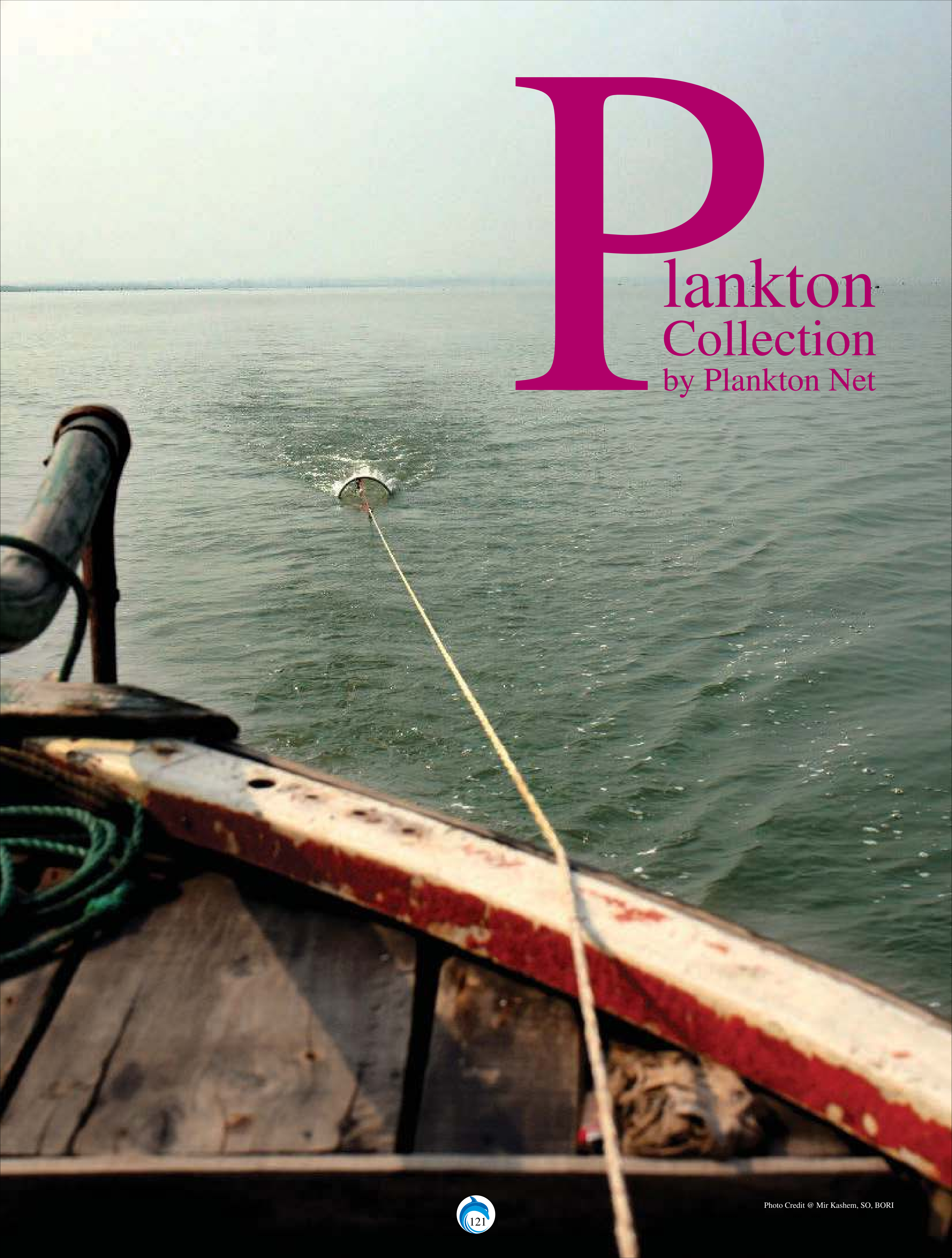
Dissolved oxygen is considered as one of the most important aspect of aquaculture. It is needed by fish to respire and perform metabolic activities. Thus, low levels of dissolved oxygen are often linked to fish kill incidents. In Australia, the reference values of DO concentration for aquaculture in marine water: >5 (ANZECC, 2000) and in India, recommended values of DO concentration is 5 for aquaculture in marine water (Table 01).

Total Dissolved Solids (TDS) includes those materials dissolved in the water, such as, bicarbonate, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. These ions are important in sustaining aquatic life (Mitchell and Stapp, 1992). The higher TDS were found at the all station in April 2021 than February 2021 due to rainfall. The mean TDS of February and April 2021 in high & low tide condition were $33.82 \times 10^3 \pm 0.432 \times 10^3$ mg/L & $34.72 \times 10^3 \pm 0.775 \times 10^3$ mg/L and $42.57 \times 10^3 \pm 0.778 \times 10^3$ mg/L & $42.12 \times 10^3 \pm 0.405 \times 10^3$ mg/L respectively (Table 2). For the TDS, only Kenya and Malaysia have a required standard, which ranges between 500 to 1,200 mg/L (Phiminaq, 2006). The mean TSS of February and April 2021 in high & low tide condition were 0.103 ± 0.02 & 0.070 ± 0.01 mg/L and 0.0855 ± 0.02 mg/L & 0.107 ± 0.02 mg/L respectively (Table 2). For the aquaculture, it is considered the average TSS value is less than 40 mg/L for freshwater and less than 10 mg/L for marine (Phiminaq, 2006).

Water nutrient depends on its surroundings environments, anthropogenic activities and local weather. Nitrogen is one of the limiting nutrients during photosynthesis. It enters into the estuary and aquaculture system through rainfall, in-situ N_2 fixation, river run-off, and diffusion from sediments, drainage systems, industrial wastes and sewage, etc. Nitrogen is largely controlled by redox reactions mediated by phytoplankton and bacteria. The processes include remineralization, ammonification, nitrification, denitrification and fixation (Phiminaq, 2006).

Nitrite is a byproduct of oxidized NH_3 or $NH_4{}^+$, an intermediary in the conversion of NH_3 or NH_4^+, into NO^3. This process is completed through nitrification which is done by the highly aerobic, gram-negative, chemoautotropic

Plankton Collection by Plankton Net



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bacteria found naturally in the system. The conversion is quick, thus high nitrite concentrations are not commonly found. However, if high levels do occur, it can cause hypoxia, due to deactivation of hemoglobin in fish´ blood, a condition known as the "brown blood disease" (Lawson, 1995).

In February 2021 (winter), there was low NO_2^- concentration (< 0.1 mg/L) found in the Channel except St. 02 (0.375 mg/L) because of, this is a root of water transportations (Moheshkhali Channel to Kutubdia Island) that may help to increase the water nutrients. Comparatively, higher NO_2^- concentration are found in Moheshkhali Channel than the Matamuhuri River in terms of NO_2^- standard, Australia, New Zealand and South Australia have the value set at less than 0.1 mg/L for marine water (Table 01). There were low NO_3^- concentration were observed in Moheshkhali Channel and Matamuhuri River in February and April 2021, while St. 04 & St. 05 NO_3^- concentration was 0. Comparatively, high NO_3^- concentration was found in St. 07 (6 ± 0.6 mg/L) in April 2021 (Table 03 & Fig. 13). The standard values of NO_3^- concentration in Australia and New Zealand: >100 mg/L (Table 01).

The highest PO_4^- concentration was found in St. 02 & St. 03 (4.75 ± 0.5 mg/L) in the Channel in February 2021 and lowest PO_4^- concentration was found in St. 08 (0.75 ± 0.2) in April 2021. Quality standards on phosphorous levels (in different forms) set by Australia, ASEAN, Malaysia, New Zealand, Norway, Philippines and United States, are between 0.02 and 0.20 mg/L for freshwater and from nil to 0.20 mg/L for marine water (Phiminaq, 2006).

Table 01: Comparing water quality parameters of the Moheshkhali Channel and Matamuhuri River with national standard and international standard for aquaculture

Parameters	DoE Standard, Bangladesh (For inland water) 2008	India Standard (Fresh/Marine Water)	Australia Standard (Fresh/Marine Water) ANZECC, 2000	Moheshkhali Channel		Matamuhuri River	
				Winter (Feb 2021)	Spring (Apr 2021)	Winter (Feb 2021)	Spring (Apr 2021)
Temp (^{0}C)	25 – 40	-	25	24.6 – 27.4	29.1 – 30.4	26.4 – 28.6	29.1-32.1
Sal (ppt)	-	-	-	27 - 33	30 – 32.4	0.11 - 0.13	0.18 – 0.2
pH	6-9	-/6.5 – 8.5	5-9/6-9	7.3 – 8.2	7.5 – 8.2	7.6 – 8.4	7.9 – 8.4
DO (mg/L)	4.5 – 8	-/5	>5.0	3.2 – 5.5	4.4 – 5.6	5 – 6.5	4 – 6.5
TDS (mg/L)	2.1×10^3	-	-	$31.2 – 37.3\times10^3$	$39 – 45.1\times10^3$	$0.3 – 0.36\times10^3$	$0.1 – 0.2\times10^3$
TSS (mg/L)	150	-	<40% / <10%	4.7 – 25%	4.4 – 22.1%	1 – 1.9%	0.5 – 0.7%
NH_3^+(mg/L)	5	-	<0.03 / <0.01	0.2 -1	0.1 – 1.1	0.1 – 0.3	0.1 - 0.5
NO_2^-(mg/L)	-	-	0.1/ <0.1	0.01 – 0.65	0.01-0.5	0.01 – 0.1	0 – 0.05
NO_3^-(mg/L)	50	-	50/ <100	0.1 - 2	0.1 - 7	0.1 - 1	0 – 0.5
PO_4^-(mg/L)	8	-	<0.1 / <0.05	0.8 - 5	0.1 -3.5	0.3 – 1.5	0.5 – 2.5

* Temp – Temperature and Sal – Salinity

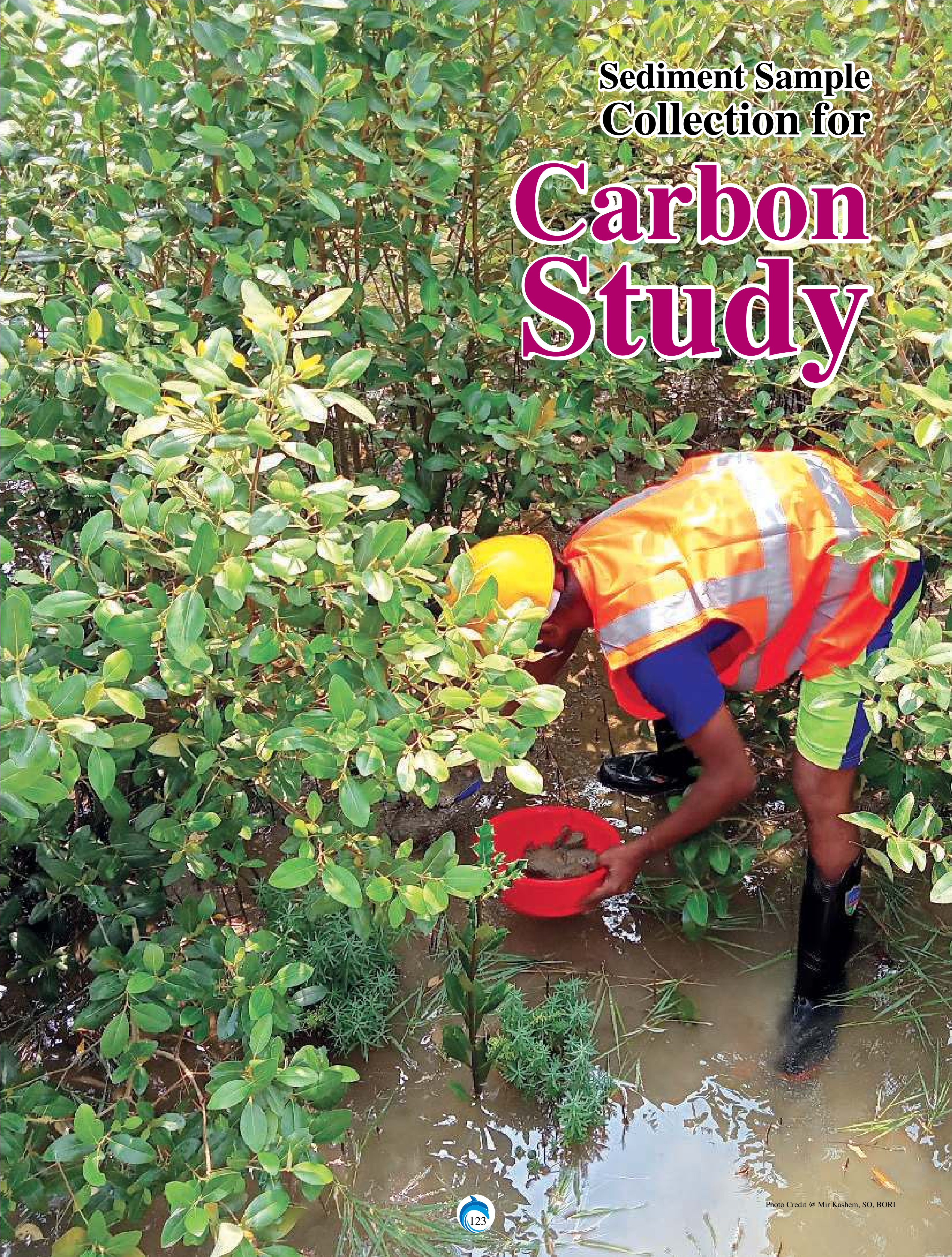
From the observation and analysis of chlorophyll-a data in winter season, it is showed that maximum surface chlorophyll-a was presence in downstream of the Channel. In April 2021 (spring season), chlorophyll-a ranged between 2.5 to 9.5 ± 0.8 mg/m^3 with an average of 5.5 ± 0.8 mg/m^3; the highest chlorophyll a was found in St. 02 (9.5 ± 0.8 mg/m^3) & St. 08 (7 ± 0.8 mg/m^3) in the Channel due to presence of sound amount nutrients such ammonia, phosphate, nitrite and nitrate (Table 01).

Primary Productivity of the Moheshkhali Channel and Matamuhuri River

Primary production refers to evaluation of the capacity of an ecosystem to build up, at the expense of external energy both radiant and chemical, primary organic compounds of high chemical potentials for further transformation and flow to higher system levels. The highest values of gross, net primary production and biotic respirations were obtained during winter due to low water temperature, higher transparency, high dissolved oxygen values, bright and clear weather where as in summer because of high water temperature leading towards higher photosynthetic rate as well as higher metabolic rate, the primary productivity also become high and lower values during rainy season due to cloudy weather (S. Mohapatra And A.K.Patra, 2012).

Primary productivity of Matamuhuri River at the one study station (St. 01) and Moheshkhali Channel at the four study stations (St.02: Tail of the Channel, St. 04: Upstream of the Channel, St. 06: Middle of the Channel and St. 08: Downstream of the Channel) was evaluated and its variation is given in the Table 06. On the observation in two seasons: winter (February 2021) and spring (April 2021), the minimum GPP (30 ± 8.63 mg C/m^3/hour) was obtained at St. 01 (Matamuhuri River) during April 2021 and the maximum (109 ± 10.21 mg C/m^3/hour) at St. 08 (Mouth of the Moheshkhali Channel) during February 2021 due to low surface water temperature, high water transparency and clear & bright sunny weather condition was existed. There is already existed indigenous aquaculture systems in the mouth of the Channel (St.08).

Sediment Sample Collection for Carbon Study



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The ratio of NPP and GPP is important for the evaluation of the amount of gross productivity available to the first trophic level consumer (Singh, A. K. and D. K. Singh, 1999). The ratio of NPP and GPP varied from 0.083 to 0.29 ± 0.03 during February 2021 and varied from 0.25 to 0.83 ± 0.15 during April 2021. The mean of the ratio was 0.20 ± 0.03 during February and 0.59 ± 0.15 during April 2021. Comparatively, higher ratio was observed in April than the February 2021.

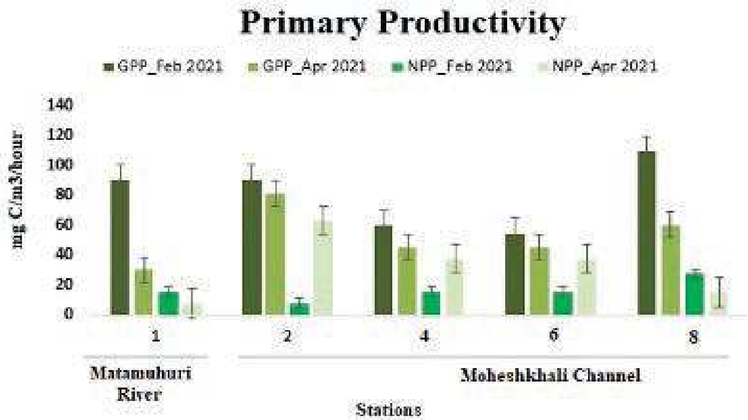

Figure 6: Variation in Primary Productivity (GPP, NPP) at St.01, St.02, St.04, St.06 & St.08.

Conclusion

The present study attempted to assess the biogeochemical process especially water quality parameters for the feasibility study of the aquaculture in two seasons e.g., winter (February 2021) and spring (April 2021) during high and low tide condition. The study summarizes the seasonal and tidal fluctuations in various physicochemical parameters, nutrient concentrations, chlorophyll-a and primary productivity in the Moheshkhali Channel and Matamuhuri river waters. The results indicate that the water quality parameters, nutrients, chlorophyll-a and primary productivity are significantly affected by seasonal changes and to some extent by variations in tidal height also.

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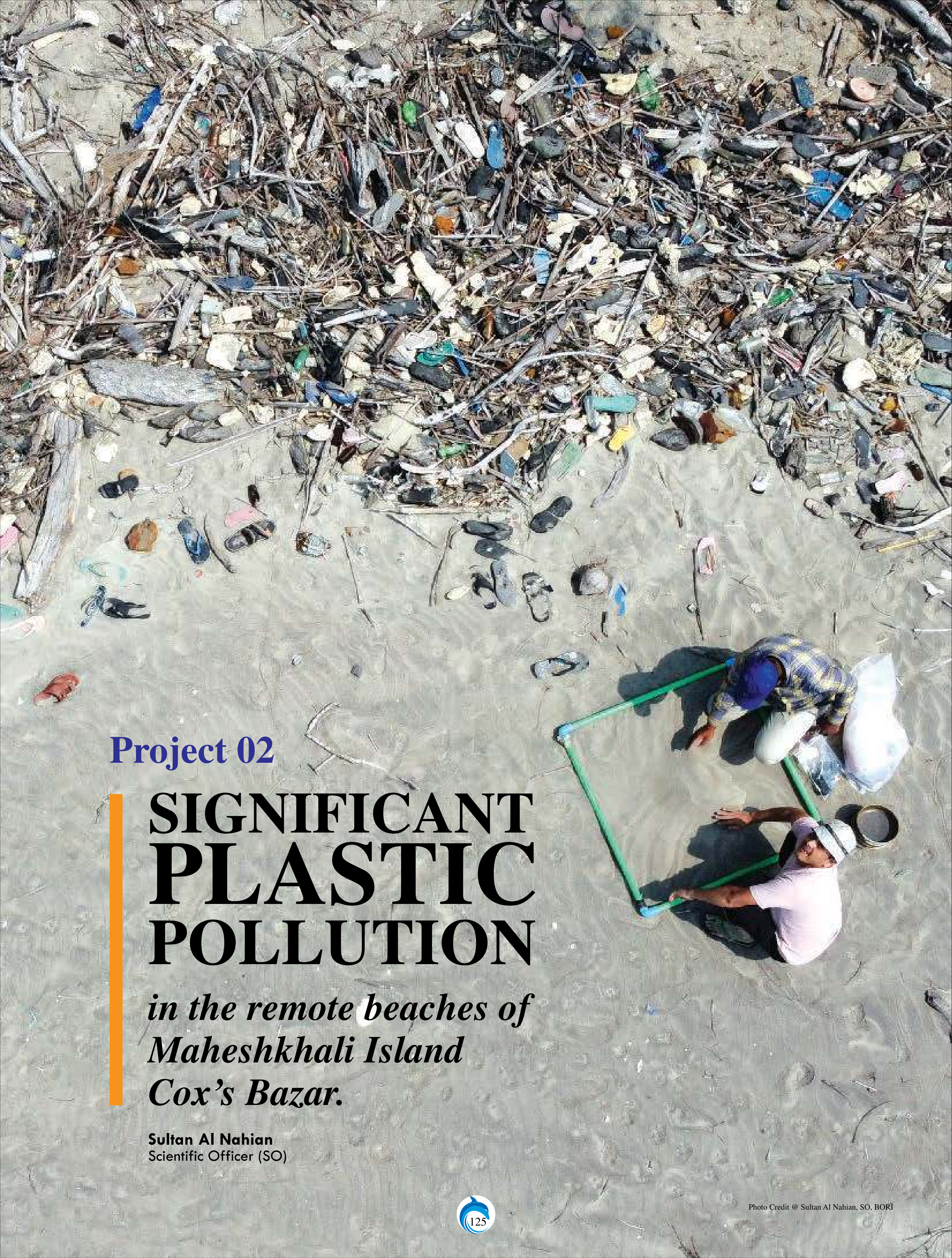

Project 02

SIGNIFICANT PLASTIC POLLUTION

in the remote beaches of Maheshkhali Island Cox's Bazar.

Sultan Al Nahian
Scientific Officer (SO)

Photo Credit @ Sultan Al Nahian, SO, BORI

Ghost crab entangled with fishing nets

Photo Credit @ Sultan Al Nahian, SO, BORI

Abstract

The present study investigated, for the first time, the assessment of plastics contamination in Maheshkhali Island. From the deepest part of the oceanic trenches to the isolated island plastic has been documented in various scientific reports and it is one of the most serious threats to the marine environment. The aim of this study was to estimate the presence, quantity, spatial distribution, types of macro (>25 mm) and micro (1-5 mm) plastics in the seven remote beaches of Maheshkhali Island. This study examines marine plastic debris using geographic information systems (GIS) & GPS, Clean Coast Index (Alkalay et al., 2007) and NOAA guideline to develop (1) a detailed map of intensity and distribution of plastic debris (2) results of baseline clean coast index (CCI) (3) a complete outline for a spatial database of shoreline plastic pollution of Maheshkhali Island. During the study period, a total of 4668 macroplastics, 2003 microplastics plastic items were recorded from the study area. An average of 237.08 macroplastics was found per $250m^2$ transect, the mean concentration of microplastics in the high tide zone registered $15.75/m^2$ and $89.43/m^2$ in the back of the beach or vegetation zone respectively. As per the clean coast index rate, Maheshkhali Island beaches can be measured as “Dirty” (>18 plastic pieces/m^2).

Introduction

Any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine and coastal environment is contemplated as marine litter pollution (UNEP, 2005). Anthropogenic plastic litter is found all over the ocean, even in Isolated Islands far away from human contact and obvious sources of pollution (Barnes et al., 2009). Plastics are already present in sufficient numbers to be considered as one of the most important types of technofossil which will form a permanent record of humankind presence on Earth (Zalasiewicz et al. 2016). Humans have been disposing of plastic waste in the sea and rivers, causing beach and water pollution (Faure et al. 2015). Basically, There are two sources of marine litter: sea-borne and land-based such as industrial wastes and litter originating from human activity on the beach (UNEP, 2005). According to the US Department of Commerce and the US Navy, approximately 80% of litter is washed off the land, blown by winds, or intentionally dumped from shore (The Ocean Conservancy, 2005). According to Cheshire et al., depending on their size variation, plastic debris is classified as macro (>25 mm), meso (25 - 5 mm), and microplastics (<5 mm)

(Cheshire et al., 2009). Macroplastics are plastic debris that is >25 mm in size; they are the most visible and noticeable form of the debris available on almost every shoreline and are easy to clear away, on the other hand, another increasingly abundant smallest form (<5 mm) of plastic litter is s microplastic. The large plastic items (macro plastic) undertakes several degradation processes and fragmentation by UV solar radiation to breakdown into microplastic which is omnipresent in every aquatic environment. As like other part of the world, Cox's Bazar coastline is highly affected by the plastic pollution. Several scientific repot shows plastic contamination in the coastal region of Bangladesh where results documented the presence, distribution and concentration of macro and microplastics in the shore sediments as well as marine fish organs (Hossain et al. 2019; Nahian, 2020; Rahman et al. 2020). Maheshkhali Island is the only hilly Island which plays an important role in wildlife migration, providing spawning and feeding grounds for millions of fish and bird species, with physical and toxicological effects of plastic pollution is a threat to the coastal ecosystem (Arefin et al. 2017). The present study was conducted on the plastic debris scattered on the tidal limits of seven selected beaches in two remote islands and two chars along the western coast of Maheshkhali Island. Considering the above, the aim of this study was to estimate the spatial distribution, types, and characteristics (color, shape, size) of macro and microplastics in the shore sediments of Maheshkhali Island.

Materials and Methods

The Maheshkhali Island is located in the far south-eastern corner of Bangladesh, including the Materbari and Sonadia lies within 21°N and 91°E and is bordered by Chakoria and Cox's Bazar in the north, northeastern eastern and southeastern part across the Maheshkhali channel (Islam et al. 2011). The ecosystem of this island was adversely affected due to the increasing rate of anthropogenic disturbances (Arefin et al. 2017). Seven locations/beaches (figure 01) were selected as sampling sites from the four most remote areas (Sonadia Island, Kaladia Char, Kuhelia Dwip, and Hasher Char) of Maheshkhali Island where human activity is very limited. The island covers coastal and mangrove plantations, salt production fields, shrimp culture firms, plain agriculture lands, human settlements, etc. 21 macroplastic and 41 microplastic samples were collected for laboratory analysis. All the samples were collected during the low tide period in the month of March 2021 and April 2021. With the aim to obtain a reliable estimation of plastic litter samples were collected from three sampling sites on each station were randomly selected, transects of approximately 50 meters in length and 5 meters wide were selected for the macro plastic survey (Noik and Tuah 2015). Microplastics were collected from triplicate samples (1 m^2 quadrat) located in the line of the high tide and vegetation line and sieved the top 3cm sand sequentially with a 1 mm^2 stainless steel sieve (Lippiatt et al. 2013). The sieved materials were stored in a zipped lock plastic bag and brought to the laboratory. The microplastics were then identified and sorted using the naked eye. Tools used consisted of a GPS handheld unit (Garmin e-trex 10), a 100-m engineer tape, four red surveying flags, and approximately 20 kg size transparent trash bags for the collection of litter from the survey sites.

Figure 01: Specific sampling location on the beach area (Blue marked) of Maheshkhali Island.

Analyzing MICRO PLASTICS using FTIR

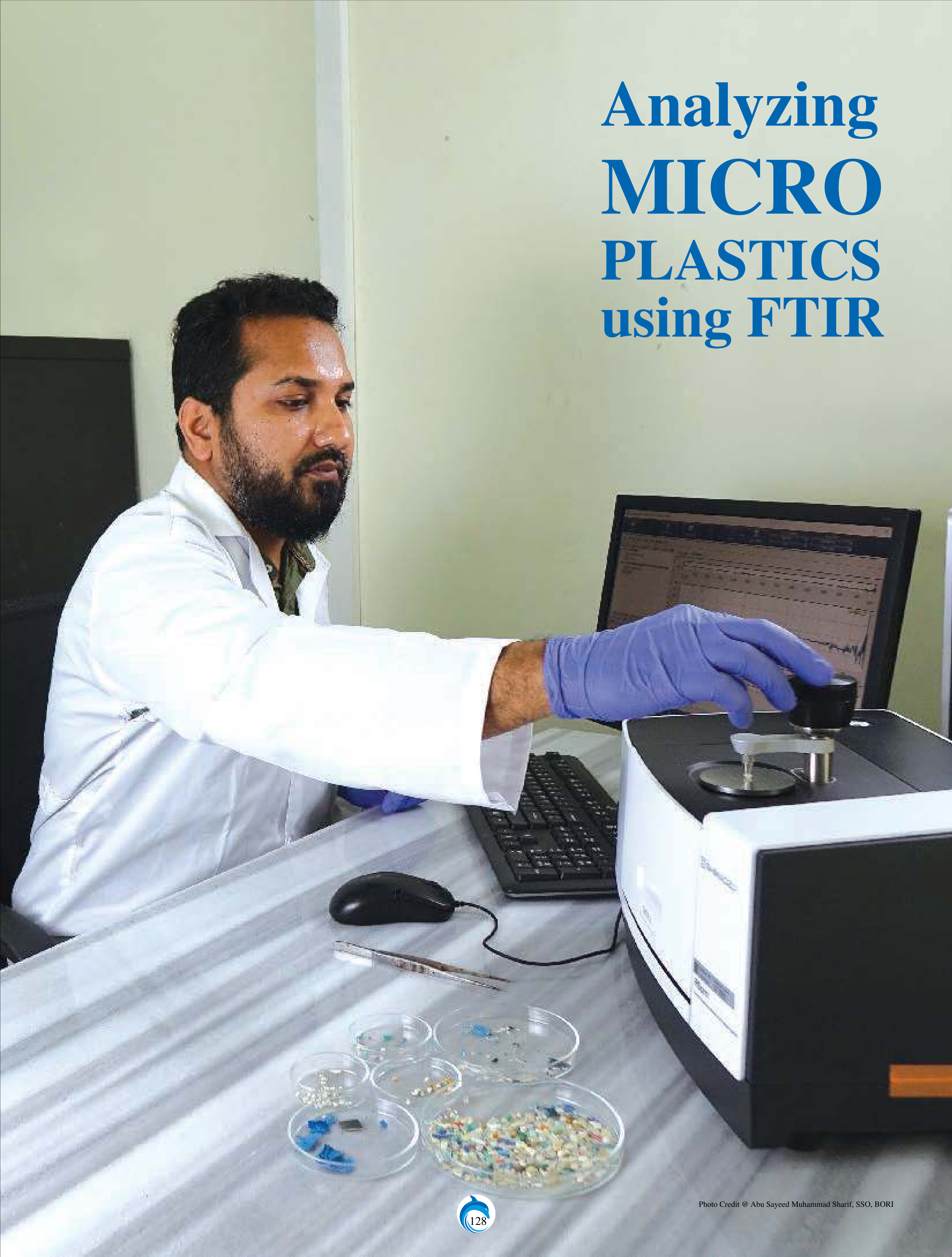

Photo Credit @ Abu Sayeed Muhammad Sharif, SSO, BORI

Result and Discussion

Macroplastics

According to the NOAA's classification, a total of 24 categories in 8 groups of macroplastic debris were recorded in this study (Lippiatt et al. 2013). They were mainly fishing-related items like plastic ropes, lines, cords, nets, floats, and plastic buoys. Expanded polystyrene (EPS) and foam-type materials were most commonly found in plastic litters. Shopping Bags, food wrappers (candy, biscuits, chips, etc.), bubble wraps, beverage bottles (mainly water and soft & energy drinks), bottle caps (and other product caps), medicine bottles, machine oil bottles, aerosol bottles, different plastic containers, disposable cigarette lighters, pens, food containers, disposable foam food containers (cups, plates, etc.), straws and spoons, toys, personal care products (toothbrush and hairbrush, cotton buds, etc.), medical products (blister packs, syringe, needles, dropping bottles, vaccine glass bottles, face masks, gloves, etc.), household appliances pieces, sandals, clothes, Shoes, and pillow. Subsequently, we summarized them into 8 groups or wider categories named expanded polystyrene (EPS) & foam, hard plastics, soft plastics, fishing items, medical & personal protected equipment's (PPE), bottles, metals & glass, and non-source & other materials.

Figure 02: (a) Macroplastics along the western part of Sonadia Island, (b) & (c) sample collection from the study area.

During the study period, a total of 4668 macroplastics items were collected from the sampling area. An average of 237.08 macroplastics was recorded per transect (~ 250 m^2), with 71.5 of the expanded polystyrene (EPS) which is related to fishing-related materials. Fishing-related items and soft plastics (bags, food wrappers, etc.) were the heaviest group of macroplastics, about >40 items per transect. As predictable, the highest volume was given by bottles (empty bottles), particularly water and soft drinks. A huge amount of medical items and personal protective equipment (PPE) mainly face masks were collected from the study area. According to the results, location wise an average the number of macroplastic items is the highest in Sonadia east beach (544.66 items/250 m^2) followed by Sonadia north beach (472 items/250 m^2), Dhal Ghata Beach (198 items/250 m^2), Sonadia wast beach (138.33 items/250 m^2), Hasher Char (127.66 items/250 m^2), Kaladia Char (46.33 items/250 m^2), Kuhelia dwip (29 items/250 m^2). Figure 3 illustrated the results of baseline clean coast index (CCI) (figure 3, panel b) and distribution of macroplastics (figure 3, panel a) of Maheshkhali Island.   According to Alkalay et al. the calculation of the CCI is presented in the following equation:

Clean Coast Index (CCI) = (Total litter on sampling unit/total area of sampling unit) x K,

Where CCI is the number of litter items per m^2, the total area of the sampling unit is generated by multiplying the sampling unit's length with the width and K is a constant that equals to 20 (Alkalay et. al., 2007).

In order to make the picture clearer for the public, results for appearance of litter on the coasts were graded as follows:

Coast Index	Very clean	Clean	Moderate	Dirty	Extremely dirty
Numeric Index	0-2	2-5	5-10	10-20	20 +

As far as the density of beach litter is concerned, two beaches have high CCI (> 20). The highest CCI is for Sonadia east beach (45) followed by Sonadia north beach (38.4), Dhal Ghata Beach (16), Sonadia wast beach (11.2), Hasher Char (10.8), Kaladia Char (3), Kuhelia dwip (2.4). The highest CCI value was obtained for beaches with dry fish and fishing activities and the lowest for beaches with no human activity. According to the clean coast index (CCI), Sonadia east and north found extremely dirty and Sonadia west beach was dirty. Dhal Ghata beach and Hasher Char were found dirty. Kuhelia Dwip and Kaladia Char were found clean according to the CCI index. Clean coast index (CCI) results showed 29% of beaches were found extremely dirty as the twice of CCI index number. 43% beach found dirty and 28% beach was clean. Most of the coastline is mostly polluted by reared fishing nets, rope, and floats other fishing-related things.

Microplastics

The collected microplastics (MPs) were categorized according to size, shape, and color. Virgin resin pellets (preproduction resin pellets) in samples could be easily separated as white, transparent, or light yellow spherical pellets and were easily identifiable. After sample collection, potential microplastics were examined using the naked eye. According to their geometrical shape microplastics were also classified into the following six classes: (1) primary microplastics (PM)/ resin pellets, (2) Expanded polystyrene (EPS), (3) Foam, (4) Fragments, (5) Filaments, (6) Line/Fiber (figure 04).

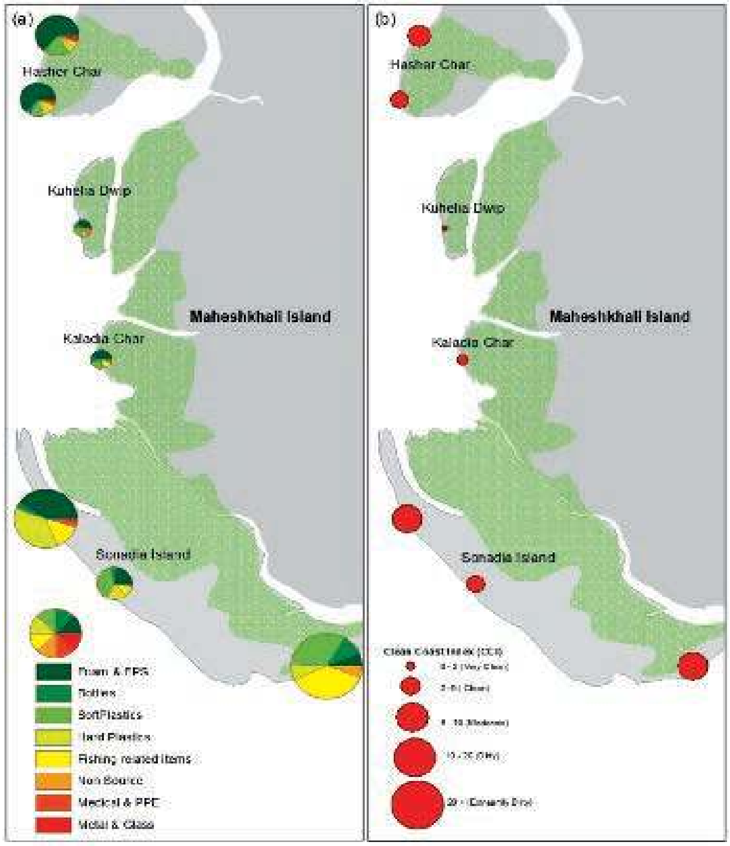

Figure 03: (a) Distribution of macroplastics based on groups; (b) Pollution status of Maheshkhali coastline according to the clean coast index (CCI).

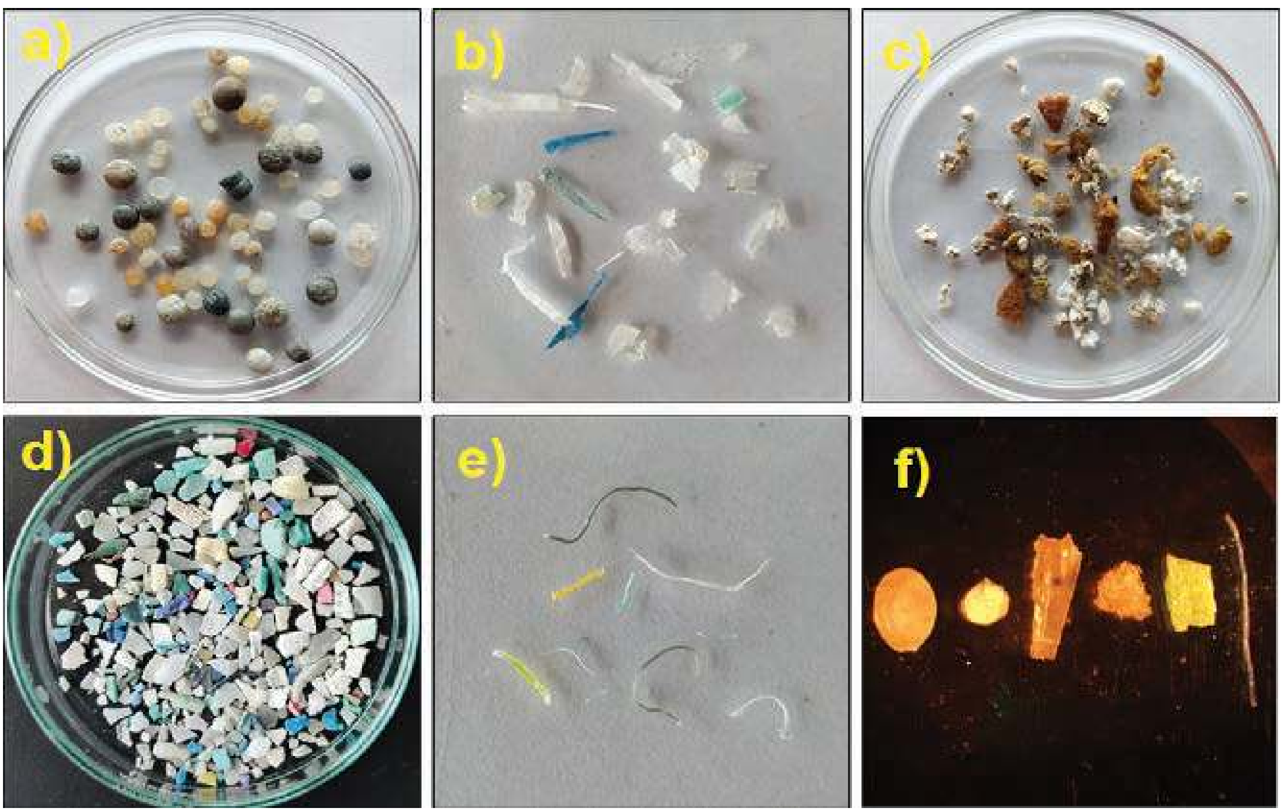

Figure 04: Photograph of plastics retrieved from beach/sediments sample (a) Resin Plastics (b) Filaments (c) EPS & Foam (d) Fragments (e) Line (f) Microscopic view of various microplastics.

Figure 05 illustrated the distribution of macroplastics based on groups (figure 05, Panel a) and Concentration of microplastics (MPs) in Maheshkhali coastline (figure 05 panel b). The morphological information from the microplastic samples can be used to indicate their potential origins. For example, primary microplastics are usually resin plastics that come from industrial effluent or accidental leakage from ships. Line/fiber usually originates from fishing lines, clothing, or other textiles, while filaments mainly originate from plastic bags or wrapping materials. Fragments are breakdown pieces of hard plastic substances. EPS and Foam type plastic comes from fishing-related activity because fishermen extensively use EPS and foam type materials to float their nets in the ocean. During the study period microplastics were found in every triplicate sediment sample in all the sampling sites and the mean concentration of microplastics in the high tide zone registered 15.75/m^2 and 89.43/m^2 in the back of the beach or vegetation zone. During sampling all together as many as 2003 pieces of microplastic debris were collected and the particles were divided into six classes: fragments (for a total of 632 items, 29%), expanded polystyrene (EPS, for a total of 431 items, 21%), (Foam, for a total of 400 items, 20%), (Line, for a total of 244 items, 12%), primary microplastics/resin plastics (RP, for a total of 209 items, 13%), and (Filaments, for a total of 87 items, 5%). The color of the collected plastic litters from the studied beaches varied greatly. The color-wise abundance of plastics on all beaches of the island followed the order, white (32%), blue (15%), Green (9%), Red (9%), yellow (17%), Grey (11%) and transparent (7 %).

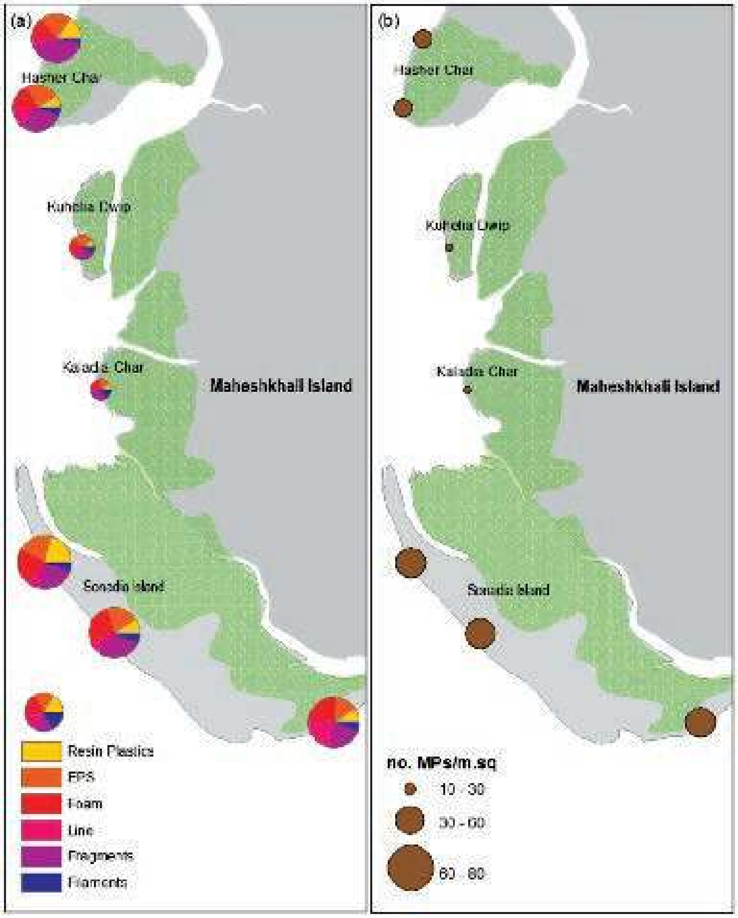

Figure 05: (a) Distribution of macroplastics based on groups; (b) Concentration of microplastics (MPs) in Maheshkhali coastline.

Photo Credit @ Environmental Oceanography and Climate Division, BORI

Conclusion

We observed high levels of marine plastic litters (macro and microplastic) in the form of different sizes of plastic in the beach sediments of Maheshkhali Island. In this study microplastic distribution fully govern by the geological location of the island, coast type, wind direction, surface current, and sedimentary budget. Spatial variation in plastic debris concentration was observed in the island due to environment and plastic source-related factors. The intentions of this work were to gain a baseline understanding of marine plastic litters in the study area to deliver a preliminary outline for future actions to address such issues in the country as well as add to global studies of marine debris in demonstrating the utility of GIS-based research. However, long-term monitoring of the plastic debris in the Maheshkhali area is required to obtain a better estimation of plastic pollution with details of different size fractions and morphotypes. The study indicates that the beaches of Maheshkhali Island are at risk from plastic pollution and require more attention. An in-depth study should be carried out on monitoring the spatiotemporal distribution of plastic particles in the beaches and its impact on aquatic biodiversity followed by its contribution to the Bay of Bengal for a clean and safe environment.

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Data Collection

Photo Credit @ Environmental Oceanography and Climate Division, BORI

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PROJECTS

- Determination of Marine Pollution by coastal water quality assessment and marine litter loads around the Coastal Area of Saint Martin's Island.
- Determination of marine pollution by assessing seasonal seawater quality and identifying the status of micro plastic in the coastal area of Saint Martin's island.

RESEARCH INTEREST

Marine Pollution, Climate Change, Blue Carbon, Oil spill, Costal Disaster Management, EIA.

TRAINING

- Climate Change Adaptation and Mitigation-DU, Bangladesh
- Environmental Safety-DUES, Bangladesh
- Ocean Research: Basics of Observationsand Instrumentations, NIO, Goa, India

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SKILLS

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R Programming,
Python
Linux
Surfer, Grapher
WRF-Model

PROJECTS

- Determination of Marine Pollution by coastal water quality assessment and marine litter loads around the Coastal Area of Saint Martin's Island.
- Determination of marine pollution by assessing seasonal seawater quality and identifying the status of micro plastic in the coastal area of Saint Martin's island.
- Determination of Marine Pollution by Assessing Seasonal Seawater Quality Monitoring and Marine Organisms in the Coastal Area of Cox's Bazar, Bangladesh.

RESEARCH INTEREST

Air-sea interaction, EIA, Marine Disasters (Cyclone, Storm Surge & Saline Water Intrusion) Biogeochemistry of Ocean, Climate Change, Marine Pollution, CZM.

TRAINING

- Ocean Research: Basics of Observations and Instrumentations (NIO, Goa, India);
- Operational Oceanography and Marine Science-NMEFC-SOA (Beijing, China);
- Development of Coupled Regional Ocean Models (FIO, SOA, Qingdao, China)

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SKILLS

MIKE, GIS

PROJECTS

- Determination of Marine Pollution by coastal water quality assessment and marine litter loads around the Coastal Area of Saint Martin's Island.
- Determination of marine pollution by assessing seasonal seawater quality and identifying the status of micro plastic in the coastal area of Saint Martin's island.
- Occurrence and characteristics of macro, meso and microplastics in the coastal area of Cox's Bazar.

RESEARCH INTEREST

Micro-Plastic, Marine Debris, Oil spill, Ecological Modeling and Marine conservation.

TRAINING

- Training on MIKE 21/3 software-NIO, Goa.
- Foundation Training-NAPD, Dhaka.

CHAPTER 8

Oceanographic Data Center

Photo Credit @ Oceanographic Data Center, BORI

Preface

With the establishment of Bangladesh Oceanographic Research Institute (BORI), Oceanographic Data Centre (ODC) has been established as a countries first Oceanographic data centre. Oceanographic Data Centre of BORI is serving as a ``data-primer'' for students and those in other fields of research who are interested in carrying out research involving the analyses of data in the oceanographic sciences. The datasets include observations from conventional oceanographic sources such as stations and ships, from satellites, and analyzed grids produced at operational weather forecast centers. Rather, the focus is upon the broad characteristics of the data sources and the datasets. The characteristics of ODC are not only including the observed variables and their spatial and temporal extent but also common problems, data limitations and sources of error of oceanographic data.

Photo Credit @ Shafiqul Islam Shafiq, BORI

Data Center

A data center is a facility composed of networked computers and storage that businesses or other organizations use to organize process, store and disseminate large amounts of data.In case of Oceanography "Data" in general refer to digital or analogue records of marine environmental observations; and “information" refers to inventories, catalogues, data products, analyses, selected bibliographies, reports and publications of the data centre or to similar products of other centers or organizations.

Advances in marine sciences and technology depend to a significant degree upon the effective flow of data/information from the collectors to various types of users. The principal purpose of an Oceanographic Data Centre is to provide on a long-term continuing basis data/information in a usable form to the so-called "secondary user" community, i.e. to individuals or organizations in the nation which have or will in the future need for data, after the primary purposes for which the data were collected have been satisfied.

Oceanographic Data

There is a broad range of oceanographic data types. Oceanographic data are collected using both in situ methods and remote sensing. The most obvious remote sensing platforms are satellites, but scientific aircraft, some special buoys, and even some ships use instruments (e.g., radiometers) to remotely sample the ocean surface. Useful in situ ocean observations come from different sources, with varying degrees of quality. The highest quality data are collected during scientific research programs, by instrumented buoys (both moored and free drifting), by ships specifically designed to collect environmental data, and by coastal or island stations that function in a manner similar to standard land stations. Lower quality data, but nevertheless quite valuable, are regularly collected aboard merchant ships as they traverse shipping routes, and by fishing fleet vessels during commercial fishing operations.

Scientific research programs collect the widest variety of in situ data. Typical ship board activities will collect sea surface data (SST, salinity, wave height, wave direction, etc.), near-surface meteorological conditions (air temperature, wind speed, wind direction, dew point temperature, barometric pressure, cloudiness, etc.) and, often, subsurface sea water characteristics (e.g., vertical profiles of temperature, salinity, dissolved nutrients, dissolved gases, anthropogenic tracers, ocean currents, and ocean bottom depth). Some research programs also deploy surface drifting buoys whose locations are monitored by satellite. These provide buoy trajectories (that approximate surface ocean circulation), and usually a few other geophysical variables (e.g., SST, barometric pressure, etc.). To a lesser extent, some free drifting buoys are located below the ocean surface. These buoys are tracked acoustically or they periodically rise to the surface for satellite tracking. Buoys of this type are used to monitor subsurface oceanic flow as well as subsurface sea water properties. Moored surface buoys with subsurface instruments below are also used by science programs. The surface instrumentation collects many types of data relevant to ocean-atmosphere boundary layer processes, while the subsurface instruments normally focus on water temperature, salinity, pressure, and ocean currents.

Data Type

- Ocean-Atmosphere Boundary Layer Data
- Subsurface Observations Data
- Sea Level, Topography Data
- Research Project Datasets
- Ancillary Datasets
- Analyzed and Model Data
- Reanalysis Datasets

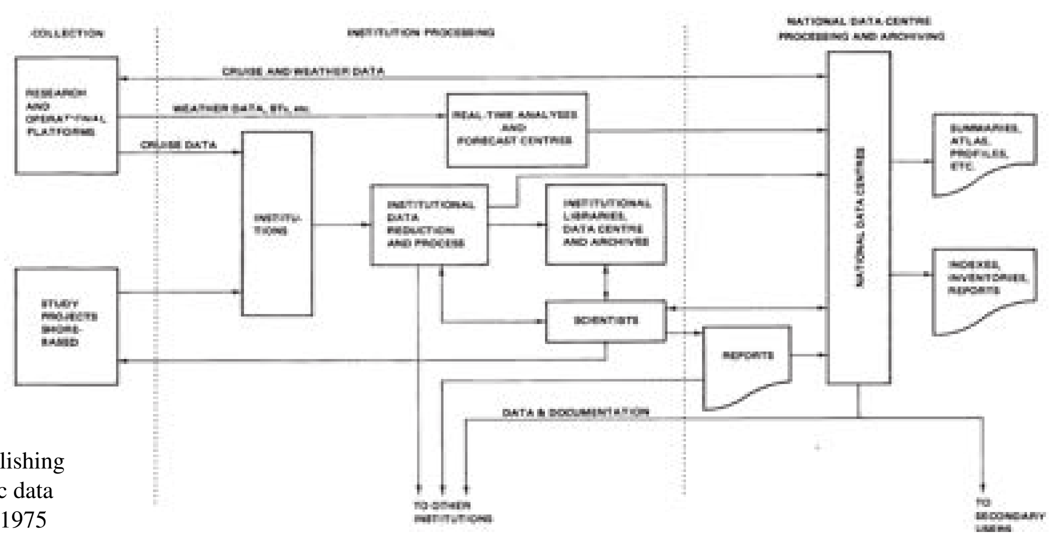
Data format

Atmospheric and oceanographic data may be archived in several different computer forms: character format, native format, packed binary or in one of several "standard" scientific data formats. Users of datasets must be aware of how the data are stored. There are different methods for storing both character and numeric values. Normally, detailed descriptions of data formats are provided and, often, software to access the data is readily available.

There are a number of "standard" scientific data formats. Documentation and software necessary to implement these formats are generally available via computer networks. Architecture independent standard formats commonly used for atmospheric and oceanographic datasets include:

1. GRIB (GRId in Binary)
2. CDF (Common Data Format)
3. netCDF (network CDF)
4. HDF (Hierarchical Data Format)
5. BUFR (Binary Universal Format Representation)

Marine Data Flow



Source: Guide for establishing a national oceanographic data centre, IOC, UNESCO, 1975

Figure 01: Generalized Marine Data Flow for Oceanographic Data Center

Data Center of BORI

With the establishment of Bangladesh Oceanographic Research Institute (BORI), Oceanographic Data Centre has been established as a countries first Oceanographic data centre. Oceanographic Data Centre of BORI (ODC-BORI) is serve as a "data-primer" for students and those in other fields of research who are interested in carrying out research involving the analyses of data in the oceanographic sciences. This ODC-BORI will describe, in very general terms, the datasets most commonly used to study the ocean system and the formats used for archival. The datasets include observations from conventional oceanographic sources such as stations and ships, from satellites, and analyzed grids produced at operational weather forecast centers. Rather, the focus is upon the broad characteristics of the data sources and the datasets. The characteristics of ODCOB are not only including the observed variables and their spatial and temporal extent but also common problems, data limitations and sources of error of oceanographic data.

Key Activity of the ODC

Its primary activity is to manage the data collected from Ocean.

- Collecting Oceanographic Data from National, Regional & International programs
- Verifying the quality of the Data
- Ensuring the long term preservation of the Data & associated information required for correct interpretation of the Data
- Making Data available nationally & internationally according to govt. rules & regulations

Targeted Function of the ODC

National

- Receiving data from researchers, performing quality control, and archiving.
- Receiving data from buoys, ships and satellites on a daily basis, processing the data in a timely way, and providing outputs to various researches and/or to other centers according to the govt. rules & regulations.
- Reporting the results of quality control directly to data collectors as part of the quality assurance module for the system.
- Participating in the development of data management plans and establishing systems to support major experiments, monitoring systems etc.
- Disseminating data on the Internet and through other means (and on CD-ROM, DVD, etc) according to the govt. rules & regulations.
- Publishing statistical studies and atlases of oceanographic variables.

International

- Participating in the development of international standards and methods for data management through international body (such as IODE and JCOMM);
- Participating in international oceanographic data and information exchange through international body (such as IODE and JCOMM);
- Assisting with data management aspects of global or regional programmes or pilot projects;
- Operating as a data assembly and quality control centre for part of an international science experiment;

Goal of ODC

- Achieve capability to provide Marine Information and Advisory Service (MIAS) nationally & internationally.
- Develop the archive of marine data & National Oceanographic Database (NODB).
- Creating and publishing the General Bathymetric Chart of the Oceans (Bay of Bengal).
- Become the country's apex center for Database Management, Data Capacity, Data Analysis and Maintenance.
- Collect Super Computer to develop vast size international standard Data management system & Analysis.

Photo Credit @ Oceanographic Data Center, BORI

Data Collection

Photo Credit @ Oceanographic Data Center, BORI

Photo Credit @ Oceanographic Data Center, BORI

Mst.Tania Islam

Scientific Officer (SO)

CONTACT

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EDUCATION

B.Sc. & M.S
Statistics
Jahangirnagar University
Bangladesh

SKILLS

Fortran, Python, SAS, R, MATLAB
SPSS, Minitab, Stata, XlSTAT
Arc GIS 10.2.

PROJECTS

- Application of Different Statistical Sampling Design to Identify Best Data Collection Method in the Costal Marine Ecosystem: A Comparative Study.
- Statistical Analysis and Future Prospecting of Non-conventional Marine Fisheries and Algae Resources in the Cox's Bazar District of Bangladesh.
- Trend analysis of temperature and rainfall in the coastal area of Bangladesh.

RESEARCH INTEREST

Data Analysis & Management, Ocean Modeling, Monitoring & Forecasting, Statistical Analysis, RS & GIS, Data science: Machine Learning.

TRAINING

- Training Course on Oceanography: Principle & Application NOAMI.
- Training course on 'New Rhythms in the Tropical Indian Ocean'.
- Training on GIS and Remote Sensing.

CHAPTER 9

Blue Economy

Plans of BORI for Blue Economy (2018-2021)

Bangladesh Oceanographic Research Institute (BORI) is working to conduct all the activities as a focal point of Bangladesh at national and international levels in the field of oceanography and Blue Economy in the context of research and development. BORI developed different types future plan based on Election Manifesto, 2018 (Chapter 3.22), Short-mid-long term plan based on Blue Economy and future plan based on the year of 2021, 2030 and 2041.

Photo Credit @ Sayeed Mahmood Belal Haider, DG, BORI

Terms	Plan	Program Description	Time Period (Fiscal Year)	Probable Budget	Source of Budget	Present Achievement (up to December, 2020)	Required Component
Short Term	Identification of Geologically important areas and possible resources by collecting baseline data in the south part of eastern coast.	Coastal areas of Bangladesh are divided into 3 zones namely Eastern, Middle and Western. Identify existing resources by determining geological parameters as well as analysis of sea water sample & bottom sediment of near-shore and coastal areas of the eastern part (from Cox's Bazar to Saint Martin's Island) in these three zones.	Short term (2 years) 2018-2019 to 2019-2020	40 Lac	Revenue Budget (Special Allocation)	According to research results 8-18% heavy minerals have been found in the Cox's Bazar sea area. Technical report has been sent mentioning research results. **Progress: 100%**	
	Determination of Baseline data related to Biological Oceanography	Identify seaweed samples collected from the coast of St. Martin's Island of Bay of Bengal. Publish taxonomic book with images- "Marine Algae (Seaweed) of Bay of St. Martin's Island, Bangladesh".	Short term (2 years) 2018-2019 to 2019-2020	50 Lac	Revenue Budget (Special Allocation)	Sample collection and sea cruise have been done by R&D projects in 2018-19 and 2019-20 fiscal years. Already 72 species of Seaweed is identified by sample analysis. Publish taxonomic book with images- "Marine Algae (Seaweed) of Bay of St. Martin's Island, Bangladesh" is on progress. **Progress: 95%**	
	Identify the quantity of zooplankton in the Bay of Bengal and publish book.	Identify zooplankton by collecting samples from the coast of Bay of Bengal to deep sea area.	Short term (2 years) 2018-2019 to 2019-2020	20 lac	Revenue Budget (Special Allocation)	BORI scientists collected samples of zooplankton from deed sea jointly with Fisheries Research Institute using RV Dr. Fritjof Nansen Ship of Norway. Zooplankton is identified by analysis from those samples of Bay of Bengal. Publish taxonomic book with images is on progress. **Progress: 80%**	
	Aquaculture	Select places for aquaculture (cage culture) by identifying different areas and implement a pilot culture.	Short term (2 years) 2018-2019 to 2019-2020	20 lac	Revenue Budget (Special Allocation)	Planning is in progress to convert this program into midterm.	
	Baseline data enrichment related to Chemical Oceanography	Baseline data enrichment of Chemical Oceanography in the coastal and near-shore area of eastern part.	Short term (2 years) 2018-2019 to 2019-2020	20 lac	Revenue Budget (Special Allocation)	Sample collection for this research is completed on October to December, 2019 and January to March, 2020 from eastern coast of St. Martin's to Moheshkahli Island. Due to COVID-19 situation sample collection is hampered for May & June, 2020 time period. A new proposal is sent for 2020-21 fiscal year. **Progress: 70%**	
	Reduce pollution of the coastal areas	Prevent plastic and waste material pollution of 250 km eastern coastal area of 720 km long sea beach of Bangladesh. To prepare marine litter action plan and implement it. To prevent ocean and coastal pollution of Bangladesh, national and international laws and regulations are to be implemented and save the ocean environment in a sustainable manner.	Short term (2 years) 2018-2019 to 2019-2020	20 lac	Revenue Budget (Special Allocation)	Related projects have been implemented from St. Martin's to Moheshkahli island in 2018-19 and 2019-2020 fiscal years. Sea cruse is done for sample collection in February, 2020 of 1st phase and March, 2020 of 2nd phase. Due to COVID-19 situation sample collection is hampered for May & June, 2020 time period. Report preparation is in progress. A new proposal is sent for 2020-21 fiscal year. **Progress: 70%**	

	Data collection in a test basis for proposed Data Center and regular update program	Forecasting by data collection and analysis of coastal weather.	Short term (2 years) 2018-2019 to 2019-2020	10 lac	Revenue Budget (Special Allocation)	Data collection and analysis is completed. Report writing is in progress. Two research papers published in international journal already. Research result presented in international seminar. **Progress: 100%**	
		To start data collection by setting up at-least one Data Buoy as a pilot project in Rezu khal beside marine drive road.	Short term (2 years) 2018-2019 to 2019-2020	30 lac	Revenue Budget (Special Allocation)	Specification and possible budget to collect these equipments in 2019-20 fiscal year has been prepared.	Budget allocation to set up Buoy
	Marine affairs related skilled manpower development with sea related awareness program	To develop skilled manpower, road map preparation with implementation approaches for national and international trainings and seminars will be programmed for the scientists.	Short term (2 years) 2018-2019 to 2019-2020	100 lac	Revenue Budget (Special Allocation)	12 scientists of BORI got 15 days training from NIO, India. DG, BORI attended oceanography related seminar at TIO, China; TIO agreed to train BORI scientists. 3 scientists got RS training. 5 scientists got training from NOAMI. Beside these, 15 officers got foundation training from NAPD. Discussion with NAHRIM and other oceanographic institutions is in process to train scientists. In this regard, a team from Malaysia visited BORI and proposed to sign MOA.	To sign co-operational MOA with experienced and skilled countries of oceanographic research.
Mid Term	Establish marine aquarium	To establish a modern research oriented aquarium in BORI.	Mid term (4 years) 2018-2019 to 2021-2022	39,577 crore	Annual Development Program (ADP Budget)	A PEC meeting is conducted in Planning Commission on 25/03/2018. According to the recommendations of PEC a revised DPP is sent in the Ministry. Information of this DPP is uploaded in AMS/RAMS of the ministry. Now the DPP is in planning commission for subsequent review work. Regular communication is going on for updated information of approval.	To approve DPP
	BORI Project (2nd Phase)	Development of physical structure with other facilities, warehouse and workshop set up, establish oceanographic data center, procurement of research ship and scientific laboratory equipments for BORI.	Mid term (4 years) 2018-2019 to 2021-2022	750 crore	Annual Development Program (ADP Budget)	Research and development expenses are estimated in the 2nd phase DPP of BORI. Proposed DPP is sent to planning commission after PSC meeting. Planning commission advised to attach PCR of 1st phase and resubmit with amendment. After refinement, the DPP is sent to the ministry on 03/01/2019. In this regard, a PSC meeting is held in the ministry. According to PSC decision, 10 recommendations are noted. Following this, a letter was sent to BCC. BORI got draft of data center already. Beside this, according to recommendation specification, primary design and estimation compilation are completed for 30 meter long research ship from Khulna Shipyard. Design compilation is on going in the department of Architecture. Information of this DPP is uploaded in AMS/RAMS of the ministry.	To complete architectural design compilation from the department of architecture

	Physical and Space Oceanography related Base Line data determination.	Base line data collection of physical parameters (ex- wave data, tide data, current data; other data of temperature, salinity, depth etc.) from the coastal and near-shore area of east and west zone of the 3 coastal zones of Bay of Bengal.	Mid term (5 years) 2018-2019 to 2022-2023	200 lac	Revenue Budget (Special Allocation)	Most of the physical parameters are determined from the near-shore of the east coast of the 2 coastal zones. Rest of the samples is collected from Moheshkhali and Kutubdia in 2019-2020 fiscal year. 45% research activity is already completed.	Ship from NAVY/DOF Set up one tide gauge in the coastal area
	Determination of biochemical composition of non-conventional animals	Determination of biochemical composition of non-conventional animals of coastal area of Bangladesh such as-snail, oyster, crab, kuchia etc. Technological innovation of sustainable and easy culture system and disseminate it widely in the field level.	Mid term (5 years) 2018-2019 to 2022-2023	100 lac	Revenue Budget (Special Allocation)	Project related to culture of non-conventional sea invertebrate (oyster) and marine invertebrate near rezu khal has been approved in BORI. Sampling is going on. Report writing is in progress. **Progress: 45%**	
	Identification of Geologically important areas and possible resources by collecting baseline data in the eastern coast.	Identify existing resources by determining geological parameters (ex-mineralogical data, sediment character, geological map, tectonic movement, erosion & deposition, valuable ore related baseline data) of near-shore and coastal area of eastern zone (from Feni to Saint Martin's Island) of three coastal zones.	Mid term (5 years) 2018-2019 to 2022-2023	80 lac	Revenue Budget (Special Allocation)	Half of the works (about 3100 sqkm) of sample collection and analysis is completed of three coastal zones.	Research vessel or boat management
	Checklist of important animals and ocean biodiversity by collecting baseline data related to biological oceanography	Quantify the amount of agar & carrageenan and analyze biochemical composition of seaweed by collecting samples from St. Martin's island of Bay of Bengal. Seaweed identification for agar & carrageenan production and work for techniques to culture and produce in the field level.	Mid term (5 years) 2018-2019 to 2022-2023	80 lac	Revenue Budget (Special Allocation)	BORI approved project related to this research works in 2019-2020 fiscal year. From 86 identified seaweed species, 20 species are commercially important. BORI approved research project for commercial use and culture of 6 seaweeds. **Progress: 45%**	Analytical service from BCSIR/BAEC
	Aquaculture	Implement pilot project of Cage Culture in specified areas	Mid term (5 years) 2018-2019 to 2022-2023	200 lac	Revenue Budget (Special Allocation)	BORI is planning to run this project form development sector.	Need technical consultation
	Identify the areas of oil spill and ways to come out from its impact	Determine the effect of oil spill in the coastal and near-shore area among the three coastal zones	Mid term (5 years) 2018-2019 to 2022-2023	100 lac	Revenue Budget (Special Allocation)	Preliminary steps are taken for this kind of project	Ship from NAVY/DOF
	Marine affairs related skilled manpower development with sea related awareness program	Awareness raising programs to save coastal forest and coastal animals. It will ensure tourism development with environmental condition.	Mid term (5 years) 2018-2019 to 2022-2023	100 lac	Revenue Budget (Special Allocation)	Training program is ongoing for scientists and officers. Already got training form NIO, Goa, India. Discussion with NAHRIM and other oceanographic institutions is in process to train scientists. Travel report and results are sent to the ministry.	

Long Term	Determination of water quality, productivity and location of fishes based on physical and space oceanography baseline data.	Develop local algorithm by collecting chlorophyll data and other physical data. By this process, using satellite image water quality, productivity and location of fishes will be determined.	Long term (above 5 years) 2018-2019 to 2027-2028	500 lac	Revenue Budget (Special Allocation)	Planning for related project is accepted. Long term project activity through short term is ongoing. **Progress: 25%**	Collect satellite image. Ship of NAVY/DOF
	Determination of Geological Oceanography related baseline data.	Identify existing resources by determining geological parameters (ex-mineralogical data, sediment character, geological map, tectonic movement, erosion & deposition, sub-surface core data, valuable ore related baseline data) of near-shore and coastal area of three coastal zones.	Long term (above 5 years) 2018-2019 to 2027-2028	500 lac	Revenue Budget (Special Allocation)	Long term project activity through short term is ongoing. **Progress: 25%**	Ship of NAVY/DOF Collect Gravity Corer
	Baseline data collection of biological and chemical oceanography in the port areas	Monitoring real status of ballast water management in the port of mongla and chottogram. Identify invasive species and take timely sustainable steps to block their entrance.	Long term (above 5 years) 2018-2019 to 2027-2028	100 lac	Revenue Budget (Special Allocation)	Related project adoption planning is completed.	Approval from port authority
	Magnetic Survey	Magnetic survey in the territorial sea & EEZ of the Bay of Bengal and identify areas of Iron bearing mineral resources. By this process, magnetic minerals with economic minerals will be identified.	Long term (above 5 years) 2018-2019 to 2027-2028	100 lac	Revenue Budget (Special Allocation)	Expense estimation is incorporated in the BORI 2nd phase DPP. Reformation of DPP is ongoing. DPP will be sent in the ministry within January.	Ship of NAVY/DOF Marine magneto-meter
	Gravity Survey	Collect economic and scientific information, determination of Geod and know geological history by using gravity survey in the territorial sea and EEZ of the Bay of Bengal	Long term (above 5 years) 2018-2019 to 2027-2028	100 lac	Revenue Budget (Special Allocation)	Expense estimation is incorporated in the BORI 2nd phase DPP. Reformation of DPP is ongoing according to PEC. DPP will be sent in the ministry within January.	Ship of NAVY/DOF Marine Gravity-meter
	Determination of Biological Oceanography related baseline data.	Coral rehabilitation and production in the St. Martin's island which will increase biodiversity index of that area. This project will be expanded upon its success. It will also increase tourism.	Long term (above 5 years) 2018-2019 to 2027-2028	100 lac	Revenue Budget (Special Allocation)	Long term project activity through short term is ongoing. **Progress: 20%**	

	Oceanographic Data Center	Ocean related information and technology enrichment with data and development expansion.	Long term (above 5 years) 2018-2019 to 2027-2028	4000 lac	Annual Development Program (ADP Budget)	Expense estimation is incorporated in the BORI 2nd phase DPP. Reformation of DPP is ongoing according to PEC. DPP will be sent in the ministry within January.	Approve DPP
		Develop ocean observation system by establishing data buoy in different areas of ocean. Real time ocean monitoring by setting up at-least 8 data buoy in the ocean.	Long term (above 5 years) 2018-2019 to 2027-2028	200 lac	Annual Development Program (ADP Budget)	Expense estimation is incorporated in the BORI 2nd phase DPP. Reformation of DPP is ongoing according to PEC. DPP will be sent in the ministry within January.	Approve DPP
	Awareness Raising Program	According to the road map of awareness raising, 50% people of the coastal areas will be under this program	Long term (above 5 years) 2018-2019 to 2027-2028	500 lac	Revenue Budget (Special Allocation)	Related project adoption planning is ongoing for long term.	

Potential Research Sector for Blue Economy Support of Bangladesh:

There are six major research field in oceanography can be revealed in Bangladesh for Blue Economy development is summarized below-

- Physical and space oceanography branches have very potentiality to monitor physical parameter such as sea surface temperature, tide, wave, current, nutrition, chlorophyll etc. to find out potential resource of fisheries and renewable energy from ocean sources. Space oceanography can be applied to measure potential fishing zone identification in Bay of Bengal.
- Geological oceanography research activity can done to find out marine mineral resources as well as source of industrial materials such Bay of Bengal have the potential zone for Phosphorite and Yttrium deposit which is very important source of Rare Earth Element (REE), the coastal and nearshore area have potentiality of heavy mineral deposit. Besides Lime Mud, Carbonated sand and construction sand can be collected form Bay of Bengal. There have possible source of Gas Hydrate in the Bay of Bengal (assumed 300 TCF reserve present in the continental shelf and continental slope zone of Bay of Bengal.
- Chemical oceanography branch is very potential sector for the development of ocean based medicine, cosmetics and minerals in Bay of Bengal. Besides several service such as oil spill management, chemical pollution and ocean acidification measurement and monitoring can be done in this field.
- Biological oceanography is most potential sector in the oceanography field of Bangladesh. Because of river discharge lots of nutrition comes with the sediment in the Bay of Bengal, which can be used for the potential development of mericulture in the coastal and nearshore area. Besides biochemical composition of marine organism, fisheries development, seaweed culture (marine algae) field have very potentiality in this area.
- Environmental measurement and monitoring of ocean, plastic and microplastic pollution monitoring, EIA support etc. can be taken under controlled by environmental oceanography research. Besides Oceanographic data management, application, dissemination and ensure the information of ocean baseline data can be arranges. Ocean observation system (data buoy) and monitoring of ocean can give us surveillance opportunity of ocean parameter and change.

CHAPTER 10

ADMIN PLANNING & FINANCE

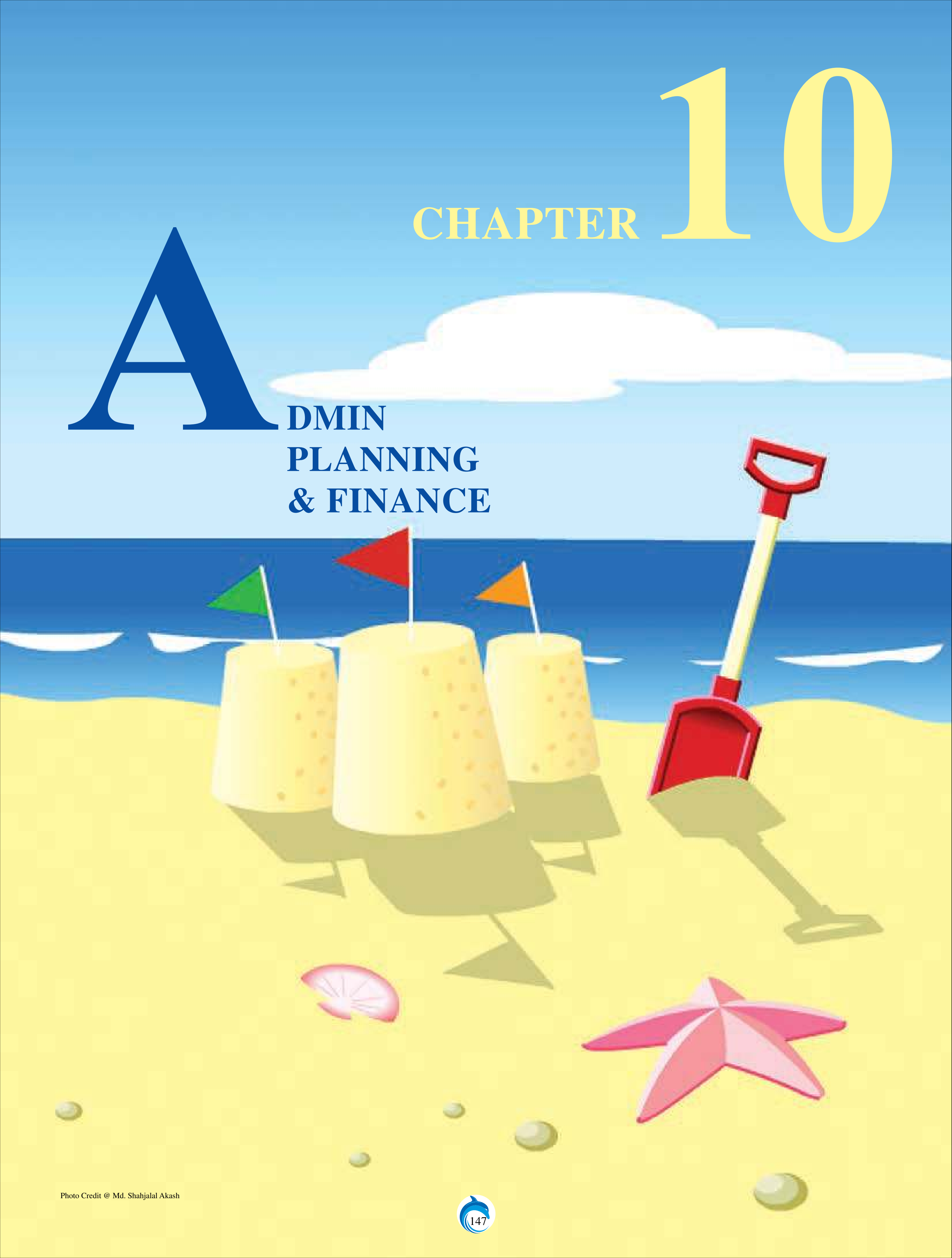


Photo Credit @ Md. Shahjalal Akash

Administrative Division

The administrative division is involved in managing overall activities of the organization and also makes plans through comprehensive strategies. It incorporates national policies that substantiate the purposes and objectives of the establishment of this research institute. Since from its origin, it strives for blue economy through its own time-bound organizational plan (Short Term, Mid Term and Long Term Plan for Blue Economy). The Election Manifesto-2018 that mostly strives for blue economy of the incumbent government is going to be accomplished through our plan.

The administrative division implement and co-ordinate the overall activities of this institute. Its activities include:

- R&D project management
- Document management
- Correspondence management
- Procurement activities
- Controlling inventory
- Ensuring security
- Human resource management & recruitment
- Conducts meetings, workshops, seminars etc.
- Communicating with different government, non-government and international bodies.

Photo Credit @ Shafiqul Islam Shafiq, BORI

Human Resource Management

Manpower

Sl	Approved post	Appointed manpower				Total	Progress
		1st class	2nd class	3rd class	Out-sourcing		
1	1st phase =137 (2015-2017 fiscal year)	18	24	12	49	103	Completed
2	2nd phase =31 (2017-2019 fiscal year)	34	-	-	-	34	On going
3	3rd phase =55 (2019-2021 fiscal year)	-	-	-	-	-	-

Trainings

To motivate and build up skillful human resources Bangladesh Oceanographic Research Institute (BORI) emphasizes on customized training programs and developed different training modules. The scenario of training programs is given below:

Foreign Trainings: BORI arranged some foreign training to get hands on experience.

Title of the training	Participants	Date	Country
China-Bangladesh cooperation training workshop	04	Apr, 2018	China
Training program co-ordinate with CSIR-NIO	12	Aug, 2018	India
Techniques for coastal mapping and monitoring using QGIS	01	Nov, 2018	India
Training program co-ordinate with CSIR-NIO	08	Mar, 2019	India

Local Training

The employees of BORI are participating to different training program to enhance their skill at particular subject. They are being trained as per the Annual Performance Plan, Annual Innovation Plan and National Integrity Plan activities. BORI regularly arranges and manages training for its employees different types of training programs:

(a) General/Technical Trainings

Office Management, Public Service Innovation, Internal Audit, EIA and DPP, PPM, APAMS, iBAS^{+}, ADP/RADP, CompTIA A+ Hardware maintenance and Trouble shooting, Welding Technology (Level-II) Training, Plumbing Technology and Marine Robotics.

(b) Scientific Training

Research Methodology, Marine Spatial Planning, Observational Physical Oceanography, Laboratory Safety Measurement, heavy mineral separation, CTD Operation, HPLC operation, Goggle Earth Engine Operation, Weather & Research Forecasting (WRF), Remote Sensing, GNSS, Drone Technology, Sub-soil investigation etc.

(c) Software Training

It also arranges regular training programs for researchers and engineers like basic software: FORTRAN, Java, C/C^{++}, MATLAB and Pythons etc., analytical & application software: R, SPSS, GIS Basics, GIS Advance and some other customized software designed for laboratory equipment.

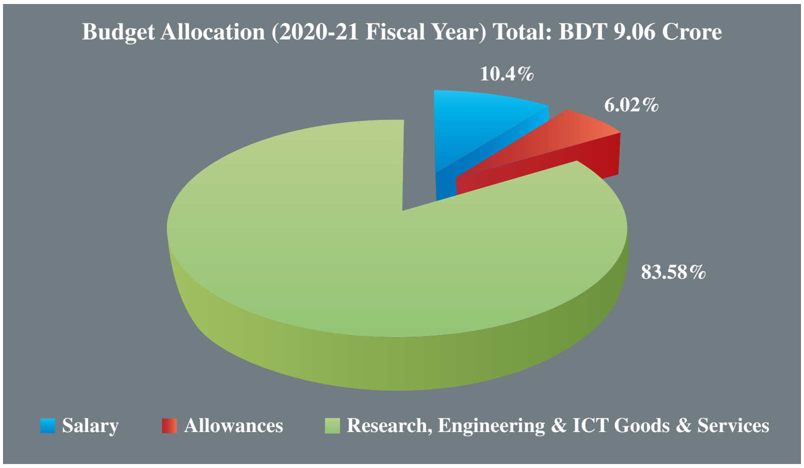
Accounts & Finance Division

BORI's Accounts and Finance Division maintained its accounts following standard accounting system. It has kept a well-printed Cash Book, General Ledger, Trial balance, Bank reconciliation, Advance Register, Budget Control Register, iBAS++ software posting (Budget and Expenditure), and other related books to record all transaction during the year accurately.

Photo Credit @ Shafiqul Islam Shafiq, BORI

Budgeting & fund management

The overall outline of the financial costs of BORI for the last 2020-2021 fiscal's year's is given below.



Audit

Bangladesh Oceanographic Research Institute has an internal auditing system. The auditor audits all kind of purchases to ensure transparency and accountability. Besides auditors from Comptroller and Auditor General Office periodically conducts auditing of BORI accounts in each year.

Engineering Division

Engineering Division has been established along with other divisions at BORI realizing the importance of scientific research through instrumentation, managing research fleets, development works and maintenance purposes. Engineering division is responsible for valuable utility services, maintenance of buildings, renovation and construction works for various tasks to the scientific effort for strengthening and expanding research and development activities in BORI.

Photo Credit @ Engineering Division, BORI

General Services/Maintenance Works

• Civil Works, • Plumbing Works, • New Construction, • Design & Planning, • Hill protection & Guide Wall

• Electrical & Electronic Repair/Maintenance, • Look after a permanent sub-station inside Institute Campus.

• Regular maintenance of electric power management and solar system

Research Fleet Services (in near future)

- To assess and execute all necessary works of repairing and maintenance for ship, boats, jetty/mooring facilities.
- To estimate and accomplish annual budget for repairing and maintenance of ship, boats, jetty, voyages and fleet staffs.
- To co-ordinate the vessel operation team, scientists and administration during voyages.
- To prepare the vessel for voyages ensuring fuel, freshwater, fooding and other requirements.

Other Responsibilities

- To plan for the development activities along with the administrative division.
- To assist administration in procurement activities, quality assurance, project management.
- Enhancing the Marine Instrumentation capacity of BORI.
- Engineering Workshop to assist scientists and other domestic engineering services.

Recent Activities

- Make plans for development activities such as preparation of DPP along with the administrative division.
- Provides conceptual design, technical specification, cost estimation for research vessels, boats, new buildings etc.
- Ensures all the utility facilities such as uninterrupted electricity, water supply, sewerage management etc.
- Liable for repairing of pumps, valves, generators, machineries etc.
- Establishes of dedicated feeder line from REB to reduce load shedding.
- Manages solar energy to lessen load shedding problem.
- Assists scientists regarding their electronic equipment.

Photo Credit @ Engineering Division, BORI

Photo Credit @ Abu Sharif Md. Mahbub-E-Kibria, SSO, BORI

Information Management Division

ICT Cell

The vision of the cell is to provide centralized facility related to Computers which includes maintenance of computers, software installation, networking, hardware troubleshooting, maintenance and internet service. The cell also maintains website management, e-mail service management, e-nothi management of the Institute. ICT Cell coordinates IT and communication development initiatives in all levels, ensuring consistency with the Organization's overall strategy.

The Mission of the ICT cell is to provide value through leadership in the development and delivery of innovative computing and information technology solutions to support the Research, Learning, and Administrative goals of the Institute.

Activities of ICT

Photo Credit @ ICT Cell, BORI

- Develop ideas to digitalize manual system.
- To ensure maximum use of need based state-of-the-art of technology.
- Monitor and ensure round-the-clock Internet and Telephone facility.
- Monitoring and Maintenance of Workstations and Networking.
- Needful IT support for CCTV system maintenance.
- Keep tracking of IT assets.
- Assist scientists to process data using programming language.
- Monitor e-filing activities in regular basis.
- Prepare tender document for procurement, publish the tender in E-GP website, complete the whole procedure timely.
- Maintaining E-hazira for all employees of the institute, take report in daily basis and backup E-hazira database daily.

CCTV Surveillance System

Whole area of the Institute campus has been brought under CCTV coverage system by installing 44 cameras in different areas of the campus.

PABX System

A central PABX system has established to smooth the communication to accelerate research and administrative works. It has 120 active lines.

Video Conferencing System

There is a Video Conferencing System in the conference room of BORI. It is now used as and when necessary. This facility is used to conduct training sessions remotely. An important government officer such as Ministry Office is communicated by using Video Conferencing.

Computer Training Lab

BORI has established a computer training lab with all facilities under the supervision of ICT cell. This lab contains 10 Computers with network printer and scanner wherein 10 (Ten) trainees can use computer at a time. Different Types of IT related training Such as : Data analysis with Python, Data analysis using MATLAB, R, FORTRAN, ARCGIS, Microsoft Office Training and many other different types of training are conducted in the lab all over the year.

Photo Credit @ ICT Cell, BORI

Future Plan of ICT cell

- Design and develop central Local area Network for whole institute.
- Implement Active directory, Application Server, File server by creating domain network to monitor and provide any types of IT support to any workstation centrally.
- Develop user friendly and efficient web/Desktop application for office's day-to-day activities depends on users' requirement to reduce bulk use of paper.

Photo Credit @ Shafiqul Islam Shafiq, BORI

Library Cell

The Library is an important organ in support and development of high quality research, research and outreach programs. Keeping up with modern technology, Bangladesh Oceanographic Research Institute (BORI) has a Library with rich collection of books, journals. Every year more than two hundreds of new books are added into the library depending on the needs of various research purposes. Now, BORI library has more than 800 hundreds of books of different categories including Physical, Chemical, Biological, Geological and Environmental Oceanography. It is accessible to Scientists, officers, staffs and other personnel associated with the Institute. The transactions of books, Internet facilities & photocopy service are available in the library.

Medical Center

Bangladesh Oceanographic Research Institute has a Medical Center with preliminary treatment facilities for all the employees of the organization. The clinic has Ultra Sonogram, ECG and other equipment as well. At present, there are one medical technician and one medical attendant giving services. The recruitment of Medical Officer is under process.

- Complete & Comprehensive Safety Plan for its employees for the ongoing Pandemic COVID-19 response.
- Distribute Corona safety items such as handrub, surgical mask and hand gloves etc.
- Manage Corona Quarantine and Isolation Area for internal patients.
- Technical support with RT-PCR as a COVID-19 response to Cox's Bazar Medical College.

Photo Credit @ Shafiqul Islam Shafiq, BORI

CHAPTER 11

Voyages of Exploration

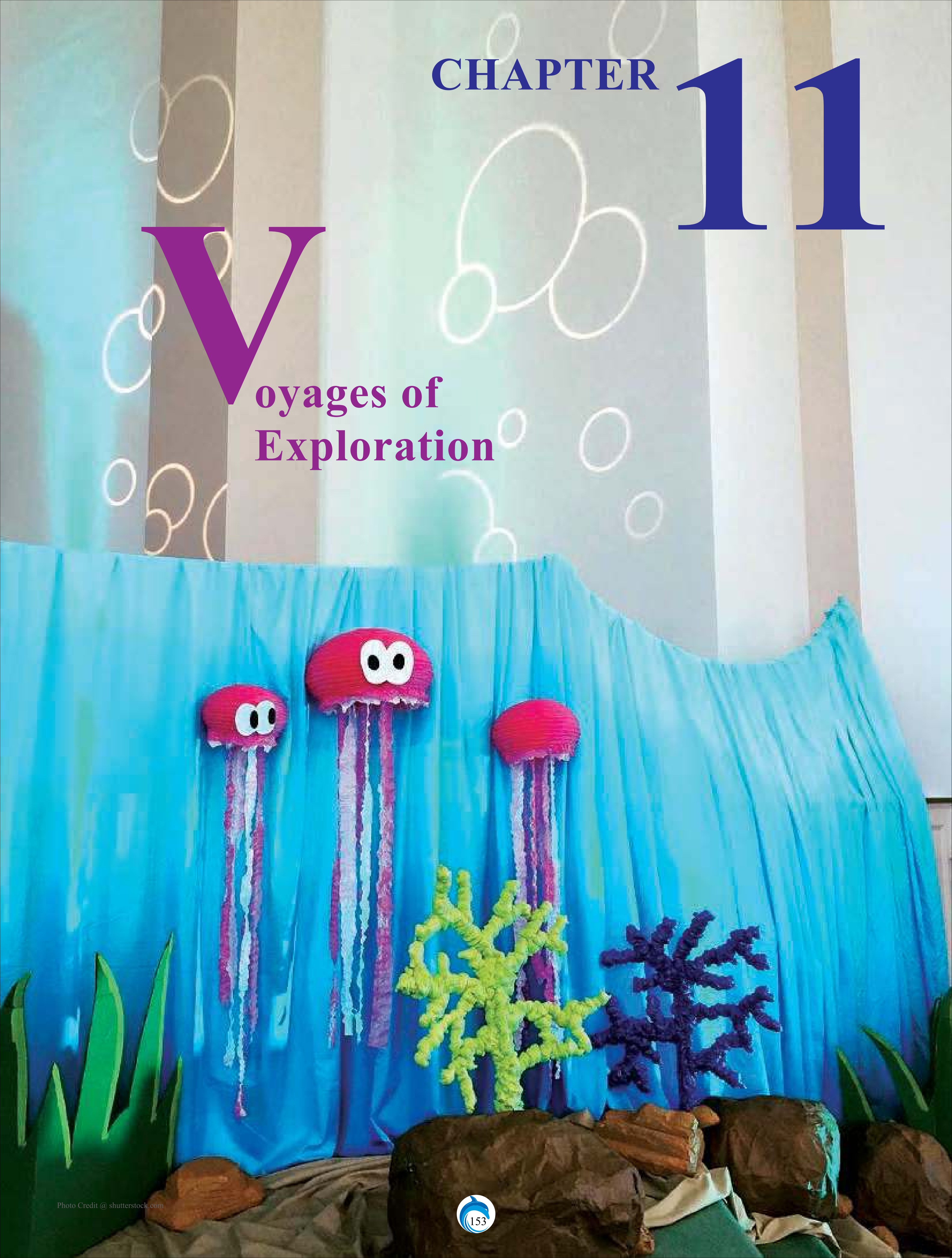


Photo Credit @ shutterstock.com

Arechitect Yeafesh Osman, Honorable Minister, Ministry of Science & Technology at BORI

Honorable Minister received flowery greetings at BORI

Honorable Minister in a Seminar at BORI

Honorable Minister in a view-exchange meeting at BORI

Honorable Minister visited laboratories at BORI

Honorable Minister in a Sea Cruise with BORI Scientists

National Mourning Day, 45th Martyrdom Anniversary of Father of the Nation Bangabandhu Sheikh Mujibur Rahman is observed at BORI

Rally organized at BORI on the occasion of Great Martyrs Day & International Mother Language Day on 21 February 2021

On National Children's Day (Birth Anniversary of Bangabandhu) a children's drawing competition is organized at BORI on 17 March 2021

Picture of lighting of Bangladesh Oceanographic Research Institute to celebrate the great Victory Day on 16 December 2020.

Discussion Meeting on Bangabandhu Sheikh Mujibur Rahman's historical 7th March speech is organized at BORI on 7 March 2021.

BORI officers celebrated Independence Day with Mrs. Iti Rani Poddar, Additional Secretary, MoST & Mr. Md. Shafiqur Rahman, DG, BORI on 26 March 2021

BORI VISIT


Mrs. Iti Rani Poddar, Additional Secretary, Ministry of Science & Technology visited different laboratories of BORI


Professor Dr. A. S. M. Maksud Kamal, Pro-Vice Chancellor (Academic) visited different laboratories of BORI


A team from Bangladesh Navy visited Bangladesh Oceanographic Research Institute


A team from National Museum of Science & Technology (NMST), visited Bangladesh Oceanographic Research Institute

SEMINAR

Mrs. Iti Rani Poddar, Additional Secretary, MoST was present in a Seminar on "Blue economy development, its challenges and results of R&D project (2019-20 FY)" organized by BORI.

Mr. Md. Shafiqur Rahman, DG, BORI was present in a workshop on "Innovation Display & Services" organized by BORI.

A Stakeholders Consultation Workshop on "BORI seaweed research and scoping seaweed research for sustainable Blue Economy of Bangladesh" organized by Biological Oceanography Division, BORI.

WORKSHOP

TRAINING

Training on "Office Management" at BORI

Training on "Fire Extinguisher & Safety" at BORI

Training on "Innovation in Public Service" at BORI

Training on "Epidemic and Disaster Management" at BORI

Training on "Innovation and Application in Service Facilitation" at BORI

Training on "Implementation Strategies for APA" at BORI

Training on "Integrity and Good Governance" at BORI

Training on "Python Programming" at BORI

"Keep the Sea, Pollution Free"

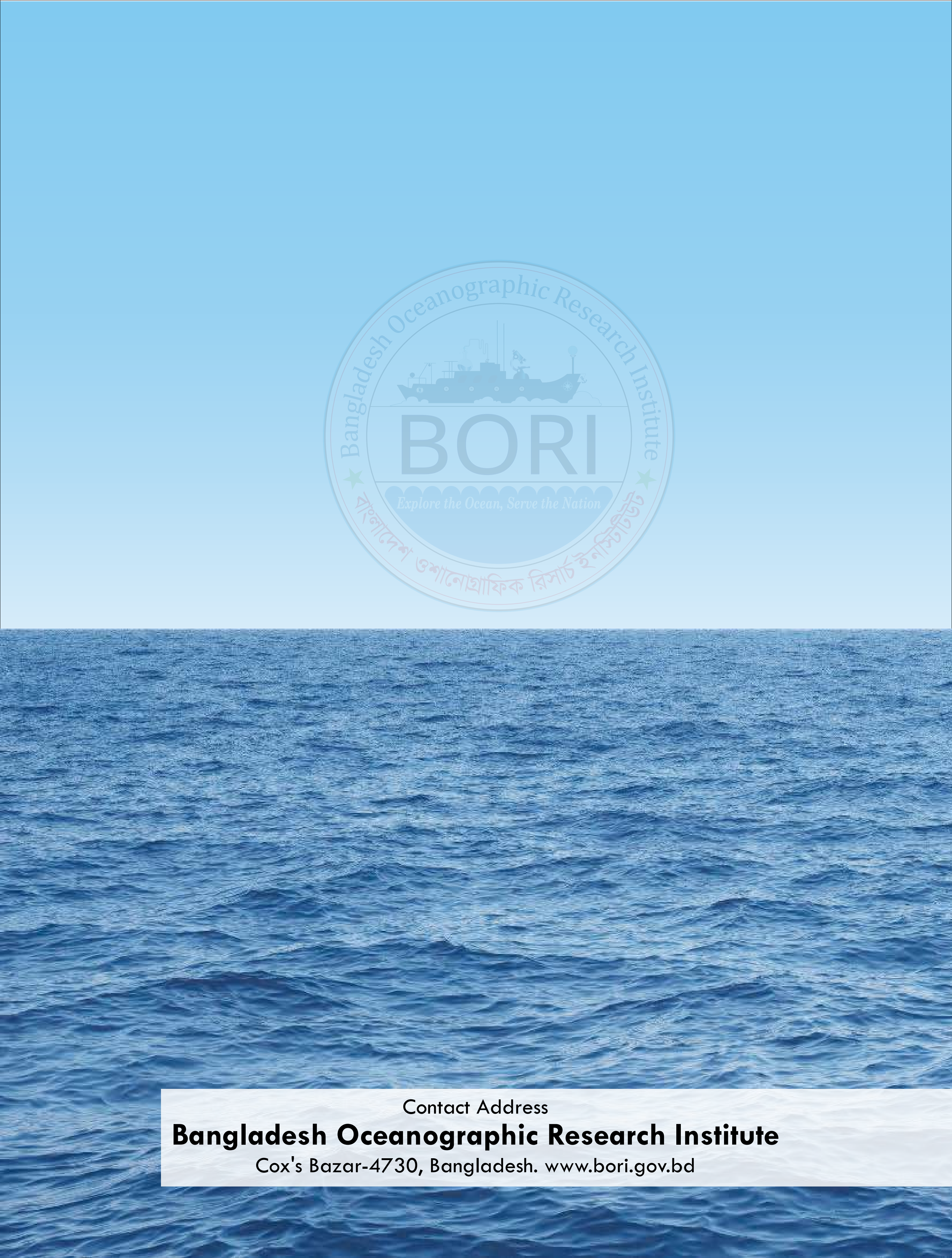
BEACH CLEAN UP PROGRAM

Environmental Oceanography and Climate Division of BORI has been conducting "Beach Clean up Program" along the costal area of Bangladesh, as a regular activity. Mrs. Iti Rani Poddar, Additional Secretary, Ministry of Science & Technology, Mr. Md. Shafiqur Rahman, DG, BORI and other officials carried out beach cleaning activity in the Inani and Patuartek Beach Areas.

Mr. Md. Shafiqur Rahman (7th form right), Director General (Additional Charge), BORI was given a farewell reception with a Crest by the BORI Officers on 20 June 2021.

Mr. Sayeed Mahmood Belal Haider (6th form left), Additional Secretary, is Welcomed as the Director General with a Crest by the BORI Officers on 20 June 2021.

1st Class Officers of BORI- 16 January, 2018 (1st Recruitment of BORI)



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