ANNUAL REPORT 2023

BANGLADESH OCEANOGRAPHIC RESEARCH INSTITUTE

Ministry of Science and Technology

Government of the People's Republic of Bangladesh

Bangladesh Oceanographic Research Institute
BORI
Explore the Ocean, Serve the Nation
বাংলাদেশ ওশানোগ্রাফিক রিসার্চ ইনস্টিটিউট

Annual Report
of
Bangladesh Oceanographic Research Institute

December, 2023

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Ministry of Science and Technology
Government of the People's Republic of Bangladesh

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Senior Scientific Officer, BORI

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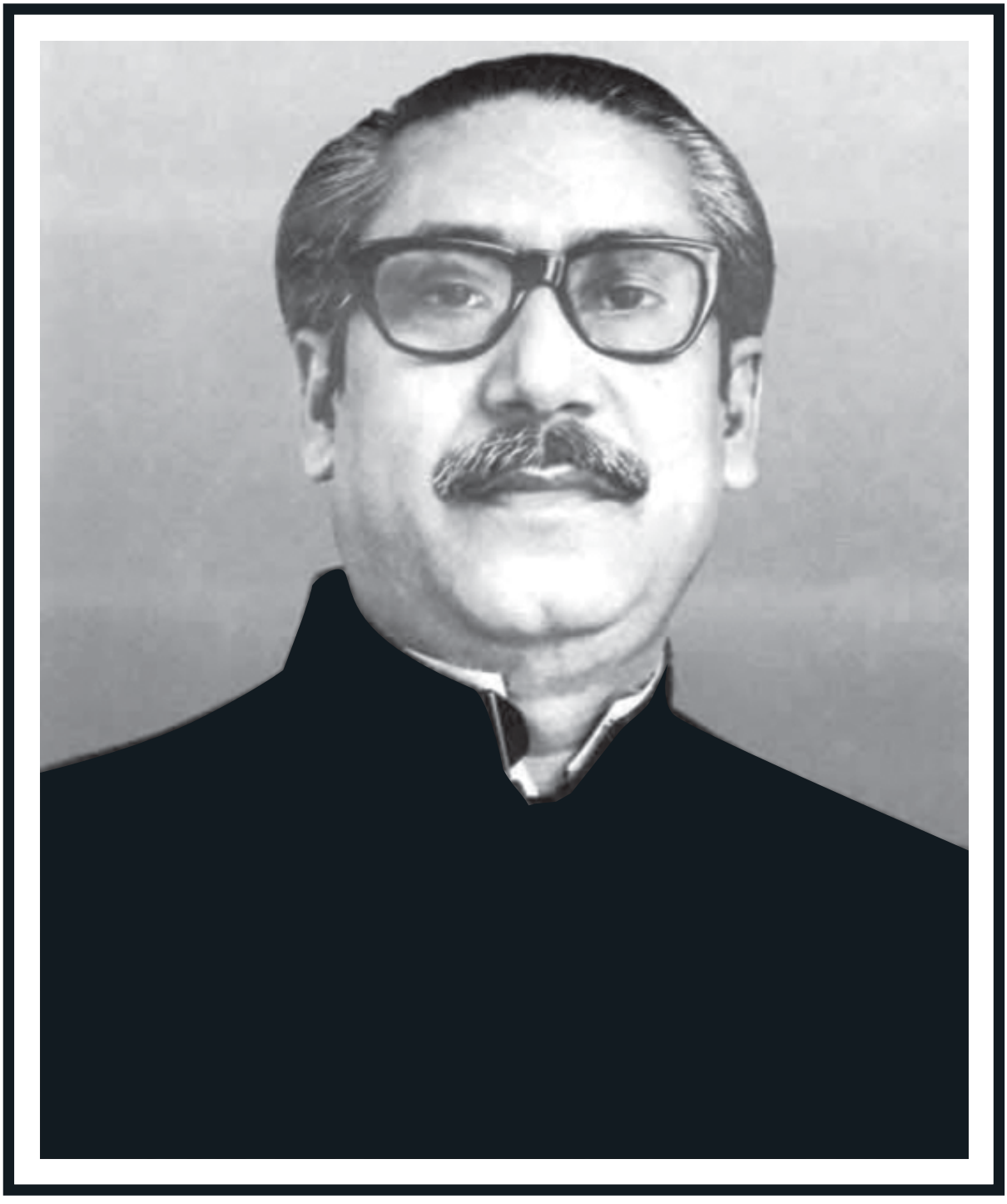

Father of the Nation Bangabandhu Sheikh Mujibur Rahman

Bangabandhu established the legal entitlements of Bangladesh maritime areas and marine resources by passing the "Territorial Waters and Maritime Zones Act-1974"

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Honorable Prime Minister Sheikh Hasina at Inani Sea Beach, Cox's Bazar (6 May, 2017)

(Photo : PID)

"There is a link between the development of human civilization and ocean.
The nearer a society is to the ocean; the better the life is of its members (14th HACGAM, 2018)"

- Sheikh Hasina

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MESSAGE

Architect Yeafesh Osman
Minister
Ministry of Science and Technology
Government of the People's Republic of Bangladesh

I am very glad to know that the Annual Report 2023, containing information on the inception research works of young scientists from Bangladesh Oceanographic Research Institute (BORI) is being published. My best regards to BORI for publishing the report.

Father of the Nation Bangabandhu Sheikh Mujibur Rahman pioneered the enactment of "Territorial Waters and Maritime Zones Act-1974". He also initiated maritime boundary negotiations with India and Myanmar, and even settled the 12 nautical miles of territorial sea boundaries with Myanmar on November, 1974.

To fulfill the dream of Bangabandhu for a developed Bangladesh, the present Awami League government has resolved maritime dispute with the neighboring countries. Now we have sovereign rights over 1,18,813 square km of sea areas for exploration and exploitation of living and non-living marine resources. If we can extract these resources, several generations in the future will be benefited and this will also play a huge role in our economy.

The present government has formulated Blue Economy policy for the safe and environmentally sustainable use of resources. We have started our work to implement this and I believe this will play a significant role in the development of Bangladesh.

I hope that the researchers of BORI will play a leading role to accomplish the dream of Bangabandhu's Golden Bengal through their talent, hard work and devotion by the exploration and utilization of sea resources.

Joy Bangla,
Joy Bangabandhu.

(Architect Yeafesh Osman)

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MESSAGE

Md. Ali Hossain
Secretary
Ministry of Science and Technology
Government of the People's Republic of Bangladesh

I am very delighted to know that Bangladesh Oceanographic Research Institute (BORI) is going to publish the 'Annual Report 2023', focusing on oceanographic researches of the Bay of Bengal, Bangladesh.

At first, I want to recall respectfully the father of the nation Bangabandhu Sheikh Mujibur Rahman who opened up the process of getting sovereign sea area for Bangladesh in 1974. After a long period of time and going through different procedures, we got our own sea area which is almost the same area of main land Bangladesh. Now we have sea resources both living and non-living to explore and exploit for future development.

The present government has already taken short-term and long-term plans that are expected to be materialized by 2030. Honorable Prime Minister Sheikh Hasina has especial interest on oceanographic resources and its use for future economic development of Bangladesh.

Ministry of science and technology is funding continuously for innovative research ideas, research works and research projects. We have already set up laboratories in BORI with variety of equipment for different stream of oceanographic research. Establishment of oceanographic data center and marine aquarium at BORI campus is on progress which is one of the top most priorities of the government for oceanographic knowledge hunt.

I hope, the scientists of BORI will come up with different innovative research ideas and do their research works accordingly for the best uses of oceanographic resources.

(Md. Ali Hossain)

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MESSAGE

Professor Dr. Towhida Rashid
Director General
Bangladesh Oceanographic Research Institute

It is definitely a great pleasure for me to know that Bangladesh Oceanographic Research Institute (BORI) is going to publish the Annual Report 2023, which showcases the achievements of project results completed by the young scientists last year.

Bangladesh is on Development Boulevard by the efficacious leadership of Jononetri Sheikh Hasina, the honorable prime minister of the present government. Bangladesh Oceanographic Research Institute (BORI) is established because of her visionary decisiveness. We achieved 1,18,813 sq km of sea area by the historic maritime delimitation settlement with the neighboring countries. Underneath of this sea area, we have huge amount of living and non-living resources. Our duty is to explore, exploit and utilize these resources to the welfare of human beings of our country. To attain this goal, Bangladesh government has taken different measures to contribute in blue economy.

Bangladesh Oceanographic Research Institute (BORI) under Ministry of Science and Technology (MOST) is doing its duty to implement the planning of the government. Scientists of BORI are expending their knowledge to research oceanographic resources and to use it in national economic development.

I thank to all the scientists for their introductory research results and to document these results as Annual Report 2023. I hope they will devote themselves more extensively in oceanographic research for the development of Bangladesh.

(Prof. Dr. Towhida Rashid)

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ACKNOWLEDGEMENT

It is my great pleasure to work in this Annual Report-2023. I would like to thank Professor Dr. Towhida Rashid, DG, BORI for his innovative inputs to enrich this report. I am grateful to all divisional heads & scientists for their resourceful contribution. Special thanks to Board of Editors for their timely support. I also thank each and every person who has helped me directly or indirectly to complete this report successfully.

Abu Sharif Md. Mahbub-E-Kibria
Executive Editor
Senior Scientific Officer & Head
Environmental Oceanography and Climate
Bangladesh Oceanographic Research Institute

NAME
Bangladesh Oceanographic Research Institute

STATUS
Statutory Body

MINISTRY
Ministry of Science and Techonology

LOCATION
Marine Drive Road, Cox's Bazar

AREA
40.62 Acres

WEBSITE
www.bori.gov.bd

LIES AHEAD

- Acquisition of a modern oceanographic Research Vessel.

  Establishment of art of the state Marine Aquarium at Cox's Bazar.
- Set up of a modern Oceanographic Data Center.
- Establishment of a modern Training Center cum International Hostel, scientific workshop and marine biological culture unit.
- Procurement of modern equipment for effective research.
- Implementation of short-mid-long term planning for sustainable Blue Economic growth.

1 CHAPTER

BANGLADESH OCEANOGRAPHIC RESEARCH INSTITUTE

Bangladesh Oceanographic Research Institute (BORI) is the first and only national research institution on marine science in Bangladesh, which will be able to play an important role in ensuring the development of Blue Economy.

After winning the maritime boundary settlement case with Myanmar on March 14, 2012 and India on July 7, 2014, Bangladesh achieved sovereign rights to a total of 1,18,813 square kilometers of sea area, 200 nautical miles of exclusive economic zone, and all types of living and non-living ocean resources. If Bangladesh can ensure the sustainable use of the ocean resources, then the economy of Bangladesh will progress faster. The potential for setting up an international level ocean research institution, development of integrated coastal zone management, mining of mineral resources, and proper utilization of ocean resources including development of tourism and mariculture have increased the interest of the international community towards the Blue Economy in Bangladesh. The prospect of this newly developed sector is unlimited. For this reason, BORI will be able to play an important role in oceanographic research and create skilled manpower. The organization will work to conduct all the activities as a focal point of Bangladesh at national and international levels in the field of oceanography. Besides conducting its own research, BORI will assist in the research work of other local or foreign organizations, colleges and universities as well.

The Father of the Nation
Bangabandhu Sheikh Mujibur Rahman *initiated the establishment of ocean research institute in 1973 with the aim to enrich the country's economy and reducing poverty through exploring, exploiting and conserving valuable resources of the Bay of Bengal. But after the brutal and tragic killing of Bangabandhu in 1975, that initiative totally stops. In 1996, Honorable Prime Minister Sheikh Hasina constituted a Review Committee for the establishment of National Institute of Ocean Science.*

After receiving the recommendation of the review committee, the decision of establishing the National Oceanographic Research Institute was acceptedin 2000. In order to ensure proper utilization of marine resources, a project under the Ministry of Science and Technology was adopted in the period from June 2000 to July 2005 for the establishment of National Oceanographic Research Institute (1st Phase). After a long time in 2009, the visible progress of the establishment of National Oceanographic Research Institute (NORI) was achieved through the intensive initiative of Honorable Prime Minister Sheikh Hasina. When presenting the proposal for establishing the institute on 4 acres of land in the ECNEC meeting on 02/07/2009, Honorable Prime Minister extended the amount of land to 40 acres instead of 4 acres. She also ordered to redesign and represent the project including laboratory, residential building, club building, playground, school buildingand marine aquarium with international quality. Acquisition of 40 acresof land in Jungle Goalia Palang Mouza of Khunia Palang Union of Ramu Upazila of Cox's Bazar district was completed in 2010. The establishment project was implemented at a cost of Taka 102.80 crore. Under the heading of "National Oceanographic Research Institute Establishment Project (NORIP) (1st phase) (2nd Revised)" has been constructedwith 13 buildings including 3-storey Institute building with laboratory, 5-storey 3 officer quarters & 2 staff quarters, 1 Director General's Bungalow, 2-storey 1 Officer Dormitory & 1 staff Dormitory, 3-storey 1 Club Building & 1 Rest House, 5-storey 1 security personnel building, and 2-storey 1 school-cum-Medical Centre. Initially BORI has been purchased about 1096 nos. of scientific instruments for oceanographic research. For the implementation of the overall function of the project, 14 officials were working including 1 senior scientific officer, 3 scientific officers, 1 administrative officer and other employees. In addition, under the project, there was 1 platoon Ansar & VDP members for the safety of the Institute and 8 daily-basis manpower to keep the Institute premises neat and clean.

BORI
at a Glance

On 5 March 2015, "Bangladesh Oceanographic Research Institute Act, 2015" was passed in the national parliament for the keen endeavor of the present Honorable Minister Architect Yeafesh Osman of the Ministry of Science and Technology. It was a great achievement for oceanographic research. The institute has been established on 08/09/2015 with the powers given in sub-section (1) of 3 of "Bangladesh Oceanographic Research Institute Act, 2015" (Act 07 of 2015). On 19/05/2017, for the appointment of officer and staff the 'employment regulatory of Bangladesh Oceanographic Research Institute, 2017' was issued. A total of 223 posts have been created for the institute. The first meeting of the Board of Governors of BORI was held on 25/05/2017. The organogram of BORI comprises 2 wings. Among them one is research wing (6 research divisions) and the other is administrative wing including engineering sector, medical centre, ICT and library cell. Considering the seer thoughts of Honorable Prime Minister Sheikh Hasina, initiatives have already been taken to establish a Marine Aquarium of international quality in the institute premises for ocean research & tourism.

The Bangladesh Oceanographic Research Institute (BORI) has emerged as an independent organization. It is the first and only national institution in the field of marine science. This institution will be able to play an important role in the exploration and development of country's marine resources and play a leading role in revenue earnings. Multiple research and development programs will be conducted in each of the research departments. Successful implementation of the current action plan will be possible through the development of sustainable technology in the country, achieving poverty alleviation programs and various development targets of the United Nations. Future research activities will be expanded more widely. If this institute effectively handles the management of the sea related research activities, application of research results and management of all the related activities, Bangladesh will emerge as a prosperous and developed country by using marine resources. We have won the sea under the dynamic and visionary leadership of the daughter of Bangabandhu, Prime Minister Sheikh Hasina, and there is no doubt that we will soon emerge as a developed nation using the sea resources. There are two wings of BORI. One is Research wing and another is Admin, Planning & Finance wing.

Research Wing
1. Physical and Space Oceanography
2. Geological Oceanography
3. Chemical Oceanography
4. Biological Oceanography
5. Environmental Oceanography and Climate
6. Oceanographic Data Center

Admin, Planning & Finance Wing
1. Administrative Division
2. Accounts & Finance Division
3. Engineering Division
4. Information Management Division • ICT Cell • Library Cell
5. Medical Center

Vision of BORI

To contribute in the economic development of the country by adopting maritime research activities, applying research results, operating, managing and controlling all related activities.

Mission of BORI

Development of mineral, agriculture, fisheries, environment and industrial sectors through utilization of sea resources and the development of environmentally friendly and sustainable technology and research activities to increase productivity for the benefits of mankind.

To improve knowledge related to maritime education, research, training and development of knowledge related to the research and use of sea resources and to take action to protect the environment.

To search all living creatures of the sea and to expedite sustainable production of those resources for economic welfare.

Identity and research the presence of offshore island, coastal areas and ocean bottom minerals, placer deposits, coal, oil and other minerals including gas.

Study of hydrography, sedimentation, astrology, meteorology, navigation & communication system and the development of commercial communications.

Encourage public and private organizations to invest in the trade and trade related to the marine and marine environment and to serve as consulting organizations.

Providing assistance in respect of the country's maritime strategies and policies and proposals for planning including maritime law.

Identify various environmental issues (coastal, deep sea circulation, delta formation, water flow, etc.) and environmental natural disaster and climate issues.

Undertake coordinated approach to improve international relations and linking the oceanography with the local and international organizations.

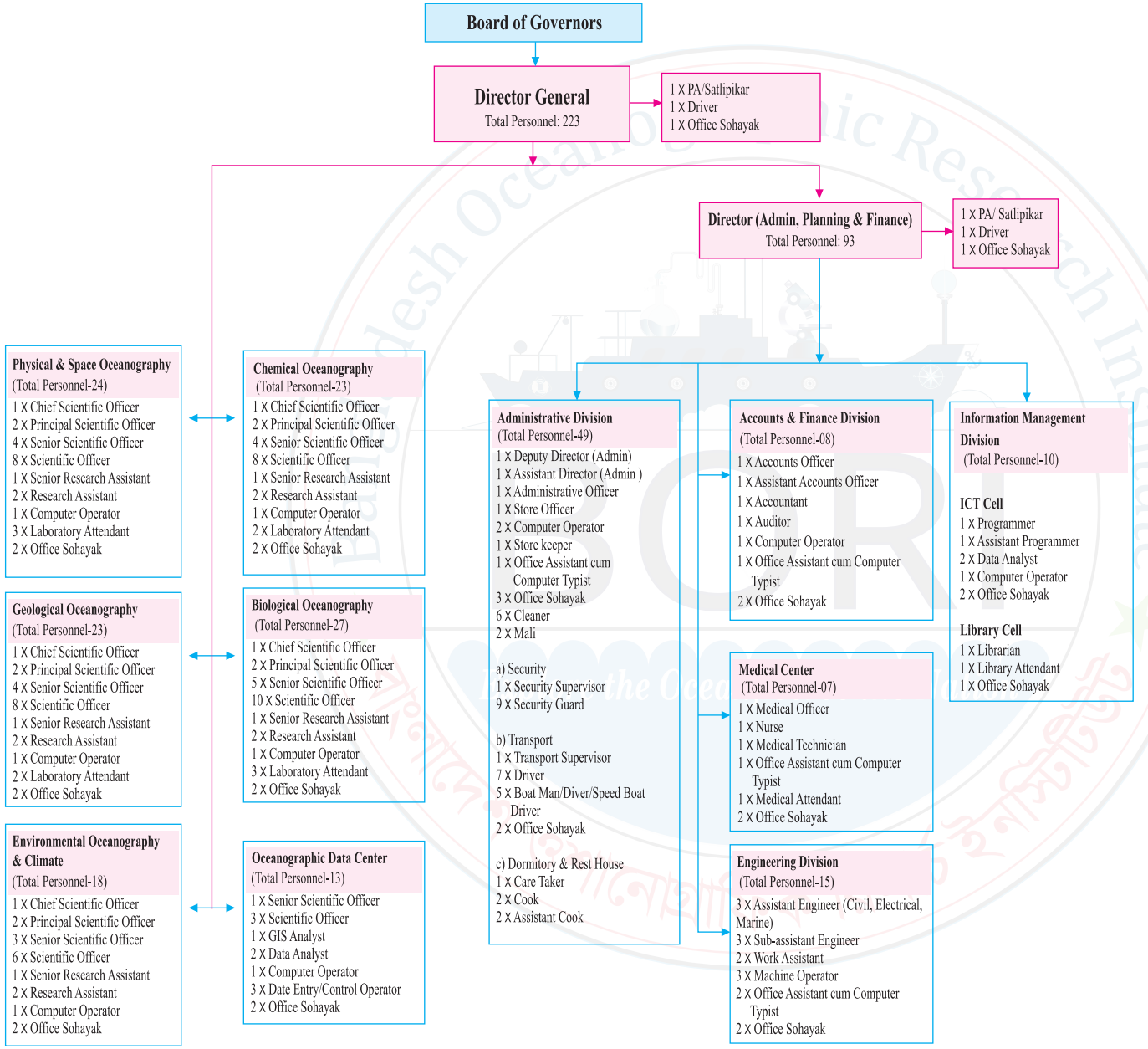
AREAS OF MARINE RESOURCES

- Experts are speculating that there is one of the world's largest fuel (oil or gas) reserves in the Bay of Bengal which can control the energy-politics and economy of the day.
- In the Bay of Bengal, Heavy Mineral, such as Ilmenite, Titanium oxide, Rootail, Zircon, Garnet, Magnetite, Monazite, cobalt etc. have been found, which can be a huge source of foreign currency.
- There are about 475 species of fishes in the Exclusive Economic Zone (EEZ) of the Bay of Bengal. Fishing capacity can be increased to the desired level by reviving modem fishing trawlers and training.
- Salt can be exported abroad by using advanced technology in salt cultivation.
- Construction of deep sea ports with modern facilities will increase the activities of feeders of international commercial vessels.
- Marine shellfish and finfish farming can bring foreign currencies. There are already many opportunities of commercially produced PUFA's (Poly Unsaturated Fatty Acids) such as omega-3 and omega-6 antioxidants from different seaweed species.
- Development of existing fish resources can be done through the use of marine biotechnology. Organic technology also can play a role in preventing oil spillage.
- Use of adequate research and advanced technology is necessary to prevent marine and coastal environmental pollution in ship breaking industry.
- Because of the high wind speed in the offshore areas of the sea, renewable energy can be generated by establishing windmills. Electricity can be produced using the wave and tide as well as by applying the Ocean Thermal Energy Conversion (OTEC) technology.
- According to various sources, by the year 2030, 10% of the output the world's cobalt, copper, zinc and Rare Earth Element (REE) will be produced from the sea.
- Construction of marine aquarium, travelling system by cruise ship & by ensuring adequate safety in the coastal area can become one of the main sources of national revenue.

MAJOR ACHIEVEMENTS OF BORI

- It has managed and financed for 8 R&D projects in FY 2019-20, 6 R&D projects in FY 2018-19 and 5 R&D projects in FY 2017-18.
- It has taken a Comprehensive Blue Economy Plan and implementing successfully.
- It has taken a Complete & Comprehensive Safety Plan for its employees for the ongoing Pandemic COVID-19 response.
- BORI has recently assisted technical support with RT-PCR as a COVID-19 response to Cox's Bazar Medical College to detect SARS-CoV-2 virus in nasal swab sample.
- A Development Project Proposal (DPP) has been proposed for establishment of marine aquarium on 10 acres of land in Institute area.
- A Development Project Proposal (DPP) has been proposed for establishment of Bangladesh Oceanographic Research Institute (Phase-II).
- 19 scientists, engineers and other officials have attended at a training program at National Institute of Oceanography (NIO), Dona Paula, Goa, India.
- In the recent meeting of JSTC with India possibility of mutual co-operation was discussed.
- A delegation of China's Third Institute of Oceanography recently visited the Institute campus in Cox's Bazar and discussed about joint activities.
- Already 104 persons against 223 posts in the revenue sector has been recruited/posted and recruitment process for the remaining posts is in progress.
- Construction works including construction of building, residential building, quarters, dormitory, guest house, DG bungalow on 40 acres of land is already completed.
- Eight modern laboratories equipped with latest equipment have been established.
- The Bangladesh Ocean Research Institute Act-2015 is passed by the Jatiya Sangsad in the year 2017. The rules of the Institute were formulated.

Organizational Structure



Summary of Manpower

SL No	Name of Post	Number
1.	Director General (DG)	1
2.	Director	1
3.	Chief Scientific Officer (CSO)	5
4.	Principal Scientific Officer (PSO)	10
5.	Deputy Director	1
6.	Senior Scientific Officer (SSO)	20
7.	Programmer	1
8.	Scientific Officer (SO)	42
9.	Other Officers Equivalent to Scientific Officer	09
10.	GRADE: 1 to 9	90
11.	GRADE: 10	10
12.	GRADE: 11	10
13.	GRADE: 13	25
14.	GRADE: 14	18
15.	GRADE: 16	5
16.	GRADE: 19	19
17.	GRADE: 20	45
	TOTAL	223

Transport and Major office equipments

	Number
1. Transport	
a) Jeep	2
b) Pick up	2
c) Microbus	2
d) Minibus	1
c) Truck	1
f) Motorcycle	5
g) Speed Boat	3
h) Fishing Boat	2
2. Office Equipment	
a) Generator	03
b) Computer & Accessories (with UPS)	115
c) Printer	15
d) Multimedia Projector	5
e) Photocopy Machine	5
f) Scanner	5
g) Fax	3

2 CHAPTER

PHYSICAL AND SPACE OCEANOGRAPHY DIVISION

PHYSICAL & SPACE OCEANOGRAPHY DEALS WITH

the research and development of remote sensing data on the world's oceans, and calibrates instruments, verifies the data, and creates products to meet the needs of users for satellite data and other information on the oceans. PSOD also focuses on describing and understanding the evolving patterns of ocean circulation and fluid motion, along with the distribution of its properties such as temperature, salinity and the concentration of dissolved chemical elements and gases. Approaches include theory, direct observation, and computer simulation. Research frequently takes place in the context of important multidisciplinary issues including the dynamics and predictability of global climate and the sustainability of human use in coastal and estuarine regions. Besides research activity, PSOD is giving oceanography based analytical service and technical support to different government and non-government institutions.

DISTRIBUTION OF PHYSICOCHEMICAL PARAMETER IN THE COAST OF COX'S BAZAR TO CHITTAGONG

Rupak Loodh
Scientific Officer

GENERAL DISCUSSIONS:

Bangladesh's coastline stretches over roughly 710 kilometers; the coastline is very dynamic for wave, tide, current, wind and other physical are highly active on the area. The coast is situated in the northern Bay of Bengal, which is the northeastern part of Indian ocean. North part is landlock and semi-annual reversing wind system are prevailed the hole tropical basin. Approximately, between latitudes 5N and 23N and longitudes 79.8E to 102E is where the Bay of Bengal is, which includes the Andaman Sea and Malacca Strait. (Sindhu, M. 2012). During the winter monsoon (November–February), winds are comparatively week (~5 ms-1) and the direction is northeast, which brings cool and dry continental air to the Bay of Bengal (Narvekar, J. et al. 2006). These dry and cold winds are responsible for ocean surface heat loss and heat transfer to the atmosphere. One of the largest rivers in the world, the Lower Meghna River, travels through this region on its route to the Bay of Bengal. The huge freshwater flux from river runoff and precipitation of the summer monsoon (ISM; May–October) are responsible for the strong salinity stratification in the Bay of Bengal (BoB) and causing a shallow mixed layer and a thick barrier layer, which potentially affects intraseasonal oscillations of the monsoon (Li, Y., Han, et al. 2017). Sengupta, D. 2016 showed that a persistence of shallow stratification in the north Bay of Bengal from moored data.

The hydrodynamic factors such as the enormous volume of river water flow, sediment transport, nutrient transport, strong tidal and wind actions, wave, salinity, and cyclonic storm surge are playing a dominant role in morphological development along the coastline of Bangladesh (Uddin, M 2014). Masud et al 2022, found that thermal inversion occurred in several Conductivity-Temperature-Depth (CTD) profiles in the NBoB. These Hydrodynamic conditions also control the physico-chemical, nutrients even the biology of coastal area (M.T. Babu, 2005). During winter, the sea surface loses heat and the surface waters of the coastal regions of the east coast of India are fairly stratified with the residual freshwater atop from the preceding southwest monsoonal discharge (Babu, S.V. et al, 2011). Our present study is to investigate oceanographic process and the relationship with the condition are favorable for ecological growth. Therefore, the objective of the present study is to quantify the coastal current, salinity-temperature structure, and physicochemical condition in the winter season.

STUDY AREA:

The present study covered Inani, Cox's Bazar coast to Chattogram coast (~25km from the coast, open ocean of Bay of Bengal). Geographically the area is bounded by 22°17" N to 21°08" N latitude and 91°40" E to 92°02" E longitude in figure 01.

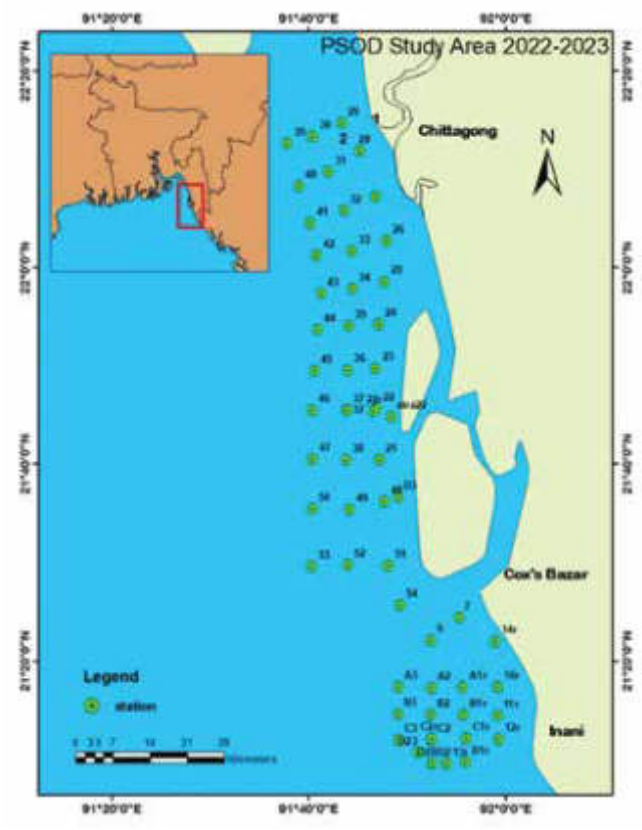


Figure 1: Study Map: North of Samlapur (Cox's Bazar) coast to Chattogram Coast.
(Total 60 stations data was collected up to ~25km from the coast towards the west).

MATERIALS AND METHODS:

Data was collected in two different months with two different cruises in December 2022 and January 2023 respectively. Base line data of physical parameters in the eastern area (Inani to Chattogram coast) was collected in 60 stations, where high resolution vertical profiles of Temperature, Salinity, Density, Pressure, by CTD (Hydro bios (Sea & Sun technology) CTD90M), Oceanic horizontal Current was collected by ADCP (Nortek Aquadopp -600), Temperature, Salinity, Density, Pressure, Turbidity, Dissolve Oxygen (DO), Chlorophyll Data was collected by STD/CTD (SAIV STD/CTD SD208) in figure 02.

For each station CTD sensor was used to collect temperature, salinity, pressure of water column and density, and sound velocity data. Secchi disk was used to collect the sunlight penetration in the water depth. Niskin water sampler was used to collect water samples in three different depths (surface, Secchi depth and the bottom depth). After collecting the water sample, it was immediately covered with fuel paper and wrapped in black plastic and kept in a

box where sunlight was not present. And within 24 hours, we analyzed nutrients analysis such as detection of inorganic phosphate (PO43-), nitrite (NO2-N), nitrate (NO3- N), Ammonia (NH3-N), and silicate (Si), following the standard methods (Grasshoff et al. 1983; APHA 1995). These ions were measured by the photometric methods (UV-1800, Shimadzu, Japan). 1000ml water was used to filtered with 2.7µm membrane filter further analysis of Chlorophyll-A.

We have perfumed different processes on CTD casts before we are calculating Brunt-Väisälä frequency (N2), atmospheric heat loss. Firstly, all the CTD data was stored with high resolution (10-12 casts per meter) both upcast and downcast. For more accuracy we only consider the downcast for avoiding the initial atmospheric effect on CTD profile. Secondly, temperature and salinity were vertically smooth with by 20 point (0.05m) running mean (considering the standard error ± 0.0025, and median value). Lastly, vertical gradients were calculated by a 0.25m least square fit. α and β were calculated by differentiating equation of state (UNESCO, 198) by temperature and salinity respectively. This occurrence frequencies of Rp values are estimated at each pressure interval or at each depth.

The ERA-Interim reanalysis dataset from European Centre for Medium-range Weather Forecast (ECMWF) is used in this study to reveal the mechanism of stratification and physicochemical parameters. Hourly era-5 reanalysis wind speed (m/s), zonal and meridian components of wind velocity at 10 m above the sea surface, latent heat flux (W/m2), sensible heat flux(W/m2), precipitation (depth in meters of water equivalent), evaporation (depth in meters of water equivalent), shortwave radiation (W/m2), and surface net heat flux (W/m2), sea surface temperature (oC), sea level pressure are taken from ECMWF data.

All sensor-derived data was analyzed, and quality controlled in PSOD lab using Matlab and Python programming language. All physical equations, models and data statistics were done in Matlab and Python using the HPC server and workstation in the PSOD lab.

Hydro bios (Sea & Sun technology) CTD90M

SAIV STD/CTD SD208

Hydro bios 5L Niskin

Nortek Aquadopp -600 ADCP

Figure 2 : Major instruments used during the field study

SCIENTIFIC METHOD:

Distribution mechanism of Physicochemical Parameter (Air-sea interaction):

Ocean heat budget has two major components: radiation, and turbulence, where sun plays main role of energy for the processes that initiative of air-sea interaction. Shortwave radiation from the sun penetrates the ocean surface and makes the ocean warmer and wind over the ocean make temperature lowers the temperature. Ocean emitted energy by the long wave radiation.

Evaporation is another way to ocean loses temperature. When water transforms its molecular structure into vapor and gets released from the ocean surface, it also takes some temperature with the water vapor (latent heat flux). At the same time, due to conduction and convection the ocean loses or gain heat to the atmosphere. This process is called sensible heat flux. In the sea surface energy budget shortwave radiation contributes highest and the latent heat flux considered as a second component (Zhang and McPhaden, 1995).

On the other hand, high wind speed is responsible for decreasing latent heat and sensible heat overall the sea surface temperature and surface humidity gradient. And the higher evaporation the higher cooling of the ocean surface, the lesser evaporation the lesser cooling. Again, this water vapor leaves the temperature in the atmosphere during the condensation to form clouds (Josey et al. 2003).

Brunt-Väisälä frequency:

The Brunt-Väisälä frequency (N^2) generally known as buoyancy frequency, is the frequency at which a vertically displaced parcel will oscillate within a statically stable environment. The larger the density gradient, the higher the frequency (Brunt-Vaisala or buoyancy frequency) and shorter the oscillation period (John A. Knauss, 1997) It is a measure of the frequency with which a parcel will oscillate about its equilibrium position, if displaced, and in the absence of friction.

$$N^2 = -\frac{g}{\rho}\frac{d\rho}{dz} \qquad \text{----------(1)}$$

Density has a great effect on the N^2. As temperature and salinity are responsible for stability of water column. So that individually temperature and salinity also effect on the N^2 properties. If gradient of temperature ($\frac{dt}{dz}$) is positive (increase with depth), it will unstable the water column (we will get negative $\frac{d\rho}{dz}$). Again, if we have positive salinity gradient ($\frac{dS}{dz}$), we have the stable water column and vise verse.

Integrating the simple equation of state in the N^2, it is easily estimating the effect of temperature and salinity on the N^2.

$$N^2 = -\frac{g}{\rho}\frac{d}{dz}\rho(1 - \alpha\Delta T + \beta\Delta S)$$

$$N^2 = -\frac{g}{\rho}\{\rho\left(0 - \alpha\frac{dT}{dz} + \beta\frac{dS}{dz}\right)\}$$

$$N^2 = \left(g\alpha\frac{dT}{dz} - g\beta\frac{dS}{dz}\right)$$

So, N^2 due to temperature will be: $N^2 = g\alpha\frac{dT}{dz} = N_T^2$ (when salinity is content)

And N^2 due to salinity will be: $N^2 = g\beta\frac{dS}{dz} = N_S^2$ (when temperature is content)

Therefore, $N^2 = N_T^2 - N_S^2$ ----------(2)

Where, ρ is the density of water column, g is the gravitational acceleration, z is the depth, temperature and salinity denoted by T & S respectively.

$\alpha = \frac{1}{\rho}\frac{\partial\rho}{\partial\theta}$ is the thermal expansion coefficient & $\beta = \frac{1}{\rho}\frac{\partial\rho}{\partial S}$ is the haline contraction coefficient.

Relative contribution of temperature and salinity on N^2 column can be identify by the following ratio fraction:

Salinity relative contribution effect $= \frac{N^2 due\ to\ salinity\ (N_S^2)}{Total\ N^2}$

Temperature relative contribution effect $= \frac{N^2 due\ to\ salinity\ (N_T^2)}{Total\ N^2}$

Wind Stress:

Wind stress parameter was calculated by following equation:

$$\boldsymbol{\tau_x = C_m\rho_a v_a(\vec{u}_a - \vec{u}_0); \tau_y = C_m\rho_a v_a(\vec{v}_a - \vec{v}_0)}$$

Where, C_m is drag coefficient (~10^{-3}) and is a function of sea state; wind speed and rainfall, ρ_a is the density of sea water; τ_x and τ_y are the eastward and northward wind stress.

Net Heat Flux:

Net heat flux is calculated from net total incoming and outgoing radiation along with the latent heat flux and sensible heat flux. The following equation is used to calculate the net heat fluxs.

$$\boldsymbol{Q = Q_{SW} + Q_{LW} + Q_L + Q_S}$$

Q_{SW} is Shortwave Radiation; Q_{LW} is Longwave Radiation; Q_L is Latent Heat Flux; Q_S is sensible Heat Flux.

Richardson number (Ri):

Stability of ocean water column and likelihood for turbulence is calculated by a dimensionless parameter called Richardson number (Ri). It is a very useful tool in oceanography for understanding and predicting the behavior of turbulent flow in the ocean and oceanic processes like ocean currents, eddies, upwelling, mixing, carbon dioxide uptake etc.

The Richardson number can be used to study the mixing of water masses in the ocean. Mixing is important for the distribution of nutrients, pollutants, and heat in the ocean. The Richardson number can be used to predict how mixing will occur and how it will affect the ocean's environment.

$$\text{Ri} = \frac{N^2}{S^2} = \frac{-\frac{g}{\rho}\frac{d\rho}{dz}}{\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2}$$

Where, N is buoyancy frequency, S is shear magnitude, ρ is potential density, g is acceleration due to gravity, u and v are the east and north currents respectively and z represent the pressure or depth of the ocean (Galperin, B., et al, 2007, Sanford et al. 2011).

A high Richardson number indicates that the water column is stable, while a low Richardson number indicates that the water column is unstable and the ratio 0.25 to 1 is often used as a threshold for distinguishing between stable and unstable conditions.

RESULT AND DISCUSSION:

Temperature, salinity, and density:

Temperature and salinity are considered as the most important physical parameter, where density is a derived product from these two basic parameters. Density controls other biological and chemical parameters of the ocean. In the study, a CTD sensor was used to collect and logged temperature, salinity, density, pressure in-situ data over the study area.

Table 1: Statistics of Temperature, Salinity & Density Data from CTD sensor.

Parameters	Minimum	Maximum	Average	Standard Deviation
Temperature (°C)	22.0297	28.8819	25.7375	± 0.3043
Salinity (PSU)	10.5003	32.9810	28.1953	± 0.5152
Density (Kg/m^{-3})	5.1680	21.4061	18.0177	± 0.3083

North of Kharnaphuli River has huge salinity (~16 PSU) differences from its south. In addition, the vertical structure of water columns experiences huge differences in the study area. There were observed two stratified regions in the study area (figure 3). One is in the north of Karnaphuli River, and another stratified region was identified in the Inani and south of Inani Region (starting point is ~ 13 km from the coast). Average ~9.58 m upper layer of the stratification was observed in the study area, where temperatures and salinity difference were observed 1.67°C and 2.85 PSU respectively from the surface layer to bottom layer.

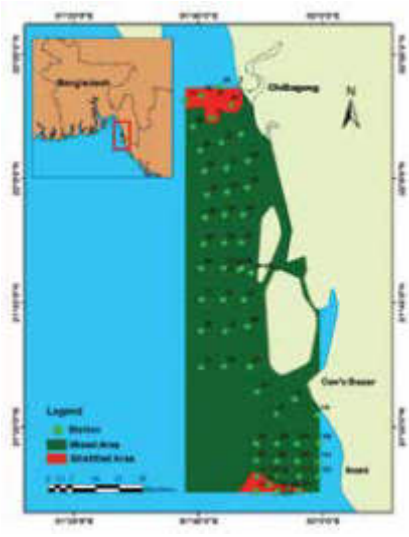
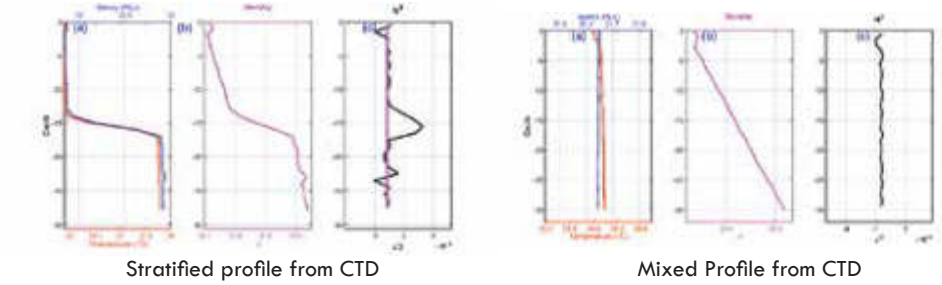


Figure 3: Stratified zone in the study area.



Stratified profile from CTD Mixed Profile from CTD

Figure 4: Stratified and Mixed profile from CTD, (a) Temperature and salinity profile, (b) Density profile, (c) Brunt-Väisälä frequency

The other three vital physicochemical parameters (Turbidity, Chlorophyll, and Oxygen) were found to be very responsive to the stratification area. Lower turbidity and lower chlorophyll-a concentration was observed in the surface layer, where high oxygen concentrations were found in that layer. Moreover, these situations were found to reversal in the bottom layer (figure 5).

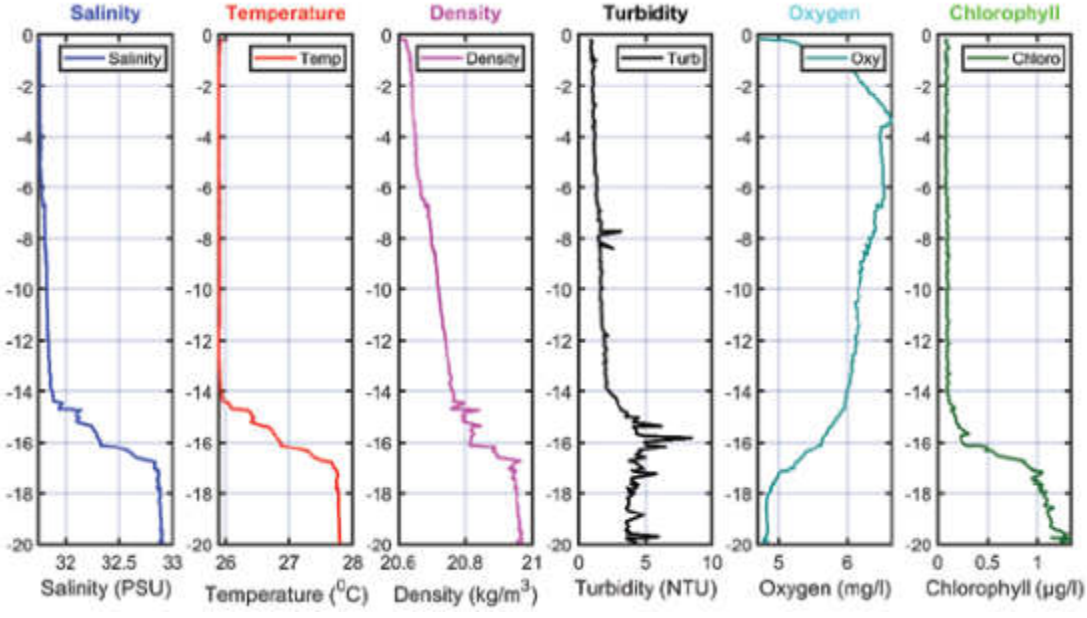


Figure 5: Distribution of Temperature, Salinity, Density, Turbidity, Oxygen, and Chlorophyll in stratified profile

On the contrary, these parameters (turbidity, oxygen, and chlorophyll) were observed well mixed in the near shore area where water column was also well mixed (figure 6).

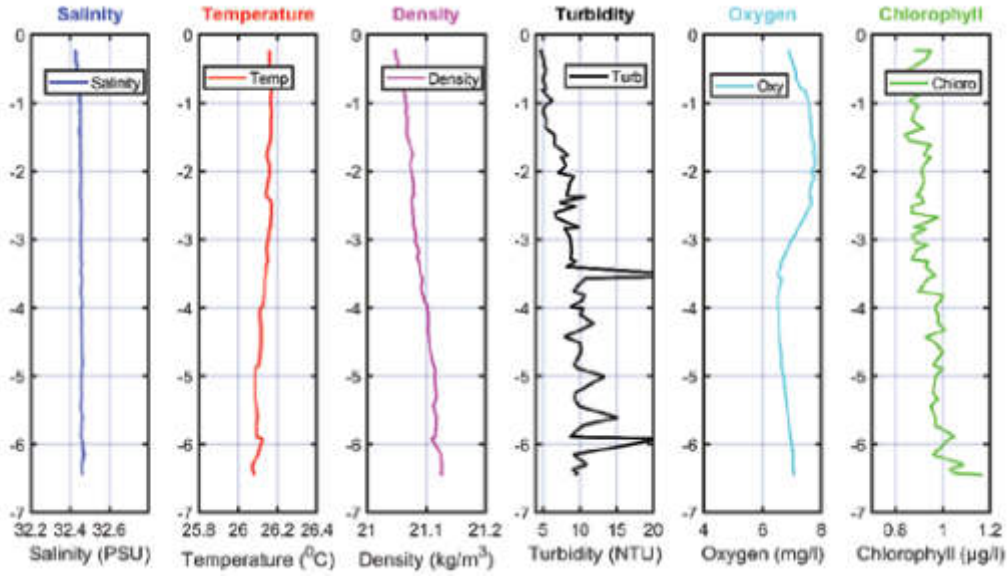


Figure 6: Distribution of Temperature, Salinity, Density, Turbidity, Oxygen, and Chlorophyll in mixed profile

Coastal Current and direction:

In-situ coastal current in every station was measured by Acoustic Doppler current profiler (ADCP). Northern part of the study area (Kutubdia-Chattogram) experienced comparatively less speed current than the southern part of the study area in figure. Average current speed was found 0.5369 m/s (±0.2626m/s) during the winter season (figure 7). The direction of the current was mostly north-east ward and a few stations observed current direction was north ward (especially in the southern part of the domain).

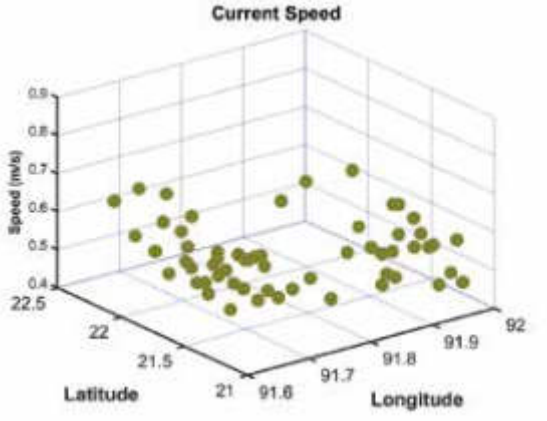


Figure 7: Coastal current from ADCP measurement

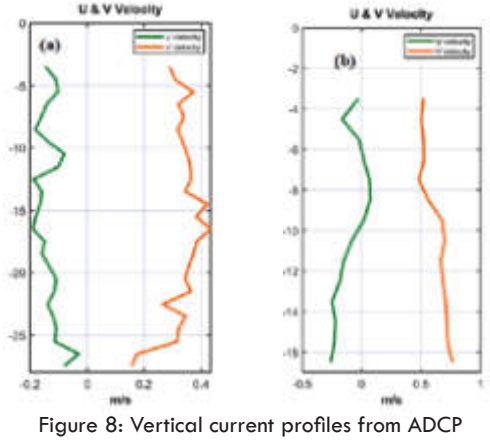


Figure 8: Vertical current profiles from ADCP
(a) Mixed layer (b) Stratified layer

Horizontal currents exhibit a vertical shear property in the stratified water layer (Fig.08). The following figure is an example of vertical shear of a stratified water layer and non-stratified water. In figure b (in a stratified layer), up to 10-meter depth, U velocity of water is ~0 ms-1 (neutral U velocity), after 10-meter U velocity is negative, which indicates west ward water movement. On the other hand, V velocity was positive (northward movement). Net movement was observed northward up to 10-meter depth, and below the 10 meter the water velocity was northwest ward. In contrast, in the mixing profile (calculated from CDT data) have northwest movement was observed (where U was negative, and V was positive value).

Air-Sea Condition:

The study air-sea parameter here for understanding the mechanism of surface low temperature, low salinity, and other physio-chemical parameters.

In December 2022, no significant wind stress observed surrounding the study area (figure 09). Average wind stress observed 0.034 Nm-2 (average wind speed ~3.5 ms-1). This was an indication low wind induce mixing were present that time or wind has minimum contribution on vertical mixing of water column.

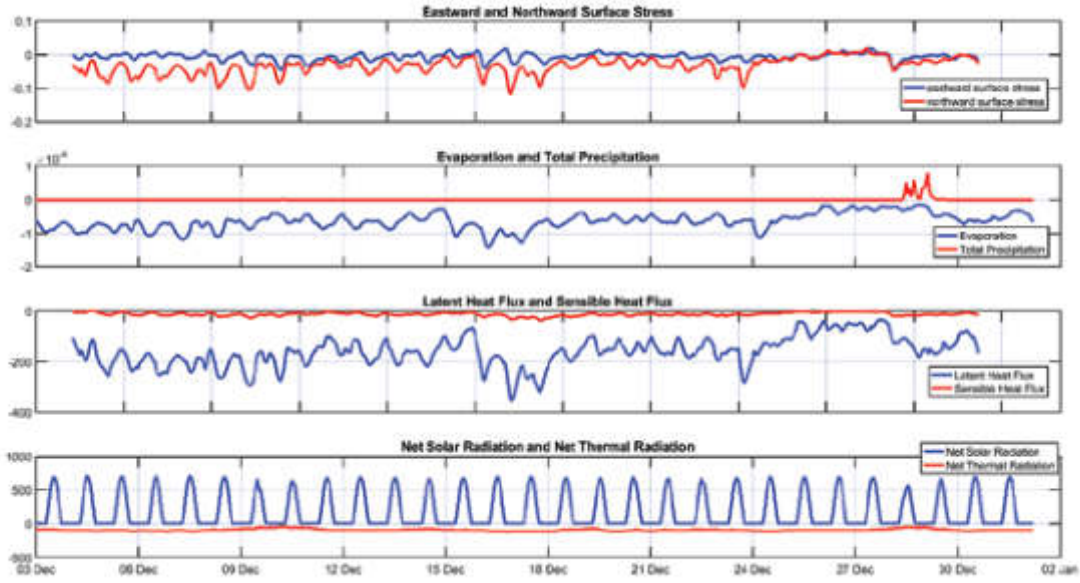


Figure 9: Considering factors are latent heat flux, sensible heat flux wind speed and direction, evaporation, precipitation, net solar radiation, net thermal radiation.

However, high evaporation due to dry wind coming from central Asia (due to the western disturbances) and higher latent heat flux was observed (as evaporation ∝ latent heat flux). On the other hand, net solar radiation (short wave radiation) height found ~700 W/m^2. Considering the heat flux (latent heat flux, sensible heat flux, net incoming heat flux, and outgoing heat flux), the average Heat Flux was about ~160 Wm-^{2} (figure 10). This amount of heat flux was a potential cause for surface low temperatures in some regions.

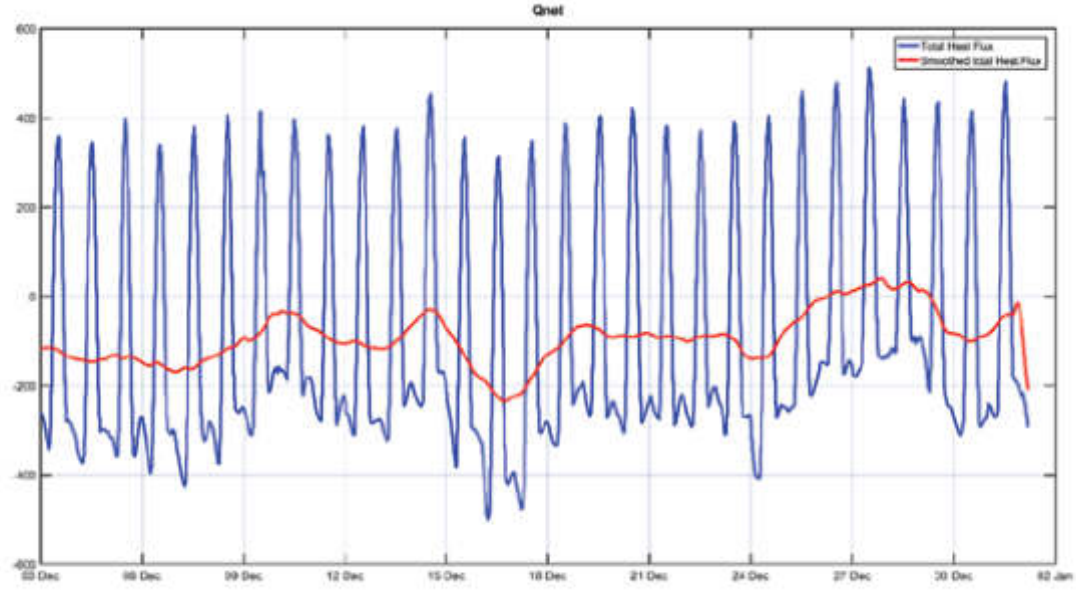


Figure 10: Net Heat Flux

1D box Model for calculating heat loss contribution in the study area:

If we assume that, ocean heat content is control only by vertical heat flux neglecting other terms (because wind stress is minimum ~0.03 N m-^{2} during the sampling time), the only heat balance would be:

$d\theta/dt=Q_{net}/(\rho C_p H)$

Where, $d\theta$ is the temperature change due to net heat flux; dt is the time difference; Q_{net} is the amount of Net Heat Flux change with the time dt; ρ is the density of sea water; C_p is the specific heat of sea water; H is the depth of temperature affected by the net heat flux.

Here, ρ = 1021kgm-3, Qnet = -200 Wm-2, H = 15m, Cp = 4200 J/k, dt = 4* 84600 sec. Then we find dθ = 2°C (which is equivalent to surface to bottom temperature difference).

So, 4* 84600 seconds or 4 days are required to 2°C temperature changes in the surface by heat loss process.

Mixing Scale and Frontal Zone:

Along the track temperature and salinity was observed with 2-minutes temporal interval, which covered about ~150 meters horizontal distance interval. There was a huge horizontal salinity difference (~4 PSU) observed within 5 kilometers spatial scale (Fig.12). That is an indication of the existence of frontal water.

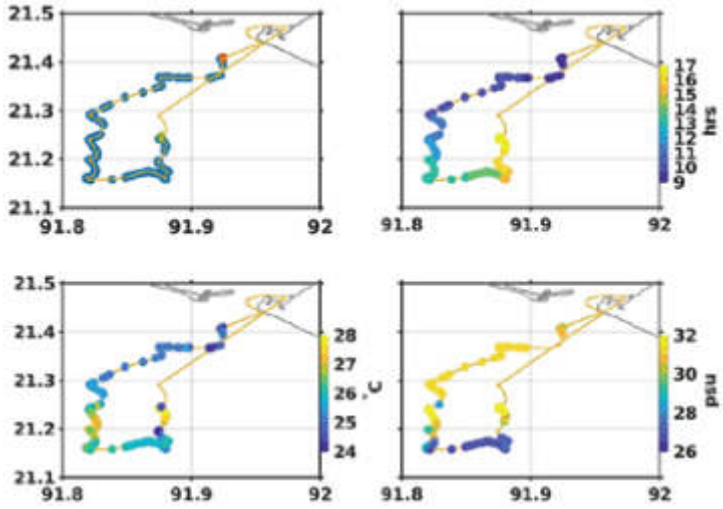


Figure 11: Along-track T-S measurements (2-minute interval; ~150m horizontal resolution)

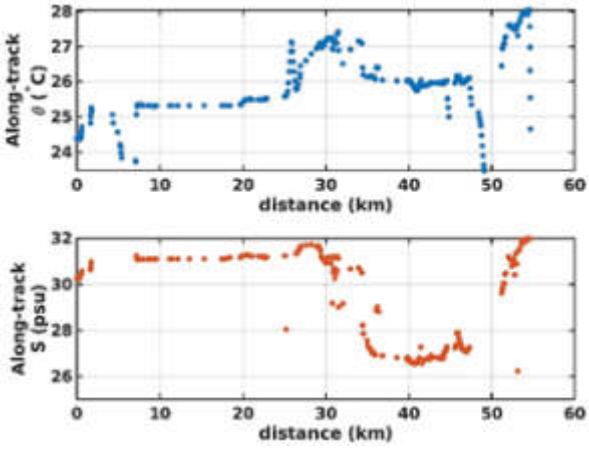


Figure 12: Horizontal Fronts of T-S in the study area

High salinity (~31 PSU) was observed near the coast well mixed area (in Moheshkhali Estuary) and it remain almost steady in southward. However, a rapid salinity reduction was observed south of Inani (17 to 25 km from the coastline), but the spatial distribution of temperature didn't follow the salinity. Temperature observed in coastal well mixed water about ~25.2°C and temperature sharply increased about ~27.1°C (almost ~2°C) within 5 km spatial interval.

Nutrients Condition in the Study area:

Five essential nutrients (Nitrate, Nitrite, Ammonia, Phosphate, Silicate) were analyzed from the in-situ sample that were collected through the Niskin sampler (table. 02). These nutrients data showed a spatial variation along with depth. In case of Ammonia, the maximum Ammonia in bottom 7.53 mg/m3; average highest in the surface 3.7534 mg/m3 with low standard deviation (±1.0024 mg/m3). Similarly, Nitrate, Phosphate, and Silicate had local maximum amount (16, 10.6 and 43 mg/m3 respectively) found in the bottom. Only Nitrite showed local maximum value in the Secchi depth area. Overall, bottom has high nutrients the surface and Secchi depth (except Nitrite).

Table 2: Nutrients condition over the study area

Nutrients	Surface				Secchi Depth				Bottom			
	Min	Max	Avg	Std	Min	Max	Avg	Std	Min	Max	Avg	Std
Ammonia	2.161	5.22	3.7534	1.0024	0.05	4.8	2.0129	1.3449	0.06	7.53	3.239	2.1044
Nitrate	0	9	4.5556	3.0867	0	8	3.9412	2.8607	0	16	5.3333	4.1133
Nitrite	0	4.2	1.75	1.4303	0	7.03	2.2	2.0632	0	6	1.6207	1.3872
Phosphate	0.06	6.14	1.6367	1.7671	0	7.18	1.9064	1.9969	0	10.27	2.5224	3.3182
Silicate	0	2	0.6667	1	0	13	2.5556	3.4924	0	43	4.2268	7.697

CONCLUDING REMARKS:

Physicochemical parameters of the northern Bay of Bengal have significant impact on the chemical, geological and biological processes. Wind stress, heat loss, air-sea interaction, stratification, front are the major drivers for the variation of physicochemical. So, the study is very important for understanding the behavior and pattern of ecosystem.

Among the 60 stations 14 stations have stratification observed (in two different regions), where average temperature and salinity variation from surface mixed layer to bottom mixed layer ~2.1°C and ~4.22 PSU, depth is more than 20m. In case of nutrient, bottom has high nutrients the surface and Secchi depth (except Nitrite). High turbidity distribution water observed in the northern part of the study area, where the southern part has less turbidity. Chlorophyll, Oxygen, and other physicochemical parameters were found responsible for stratification and frontal zone.

Winter horizontal coastal current (average speed 0.5369 m/s ±0.2626m/s) along the coast was identified and current direction was mostly northwest and fewer were north direction. The horizontal frontal area was identified (the zone is significant for any physical, geological, biological, and chemical processes) in the south of Inani region, and the spatial horizontal scale of this frontal zone was measured (five km, ~4 PSU). These processes are critical in coastal hydrodynamics.

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Geological Oceanography Division

CHAPTER 3

A SHORT BRIEF

Research Activity:

The activity of Geological Oceanography Division (GEOD) started by the mandate of BORI Act, 2015 (article 8) with the starting of BORI. Research activity has been started on 2017-2018 FY with taken a R&D project in the nearshore area of Saint Martin's Island. In the next FY 2018-2019, a R&D project has been taken on the nearshore area of Teknaf to Maheshkhali Island. During research and survey, seabed sediment sample has been collected in the coastal and nearshore area of north-eastern part of Bay of Bengal covered about 5000 sq. km. A cruise has been operated with the help of Bangladesh Navy BNS Saibal on December 2018 and the survey area was about 900 sq. km, distance was 50 km seaward from the coastline of the Cox's Bazar. During 2019-2023, three consecutive research and field surveys carried out in the coastal marine area of Maheshkhali-Kutubdia and Chattogram region (Kutubdia to Feni) for sedimentological and heavy mineral investigations and for the baseline study of geological oceanography parameter. In total, the study area covered about 7500 sq. km of coastal marine area along the eastern to middle coastal zone of Bangladesh.

In addition, the coastal sand dune investigation programme has been carried out during 2022-23 FY. It has been identified different type of coastal dune and observing their mechanism of formation along the coast.

Research completed during 2022-2023 FY:

Research completed in the 2022-23 FY under BORI titled "Investigation of Sedimentology and Mineralogy of the Coastal Marine Area of the Chattogram Region of Bangladesh".

Publications:

Zakaria, M., & Islam, M.T. (2023), Assessment of Organic Carbon and Carbon Stock in the Sediments of the Estuarine Area of Naf River and Maheshkhali Channel, Bangladesh: Investigating the Influence of Sediment Texture and Depositional Conditions, Songklanakarin Journal of Science and Technology, 45(5), 552-560.

Zakaria, M., Islam, M.T., & Haider, S.M. (2023), Coastal and nearshore sediment data along the eastern coastal zone of Bangladesh of the northern Bay of Bengal, Data in Brief, Vol.47, https://doi.org/10.1016/j.dib.2023.109028

Zakaria, M. and Islam, M.T. (2022), Determination of Sediment Distribution and Suspended Sediment Discharge in the Kutubdia Channel of Bangladesh, The Journal of NOAMI Vol. 37, Number 1&2, pp. 1-24.

Investigation of Sedimentology and Mineralogy of the Coasta Marine Area of the Chattogram Region of Bangladesh

Md. Zakaria
Senior Scientific Officer

Abstract

This study deals with the determination of the distribution of sedimentological characteristics and heavy minerals in the nearshore area of Chattogram in the eastern coastal area of Bangladesh. The study area lies in the complex geological and hydrodynamic conditions. The study area mainly consists of very fine sand sediment with some fine sand in size. Different grain-size parameters have been studied to delineate the sediment distribution in the study area. Grain-size parameters such as mean size, sorting, skewness, kurtosis, histogram, cumulative curve, and provability curve, along with bivariate plots of each parameter, were performed in the study to delineate sediment depositional systems and the source of the sediment. The sediments are mostly bimodal and poorly sorted in nature. A linear discrimination function (LDF) and a multigroup discrimination function (MDF) have been applied to differentiate sedimentary sub-environments. From the analysis, it is observed that the depositional system of the study area belongs to a shallow marine with turbidity current deposit. Besides, the bivariate plot shows different classification of depositional process named in this report as "nearshore marine process". The concentration of heavy minerals shows variations. The border zone of the study area (near the coast) contain heavy mineral in the sediments. One samples shows above 64% of heavy mineral and being the highest figure ever recorded. Also, the Passega C-M plot shows that the sediments deposited by turbidity current with suspended and rolled sediments.

Keywords: Chattogram, Sediment Texture, Depositional Process, Heavy Mineral

Objectives

The objectives of the research project given below-

To know the Surface Sedimentological/Lithological composition (sand, silt & clay) of the study area

To identify mineral composition as well as economic mineral assemblage of the nearshore sediment of the study area.

To know the sedimentary process of the area.

Study Area

The study area lies in the nearshore zone of the Chattogram district. The study area is bounded by N 22°01' to N 22°45' latitudes and E 91°25' to E 91°55' longitudes in the nearshore marine area.

Materials and Methods

Field Investigation

The field investigation and sample collections will be carried out in the nearshore area of Chattogram. For systematic study of the area, GPS as well as traversing and spot location methods were used. The sample has been collected along according to grid pattern with approximately 4-5 km of distance between the points. Sampling has been collected using Van Veen Grab sampler by local fishing boat. Multiparameter (Aquared AP5000) has been used to measure water quality data during survey. During survey and data collection using multiparameter an incident has been occurred. During measurement of bottom water quality parameter in the nearshore area of Chattogram, the multiparameter sensor and logger was bitten by a quickly running shark and cut out the logger wire with sensors and gone within 10 seconds of time. Two investigators were injured to save the instrument. Surface and near bottom water samples has been collected using Niskin bottle for investigations of hydrographic parameters such as temperature, total suspended sediments (TSS), salinity etc. Transparency of water has been measured using Secchi disk in the area for further research purpose.

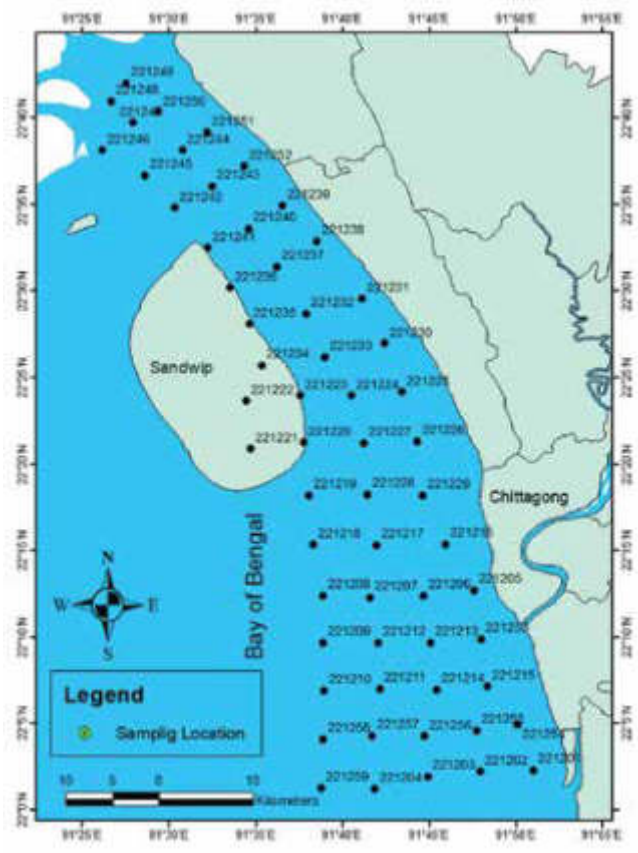

Figure 1.1: Study area map including sampling location in the marine area of Chattogram.

Sedimentary Texture

At first sedimentary texture has been delineated using laboratory measurement. After field investigation, grain size distribution measured by sieve methods. The remaining sediment sampled dried in oven to perform sieve analysis. To perform sieve analysis 100 g samples are taken. All the samples are falls in lower than 2mm size. So 10, 18, 35, 60, 120, and 230 US Standard sieve mesh used to perform sieve analysis.

The statistical parameters of grain-size distribution were calculated using equation proposed by (Folk & Ward, 1957). The parameters employed to describe the grain size distribution are categorized into four main groups that include, the mean, standard deviation, skewness, and kurtosis. Graphic mean, Standard Deviation, graphical Skewness and graphical Kurtosis calculated from cumulative graph value (ϕ10, ϕ25, ϕ60, ϕ75, ϕ99) using equation stated below-

Graphic mean (M_Z)	$M_Z = \frac{\varnothing_{16} + \varnothing_{50} + \varnothing_{84}}{3}$
Inclusive graphic standard deviation (σ_i)	$\sigma_i = \frac{\varnothing_{84} - \varnothing_{16}}{4} + \frac{\varnothing_{95} - \varnothing_5}{6.6}$
Inclusive graphic skewness (SK_i)	$SK_i = \frac{(\varnothing_{84} + \varnothing_{16} - 2\varnothing_{50})}{2(\varnothing_{84} - \varnothing_{16})} + \frac{(\varnothing_{95} + \varnothing_5 - 2\varnothing_{50})}{2(\varnothing_{95} + \varnothing_5)}$
Graphic kurtosis (K_G)	$K_G = \frac{(\varnothing_{95} - \varnothing_5)}{2.44(\varnothing_{75} - \varnothing_{25})}$

Where $\varnothing_5$, $\varnothing_{16}$, $\varnothing_{25}$, $\varnothing_{50}$, $\varnothing_{75}$, $\varnothing_{84}$ and $\varnothing_{95}$ represents 5^{th}, 16^{th}, 25^{th}, 50^{th}, 75^{th}, 84^{th} and 95^{th} percentile, respectively, on the cumulative curve.

Bivariate scatter plots were employed to discriminate between depositional settings based on the textural variations of sediment. Bivariate plot of Skewness vs. standard deviation has been done using MS Excel. The Sahu's [1962, 1964] linear discriminant function (LDF) used to determine and distinguish processes and environments of deposition. To delineate depositional environment Linear Discriminate Function (LDF) has been applied by below equation-

Equation (i) will be used to distinguish between shallow agitated water (SA) and beach (B) environments.

Y1(SA:B)= -3.5688M+3.7016r2-2.0766SK+3.1135KG ..... (i)

If Y1 is < -2.7411, the environment is "shallow agitated water" and if Y1 is > -2.7411, the environment is "beach".

Equation (ii) will be used to distinguish between beach (B) and shallow marine (SM) environments.

Y2(B:SM)= 15.6534M+65.7091r2+18.1071SK+18.5043KG ..... (ii)

If Y2 is < -63.3650, the environment is "beach" and if Y2 is > -63.3650, the environment is "shallow marine".

To distinguish environment of deposition between shallow marine (SM) and deltaic or lacustrine (L), equation (iii) was applied:

Y3(SM:F)= 0.2852M-8.7604r2-4.8932SK+0.0482KG..... (iii)

If Y3 is > -7.4190, the environment is "shallow marine" and if Y3 is < -7.4190, the environment is "deltaic or lacustrine".

To discriminate between deltaic (D) and turbidity current deposit, equation (iv) below was applied:

Y4(F:T)= 0.7215M-0.4030r2+6.7322SK+5.2927KG..... (iv)

To discriminate between deltaic (D) and turbidity current deposits, equation (iv) below was applied:

If Y4 is < 9.8433, it indicates turbidity current deposition and if Y4 is > 9.8433, it indicates deltaic deposition, where M, r, SK and KG represents mean grain size, standard deviation, skewness and kurtosis, respectively. Also, multigroup discriminant function (MDF) has used to discriminate the environment as per Sahu's (1983) method.

Heavy Mineral distribution:

Heavy Mineral concentration has been measured with heavy liquid separation method using Bromoform (BrH3). To separate heavy mineral 25gm of samples has been taken and Bromoform taken three times higher (1:3). Then heavy and light mineral has been weighted and calculated the percentage. Among 59 samples, 16 samples have sufficient sand grains for heavy mineral study. So, these 16 samples have been investigated for the heavy mineral study. The procedure mentioned in Faupl et al. (1998), 25 g has been taken from each sample. Gravitational heavy liquid separation of the sieve fraction 1 to 0.063 mm size was carried out using Bromoform as heavy liquid (density 2.89 g/cm3). After mounting the grains in Canada balsam, the grains has been examined under the polarizing microscope. More than 450 translucent grains of each sample have been counted with the ribbon count method.

Results

Graphic classification of sediment

Frequency curve

Figure 3.1 shows the frequency curve of the sediment samples of the study area. From the graph it is found that the sediment is bimodal population. Some (very few) sediments in the frequency curve shows unimodal populations.

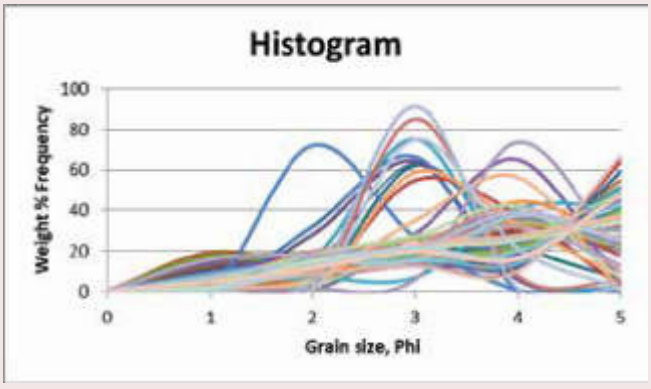

Figure 3.1: Frequency curve based on sediment size and individual weight percentage

Cumulative curve

The samples are mostly belongs to very fine grained sand size with some fine grain sand. Most of the curve (Fig. 3.2) shows gentle slope and straight. Some curve shows show steep slope. It indicated the sediments of the study area is mostly poorly sorted.

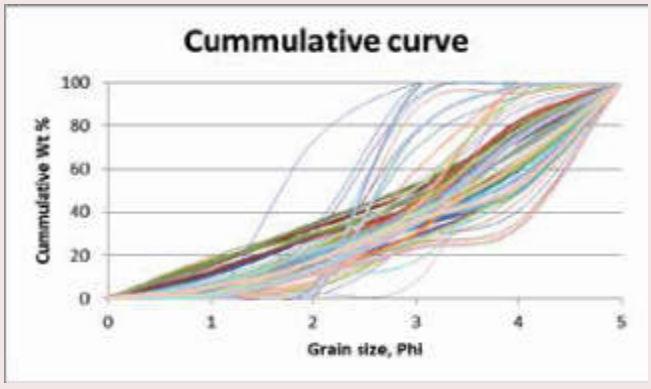

Figure 3.2: Cumulative weight percentage logarithmic curve based on grain size

Grain-size parameters

Figure 3.3-3.6 shows the value of different grain size parameter such as mean, standard deviation (SD), skewness and kurtosis of the Chattogram area sediment deposits. The calculations have been carried out using Folk & Ward (1957) method.

Mean Grain Size: This depicts the aver¬age particle size or the central tendency of parti¬cles. The mean size of the sediment of the study area belongs to very fine sand to fine sand in size (Fig. 3.3).

Standard deviation: This measures the sort¬ing or uniformity of the grains indicating energy conditions that prevailed during transport and deposition. Sorting is varies between poorly sorted to well sorted but poor sorting are very dominant in the study area indicate high energy condition of deposition (Fig. 3.4).

Skewness: Skewness is a measure of symmetrical dis¬tribution, i.e. the proportion of coarse or fine fractions. A symmetrical curve with excess fine material shows a positive value, whereas one with excess coarse material shows a negative value; a zero value is indicated by a symmetri¬cal curve. The study area sediment is mainly coarse skewed to strongly coarse skewed. Very small number sediment showed fine skewness (Fig. 3.5).

Kurtosis: The kurtosis expresses the packedness of the grain size distribution. The study area shows leptokurtic and very leptokurtic nature of sediment (Fig. 3.6).

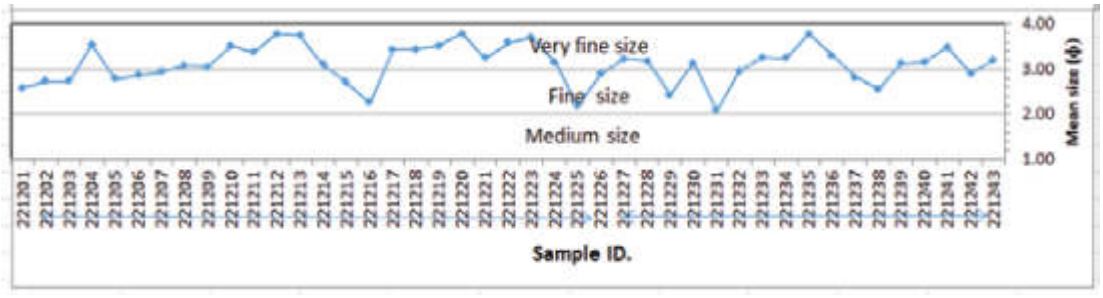

Figure 3.3: Graphical plot of mean size of the sediment

Figure 3.4: Graphical plot of standard deviation (sorting) of the sediment

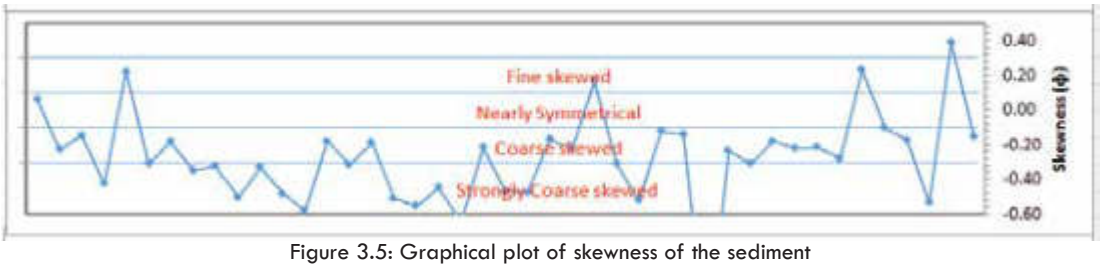

Figure 3.5: Graphical plot of skewness of the sediment

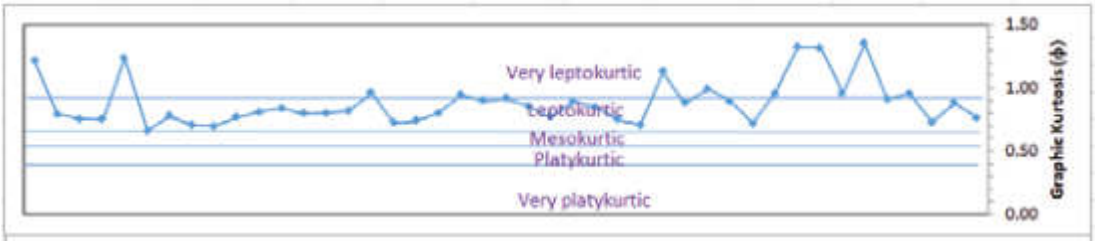

Figure 3.6: Graphical plot of kurtosis of the sediment

C-M Plot:

According to Passega (1957, 1964), C-M diagram can be used as analysis of depositional environment. In this study, C-M diagram plotted based on C and M parameter where C represents one percentile (Φ1), and M represents fifty percentile (Φ50) diameter

(in microns). Most of the sample of the study area fall in the 2 and VI segment indicates turbidity current deposts with suspended and rolled sediment (<1 mm size) area transported in the study area (Fig. 3.7).

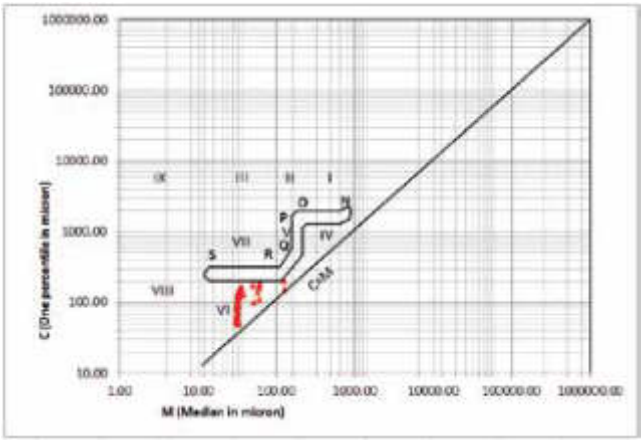

Figure 3.7: CM plot of sediments of the study area.

Environmental Condition

Linear discriminate function (LDF):

The use of statistical analysis to interpret the variations in energy and fluidity factors during/prior to sediment deposition seems to have a very good correlation with the different processes and depositional environments (Sahu, 1964). The linear discriminant functions were modified and used to discriminate between the different processes and depositional environments of Y1 (shallow agitated water and beach), Y2 (beach and shallow marine), Y3 (shallow marine and deltaic or lacustrine) and Y4 (turbidity and deltaic).

The Sahu's (1964) LDF classification indicates the sediment deposition environment of the study area belongs to shallow marine with shallow agitated water with turbidity current deposits.

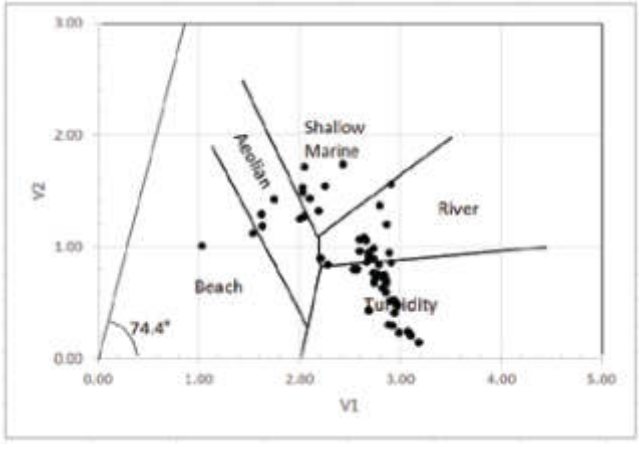

Figure 3.8: Discrimination of depositional environment of the study area using V1-V2 plot after Sahu (1983).

Multigroup Discrimination Function (MDF):

Tucker and Vacher (1980) questioned about the effectiveness of liner discrimination function. As LDF yield result for two environments conjugately, so Sahu (1983) employed Multigroup Discrimination Function (MDF) to find out distinguished environment for the sediment deposition. In this case of MDF, discriminating Eigen's vector V1 and V2 used and expressed as-

V1 = 0.48048M + 0.62301r2 + 0.40602SK + 0.44413KG

V2 = 0.24523M + (-0.459051r2) + 0.15715SK + 0.83931KG

Where M, r, SK and KG represents mean size, standard deviation, graphic skewness and graphic kurtosis respectively.

The value obtained for V1 and V2 has been plotted in the diagram after Sahu (1983). The position of the point falls in the shallow marine and turbidity deposits in the diagram (Fig. 3.8).

Bivariate Plot of data:

Bivariate plot skewness vs. standard deviation shows that the sediment deposited in the study area beyond the classification by Stewart (1958). The data position of the plot shows different depositional process. It can be state that the sediments of the study area are belongs to the separate process which can be named as "nearshore marine process" in this paper considering the depositional environment using LDF and MDF discussed in this report/paper.

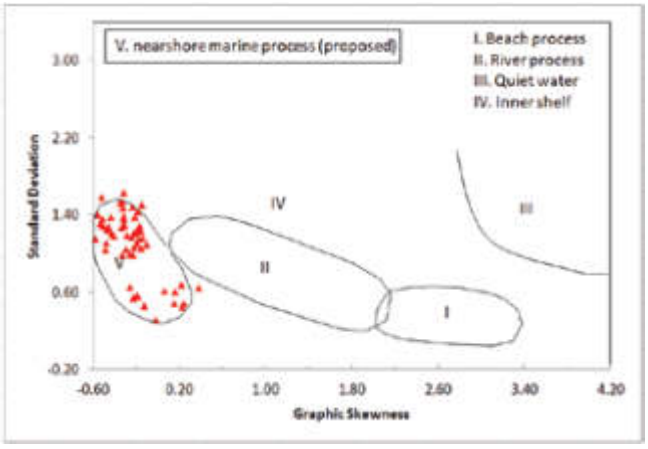

Figure 3.9: Classification based on bivariate plot of skewness vs SD after (Stewart, 1958)

Heavy Mineral Concentration

Heavy mineral has been separated using gravity separation (Bromoform). Among the samples of the study area, 16 samples have sufficient sand with greater than 63 µm size. Most of the sample shows (Table 3.5) low amount of heavy mineral (0.38 to 64.73%) where some samples shows very high percentage (>9%). The sediment shows (Fig. 3.10 & 3.11) high variation of heavy mineral distributions. Heavy mineral samples shows that (Fig. 3.11) the heavy mineral present in the samples which is near to the coast or land area, which indicate the shallow depth margin zone have favorable conditions for heavy mineral concentrations. The exceptional more 64% of heavy mineral shows in the sample number 221242 which is located just top (north) of the Sandweep Island where the sediment of GBM estuary just straight strikes. The surrounding samples also bear high percentage of heavy minerals.

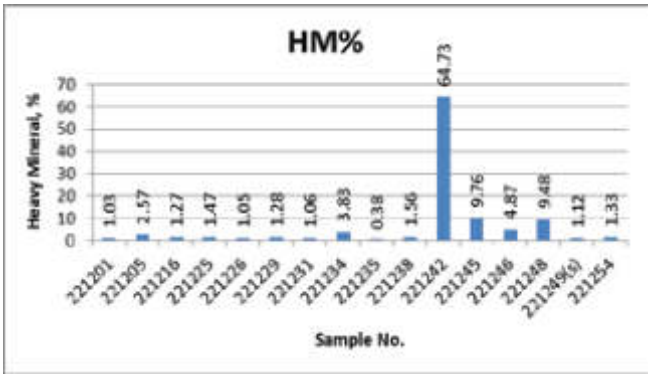

Figure 3.10: Heavy mineral percentage graph as per sample.

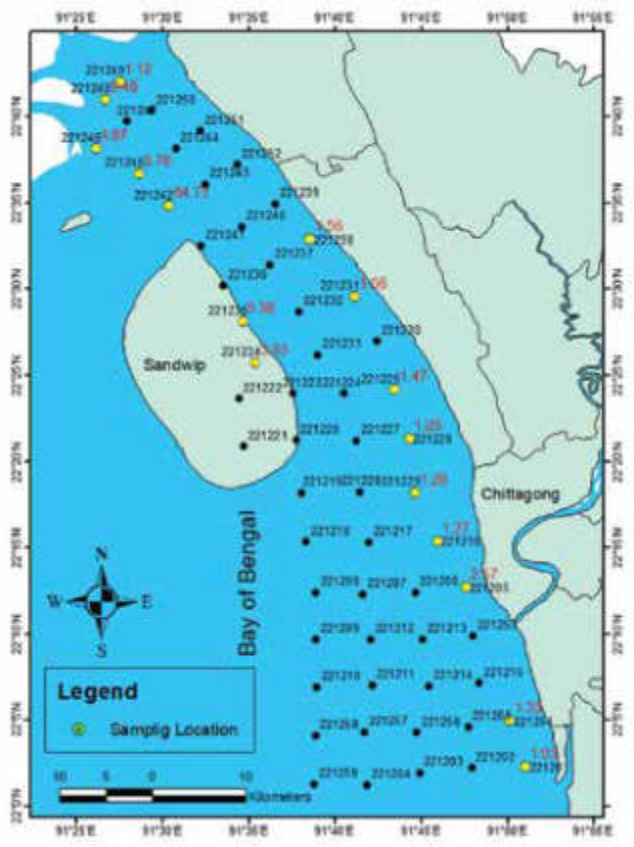

Figure 3.11: Heavy mineral (HM) distribution map of the study area (yellow point contain HM, and red value shows the HM%).

Conclusion

The depositional system of the study area may controlled by the geological system. Shallow marine and shallow agitated water process are dominated in the study area. The depositional process in the study area is mainly controlled by turbidity current. The study area is carries bimodal very fine sand mostly. Also the sorting is poorly sorted indicate near source of sediments as well as high energy conditions. Cumulative curve shape indicates high kinetic energy and velocity during sediment deposition. Mean size of sediment indicate uniform distribution of energy along the study area. The CM plot indicates turbidity current deposit with suspended and rolled sediment transportation. The bivariate plot shows new classifications of the depositional process in the study area named in this paper as "nearshore marine process". Heavy mineral concentration shows distinct variations with high value in the near zone of GBM estuary indicate potential zone for economic mineral assemblages. Besides the overall study area shows very low to not potentiality of heavy mineral. Detail long term study required to delineate the suitable zone of economic mineral as well as to understand the marine process in the study area.

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CHARACTERISTICS AND SPATIAL PATTERN OF COASTAL SAND DUNE ALONG THE COASTLINE OF COX'S BAZAR, BANGLADESH

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Introduction

The main purpose of this research is to identify and classify the current feature of coastal sand dunes along the Cox's Bazar coast of Bangladesh. Vegetation, grain size analysis, pH, moisture and height measurement of dune system area is the main procedure to classify the coastal sand dune system. Most of the coastal sand dune observed in highly erosional phase to intermediate phase.

Methods

Methodologies used for the field investigation are pH and moisture content taken using soil pH and moisture tester instrument. Surface sediment sample collection for grain size analysis using sieve and hydrometer, and water sample collection from Dune slack area for laboratory analysis, examine vegetation cover, and physical feature of dunes. This methodology had helped to classify the total Coastal sand dune system from Cox's Bazar coast to Teknaf coast.

Study Area

The investigated area are designed by the location name such as Reju khal river area, Inani beach area, Shamlapur area, Bardeil area, Teknaf area and Reju khal to Nazirtak area from Cox's Bazar coast to Teknaf coast of Cox's Bazar district, Bangladesh.

Observations

In Zone-A, (Section 36 to 44): Five embryo, two foredune, and three mid dune has been observed in this zone.

In Zone-B, (Section 1 to 7): Three types coastal sand dunes observed in this zone including mid dune, Fore-dune and Embryo dune. It has been observed four embryo dune, and mid dune had identified by the height of dune equal to 7m.

In Zone-C, (Section 8 to 19): Three Embryo dune, two foredune and mid dune observed. Also three dune slack and mature dune have observed in this zone

In Zone-D, (Section 20 to 29): five embryo dune, two foredune, and two dune slack and mature dune have observed in this zone.

In Zone-E, (Section 30 to 35): Two embryo dune, three foredune, and two mature dune have been observed in this zone.

Embryo dune system continued from Teknaf area to sabrang tourism spot.

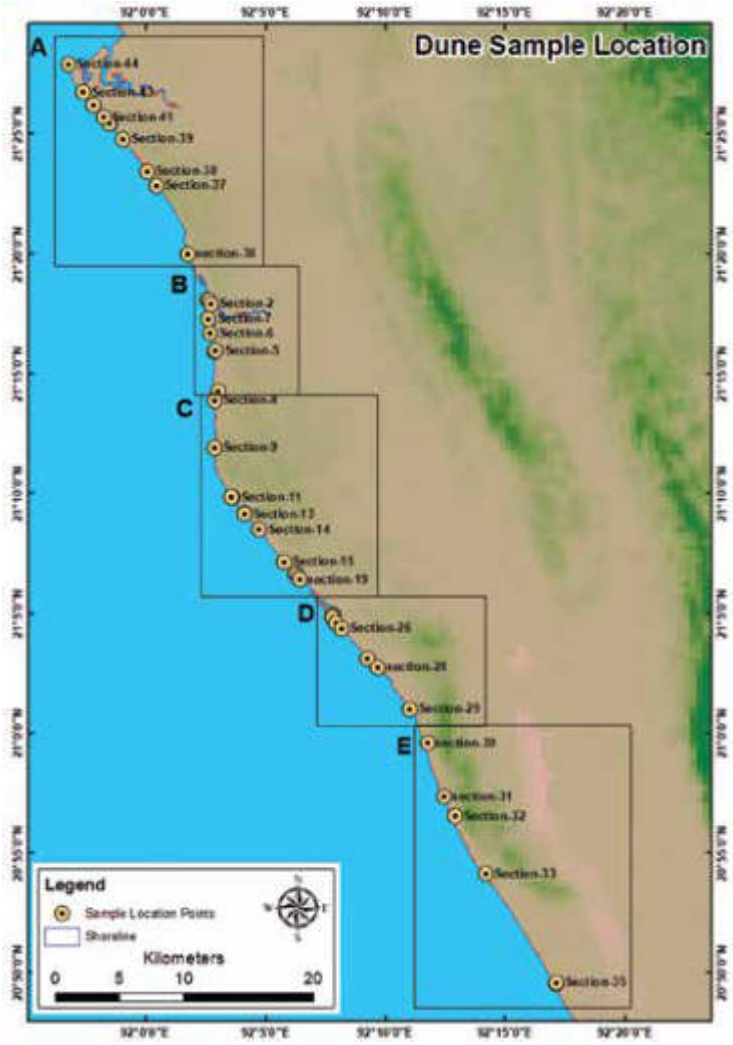

Figure: Investigation area divided into 5 zones (Zone A, B, C, D, E) for Coastal Sand Dunes along the Coastline of Cox's Bazar, Bangladesh

Pictures of Coastal Sand Dune Classification along the Coastline of Cox's Bazar

Figure: Embryo Dune

Figure: Foredune

Figure: Mid Dune

Figure: Dune Slack

Pictures of Coastal Sand Dune Classification along the Coastline of Cox's Bazar

Figure: Mature Dune

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4

CHAPTER

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BIOCHEMICAL COMPOSITION, MORPHOMETRIC VARIABILITY AND HABITAT DISTRIBUTION OF HORSESHOE CRABS ALONG THE COASTAL AREA OF BANGLADESH

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Abstract

A study conducted in Bangladesh coastlines from July 2022 to June 2023 explored the biochemical composition, morphometric variability, and habitat distribution of horseshoe crabs (HSC) in mangroves and saltmarsh areas. Two HSC species, Carcinocorpus rotundicauda (99%) and Tachypleus gigas (1%), were identified and it was found that T. gigas is larger than C. rotundicauda. C. rotundicauda predominated in Naf River estuary, Rezukhal estuary, Sonadia, Maheshkhali, and Dublarchar, while T. gigas was exclusive to sandy beaches in Cox's Bazar. The study on C. rotundicauda highlights significant morphometric variations, with females being notably larger and heavier than males, excluding telson length. Allometric analysis reveals a positive growth trend ($b>3$) in length/width-weight relationships for both sexes (TL-BW, PW-BW, CL-BW), while length/width-length relationships (CL-PW, TL-PW, CL-TEL, TL-TEL) exhibit negative allometric growth ($b<1$), except CL-PW in females, indicating isometric growth ($b=1$). Strong correlations across body parts suggest interdependence. Changes in body dimensions may reflect influences of population density, feeding efficiency, food availability, and local environmental conditions on C. rotundicauda. Leucine (0.5%), isoleucine (0.3%), and valine (0.3%) were the prevalent amino acids. High levels of copper (149 mg/kg), cadmium, lead, and mercury (34 µg/kg) were recorded. Protein concentration in HSC was 7.6%, and their haemolymph contained a copper-containing pigment for rapid endotoxin detection. Bioinformatics analysis revealed proteins and peptides in HSC blood with potential applications in treating diseases like SARS-CoV, cancer, etc. These findings serve as valuable baseline data for horseshoe crab management initiatives.

Keywords: Horseshoe Crabs, Biochemical Composition, Morphometric, Haemolymph, Endotoxin

Introduction

Horseshoe crab is unique with a strong immune system and famous for the utilization of their haemolymph in endotoxin detection (Fennrich et al., 2016). Horseshoe crab (HSC) belongs to phylum: Arthropoda, subphylum: Chelicerata, class: Merostomata, order: Xiphosura, family: Limulidae and it is a crab-like animal with blue hemolymph and a brown body composed of the cephalothorax, abdomen, and sword tail (Cartwright-Taylor et al., 2009; Delvaeye and Conway, 2009). There are four different types of horseshoe crabs such as Limulus polyphemus (Linnaeus, 1758), Tachypleus tridentatus (Leech, 1819), Tachypleus gigas (Müller, 1785), and Carcinoscorpius rotundicauda (Latreille, 1802) are globally available and distributed in countries like America, Japan, China, Indonesia, Thailand, Malaysia, Singapore, Philippines, Taiwan, Myanmar, Bangladesh and India. They are existing since 450 million years without any morphological modifications and were thus widely known as "Living fossil" (Sekiguchi and Sugita, 1980; Rudkin and Young, 2009). Among them two species namely Carcinoscorpius rotundicauda and Tachypleus gigas are available in Bangladesh (Chowdhury S.H. and Haffizuddin A.K.H., (1980). In Bangladesh it is popularly known as Sagar Kakra or Raj Kakra.

The Haemolymph of Horseshoe Crab possess copper containing pigment i.e., haemocyanin which makes it blue color (Mikkelsen, 1988), and is able to quickly detect few nano grams of endotoxins (Levin and Bang, 1968). Horseshoe crabs have medical importance given that they produce reagents for testing bacterial endotoxins (Levin and Bang, 1964; Cooper et al., 1971; Novitsky, 1984; Berkson and Shuster, 1999; Swan, 2002; Kreamer and Michels, 2009) and vaccines (Maloney et al., 2018). With the progress in scientific research, specifically, biomedical research (Shuster, 1962), researchers explored and revealed the visual, endocrine, and physiological processes of horseshoe crabs (Berkson and Shuster, 1999; Zaldívar-Rae et al., 2009; Carmichael and Brush, 2012). The biology and biotechnological potentials of Limulus polyphemus species of the HSCs has been studied extensively in USA (Botton and Ropes 1987, Rudloe 1983, Sekiguchi 1988, Shuster 1982, Thompson 1997&1999, Walls et al 2002). Similarly, the Japanese species of HSCs i.e., Tachypleus tridentatus has also been studied extensively. But the biology of Bangla species, T. gigas & C. rotundicauda have not been properly and systematically studied so far.

Horseshoe crabs are widely utilized as biological resources in various fields. HSC can be used to detect endotoxin concentration in the environment (Novitsky, 2009) and are regarded as an indicator of coastal ecology (Chen et al., 2004). HSC are use in fertilizer and livestock feed. L. polyphemus has been mass harvested for use as eel and whelk bait in commercial fishery in the last century (Berkson and Shuster, 1999; Smith et al., 2009). In China and Southeast Asia, T. tridentatus and T. gigas are regarded as food and traditional Chinese medicine and thus consumed by local people or travelers (Fu et al., 2019). In the marine ecological community, horseshoe crabs form prey–predator relationships with many animals and play a vital role in estuarine and coastal communities (Botton, 2009).

Horseshoe crabs have faced multiple threats (Maloney et al., 2018). The abuse of HSC biological resources, along with other factors, such as environmental pollution and shoreline retreat, has caused the population of horseshoe crabs to severely decline (Rudloe, 1982; Widener and Barlow, 1999; Cartwright-Taylor et al., 2011; Smith et al., 2017; Vestbo et al., 2018). Populations of HSC world-wide are currently in decline (e.g., Cartwright-Taylor et al., 2011; Kwan et al., 2016; Smith et al., 2017), and the IUCN (International Union for Conservation of Nature, 2013) Red List of Threatened Species now describes L. polyphemus as vulnerable (Smith et al., 2016). Although the Asian horseshoe crab species are thought to be in greater decline than L. polyphemus, these species are currently listed as data deficient (World Conservation Monitoring Centre, 1996a).

The aim of the research is to identify the species, their occurrence and distribution, biochemical composition and to describe the morphometric variability for C. rotundicauda as well as to introduce allometry as the method in statistical shape analysis for growth rate inorder to protect and monitor the living of this species from the coastal waters of Bangladesh. Though a plenty of information including biology, physiology and behaviour have been reported on American horseshoe crab (L. Polyphemus) and also in other Asian species (T. gigas, T. tridentatus & C. rotundicauda), however, a detailed knowledge on the morphometry & haemolymph biochemical parameters of Bangladeshi HSCs (T. gigas & C. rotundicauda) are not yet known. Hence, it has been felt necessary to carry out a comprehensive study on the horseshoe crab for sustainable use of the species on a long-term basis and also to evolve effective conservational plans to protect this valuable creature from extinction along the Bangladesh coastline.

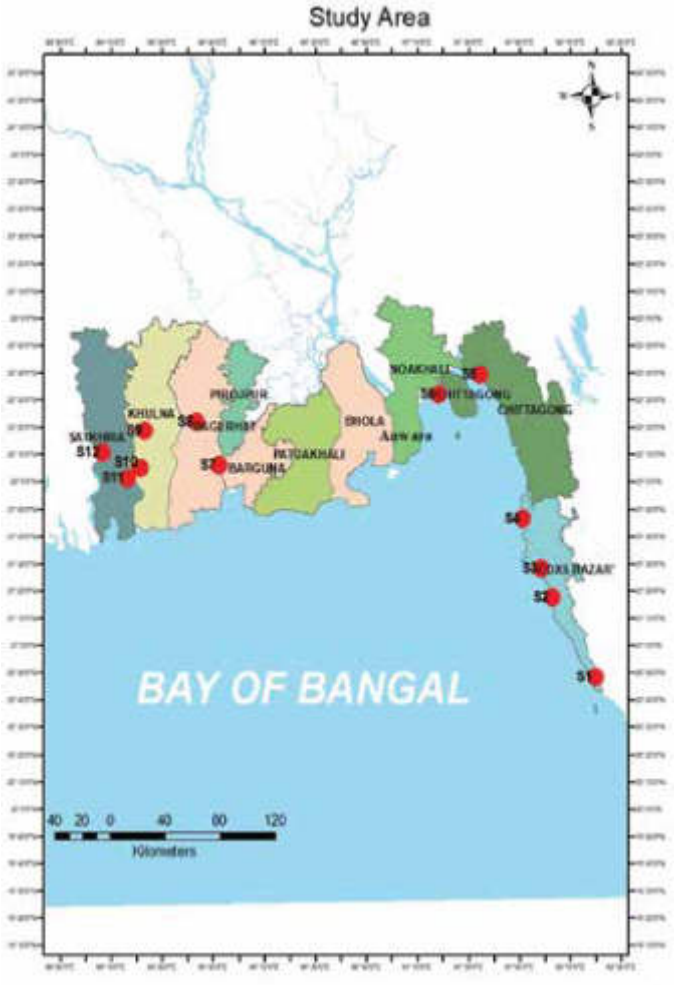


Figure 1: Study Area

Materials & Methods

Study Area

The live sample was collected from the coastal waters of Bangladesh specifically in Saint Martin's Island, Naf estuary, Shamlapur, Rezukhal estuary, Dariyanogor, Bakkhali, Moheshkhali, Sonadia Island, Kutubdia, Chittagong, Bagerhat and Satkhira coastal waters of Bangladesh. This area comprises a variety of wetland habitats including mangroves, saltmarsh, mudflats, sand dunes, sand bars, lagoons, saltpans and beaches which are the favorable requirements for horseshoe crab's habitat (Shuster, C. N. Jr., and Sekiguchi K., 2009).

Morphometric Variability of Horseshoe Crabs:

Sample Collection

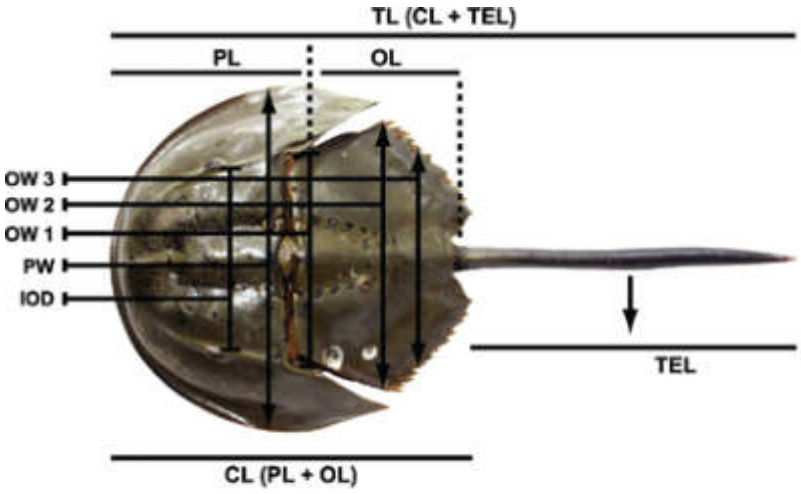
Sample collection was conducted by Visual search methods and Bycatch methods (Soykan, C.U., Moore, J.E, 2008). Search methods were dictated by the fact that mangrove horseshoe crabs of all sizes are readily found on the mud surface when the tides recede. Individuals can be seen moving slowly over the surface of the mud or resting on the mud. Some but not all settle into the surface so that they are partly covered by the mud, particularly the anterior part of the carapace. Then they were picked out of the mud by hand. All horseshoe crabs were found then brought to the research lab for further investigation.

Search Times and Dates

- Parent time of Field Work: Full moon and new moon.
- Specific time of Field Work: During low tide of full moon and new moon.
- Visiting the possible spot of Field Work: three days before and after of full moon and new moon both during day and night time in each month.
- Duration of Field Work: 5 hours (two hours before and after of low tides).

Morphometric Measurement

Ke Yang and Hyun Sook Ko (2015) operated a study in 2015 to distinguish between C. rotundicauda, Tachypleus gigas, and Tachypleus tridentatus by using cross-section morphology of the telson. A similar study has been studied in different years in where it has been seen that the telson is triangular for both Tachypleus species whereas circular for C. rotundicauda (Cartwright-Taylor et al., 2009; Dolejš and Vaňousová, 2015; Tanacredi et al., 2009). It has also been seen that females have a chelate clasper like scissors while the male has a hemichelate clasper like hooks on the first and second walking legs. For this study, female and male were identified as well as morphometric measurements were recorded (Figure 2). A total number of 178 adults [♂ =117 (59.2%) and ♀ = 61 (40.8%)] of C. rotundicauda had been studied.



PL = Prosomal Length
PW = Prosomal Width
OL = Opisthosomal Length
OW = Opisthosomal Width
CL = Carapace Length
TEL = Telson Length
TL = Total Length
IOD = Inter Ocular Distance

Fig 2. Morphometric Measurements of the Horseshoe Crab (*Carcinoscorpius rotundicauda*)

The prosomal length (PL), opisthosomal length (OL), prosomal width (PW), opisthosomal width (OW 1-3), distance between the anal length (AL), distance between the compound eyes, telson length (TEL), carapace length (CL) as well as the total body length (TL) were recorded to ±1 cm accuracy while the body weight (BW) was recorded to ±1gm accuracy. All the measurements of data were combined based on the species and sex (table 1). The difference in morphometric parameters between the males and females were observed through frequency distribution histogram using MS-Excel program (Figure 2).

Fig 3: Measurement of HSC by Digital Vernier Calipers

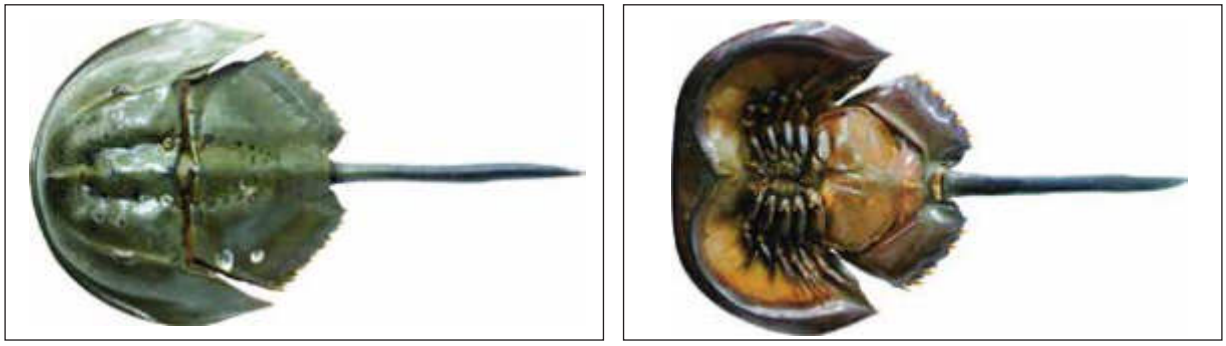


Fig 4: Dorsal & Ventral view of Horseshoe crab

Allometric Analysis

The allometric relationship were analyzed as 'log y = log a + b log x' [Amaral et al., 2014; Chen Y et al., 2010] where 'x' is the independent variable; total length (TL) and carapace length (CL) refer to a basis for all other measurements while 'y' is the dependent variable determined as body weight (BW), prosoma width (PW), and telson length (TEL), then 'log a' is the intercept of the line on the y-axis and 'b' is the slope of the line also known as the regression coefficient.

The growth pattern for weight relations (TL-BW, PW-BW, CL-BW) can be interpret by 'b' value; 'b = 3' represent isometric allometry growth, 'b > 3' represent as positive allometry and 'b < 3' as negative allometry while in the other hand different interpret for length variables (CL-PW, TL-PW, CL-TEL, TL-TEL); 'b = 1' as isometric, 'b > 1' as positive allometry and 'b < 1' as negative allometry [Chen Y et al., 2010, Srijaya TC et al., 2010].

The comparison between slopes of all logarithm value body parameter was carried out by means of Student's t-test (Hegele-drywa et al., 2014) considered as significant differences from the isometric value (b = 3 or b = 1) with the significant level at 5% ($P < 0.05$) using SPSS Statistics software version 20.0.

The student's t-test or known as Bailey's t-test was expressed as follows (Nair et al., 2015; Thomas, 2013);

$$Ts = |(3-b)/Sb| \text{ or, } Ts = |(1-b)/Sb|$$

where:
Ts = the student's t-test or Bailey's t-test
Sb = standard error of the b coefficients
b = slope or coefficients regression
3 = isometric value for the TL-BW, PW-BW and CL-BW relationship
1 = isometric value for the CL-PW, TL-PW, CL-TEL and TL-TEL relationship

Data analysis

All data were recorded on site and lab data collection sheets and later entered into computer spreadsheets. A thorough check of data and information entries was performed on all manually entered data to ensure accuracy. Before running any tests, data were checked for normality and homogeneity of variance, and selected tests were appropriate for the data and hypotheses being tested. Statistical analysis was performed using Excel and the R project for statistical computing. Additionally, all outliers were rechecked and corrected if necessary.

Results and Discussion

Occurrence and Habitat Distribution of Horseshoe Crabs

Horseshoe crabs are known to inhabit three distinct habitats, namely coastal bays, intertidal mud or sand flats, and deep water (Emily, 2011). Horseshoe crab spawning activity usually occurs in the intertidal zone (Brockmann and Smith, 2009) on a full and new moon night (Zaleha et al., 2012). The typical natural habitat of C. rotundicauda is muddy and brackish areas (Robert et al., 2014). Meanwhile, T. gigas is found in sandy to muddy areas (Tan et al., 2012). Horseshoe crab spawning activity was influenced by various environmental factors of the habitat such as salinity, temperature, pH, dissolved oxygen (DO) level of the water and sediment characteristics (Smith et al., 1991; Nelson et al., 2015). In addition, human activities such as active use by local people, commercial purposes, habitat destruction and natural causes (beach erosion) have raised concerns that may contribute to the extinction of horseshoe crabs in the coastal waters of Bangladesh. Additionally, no conservation efforts or any protection has been done by local government agencies to conserve these valuable horseshoe crabs in the coastal waters of Bangladesh. Therefore, this study was essential to determine the status of horseshoe crabs in different habitats. The objective of this study was to provide a baseline data on the distribution of two species of horseshoe crab from different locations in coastal waters of Bangladesh including their preferred habitat and associated environmental factors such as particle size, total organic matter (TOM) and physico-chemical parameters.

A line transect method was used to determine species distribution where Sonadia Island and Maheshkhali Island Mangroves area had the highest density of C. rotundicauda caught with of 3 individuals per hectare. Based on sediment analysis, C. rotundicauda was mostly collected from mangrove area (high content silt-clay) with sediment size less than 63 mm and total organic matter ranging from 0.35% to 27.91%. Meanwhile, T. gigas was found mainly in sandy beach of Shaplapur, Inani, Dariyanagor beach with total organic matter and the sediment size ranging from 0.39% to 10.9% and 125 mm to 250 mm, respectively. The findings of this research indicated that the distribution of T. gigas and C. rotundicauda in different preferred habitat in the coastal waters of Bangladesh were influenced by the in-situ physico-chemical parameters, type of sediment, lunar cycle and spawning season. Conservation of horseshoe crabs worldwide has become challenging as the number of horseshoe crabs were decreased due to human activities. Therefore, this research was designed to assess the habitat of horseshoe crabs by determining their distribution at different locations along the Bangladesh coastal waters.

Morphometric Measurement's

Morphometric can be used as an effective tool to study the variation in shape and size of organisms (Webster, 2007). The morphometric studies also useful for comparing various living organisms through the quantitative studies of various body parts (Srijaya et al., 2010). To understand the basic biology and physiology of the horseshoe crab it is highly essential to study the morphological and normal biochemical composition of the hemolymph, which is the main circulating fluid of this arthropod species.

Table1. Morphometric measurement records of Carcinoscorpius rotundicauda male and female.

Parameters (cm)	Males (N=117)		Females (N=61)	
	Mean	Std. Dev.	Mean	Std. Dev.
BW (gm)	189.49	39.27	284.10	81.80
TL (CL+TEL)	28.81	2.83	30.47	4.20
CL (PL+OL)	13.71	1.21	15.57	2.16
TEL	15.14	2.17	15.09	2.99
PL	7.84	0.67	9.20	1.32
OL	6.01	0.61	6.48	0.81
PW	13.49	1.29	14.87	2.03
OW 1	6.84	0.56	7.63	0.94
OW 2	9.49	1.25	10.56	2.10
OW 3	10.38	1.23	11.49	1.30

The results show that the average body weight (BW) of males is 189.49 gm whereas females average body weight is 284.10gm (Table 1). The results also show that the highest number (42 out of 117) of male species are weigh-in between the class 171-200 gm, while the highest number (12 out of 61) of female species are weigh-in between the class 231-260 gm [Fig 5. (a)].

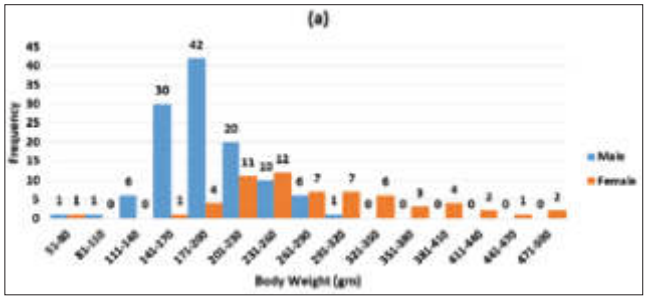


Fig. 5. (a). Frequency Distribution Histogram for the total body weight (BW) which measures in gm unit.

Like the total body weight (BW), significant differences have also been observed in terms of total body length (TL= CL+TEL) between the sexes. Total length is calculated by adding carapace length (CL) and telson length (TEL). Since the results (Table 1) show that there is a difference in both carapace length and telson length between the sexes, there is also a difference in total length. For example, from the above morphometric measurements (Table 1.) it is seen that the average carapace length and telson length of male species is 13.71±1.21 cm and 15.14±2.17 cm respectively. So, if these two values are added, the average of total body length of male species obtains which is 28.81±2.83 cm. And in terms of female species, the average carapace length and telson length is 15.57±2.16 cm and 15.09±2.99 respectively. So, we have a total of 30.47±4.20 cm of total length on average of female species. Additionally, the results also implies that both the larger number of species of both males and females are found in TL-class 29.1-31 cm [Fig. 6. (b)]. Though most of the male species are found in that class, however, in the case of female species, there is also adequacy in the TL-class 31.1-33 and 33.1-35 cm [Fig. 6. (b)].

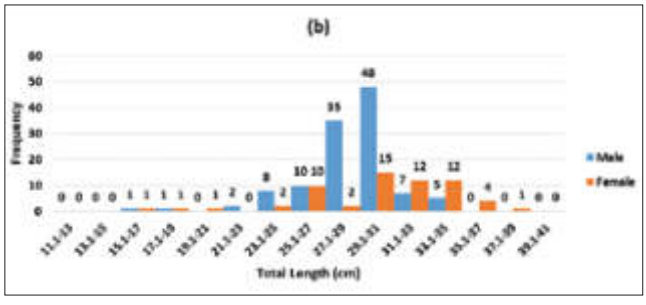


Fig. 6. (b). Frequency Distribution Histogram for the total body length (BL) which measures in cm units.

There are also differences between the sexes when it comes to the width parameter. Like for the parameter of prosomal width (PW) male species are 13.49±1.29 cm wide on average, on the contrary, female species are average of 14.87±2.03 wide (Table 1.). Besides, about 93 male species (out of 117) exist in PW-class 11.1-14 cm while most female species (35 out of 61) exist in PW-class 14.1-17 [Fig. 7. (c)].

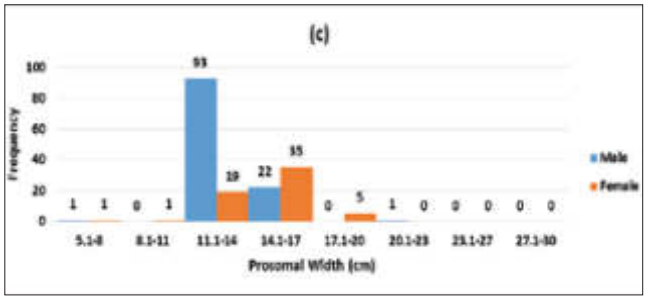


Fig. 7. (c). Frequency Distribution Histogram for the prosomal width (PW) which measures in cm units.

The same result is being observed in the case of opisthosomal width (OW 1-3) which indicates that female species have bigger opisthosomal than the male species (Table 1). Moreover, most male species are found in OW-1-class 5.1-7 cm while most female species are in OW-1-class 7.1-9 cm [Fig. 8. (d.1.)]. Similar results have also been observed for OW-2 and OW-3 [Fig. 8. (d.2., d.3.)]

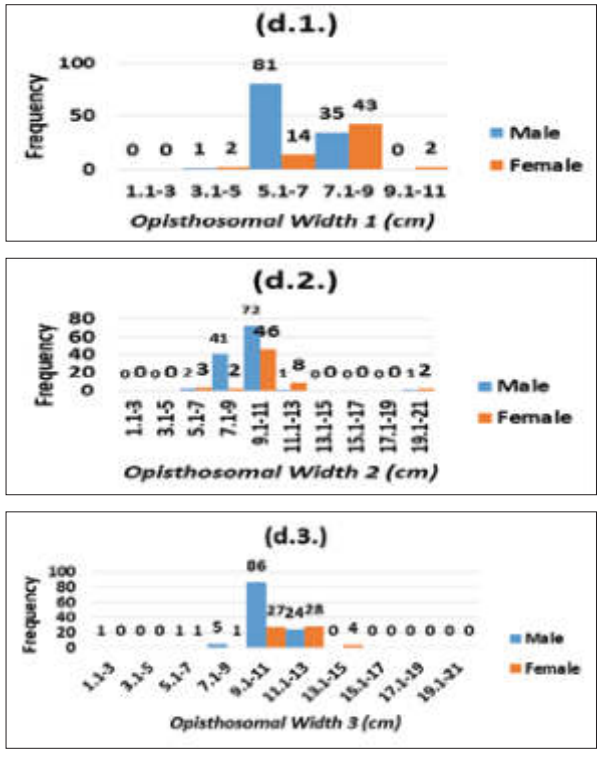


Fig. 8. (d.1) (d.2) (d.3.) Frequency Distribution Histogram for the opisthosomal width (OW 1-3) which measures in cm units.

Allometric Analysis

Allometry is the study of physical or morphological changes with size that may be changed by factors such as age, environment and population density within the same species. The allometry has been demonstrated into biological scaling relationships in terms of log transforming by linear regression. The concept of allometry was first postulated by Huxley & Tessier (1936) and since then it has been extensively applied by many biologists to estimate the population growth characteristics of multitude organisms. It is anticipated that present research attempted to provide baseline information for the growth of C. rotundicauda on the basis of the morphometric variability and allometry

relationships studies and the information generated from this research will contribute substantially in the ongoing research programs of the horseshoe crab, globally.

Table 2. Different parameters of length-weight, width-weight, width-length and length-length relationships of male and female of C. rotundicauda.

Parameters	Male					Female			
	b	R^2	T_s	Allometric Growth pattern		b	R^2	T_s	Allometric Growth pattern
TL-BW	9.305	0.425	4.839^S	+ve		7.691	0.142	1.704^{NS}	+ve
PW-BW	25.003	0.539	7.908^S	+ve		18.667	0.232	3.162^S	+ve
CL-BW	23.736	0.585	8.626^S	+ve		16.373	0.178	2.607^S	+ve
CL-PW	0.782	0.737	3.893^S	-ve		0.954	0.908	1.055^{NS}	iso
TL-PW	0.300	0.512	20.00^S	-ve		0.271	0.266	11.055^S	-ve
CL-TEL	0.684	0.199	1.915^{NS}	-ve		0.124	0.006	3.912^S	-ve
TL-TEL	0.643	0.830	10.2^S	-ve		0.690	0.726	5.00^S	-ve

Note: b = Slope; R^2 = Correlation coefficient; Ts = Bailey's t-test for allometric values; S = Significant; NS = Not significant; +ve = positive allometry, -ve = negative allometry; iso = isometric.

Allometric growth in TL-BW for both sexes expressed as b–values indicated as positive allometric growth in where b = 9.305 for male with significant differences ($p < 0.05$) but no significant differences has been observed for females with b = 7.691. The relationship between PW/CL-BW also recorded positive allometry for both of the sexes having significant differences with the significant level at 5% ($P < 0.05$). A straight line on log 'a' (intercept) over 'b' (slope) of male and female of C. rotundicauda also indicates uniform growth pattern of body dimensions with the advancement of growth in TL/PW/CL-BW relationships (Fig.7 Fig.8 & Fig.9).

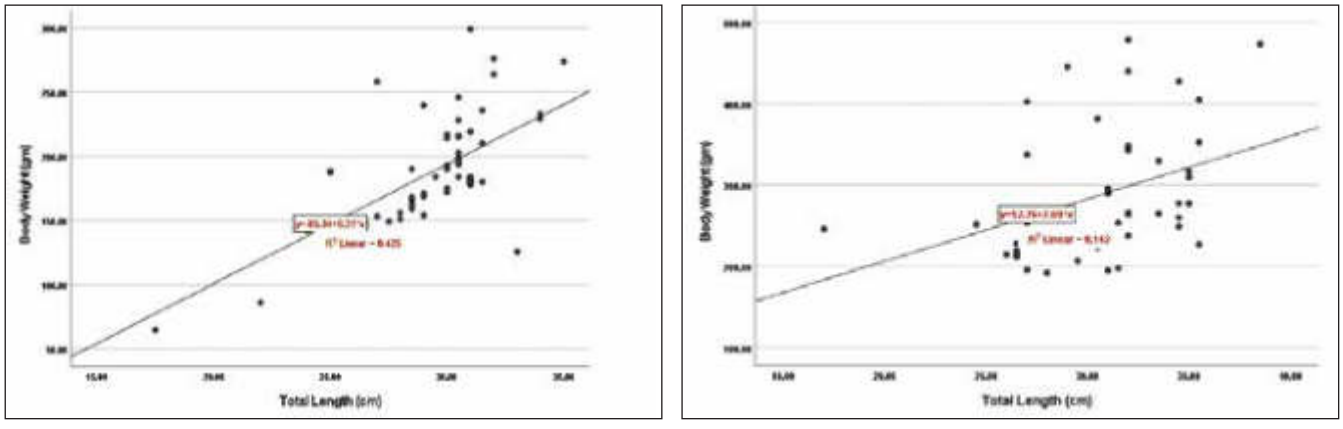


Fig 9. Total Length-Weight (TL-BW) relationship of Carcinoscorpius rotundicauda for both males (left) and females (right).

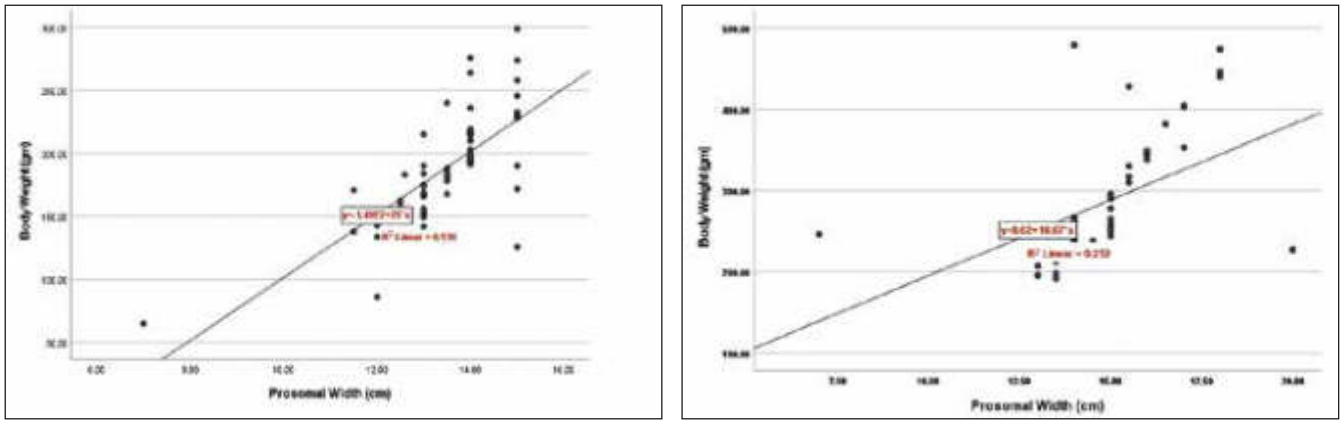


Fig 10. Prosomal Width-Weight (PW-BW) relationship of Carcinoscorpius rotundicauda for both males (left) and females (right).

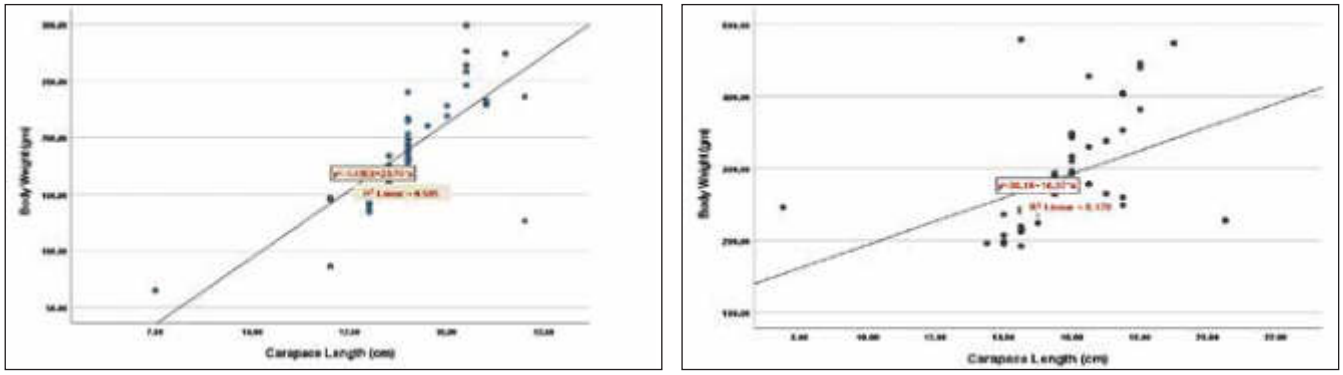


Fig 10. Prosomal Width-Weight (PW-BW) relationship of Carcinoscorpius rotundicauda for both males (left) and females (right).

However different growth patterns have been observed in case of length variables (CL-PW, TL-PW, CL-TEL, TL-TEL) where each relations shows negative allometric growth except CL-PW for females which shows an isometric growth; b = 0.954 (CL and PW grew at the same rate). Moreover, each relationship having significant differences between themselves except CL-TEL for males and CL-PW for females with the significant level at 5% ($P < 0.05$) (Fig.10 Fig.11, Fig.12 & Fig.13).

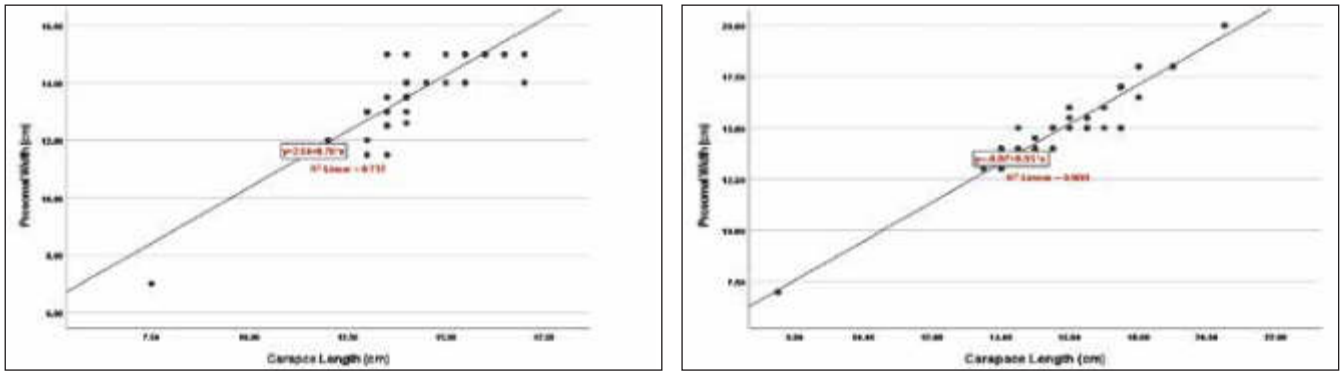


Fig 12. Carapace Length - Prosomal Width (CL-PW) relationship of Carcinoscorpius rotundicauda for both males (left) and females (right).

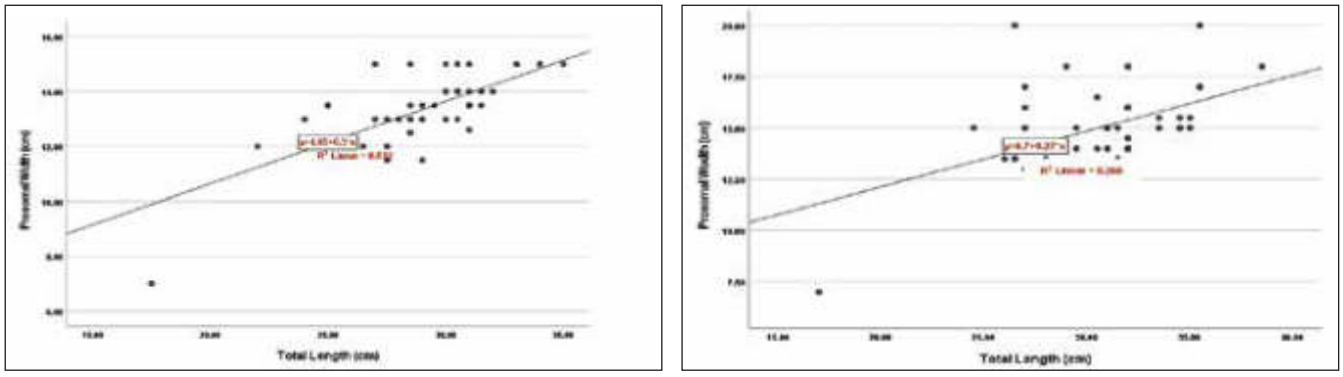


Fig 13. Total Length - Prosomal Width (TL-PW) relationship of Carcinoscorpius rotundicauda for both males (left) and females (right).

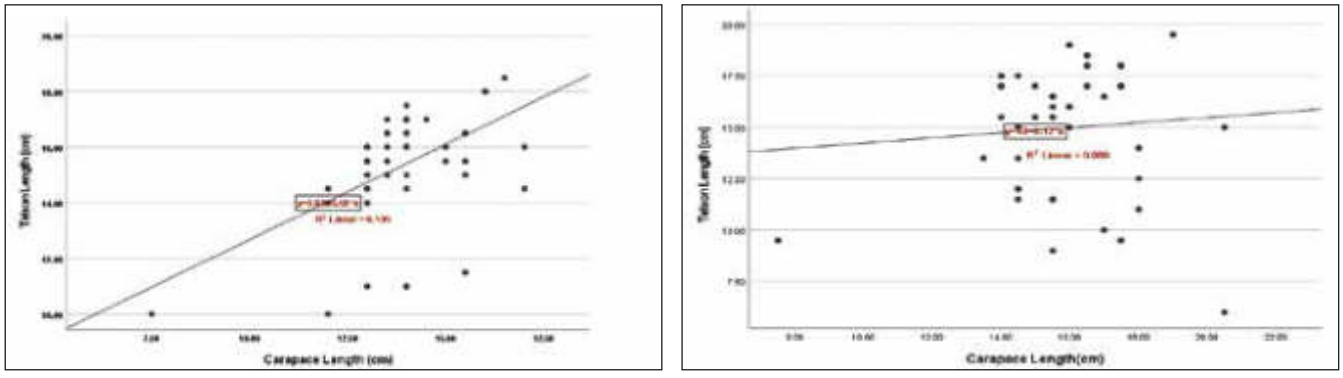


Fig 14. Carapace Length - Telson Length (CL-TEL) relationship of Carcinoscorpius rotundicauda for both males (left) and females (right).

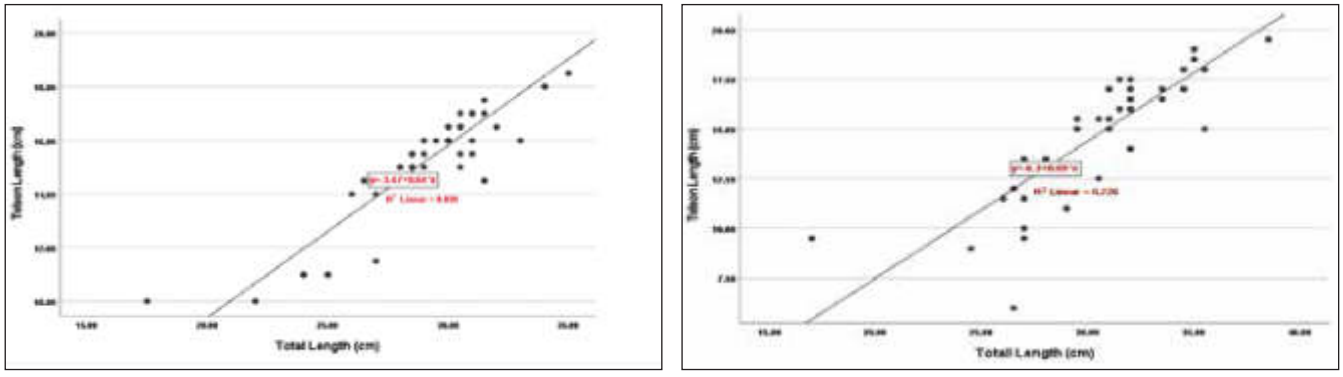


Fig 15. Total Length - Telson Length (TL-TEL) relationship of Carcinoscorpius rotundicauda for both males (left) and females (right).

Furthermore, in terms of the R^2 value (table 2), all relations between the major body parameters of C. rotundicauda indicated a strong correlation with each other. The highest R^2 value in the regression model was shown in females for the CL-PW relationship ($R^2 = 0.908$) (Fig.12) whereas the lowest was female for the CL-TEL relationship ($R^2 = 0.006$) (Fig.14).

Carcinoscorpius rotundicauda is considered a threatened species [Cartwright-Taylor L et al. 2011] and unfortunately in Bangladesh has not been gazetted under conservation laws. These study results provided important data that related to the difference of various body parameters for C. rotundicauda males and females from eastern coast of Bangladesh since no information and publication before thus became the first record on morphometry and allometry of horseshoe crabs in south eastern coast, Cox's Bazar, Bangladesh. An understanding of the relationship between one body parameter to the other of horseshoe crabs is essential to know their growth (Panda and Naik, 2017).

The morphometric analysis of each body parameters reveals that there are significant differences between the male and female species of C. rotundicauda which are females are significantly heavier (BW parameter) and larger (TL parameter) than males, same as reported by Yamasaki et al., (1988), Chatterji (1994), Chiu & Morton (2003) and Itow et al., (2004), Cartwright-Taylor et al., (2009), Srijaya et al., (2010), Noor Jawahir A. R. et al., (2017), Panda and Naik (2017), Syuhaida N.I et al., (2019). There is also a noticeable distinction between the sexes of C. rotundicauda revealed from our morphometric analysis. Though the female species are both heavier and larger in every aspect, they are not significantly larger than the male species for the TEL size. A similar study has been studied in 2019 by Fauziyah et al., which also showed that unlike every parameter, the male species of C. rotundicauda have a bigger length of telson (TEL) than the female species.

The allometric analysis shows that male and female of C. rotundicauda in mangroves area of Cox's Bazar, were growing at different rates from the rest of the body. Differences in b values were found in relation to sex of horseshoe crab with statistically significant ($p<0.05$). Despite the body form pattern of the organism being described by growth allometric parameter, b value also has an impact in catching variation size at that sampling area (Kimmerer W et al., 2005). Application of length and width against weight relationships is the most important way to estimate the growth rate and condition of horseshoe crabs as well as the life cycle and histories from different regions of one species is detected through total length and body weight relationship (Moutopoulos DK et al., 2002).

The log-transformed data for length-weight and width-weight (TL-BW, PW-BW, CL-BW) relationships for both male and female horseshoe crabs from mangroves area of Cox's Bazar showed the increment of body weight more swiftly than the TL, PW and CL. These indicated that the environment along eastern coastal area is suitable for growth of horseshoe crabs (Vestbo S et al. 2018).

In case of length/width-length relationships (CL-PW, TL-PW, CL-TEL, TL-TEL) the allometric growth is negative except CL-PW for females which express an isometric growth. Such variation in length/width-length relationship is associated with habitat differences in C. rotundicauda (Srijaya TC et al., 2010). The length–length relationship in horseshoe crabs can be affected by seasonal effects and the discrepancies of habitat conditions in different locations (Md Razak et al., 2018)). The favorable environments allowing the growth of marine organisms have isometricity in all their body parts (Chatterji et al., 2014). The growth of C. rotundicauda could indirectly be influenced by population density, feeding efficiency, food availability, and local environmental conditions (Le Cren, 1951; Jawahir et al., 2017; Panda and Naik, 2017; Srijaya et al., 2010; Vijayakumar et al., 2000).

Biochemical Composition of Horseshoe Crabs

We are trying to analysis the biochemical composition of HSC by following standard method which are given Table 3.

Leucine was the most prevalent (0.5%) amino acids followed by isoleucine (0.3%) and valine (0.3%). Among the heavy metals, the amount of Copper (Cu) was recorded high (149 mg/kg), followed by Cadmium (Cd) and Lead (Pb). Mercury (Hg) was also recorded 34 µg/kg in the body of HSC. Protein concentration was recorded 7.6% in Horseshoe Crabs.

Table 3: Biochemical composition of Horseshoe Crabs

S/N	Parameter	Method/Instrument	Unit	Result
01	Total Amino Acid	LC-MS/MS	%	2.2
1.01	Phenyl Alanine	LC-MS/MS	%	0.2
1.02	Tyrosine			0.1
1.03	Leucine			0.5
1.04	Methionine			0.01
1.05	Isoleucine			0.3
1.06	Valine			0.1
1.07	Glutamic Acid			0.2
1.08	Proline			0.3
1.09	Threonine			0.02
1.10	Alanine			0.06
1.11	Aspartric Acid			0.00
1.12	Serine			0.03
1.13	Glycine			0.06
1.14	Histidine			0.001
1.15	Lysine			0.04
1.16	Glutamine			0.02
1.17	Arginine			0.08
02	Arsenic (As)	AOAC 2015.01	µg/kg	<dl*
03	Ash	AOAC 920.153	%	3.2
04	Cadmium (Cd)	AOAC 2015.01	mg/kg	2.2
05	Calcium (Ca)	AOAC 985.35	%	0.2
06	Carbohydrate	BY difference	%	0.52
07	Copper (Cu)	AOAC 999.10	mg/kg	149
08	Fat	AOAC 922.06	%	1.3
09	Iodine Content	AOAC 925.56	mg/kg	0
10	Iron (Fe)	AOAC 999.10	mg/kg	<dl*
11	Lead (Pb)	AOAC 2015.01	mg/kg	2.4
12	Magnesium (Mg)	AOAC 985.35	%	0.08
13	Mercury (Hg)	US EPA 7473	µg/kg	34
14	Moisture	AOAC 945.62	%	87.4
15	Protein	AOAC 981.20	%	7.6
16	Sodium (Na)	AOAC 985.35	%	0.6
17	Zinc (Zn)	AOAC 999.10	mg/kg	52.3

Note: Detection Limit (dl*) for As is 5 µg/kgand Fe is 0.3 mg/kg respectively.

Antimicrobial Activity of Haemolymph of Horseshoe Crabs

Haemolymph is collected by inserting a needle into a joint between the cephalothorax and abdominal region. Ten to 20 ml of the haemolymph per individual is drawn under sterilized condition, and the haemocytes/amoebocytes were collected by centrifuging pooled haemolymph at 2,500 rpm for 10 min. Haemocytes thus prepared are lysed and the lysate is used for endotoxin assay. On the basis of cell morphology, the haemocyte is an oval, and plate shaped structure, 15~20 µm in its longest dimension [Muta T, Iwanaga S Curr 1996; Kawabata, S., Muta, T. and Iwanaga, S. (1996)]. The cell contains numerous dense granules will be classed into two major types: large(L) and small(S) granules (Iwanaga S, Muta T, Shigenaga T, et al.,1994). The former is larger (up to 1.5 µm in diameter) and less dense than the latter (< 0.6 µm in diameter). The L-granules contain more than 25 proteins, the majority of which will have molecular masses between 8 and 123 kDa (Iwanaga S, Lee BL J, 2005; Osaki T, Kawabata S, 2004; Muta T, Iwanaga S 1996).

In contrast, the S-granules contain at least 6 proteins with molecular masses of less than 30 kDa, in addition to several antimicrobial peptides and their analogues, such as tachyplesins, tachystatins, tachycitins and big defensins, all of which show antimicrobial activities against Gram-negative and Gram-positive bacteria and fungi [Beisel, H.G., Kawabata, S., et al. (1999); Kairies, N., Beisel, H.G., et al. (2001)]. When the haemocytes will be exposed to LPS, it should result in cell adhesion and aggregation associated with rapid degranulation (Ariki S, Koori K, Osaki T., et al. 2004) and clot formation, the process should complete within 90 sec (Iwanaga S, 1993; Iwanaga S, Miyata T., et al. 1992). The clot is softer than mammalian fibrin clot and contains coagulin gel generated from its precursor, named coagulate (Iwanaga S, Thromb Haemost. 1993).

The haemolymph of Horseshoe Crab possess copper containing pigment which is able to quickly detect few nano grams of endotoxins. The present study revealed that it has been possible to identify some proteins and peptides in the blood of Horseshoe crabs through bioinformatics analysis which can be used to treat serious diseases like SARs COP virus, cancer etc.

Biomedical Uses of Horseshoe Crabs

Horseshoe crabs are crucial in biomedical applications, particularly for their blue blood, which contains Limulus Amebocyte Lysate (LAL). LAL is used to test medical equipment and vaccines for endotoxins, ensuring they are safe for human use. The LAL test exploits horseshoe crab blood's ability to clot in the presence of bacterial endotoxins. This sensitivity makes it a reliable method for detecting even tiny amounts of endotoxins in medical products, helping to prevent contamination and ensure the safety of pharmaceuticals and medical devices.

Apart from LAL, horseshoe crab blood is used in research related to immunology and cancer. The unique properties of their blood, such as the presence of coagulation factors, contribute to studies on the human immune system and the development of new medical treatments.

Horseshoe crabs also play a role in the field of vision research. Their compound eyes are studied to understand visual processes, and their unique photoreceptors have inspired advancements in optics and imaging technology. Furthermore, horseshoe crab hemocyanin, a copper-based respiratory pigment, has been investigated for potential uses in medicine, including as an oxygen carrier for transfusions and in wound healing applications. In addition to their biomedical contributions, horseshoe crabs play a vital ecological role. Their eggs are a crucial food source for migratory shorebirds, impacting the health of these bird populations. Horseshoe crabs are also of interest in the field of regenerative medicine. Researchers are studying their remarkable ability to regenerate damaged tissue, especially their exoskeleton and limbs. Understanding the mechanisms behind this regenerative capability could provide insights for developing regenerative therapies in humans. While this area of research is still in its early stages, it highlights the potential broader applications of studying and learning from the unique biology of horseshoe crabs. However, efforts are being made to develop alternative methods to reduce the impact on horseshoe crab populations. Additionally, the biomedical industry is exploring sustainable alternatives to horseshoe crab blood due to conservation concerns surrounding their populations. Research continues to uncover new ways to harness the biological properties of horseshoe crabs for diverse biomedical purposes. Sustainable practices and alternative testing methods are being explored to mitigate the impact on horseshoe crab populations while still meeting biomedical needs. Conservation efforts aim to balance the biomedical use of horseshoe crabs with the preservation of their habitats, recognizing the interconnectedness of these ecosystems.

Ecological Importance of Horseshoe Crabs

Horseshoe crabs play a crucial ecological role, especially in coastal environments. Their eggs serve as a vital food source for migratory shorebirds, contributing to the health of various bird species. Additionally, their feeding activities help control population levels of small invertebrates, influencing the balance of local ecosystems. Furthermore, horseshoe crabs are considered "living fossils" with a lineage dating back hundreds of millions of years, providing valuable insights into evolutionary biology and the history of life on Earth. Their presence also supports biodiversity by creating habitats for other species as they burrow in sediment. Horseshoe crabs contribute to nutrient cycling in coastal areas through their feeding and excretion processes, influencing nutrient availability in surrounding ecosystems. Horseshoe crabs are instrumental in nutrient cycling within coastal ecosystems as they consume detritus and small organisms, contributing to the breakdown of organic matter. Their presence helps maintain water quality by preventing excessive nutrient buildup. Moreover, their eggs provide a critical energy source for juvenile fish, influencing fish populations and supporting commercial and recreational fisheries. The intricate interplay of horseshoe crabs with various species underscores their ecological importance, making their conservation vital for the overall health and sustainability of coastal ecosystems. Conserving these ancient creatures is essential for maintaining the ecological balance and the health of coastal environments.

Causes of Declination of Horseshoe Crabs

The decline of horseshoe crabs in Asia as well as Bangladesh can be attributed to factors such as habitat loss due to coastal development, pollution affecting their breeding and feeding grounds, overharvesting for the biomedical industry (blood harvesting for Limulus amebocyte lysate used in endotoxin testing), and climate change impacting their reproductive success and migration patterns. Conservation efforts are crucial to address these threats and ensure the survival of horseshoe crab populations. Additionally, increased fishing pressure, both for human consumption and bait in the fishing industry, poses a threat to horseshoe crab populations. Destruction of nesting sites, where females lay their eggs, due to coastal development disrupts their reproductive cycle. Changes in water quality, including pollutants and contaminants, can impact their health and survival.

Conservation measures like habitat protection, sustainable harvesting practices, and public awareness campaigns are essential to mitigate these threats and support the conservation of horseshoe crabs in Bangladesh. Collaborative efforts involving local communities, governments, and scientific communities are crucial for effective conservation strategies. Furthermore, the disturbance of coastal ecosystems through activities such as dredging and shoreline alterations can negatively affect horseshoe crabs. Predation on their eggs and larvae by other species, as well as the spread of invasive species, may also contribute to population declines. Additionally, the interconnected nature of ecosystems means that changes in one area can have cascading effects on horseshoe crab populations.

The global decline in horseshoe crab populations is mainly due to anthropogenic activities. For L. polyphemus the decline has primarily been due to overharvesting and loss of breeding habitat (Smith et al., 2017), as this species breeds on beaches with slight slopes; a habitat commonly used for real estate construction and development (Nordstrom, 2006). Coastal armouring as a response to erosion is an additional factor reducing available breeding habitat (Jackson et al., 2015). Wild caught horseshoe crabs are used commercially in medicine, where substances from their haemolymph (Carcinoscorpius, Limulus, and Tachypleus Amoebocyte Lysate, CAL, LAL, and TAL) are used to test if drugs, blood products, and pharmaceutical devices are

free from bacterial contamination (Levin and Bang, 1968; Rao and Bhagirathi, 1989; Levin et al., 2003).

As for L. polyphemus, the expansion of urban infrastructure into coastal areas, as well as coastal armouring present additional anthropogenic habitat disturbances for the Asian horseshoe crabs, thus in some areas, such as Japan and Peninsular Malaysia, horseshoe crab breeding habitats are now almost completely lost due to coastal infrastructure development (Botton, 2001; Nelson et al., 2016). In response to the declining horseshoe crab's populations, Marine Protected Areas (MPAs) have been established, especially in the USA (Carl N. Shuster Jr. Horseshoe Crab Reserve, Delaware Bay) and Japan (Saikai National Park in Nagasaki). However, in most of South Asia MPAs protecting critical horseshoe crab habitats are still scarce.

Human activity probably accounts for the greatest proportion of adult horseshoe crab mortality. Between the 1850s and the 1920s, over one million horseshoe crabs were harvested annually for fertilizer and livestock feed (Shuster, 1982; Shuster and Botton, 1985). Reported harvests in the 1870s were four million horseshoe crabs annually. Between 1880 and 1930, the harvest was 1.5 to 1.8 million animals (Finn et al., 1991). Shuster (1960) reports that in the late 1920s and early 1930s 4 to 5 million crabs were harvested annually. Shuster (1960) reports over one million crabs were harvested annually during the 1940s and 500,000 to 250,000 horseshoe crabs were harvested each year in the 1950s.

Coastal and intertidal areas are currently under threat globally due to a range of anthropogenic activities, including infrastructure development and coastal protection, as well as effects of climate change, such as rising sea levels pushing coastal areas closer to anthropogenic structures, resulting in "coastal squeeze" (Defeo et al., 2009). Coastal areas are characterized by high productivity and species richness (Ketchum, 1972; Ray, 1991), and humans depend strongly on a variety of species that are living and reproducing in the coastal zone, such as fishes (Allison et al., 2009; Bell et al., 2009), sea cucumbers (Purcell et al., 2013), and horseshoe crabs (Chatterji, 1994), thus the conservation of such species is of great importance. According to Biswal et al., 2016 a recent territory-wide survey showed that the density of juvenile horseshoe crabs on nursery shores in India has significantly reduced due to loss of tidal flats and spawning beaches, and the deterioration of quality of coastal waters.

Climate change-induced sea level rise and alterations in temperature and ocean currents can impact the distribution and availability of suitable habitats for horseshoe crabs. These environmental changes may disrupt their migratory patterns and affect the success of spawning events. To address these complex challenges, comprehensive conservation strategies should consider both local and global factors, incorporating sustainable practices, habitat restoration, and international cooperation to ensure the long-term viability of horseshoe crab populations in Bangladesh.

Conclusion

The study underscores the significance of horseshoe crabs in marine ecosystems, particularly in estuarine and coastal communities. The observed morphometric variations in C. rotundicauda highlight potential links to population dynamics, food availability, and environmental factors. The research aims to enhance our understanding of horseshoe crab population biology and ecology, essential for implementing effective conservation measures. Immediate action by local government agencies, including legal protection and community education, is crucial to safeguard this unique creature from further decline along the Bangladesh coastline. Continued research and monitoring are essential for the sustainable management and long-term conservation of horseshoe crab species.

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5

CHAPTER

BIOLOGICAL OCEANOGRAPHY DIVISION

OPTIMIZATION OF AGAR AND CARRAGEENAN EXTRACTION CONTROL AND CONTINUATION OF SEAWEED TAXONOMIC STUDY

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Abstract

Seaweed has been part of the common diet of many South East Asian countries since ancient times. While the discovery of hydrocolloids, exclusively agar and carrageenan, added new dimensions to a wide range of industrial sectors because of their unique gelling, thickening, and stabilising properties in aqueous solutions. Primarily, the commercial agar is extracted from the Gracilaria, Gracilariopsis, Gelidium, on the other hand, carrageenans from Eucheuma, Kappaphycus, Gigartina, Chondrus, and Hypnea in different parts of the world. In Bangladesh, Saint Martin's Island is the hotspot for diverse natural seaweed growth from November/December to April/May. But still, the phycocolloid seaweeds are unexplored in Bangladesh. In this investigation, the targeted potential agarophyte and carragenophyte samples were collected from natural habitats and pre-set seaweed attaching materials (rope, and net) from the low intertidal and Subtidal zones of different locations. The occurrence and distribution of the phycocolloids were not similar around the island. The Agar and carrageenan were extracted from the processed samples at the Bangladesh Oceanographic Research Institute (BORI) laboratory to explore commercial seaweeds for sustainable Blue Economy development extension. The maximum agar yields for the dry biomass were Gracilariopsis lemaneiformis 14.56±0.53%, Gracilaria gracilis 48.57 ± 0.54% Gracilaria canaliculated 12.32±0.24, Gracilaria blodgettii 38.65±0.71%, and Gracilaria textorii 17.26±0.26%. While the carrageenan yields from the dry biomass from Hypnea cervicornis was 37.98±0.43, Hypnea valentia 34.51±0.32%, Chondrus crispus 31.32±0.62%, and Halymenia Dilatata 8.11±0.58%.

Keywords: Explore, agarophyte, carragenophyte, extraction, agar, carrageenan, optimization.

Introduction

Seaweed are phototropic, multicellular, macroscopic or macroscopic, marine flora that grow on solid substratum. Seaweed are not a true plant because they do not have vascular tissue system, true roots, stems and leaves instead of these they have holdfasts, stipes, blades accordingly (and air bladders in some seaweed). The whole body of a seaweed is called thallus. All the parts of a seaweed deeps or submerged in the water, it doesn't need an internal transport tissue system as of terrestrial plants do; they absorb what they need directly from the water through surface tissues. Seaweed are divided into 3 major groups on the basis of color, these are red seaweed (Chlorophyta), brown seaweed (Phaeophyta) and green seaweed (Rhodophyta). Seaweed are distributed around the marine and shallow coastal waters and on rocky shores. They grow on substratum surface like rocks and stones, shells, shells, corals, sand and on other plants like mangroves; submerged anthropogenic hard structures and materials as well as ropes, net depending on water conditions. Only a few species of green algae are seen in and around the mangrove sites and coastal structures, along the coastal area of Bangladesh while water clarity, salinity and temperature became favourable during post-monsoon to pre-monsoon season. There is a small patch of red seaweeds bed at Nuniarchora of Cox's Bazar and Ghotivanga and Chorpara of Moheshkhali. But, Saint Martin's island is the hotspot of seaweed and occurs from September/October to May.

Commercial seaweed refers to the seaweed that are well accepted as human foods, cosmetics, fertilisers, and for the extraction of industrial gums and chemicals (Zhou and Ragan 1995; Cheney and Kurtzman1992; Tseng 1944; Renn 1997; Venugoapl 2009; Cheong-Xin Chan, et al., 2006). A total of 221 species of seaweeds are recognized as commercially important of which, 125 Rhodophyta, 64 Phaeophyta and 32 Chlorophyta. Among them 145 species are consumed as food of which 79 Rhodophyta, 38 Phaeophyta and 28 Chlorophyta. There are 101 potential seaweeds identified for phycocolloid extraction (41 alginophyte, 33 agarophyte and 27 carragenophyte). Among the commercial seaweeds 24 species are used as traditional medicine and skin care, 25 species in agriculture, animal feed and fertilizers.

Seaweeds are popular in many eastern countries like Japan, China, Philippine, Korea, Indonesia, Malaysia, Vietnam, Thailand, and Myanmar since prehistoric times (Critchley, et al., 2006) as food. It's popularity as food is growing in many coastal countries of Europe, America and Africa. Research on seaweed discovered it as a super food since they are rich in nutrition (such as carbohydrate, protein, fiber, omega lipids, vitamins, and

numerous macro, micro and tress minerals). They are also being consumed in many European, Africana and American countries coastal societies for potential rich nutrition and are becoming popular being treated as "superfoods".

Demand of seaweed is increased after, the discovery of hydrocolloids especially agar and carrageenan opened new windows in pharmaceuticals, cosmetics, and toiletries as we as food and beverage industry sectors. The growing demand for (hydrocolloids) agar and carrageenan promote seaweeds to be a prospective candidate in the blue economy for their multidimensional uses in many different industries in recent years. Phycocolloids are certain Hydrocolloid (a colloid system wherein the colloid particles are hydrophilic polymers dispersed in water) polysaccharides (heterogeneous group of long-chain polymers of polycarbohydrates) that are derived from some red seaweeds. Many of the seaweed has hydrocolloid, anti-biotic, anti-fungal, anti-obesity, anti-cancer, anti-obesity, insecticidal properties. As a source of phycocolloids (agar, carrageenan, and alginates) seaweed demand is great at industrial level. In recent years, the demand of seaweed increased dramatically as their product is used as raw materials in various industries like, pharmaceutical, cosmetics, toiletries, food & beverages, food processing, paint and dye, as well as microbiological and molecular research.

Ecological services of seaweed are remarkable since they produce oxygen, great actor of carbon sinking, regulates eutrophication; provide food and shelter for many other associated organisms, acts as a nursing ground of many marine fauna, enrich aquatic habitat. Being a marine bio-indicators maintain ecosystem balance, enriches and protects marine biodiversity.

Discovery of agar (a hydrocolloid) is an interesting incident in 1658 when, a Japanese innkeeper named Minoya Tarazaemon, noticed that some unused remains of a seaweed soup gelled, during a cold winter night after being thrown away (Matsuhashi, 1990). In the recent world, the development and application of agar is multidimensional in different sectors. It was first described for use in microbiology in 1882 by the German microbiologist Walther Hesse, Robert Koch's laboratory assistant, at the suggestion of his wife Fanny Hesse. Armisen & Galatas (2009) reported that agar is used in the human food industry for its hydrophilic colloid property, 80% of its consumption while the remaining 20% is used for biotechnological applications. The agar gel in strengths greater than 700 g/cm2 (1.5% solution) is referred to as the best quality agar and is most demanded in the international market (Armisen, 1995). The use of agar in different industrial products depends on its chemical composition (sugar, methoxyl sulphate etc. contents) which is significantly subjected to the extraction control in processing (Pereira-Pacheco, et al., 2007). The Gracilaria are the major agar source worldwide (McHugh, 2002) and numerous studies have been conducted on the agar yield quality from different geographical areas (Freile-Pelegrin & Murano, 2005; Marinho-Soriano, 2001; Falshaw, et al., 1999; Marinho-Soriano, et al., 1999; Doty, Santos, & Sin, 1983). While carrageenans were introduced in food and beverage manufacturing industries on large scale in the early ninety's but they were known to be used in China since around 600 BCE (Pérez-Lloréns, et al., 2020) and in Ireland around 400 CE (Loureiro, et al., 2017; Mitchell & Guiry 1983. Although the application of Irish moss (carrageenans) extract was reported in 1837, its formal production was initiated only in the 1930s in the United States (FAO1). A total of 101phycocolloid species are identified for industrial hydrocolloid production (Zemke-White & Ohno, 1999).

Agar (agar-agar) is a jelly-like, semi-solid gelatinous (hydrocolloid) substance generally used as a solidifying agent and/or media. Agar is a boiling water soluble compound that forms into gel at 32–40 °C and does not melt below 85 °C (Bixler and Porse, 2011; Meena et al., 2008; Marinho and Bourret, 2003; Freile and Murano, 2005; and Sousa et al., 2010). Agar is a cellular compositions of certain red seaweed to support the cell wall, which can be released from the cell wall, extracted through processing and commercially available in the form of flakes, powders, sheets bars and threads. The commercially extracted agar is a mixture of the linear polysaccharide agarose and a heterogeneous mixture of smaller agaropectin molecules. The agar-yielding seaweed is commonly known as agarophyte. Agar is a polysaccharide mixture consisting of two basic structures, (I) high-gelling natural polymer agarose (70%) and low-gelling sulfated polysaccharide agaropectin (30%). Natural Agarose, is a linear repeating disaccharide agarobiose (d-galactose and 3,6-anhydro-lgalactopyranose) unit.

Importance of agar is worldwide. Some of the common uses of agar are:

- In chines culinary and desserts ingredients,
- As jelly in making desserts like puddings, custards, faluda, buko pandan, agar flan, halo-halo, fruit cocktail jelly, and in various fruit salads
- As thickener for soups, in fruit preserves, ice cream, and other desserts
- As a clarifying agent in brewing, and for sizing paper and fabrics.
- As a laxative, an appetite suppressant, a vegetarian substitute for gelatine
- In microbiology as a solid substrate to contain culture media for microbiological work for Motility assays

• Plant biology for supplemented with a nutrient and/or vitamin mixture that allows for seedling germination

• As an impression material in dentistry.

• As a medium to precisely orient the tissue specimen and secure it by agar pre-embedding for histopathology processing

• To make salt bridges and gel plugs for use in electrochemistry.

• as a transparent substitute for sand and a source of nutrition.

• As a natural ingredient in forming modeling clay for young children to play with.

• As an allowed biofertilizer component in organic farming.

• As a substrate for precipitin reactions in immunology.

• As a substitute for gelatin in photographic emulsions, arrowroot in preparing silver paper and as a substitute for fish glue in resist etching

Carrageenans are natural semi-solid hydrocolloid agents extracted from edible red seaweeds (commonly known as Irish Moss). Carrageenan forms in several red seaweeds to support the cell walls structure that can be released and extracted. Carrageenans are widely used as additives to thicken, emulsify, and preserve foods and drinks in many food and beverage manufacturing industries. In recent years, scientists discovered native glycosaminoglycans (GAGs)in carrageenans as a prospective component that can widely be used in tissue engineering, drug delivery, wound coverage regenerative medicine, and biotechnological applications. On the basis of chemical structure, Carrageenan is a hot water soluble linear, sulphated galactan. It is composed of alternating 3-linked b-D -galactopyranose and 4-linked a-D -galacto- pyranose or 4-linked 3,6-anhydro-a-D-galactopyranose, thus forming their disaccharide repeating unit (Usman et al., 2017; and Knutsen et al., 1994 & Knutsen et al., 1995). The galactose and sulphate groups, other carbohydrate residues (Viz., uronic acids glucose, or xylose,) and substituents (viz., pyruvate groups, and methyl ethers) may also be present (Van De Velde et al., 2002). On the basis of the number and position of sulphate groups, and the presence of 3,6-anhydro-bridge in galactose residues, the polysaccharides are typically classified into ten basic forms but the most known are these six groups, namely iota-(ι), kappa-(k), lambda-(l), mu-(m), nu-(n), and theta-(q) carrageenan (Knutsen et al., 1994 & 1995; Cardozo et al., 2007; Kraan, 2012; Lahaye, 2001; Cunha, & Grenha, 2016; and Li, & Shao, 2014). Commercial carrageenans are 3 types iota-(ι), kappa-(k) and lambda-(l) carrageenan. In general, the Carrageenan-yielding seaweed is commonly known as Carragenophyte (Carrageenan containing red seaweed).

Carrageenan are widely as a rawmaterial in many different type of industries

• Application in food industry is worldwide for their gelling, thickening, and stabilizing properties.

• Used in many food and desserts preparation like; carrageen, ice cream, cream, milkshakes, yogurts, salad dressings, sweetened condensed milks,

• Used in dairy and meat products due to their strong binding with food proteins.

• It is emerged as a promising candidate in tissue engineering and regenerative medicine applications as they resemble native glycosaminoglycans (GAGs).

• Widely used in tissue engineering, wound coverage and, drug delivery

• Used in sauces to increase viscosity

• Used in beer as clarifier to remove haze-causing proteins

• Used in pates processed meats (e.g., ham) as a substitute for fat, to increase water retention volume and to improve slicing

• Used in toothpaste as stabilizer to prevent constituents separating

• Used in fruit Gushers as an ingredient in the encapsulated gel

• Used in firefighting foam as thickener to make foam sticky

• Used in skincare cosmetic creams as thickener

• Used in shoe polish to increase viscosity

• In biotechnology to immobilize cells and enzymes

• In pharmaceuticals as an inactive excipient in pills and tablets

• In soy milk and other plant milks as thickener

• In diet sodas to enhance texture and suspend flavors

• In Pet food as binder

• Used for personal lubricants in health care industries

Phycocolloids (agar or carrageenan) extraction controls, involves the leaching hydrocolloid content from seaweed to water, separating them from water (Armisen & Galatas, 1987), washing and drying. The principles of agar or carrageenans extraction are similar (Andriamananatonio, Chambat, & Rinaudo, 2007; Arvizu Higuera, et al., 2008; Freile-Pelegrin & Murano, 2005; Li et al., 2009; Marinho-Soriano, 2001; Orduña-Rojas et al., 20081; Pereira-Pacheco et al., 2007; Tako, et al., 1999). The extraction control variables magnitude may differ even for the same species, the change in extraction variables frequently affects agar yield and its properties (Arvizu-Higuera et al., 2008; Hurtado-Ponce, 1992; Pereira-Pacheco et al., 2007). The extraction controls have impact on agarophyte and carragenophyte species in their respective extractions (Arvizu-Higuera et al., 2008; Hurtado-Ponce, 1992; Pereira-Pacheco et al., 2007; Duckworth, Hong, & Yaphe, 1971; Freile-Pelegrin & Murano, 2005; Freile-Pelegrin & Robledo, 2011;

Orduña-Rojas et al., 20082). Therefore, it is essential to standardize the extraction process to optimize the agar yield and quality for future industrial development.

The taxonomic study on seaweed is the basic for phycology. It is urgent to know the appropriate species for any specific biochemical composition extraction from seaweed. Algae base is one of the most popular web portal for seaweed taxonomic guides and information which, is updated on a regular basis. According to Guiry & Guiry, (2022) there are About 12,000 seaweeds have been identified (described till to date- August 2022), of which more than 7,000 red algae over 2,000 brown; some 1,500 green; and 1,500 blue-green algae. Among the seaweeds, 221 species (32 Chlorophytes, 125 Rhodophyta and 64 Phaeophyta) are recognized as commercial species globally (Zemke-White & Ohno, 1999).

Bangladesh Oceanographic Research Institute (BORI) is working to explore commercial seaweeds for sustainable uses since 2018. A total of 143 seaweeds were identified from Saint Matrin's Island under the Research and Development (R&D) projects of which 38 Chlorophyta, 71 Rhodophyta and 34 Phaeophyta species.

The present study was designed to explore commercial Agarophyte and Carragenophyte seaweeds from Saint Martin's Island and extract respective hydrocolloid. The extraction of agar and carrageenan depends on several conditions, were observed. This investigation would play a significant role in developing agar and carrageenan production industries as a part of exploring commercial seaweeds for sustainable blue-economy establishment and reaching the SDG targets for Bangladesh. The extraction process for agar and carrageenan were optimized in this investigation.

Objectives of the present investigation was conducted to:

• Explore potential Agarophyte and Carragenophyte through experimental hydrocolloid extraction

• Extraction of agar and carrageenan form respective Agarophyte and Carragenophyte

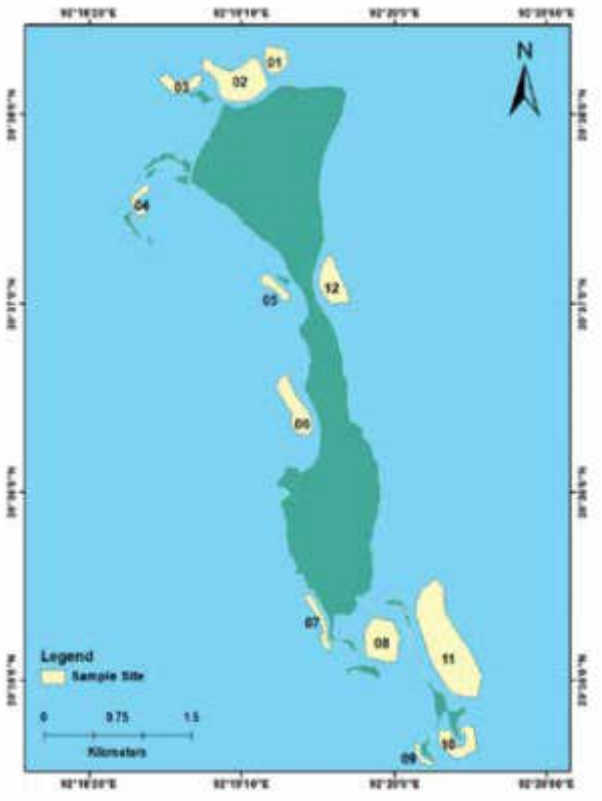
• Optimization of agar and carrageenan extraction control

• Continuation of seaweed taxonomic baseline study

Materials and methods

Study area

Geographically Saint Martin's Island is the most suitable habitat for seaweed natural growth in Bangladesh. These occur naturally surrounding intertidal, subtidal, and shallow neritic areas on rocks and corals from October/ November to May/June when the environment becomes favourable (Islam, 1970; 1974, and 1976; Aziz and Islam, 2009). The present study aims to explore hydrocolloid-containing seaweed available around Saint Martin's Island. The targeted agarophyte and carragenophyte were recorded in certain confined locations but their availability was poor or. Considering the previous experiences, the study was designed to visit the place and find the target samples (Map 1). At the same time, three different types of seaweed attaching materials are placed in the same locality to observe and collect the target specimen for the study in early January 2022.



Map 1: Map showing sampling sites at Saint Martin

Sample collection:

Sampling from natural habitat: Seaweed samples were collected from 4 sites by diving and snorkeling and 2 sites of intertidal shore sample collection were conducted by direct visit. The occurrence and availability of seaweed samples are not frequent. The sampling cruise were conducted from January to May. The collected target samples were initially kept in a separate net bag or Ziploc Polly bag. The in-situ target seaweed images were captured from underwater and intertidal sampling locations.

Sampling from artificial-set material: Four types of seaweed attaching material were placed in the selected lower intertidal and sublittoral zone at a depth of 0-2 meters. These are (1) Marine, Commercial, Utility Rope 2m long and 120mm dia, (2) Used Old fishing net, about 30-50 cm (3) Thin nylon rope 2m long and 5/6mm dia, (4) commercial nylon rope 2m long and 10-15mm dia and (5) The Gudda (anchoring material) were placed in

the site for attaching samples (Fig 1-6). The locally available fishing net weight material called Gudda was tied at one end of the rope and keep it in the soil for about 8-12 inches and the rest remain on the bottom surface to grow seaweed. These artificial materials were checked every month and the target samples were harvested and the rest were cleaned during the investigation.

Fig 1: Rope, Old Fishing Net and Thin Nylon

Fig 2: Thick Nylon and Gudda (anchoring material)

Fig 3: Rope attaching Gudda

Fig 4: Thick Nylon attaching Gudda

Fig 5: Net on Gudda

Fig 6: Thin nylon on Gudda

Sample processing at Saint Martin: The collected samples were immediately transferred to the temporary lab at the hotel (Saint Martin). The samples were washed and sorted further to remove unwanted species and other materials carefully. Finally, they were washed again and transferred to the dryer, labelled/tagged with code and placed in the shed. Some small part of the same samples was kept in three different vail for scaled photography (detailed and scaled image were captured at the hotel lab), preserved in 5-6% formalin and preserved in 70% alcohol (ethanol) with the same sample ID code and label/tag. All the samples were finally transferred to the BORI laboratory for further analysis.

Sample processing at BORI

The dry samples were soaked for 4 to 6 hours, carefully sorted, cleaned and washed under running tap water for 3 to 4 hours to remove all the salts and sand particles. Then samples are placed in a dryer for air drying for 4 to 6 hours and placed in an oven for further drying at 60° C temperature for 6 to 8 hours. The oven dry samples are kept in Ziploc and stored for further analysis of agar and carrageenan extraction.

Seaweed morphometric identification:

The formalin preserved samples were washed and observed under a microscope and identified following the algaebase.org, marinespecies.org, Macro-algal Herbarium Consortium Portal, high-impact journal articles and identification manuals and corresponding scientists around the globe.

Experimental Phycocolloids extraction:

- Agar Extraction after (Armisen and Galatas, 1987 recommended by FAO) Method: [Hot Water Extraction Method] / [Boiling Method]
- Carrageenan Extraction after (McHugh, 1987) recommended by FAO Method: [Potassium Precipitation method]

Photography:

Underwater still images were captured by OLYMPUS TG-6 and Sony a7II Camera using respective housing; while underwater video shoots were captured by GoPro Hero 10 Action Camera and OLYMPUS Tough TG-6. In the laboratory, the scaled sample images were captured by Sony Cyber-shot DSC-RX10 Digital Camera and the Sony a7II Mirrorless camera.

Results and Discussion:

Seaweed is a potential sector of the blue economy around the globe. Considering the commercial importance, seaweed can be classified into edible seaweed and industrial seaweed. In Bangladesh, we are little far from its commercial uses. Only a few Rakhine at cox's Bazar and Chakma community from Chittagong hill tracts of Bandarban district accept seaweed as food in a different form. In recent years, different government and non-government organizations are working to make it popular as food. The Bangladesh Oceanographic Research Institute (BORI) is investigating to explore commercial seaweed for potential biochemical compositions which have industrial uses. In this regard BORI biological division took some short, mid and long-term initiatives (Fig: 7) that can play a significant role in blue economy perspectives. In Bangladesh, Saint Martin's Island is the hotspot for diverse natural seaweed growth from November/December to April/May.

In the present study, the sampling cruises were conducted from January to April/May for 6-7 days in each month. The team travelled to Saint Martin by tourist ships while it was available, and need to hire local service boat. A small team also visited Saint Martin in early December to set rope/net materials (for seaweed attachment) in three different places.

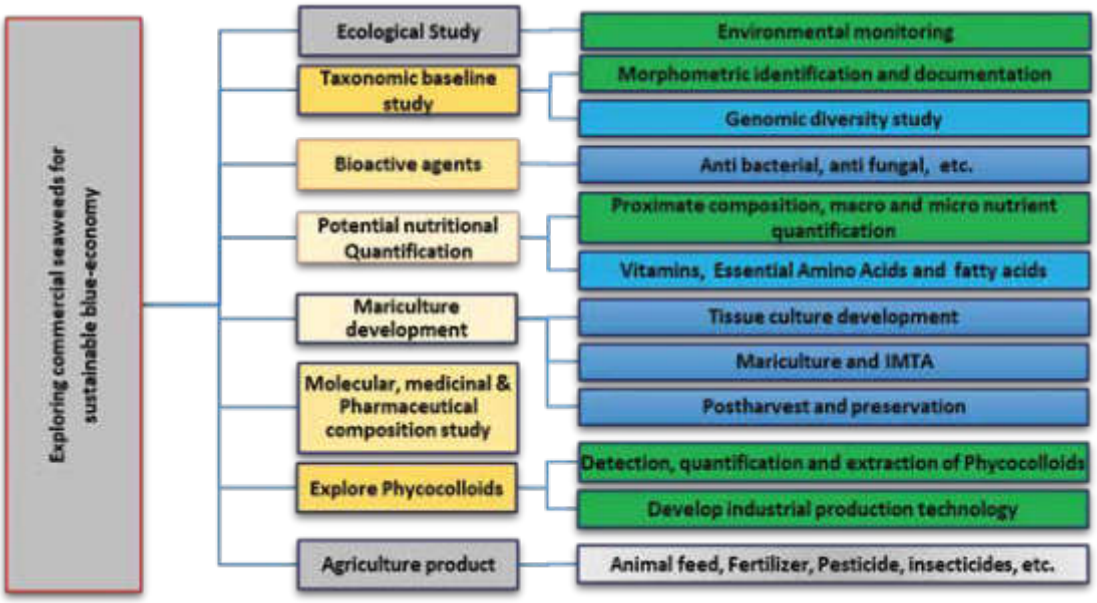


Fig 7: Short, mid and long-term initiatives from BORI to explore commercial seaweeds for sustainable blue-economy

The study was designed to collect agarophyte and carragenophyte seaweed samples from different locations of low intertidal and subtidal zone by snorkeling and spot visit. During the sampling representatives of seaweeds were also collected as a part of the taxonomic baseline study. It was observed that agarophyte and carragenophyte seaweed abundance was relatively poor for in January. It is important to note that excessive tourists somehow disturbance for seaweed growth in the lower intertidal areas. Again some curious tourists removed the pre-set rope materials that were placed in early December.

The morphometric identification of seaweeds is a part of the seaweed baseline study. It is urgent to know the seaweed properly. Under this taxonomic study a total of 143 seaweed specimens are recorded from the waters of Saint Martin's Island of which 38 Chlorophyta, 71 Rhodophyta and 34 Phaeophyta. There are some cryptic seaweed makes seaweed identification difficult only by morphologic examination. It was observed that the shallow intertidal and subtidal zone is suitable for Chlorophyta growth; Rhodophyta occurs most in the subtidal zone up to 14m depth and Phaeophyta was mostly available at a depth from 0 to 8m depth zone around the island. The distribution pattern of seaweed is not similar in each sites of the island. There are 165 species (38 Chlorophyta, 5 Chrysophyta, 46 Phaeophyta, 49 Rhodophyta and 27 Cyanophyta) recorded along the coastal waters of Bangladesh (Islam, 1976). In next, Aziz, Towhidy, & Alfasane (2015) recorded 200 species under 77 genera (47 Chlorophyta, 49 Phaeophyta and 94 Rhodophyta). Further, Aftab et al., 2019 reported 150 species (29 Chlorophyta, 43 Phaeophyta and 78 Rhodophyta) from the Bangladesh coast and Islam et al., 2019 reported 132 species (28 Chlorophyta, 35 Phaeophyta and 69 Rhodophyta) from Cox's Bazar coast of Bangladesh. Oza and Zaidi (2001) updated the Indian seaweed checklist and reported a total of 844 species (216 Chlorophyta, 194 Phaeophyta and 434 Rhodophyta) occur in India. In the case of Myanmar, a total of 307 species under 122 genera of seaweeds were recorded (Soe-Htun, Kyaw, & Wai. 2021) and a total of 440 taxa, belonging to 148 genera were recorded from Sri Lanka (Baldwin ed., 1991; Silva et al., electronic version).

The present experiment was more focused on agar and carrageenan extraction from targeted potential agarophyte and carragenophyte seaweeds. It was reported that there are 221 commercial seaweeds of which 32 Chlorophyta, 125 Rhodophyta and 64 Phaeophyta. Between the seaweeds145 species (i.e. 66%) are directly consumed as the food of which 28 Chlorophyta, 79 Rhodophyta, and 38 Phaeophyceae; again, 101 species are used in the phycocolloid industry of which 33 agarophyte, 27 carragenophyte and 41 alginophyte; further, 25 species in animal feed, fertilizer and agriculture; 24 species in traditional medicine; 12 species in another agronomy (Pereira, et al. 2009; Zemke-White and Ohno, 1999). Further, it was reported that globally 291 species are used in 43 countries (Tiwari, & Troy 2015) and 95% of industrial seaweed (used in food & beverages, pharmaceuticals, and cosmetics, toiletries animal feed additives, personal care, and agricultural fertilizers) comes from farming (FAO. 2018). It was also observed that commercial seaweed especially agarophyte and carragenophyte has a wide market and is increasing rapidly. The price of hydrocolloid always depends on its quality. And again the hydrocolloid extracted from the same species differs in geographical locations as well as extraction conditions. In the present study, the agar and carrageenan-containing seaweeds were explored.

Agar yield

Agar is a structural component of cell wall in many red seaweeds. Among them more than half of the commercial agar comes from Gracilaria (McHugh, 1991). In the present study a total of 5 agarophyte were found from Saint Martin's Island. These are Gracilariopsis lemaneiformis, Gracilaria gracilis, Gracilaria canaliculated, Gracilaria blodgettii, and Gracilaria textorii. The agar extraction was by FAO recommended standard hot water extraction method commonly known as boiling method (Armisen and Galatas, 1987). The extracted agar was dried and milled according and preserved in air tied falcon tube for further study Fig 9. The extraction yield for each samples are detailed bellow.

Figure 8: figure showing extracted agar

Gracilariopsis lemaneiformis

The Gracilariopsis lemaneiformis samples were collected from Mudirchora Moheshkhali cultivation site. It was observed that the agar yield within Gracilariopsis lemaneiformis differs from geographical locations as well as extraction conditions. In the present experiment, the agar yield from dry biomass for Gracilariopsis lemaneiformis were 8.95±1.65% to 14.56±0.53% in different control conditions. While agar in Gracilariopsis lemaneiformis was extracted 16.08% (Chen et al., 2020) from Chain, 22.4-28.4 % (Pei etal., 2012); 25-29% (H. Li, Yu, et al., 2008); 12-15% (Qiong Xiao et al., 2018 & 2019) from China, 25.8% (González-Leija et al., 2009a) from the Gulf of California, 21-35% (Chirapart, Katou, et al., 1995) from Japan, 9.9% (Chirapart, Ohno, et al., 1995) from Japan, 8.1-15.4% in autumn and 35.5 to 47.8% in winter (Fausto Arellano-Carbajal et al., 1999) from Mexico. In this investigation, Gracilariopsis lemaneiformis agar yield percentage showed competition among the records of other countries.

Figure 9: Gracilariopsis lemaneiformis

Gracilaria gracilis

The Gracilaria gracilis samples in the investigation were collected from Saint Martin's island low intertidal zone. It does not occur frequently. Considering the occurrence, three types of materials (soft rope, nylon rope and used old fishing net) were set in of sample low intertidal and subtidal zone where they usually grow. Within the materials only used the old fishing net and soft rope responded well for their growth. In the present experiment, the agar yield from dry biomass from Gracilaria gracilis were 07.89 ± 0.22% to 48.57 ± 0.54% in the trial of different control and conditions. It was also clearly observed that Gracilaria gracilis agar yield varies with the geographical distribution. The agar yield from Argentina was 27- 34% (Rodríguez et al., 2009), from Brazil 30 - 34.8% (Marinho-Soriano, 2001), from Russia 36.8–46.6% (Skriptsova & Nabivailo, 2009), from Portugal 13% (Silva-Brito et al., 2021), 20.5% and from Morocco coast 15.6% (Belattmania. et al. 2021).

Figure 10: Gracilaria gracilis

Gracilaria canaliculata

The Gracilaria canaliculata samples in the investigation was collected from the upper subtidal zone of Saint Martin's island this species was found only in March. In the present experiment, agar yield percentages from Gracilaria canaliculata dry biomass were 6.41±0.33 to 12.32±0.24%. It was observed that the agar yield from Gracilaria canaliculata dry biomass was 31.07% from Hawaii (Santos & Doty, 1983) and 22.9%-27.1% from the India (Selvavinayagam & Dharmar, 2018).

Figure 11: Gracilaria canaliculata

Gracilaria blodgettii

The Gracilaria blodgettii samples in the investigation was collected from the lower intertidal to subtidal zone of Saint Martin's island this species was found in March and May. In the experiment agar yield was 7.95±0.67 to 38.65±0.71%. The agar yield from Gracilaria blodgettii is reported 27.66% from Mexico (Freile-Pelegrín & Murano, 2005); 15-21% and from Philippines (Hurtado-Ponce, 1992), and 14.75% from Hawaii (Santos & Doty, 1983).

Figure 12: Gracilaria blodgettii

Gracilaria textorii

The Gracilaria textorii is another a potential agarophyte because of its higher percentage of agar yield collected from Saint Martin's natural bed and pre-set material of rope and net. The experiment results 5.31±0.81 to 17.26±0.26% agar yield dry biomass in experimented control condition. Whereas, dry biomass agar yield was 36.3% from china (Minghou. et al., 1988); 10.3±0.3 to 8.8±0.3% from India (Oza M D et al., 2011).

Figure 13: Gracilaria textorii

Carrageenan yield

In the present investigation only 4 carragenophyte were found from Saint Martin. It is important to mention that among the carragenophyte Kappaphycus is one of the most popular one. Unfortunately, it is very rear in our locality. In the present study Hypnea cervicornis, Hypnea valentiae, Chondrus crispus, and Halymenia Dilatata were considered for carrageenan extraction following FAO recommended standard extraction method after (McHugh, 1987).

Hypnea cervicornis:

The Hypnea cervicornis samples in the investigation were collected from the lower subtidal zone of Saint Martin's island this species is available from February. In the present experiment, the carrageenan yield percentage from Hypnea cervicornis dry biomass was 9.96±0.65 to 37.98±0.43. It was observed that the agar yield from Hypnea cervicornis dry biomass were 36.0±1.3 to 61.8±1.1 from china (Han, J. et al., 2021)

Figure 14: Hypnea cervicornis

Hypnea valentiae

The Hypnea valentiae samples in the investigation were collected from Saint Martin's island low intertidal zone. It does not occur frequently. Considering the three types of materials (soft rope, nylon rope and used old fishing net) were set in of sample low intertidal zone where they usually grow. Within the materials only used the old fishing net and soft rope responded to their growth. In the present experiment, the carrageenan yield from dry biomass from Hypnea valentiae was 12.65±0.39 to 34.51±0.32% in the trial. It was also observed that Hypnea valentiae carrageenan yield varies with the geographical distribution. The carrageenan yield from India was 34.5±1.35% (Ushakiran et al. 2021), from Pakistan 18-46.93% (Qari R. et al., 2018), from Mexico and 43.0% (Freile-Pelegrín, Azamar & Robledo 2011). Importantly the carrageenan extraction control parameter is not the same for all the experiments in different countries.

Figure 15: Hypnea valentiae

Chondrus crispus

The Chondrus crispus can be a potential carragenophyte because of its higher percentage of carrageenan yield; collected from Saint Martin's natural. The experiment results 16.43±0.52% to 31.32±0.62% carrageenan yield from Chondrus crispus dry biomass, Whereas, whereas dry biomass carrageenan yield was 23.3±0.6 to 24.2±0.5% yield from Portugal (Pereira, 2013); 37.4±1.68 to 29.13±0.76% from Spain (Oza M D et al., 2011).

Figure 16: Chondrus crispus

Halymenia Dilatata

The Halymenia Dilatata was collected from Saint Martin's natural bed from a depth of 2-8m. The experiment results 1.92±0.67 to 8.11±0.58% carrageenan yield from Halymenia Dilatata dry biomass, Whereas, whereas dry biomass carrageenan yield was 9.74±0.93% yield from Philippines (Minghou. et al., 1988) and 10.3±0.3 to 8.8±0.3% from India (Oza M D et al., 2011).

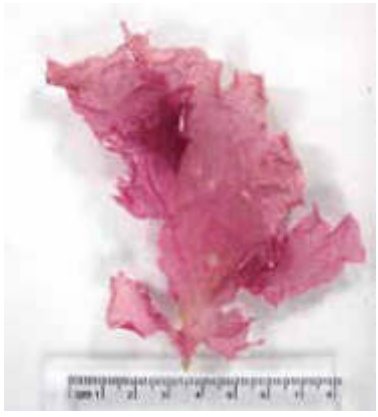


Figure 17: Halymenia Dilatata

Conclusion

Several investigations have been carried out around the world to explore suitable agarophyte and carragenophyte to extract agar and carrageenan for their multi-dimensional industrial increasing commercial demand. In this investigations, a total of 5 agarophyte and 4 carragenophyte have been explored for respective hydrocolloid extraction. As a baseline data so far a total of 143 seaweeds were identified. The study on Exploring commercial seaweed and their sustainable application in grass root level need to be continued.

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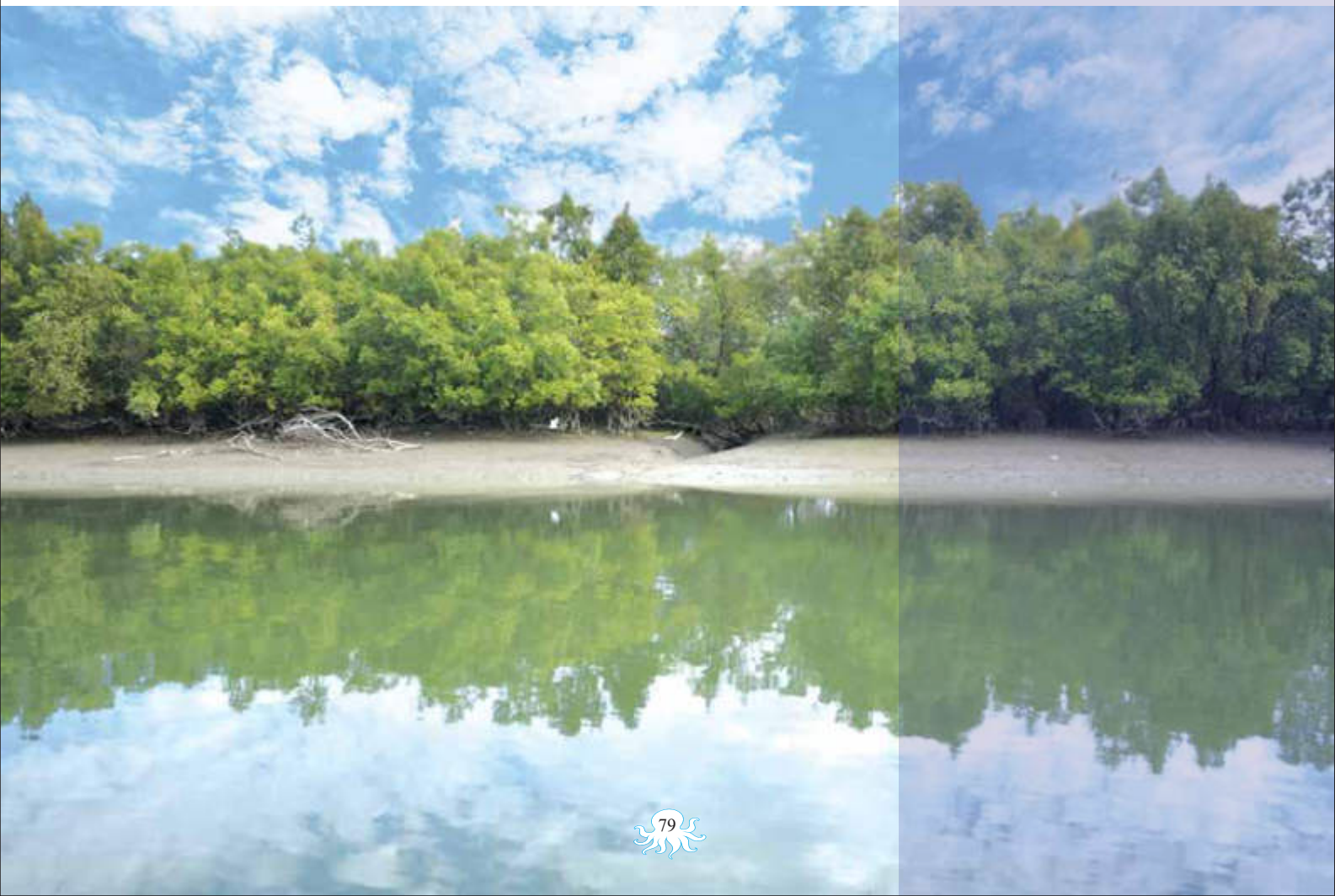
CHAPTER 6

ENVIRONMENTAL OCEANOGRAPHY & CLIMATE



Oil-Grease Concentration level in the South Eastern Coastal Sediment of Bangladesh

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General Discussion

Coastal zone of Bangladesh is geomorphologically and hydrologically dominated by the Ganges Brahmaputra Meghna (GBM) river system; their tributaries and Bay of Bengal [1]. The Eastern Coastal Zone extends from Teknaf upazila to Mirsarai upazila along the estuary of the Feni river and it is the most stable part of Bangladesh coast [2]. This zone has become an aggregate of many rivers and dozens of tributaries that are considerably polluted. The massive anthropogenic activities and dispose of waste to the riverine, decreasing environmental quality [3]. In recent decades, almost an average of 50% of the total oil production was transport of oil in the marine worldwide [4], including south eastern coast as fishing boat activity, shipping line and cargo activities both domestic or international. Oil and grease (OG) are one of the most widespread contaminants in the sea [5], estimated that 1 to 10 metric tons of oil came into the sea from various sources and accumulated in the coastal significantly [6].

OG consists of volatile hydrocarbons or oil released from the engine's incomplete combustion emissions, found higher than oil that directly into the sea [7]. From the eco-toxicological perspective, Tam et al. [8] reported that 100% mortality of Flounder fry occurred at an oil content of 1,000 µgL-1 (1 ppm), abnormal growth occurred at an oil level of 10 µgL-1 (0.01 ppm). The source of OG pollution can be due to the oil spilled from leakage of tanker shipping, river runoff, domestic pollution, sea transportation, or fishing boat activities in south eastern coastal waters and its surrounding [9].

This case always attracted great attention from the broader community because of adverse effects around the coast and has significant damage to organisms in aquatic environments [10]. Furthermore, oil pollution can degrade the quality of seawater physically, chemically, and biologically such as disruption of photosynthesis and respiration process in marine organisms [11,12]. This pollutant can also be harmful to the living biota because it is affected by organisms' fertilization [13]. Therefore, it is necessary to assess the contamination level and oil distribution pattern in these seawaters. Besides, the study of OG level in sediment is still limited data in these regions.

This study aims to determine the pollution level and spatial distribution of OG in sediment in south eastern coast of Bangladesh, especially in Saint Martin's Jetty area, Teknaf Jetty area, Shaplapur fishery ghat area, Cox's Bazar fishery ghat area, Kutubdia fishery ghat area, Karnafuli fishery ghat area, Chittagong port area and Shitakundu ship breaking area. Due to part of the Bay of Bengal ecosystem, these locations were chosen, densely anthropogenic activities, particularly industrial and shipping activities. Providing information about OG concentration and distribution can be a guideline for local governments to manage marine ecosystems' sustainability.

Objective of the Study:

The objectives of the study are-

- To know the status of Oil-Grease concentration in sediment
- To analyze the pollution level in the coastal sediment

Study Area

The study sites and locations lies in the south eastern coast of Bangladesh, especially in Saint Martin's Jetty area, Teknaf Jetty area, Shaplapur fishery ghat area, Cox's Bazar fishery ghat area, Kutubdia fishery ghat area, Karnafuli fishery ghat area, Chittagong port area and Shitakundu ship breaking area (Figure 1).

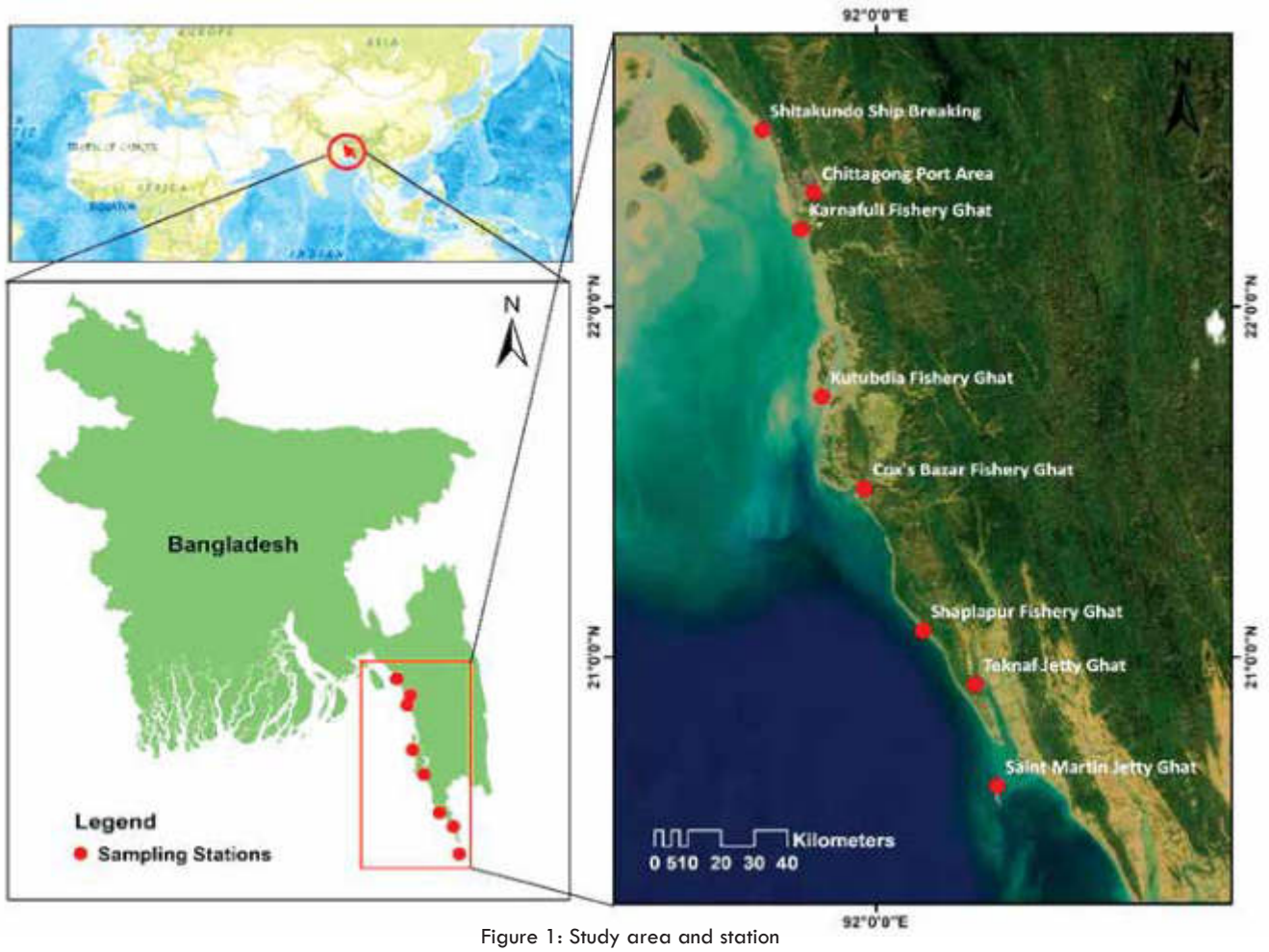

Figure 1: Study area and station

Materials and Methods:

Sample Collection:

This research was conducted from November 2022 to March 2023 in 8 (eight) locations presented in Figure 1. A total of 40 (forty) samples for sediment were retrieved. In particular, every location distributes to 5 (five) selected points. Sediment samples were kept in cool boxes (4°C) prior to analysis in the laboratory.

Sample Analysis:

The analysis was based on the APHA 5520 B method applied as Liquid-Liquid, Partition-Gravimetric Method. Briefly, the extract of the samples were filtered through 0,45 µm glass fiber filters (Whatman GF/C), and 2 L filtrate water was extracted by n-Hexane solvent (emsure grade, Merck) with 60 mL, 30 mL and 30 mL using a separator funnel, respectively. Water residue was removed by sodium sulphate anhydrous from organic. Then the organic phase was evaporated in a rotary evaporator for 60 minutes at 40°C until 1 mL. The last sample was added by tetrachloroethylene solvent to 4 mL. The concentration of OG was measured by calculating equation mentioned in the analysis method.

Data Analysis:

The data presented here were calculated using Microsoft Office Excel 2016 for OG, and the graph was generated using the Golden Software. Maps showing the sampling location were produced using ArcMap10.1, Environmental Systems Research Institute, ESRI®.

Result and Discussion:

Spatial distribution of OG extent for sediment measured from 40 sampling stations showed similar special pattern among three locations, Saint Martin Jetty Ghat, Teknaf Jetty Ghat and Shitakundu Ship Breaking Area (Figure 2). Average OG concentration of seawaters from three areas are 1.22 mg/kg, 1.24 mg/kg and 1.33 mg/kg respectively (Figure 3). On the other hand, three locations of Shaplapur Fishery Ghat, Cox's Bazar Fishery Ghat and Kutubdia Fishery Ghat (Figure 2) almost have alike spatial distribution with average OG concentration of 0.78 mg/kg, 0.92 mg/kg and 0.92 mg/kg respectively (Figure 3). Totally dissimilar distribution pattern found between Kornofuli Fishery Ghat and Chittagong Port Area (Figure 2) with average OG level of 0.42 mg/kg and 2.02 mg/kg respectively (Figure 3).

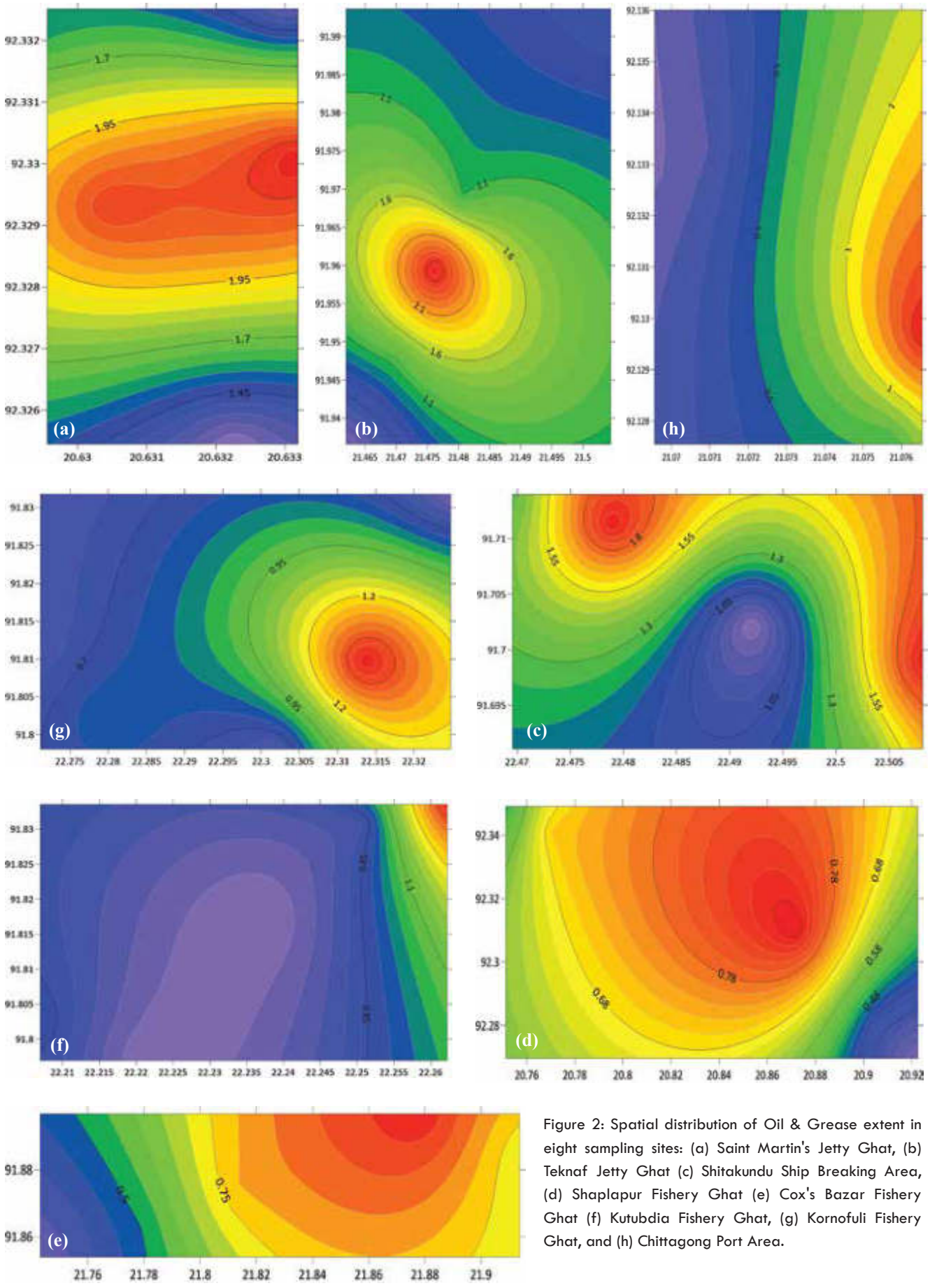

Figure 2: Spatial distribution of Oil & Grease extent in eight sampling sites: (a) Saint Martin's Jetty Ghat, (b) Teknaf Jetty Ghat (c) Shitakundu Ship Breaking Area, (d) Shaplapur Fishery Ghat (e) Cox's Bazar Fishery Ghat (f) Kutubdia Fishery Ghat, (g) Kornofuli Fishery Ghat, and (h) Chittagong Port Area.

In general, the OG concentration of sediment in one of the sampling stations of Chottogram Port Area was the highest followed by Shitakundu Ship Breaking Area and Teknaf Jetty Ghat whereas the lowest among the maximums is in one of the sites of Karnafuli Fishery Ghat Area. (Figure 4). The lowest concentration of OG among the minimums is in one of the sampling sites of Shitakundu Ship Breaking Area (Figure 4).

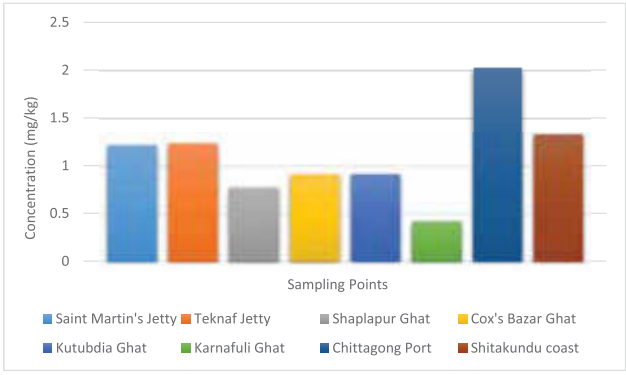

Figure 3: Average Oil & Grease concentration at each of eight sampling sites

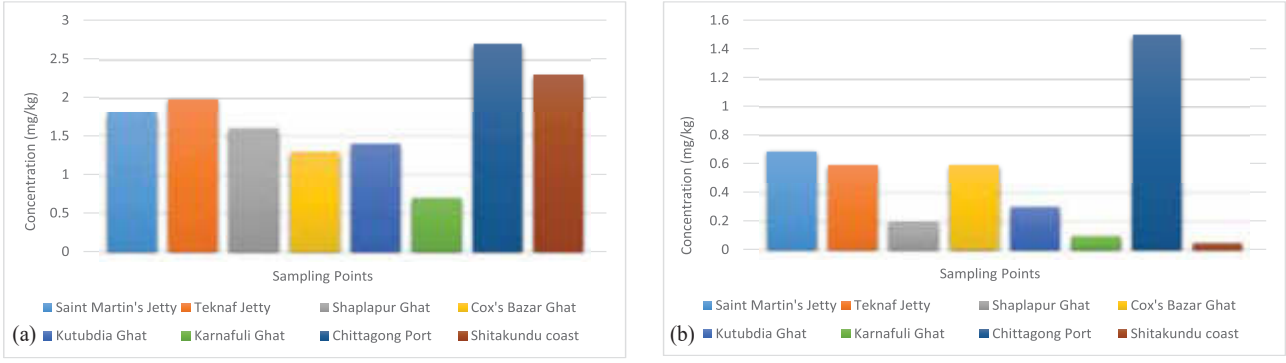

Figure 4: (a) Maximum and (b) Minimum concentration of OG in various sampling sites of eight sampling locations

The correlation matrix shows that there is positive relationship between OG concentration in sediment and with the parameters of TDS, Pressure and Depth (Figure 5). On the contrary, there is negative relationship between OG concentration and some parameters; such as DO, Salinity, pH, TDS, Conductivity and DO. This indicates high physical and microbial activity, which reduce OG compound from terrestrial area [14]. Overall, the OG content in sediment does not surpass the standards of Decree No. 51 of the Environment Ministry on sediment quality standards [15].

	Tem (°C)	Salinity (ppt)	pH	TDS (mg/l)	Cond (mS/cm)	DO (mg/l)	Pressure (atm)	Depth (m)	OG (mg/kg)
Tem (°C)	1								
Salinity (ppt)	-0.107781741	1							
pH	-0.005182425	0.890035425	1						
TDS (mg/l)	0.014890805	-0.854457838	-0.883064681	1					
Cond (mS/cm)	-0.090244102	0.995160047	0.886204708	-0.861902081	1				
DO (mg/l)	-0.164184515	0.843178288	0.950518499	-0.891944245	0.840495407	1			
Pressure (atm)	0.038290008	0.189089375	0.485470009	-0.350974399	0.177771053	0.446904701	1		
Depth (m)	-0.015071094	-0.103670405	-0.104024789	0.034598292	-0.109343331	-0.038245576	-0.205130407	1	
OG (mg/kg)	-0.060643457	-0.092229727	-0.066818862	0.000846782	-0.091398368	-0.041348043	0.013719446	0.22040296	1

Figure 5: Correlation Matrix between Oil & Grease and Physico-chemical parameters of different sampling locations.

Oil content in either the eight locations does not intensely affect oceanographic parameters such as salinity, temperature, and pH (Table 1). However, this contradicts the composition of physical chemistry in oil. High salinity will affect the solubility of one oil fraction, namely the structure of polycyclic aromatic hydrocarbons (PAH) in seawater [16], which will impact marine organisms.

The hydrodynamic condition and organic matter contents could be affected by the spreading of oil contaminants in seawater and sinking processed oil contaminant particulates in sediment. Even more, Saint martin's Island was located in the open sea that was affected by the monsoon regime. In coastal waters, the source of oil contaminants was dominated come from riverine input, and its spreading was affected by the current and tidal regime [17].

EXTREME

OIL POLLUTION

OCCURS SOMETIMES IN BANGLADESH COAST

Table 01: Physico-chemical parameters of seawater in each sampling station

Sampling Station	Temperature (°C)	Salinity (ppt)	pH
SM 01-01	23.45	30.73	8.09
SM 01-02	23.41	30.71	8.1
SM 01-03	23.33	30.53	8.11
SM 01-04	23.3	30.26	8.08
SM 01-05	23.45	30.66	8.11
TF 02-06	22.21	26.02	7.82
TF 02-07	22.48	26.67	7.79
TF 02-08	22.65	26.59	7.81
TF 02-09	22.55	27.66	7.84
TF 02-10	23.3	27.14	7.85
SP 03-11	22.95	31.5	8.14
SP 03-12	22.89	31.35	8.14
SP 03-13	23	31.2	8.13
SP 03-14	23.34	31.26	8.11
SP 03-15	22.24	31.2	8.14
CB 04-16	23.07	29.23	7.67
CB 04-17	23.1	30.01	7.84
CB 04-18	22.84	30.28	7.91
CB 04-19	23.19	30.71	8.01
CB 04-20	23.17	30.58	7.99
KD 05-21	25.45	27.12	8.01
KD 05-22	25.55	26.46	7.94
KD 05-23	25.47	28.5	7.94
KD 05-24	25.52	28.36	7.95
KD 05-25	26.05	28.63	7.97
KF 06-26	23.55	7.81	7.25
KF 06-27	23.66	7.27	7.28
KF 06-28	23.6	6.92	7.28
KF 06-29	23.69	6.35	7.35
KF 06-30	23.7	6.97	7.36
CP 07-31	23.65	7.75	7.35
CP 07-32	23.58	8.22	7.25
CP 07-33	23.56	10.36	7.41
CP 07-34	23.51	12.12	7.49
CP 07-35	23.48	19.62	7.97
SK 08-36	23.54	17.77	7.95
SK 08-37	23.53	18.21	7.94
SK 08-38	24.14	18.31	7.91
SK 08-39	24.44	18.47	7.93
SK 08-40	23.89	18.59	7.92

Note: SM-Saint Martin, TF-Teknaf, SP-Shaplapur, CB-Cox's Bazar, KD-Kutubdia, KF-Kornofuli, CP-Chittagong Port, SK-Shitakundu.

High levels of oil in sediment will reduce the absorption of oxygen, so that will cause an environmental hypoxic condition. Also, the performance of oil-breaking microbes is disrupted by the reduction in dissolved oxygen levels [18]. According to Zobell and Hittle [19], for complete oxidation of one gallon of crude oil, dissolved oxygen is needed from 320,000 gallons of seawater saturated with air. The natural remediation process by these microbes will break the fraction of regular paraffin crude oil. In contrast, oils with a more toxic aromatic ring will be solved longer (degradation) [20]. Disturbance to the life of marine biota against oil pollution generally occurs around estuarine and beaches because the frequent oil pollution usually occurs [21]. However, when the ability to recover from the environment has exceeded, then marine biota damage could happen very quickly. As the recovery of this damage in marine biota takes a long time [22], this scenario could pose a serious danger to the marine ecosystem where the contamination occurs.

The literature study shows that when the OG fraction enters waters, it will reduce by a natural evaporation process [23]. However, this is a complicated process in oil accumulation of sediments and biota [24]. The bioaccumulation process will bind to fat tissue and naturally concentrated following the food chain pathway to a higher consumer level [25]. Fish and other seafood as an essential protein intake for humans will have a high risk to human health if they accumulate compounds from highly toxic and persistent oil fractions such as PAH [26]. Therefore, it needs circumspection and vigilance to benefit from fish and other marine biotas as a daily consumption due to oil contaminants content.

Concluding Remarks:

The average mean concentration of oil and grease in southeastern coastal sediment and its surroundings is 1.11 mg/kg. OG contaminants were detected and distributed in each sampling station with a variety of concentrations. The results indicated that the level of OG obtained in most of these sediments are lower than the threshold value for normal marine animations based on the US EPA water quality criteria guidelines. It is necessary to monitor and evaluate the environmental quality of this coastal zone through analyzing seawater and sediment samples frequently. In case of an oil spills incident both from the off-shore incidents or tanker shipping, environmental baseline data has been provided. Strict supervision is needed for all ships and boats across these waters, including ships docking process and oil dumping waste.

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Carbon Sequestration Capacity of Tidal Marshes and Mangroves Soil and their Response to Climate Change in the Deltaic Central Coast of Bangladesh

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Abstract

Tidal marshes and mangroves are coastal ecosystems that play an important role in carbon sequestration and climate change mitigation. However, these ecosystems are vulnerable to climate change impacts such as sea level rise and increased storm intensity. This research project aims to assess the carbon sequestration capacity of tidal marshes and mangroves in the deltaic central coast of Bangladesh and investigate their response to climate change. This is a two-year project. 40 soil core samples from mangroves and saltmarshes (N=40) were taken from various Noakhali islands, including Hatiya, Nijhumdip, Domar Char, Shahapara Char, Bendir Char, and Jaglar Char, as well as Char Monpura, Char Alin, Char Pataliya, Sarsa Char, Char Paliya, Dhal Char, Char Nizam, and Char Kukrimukri. The remaining study areas (50%), such as Sandwip, Borguna, and Potuakhali, where soil core samples (N=45) from saltmarshes and mangroves will be taken this year. Loss of Ignition (LOI%) process (measuring organic carbon) is going on in the lab. The study will estimate the present status of soil carbon stock, develop a map of the soil carbon stocks, investigate the contribution of these ecosystems to climate change mitigation, and investigate the changes pattern of tidal salt marshes and mangrove ecosystem using remote sensing and satellite imagery. The research findings will be used to develop recommendations for the management and conservation of these important ecosystems and also be helped to make carbon trade policy through the blue economy of Bangladesh.

Keywords: Carbon sequestration, Climate change, Mitigation, Detaic coast, Mangrove forest, Saltmarshes and sediment

Introduction

Bangladesh is a promising country in South Asia. The deltaic system e.g., Ganges Brahmaputra Meghna (GBM) river system and the Bay of Bengal dominate the geomorphology and hydrology of Bangladesh's coastal zone. The coastal zone comprises 47,201 km2 and the landmass of 19 districts accounts for nearly 32% of the country's total landmass. Bangladesh's coastal zone is divided into three sections based on geographic features: (a) the eastern, (b) the central and (c) the western zone. The semi-active delta is crisscrossed by numerous canals and creeks in the western portion known as the Ganges tidal plain. The center region has the most vigorous and constant accretion and erosion processes of all the regions. This zone includes the estuary of Meghna River (Thomas MB, Wratten SD, Nick S, 1992).

Tidal marshes rank among the ecosystems with the highest capacity to sequester and store organic carbon (Corg) on earth. Mangroves are also recognized as one of the most carbon-dense forest types in the world due to their efficient carbon sequestration capacity into both above and below ground carbon pools (Donato et al., 2011; Alongi, 2012). Despite only making up 0.5% of the world's coastline land, mangrove forests transfer more than 10% of terrestrial particulate carbon, including dissolved organic carbon (DOC), into the ocean (Dittmar T. et al., 2006). According to Curnick D. et al. (2019), mangroves are seriously endangered, and more than 35% of their original area has been destroyed since the 1980s. Proper evaluations of blue carbon, particularly the carbon stock found in mangrove ecosystems, can aid efforts to reduce greenhouse gas emissions and counteract global warming. (Donato D C et al., 2011; Pendleton L et al., 2012). In general, tidal marshes can be found in a variety of geomorphic and depositional environments, and soil Corg stocks can vary greatly over a wide range of spatial and temporal scales. At the global level, historical sea level rises, which regulated the vertical accretion of mineral and organic elements, are the main causes of variation in tidal marsh soil Corg stocks.

Objectives of the Research Project

To estimate the present status of soil carbon stock in tidal salt marshes & mangroves in the central coast

To develop the mapping of the soil carbon stocks of tidal salt marshes & mangroves in the central coast

To investigate the contribution of mangroves and salt marshes that how to mitigate the climate change

To investigate the changes pattern of tidal salt marshes and mangroves ecosystem in the deltaic central coast by using remote sensing and satellite imagery

Methodology

Study Area

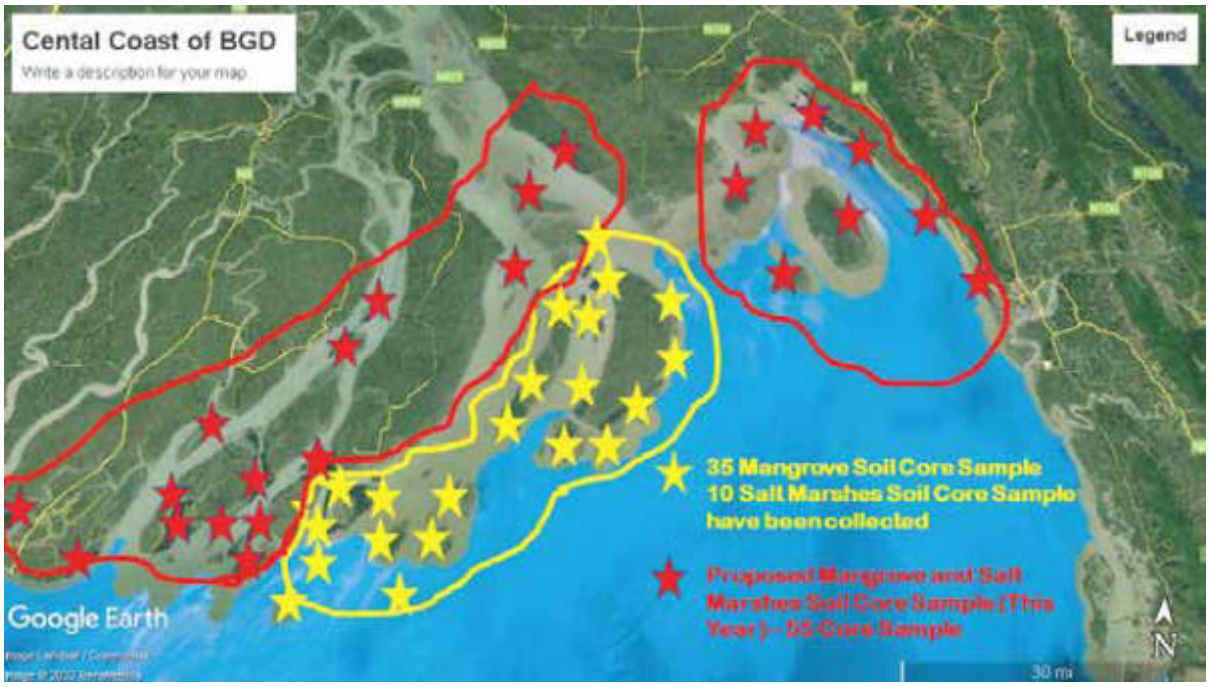

Figure 01: Research Area where mangrove and saltmarshes soil core samples are collected (Yellow Color: Completed soil core samples) and will be collected (Red Color: Proposed soil core samples) from the deltaic coast of Bangladesh.

Materials and Method

Soil sample collection

An open-face PVC sediment auger having 100 cm length and 5 cm radius is used for the collection of soil samples from several selected stations (37) for tidal salt marsh soils and mangrove soils in the deltaic coast of Bangladesh. The soil samples are collected from several depths (0– 5 cm), (5 – 10 cm), (10 – 30 cm), (30 – 50 cm) and (50 -100 cm) using the PVC sediment auger and soil samples are labeled, sealed in plastic bags, and shipped to the laboratory and stored at 4 °C until processing.

Soil analysis

Soil particle size analysis will be made by soil particle analyzer (Computerizied system).

Bulk density

On returning from the field, soil samples are oven-dried to a constant mass at 60 °C for 48 hours. Higher temperatures are reduced the carbon in the sample and should be avoided (In many protocols, drying at 105°C is recommended for bulk density determination (Aryal et al. 2018; de Blécourt et al. 2013; Motsara and Roy 2008; Sheikh et al. 2009). It will be air dried, powdered, and sieved (2mm sieve) for further analysis. Three replications of the samples will be collected in all cases.

Bulk density is determined by dividing the oven-dry soil sample by the volume of the sample. The bulk density equation is as follows:

$$\text{Soil bulk density, BD (kgm-}^{3}\text{)} = \text{Oven-dry sample mass (kg)} / \text{Sample Volume (m}^{3}\text{)}$$

Soil organic carbon (SOC):

Assessment of soil carbon stocks to 1 m depth followed standard methods (Howard et al., 2014). We are collected 50 cores (from 50 subplots) of soil samples from the established planted mangroves across the coastal regions of the Bangladesh Delta. The soil is sampled at intervals down core (Donato et al., 2011) with fifty subsoil depths (0–2 cm, 2–4 cm, 4-6 cm….98–100 cm).

After collection soil core samples, soil samples are oven dried at 60°C at the Environmental Oceanography and Climate Lab (EOCD). The dried samples are then ground and sieved through a 2 mm wire mesh.

Bulk density (BD, g cm−3) is determined by dividing the oven-dry soil sample mass (g) by the volume (cm3) of the sample. We will be used the loss on ignition (LOI) method at a temperature of 550°C to obtain %LOI (Dean, 1974).

Soil carbon stocks: Soil carbon stocks (SCS) in each layer will be determined as:

$$\text{SCS (Mg C ha-1)} = \%OC \times T \times BD$$

where OC is organic carbon concentration (%), T is the layer thickness (m), and BD is the bulk density (gcm−3).

Mapping soil carbon stocks: Arc GIS 10.5 tools will be used for the special distribution mapping of soil carbon stocks of tidal salt marshes & mangroves on the deltaic central coast of Bangladesh.

Statistical analyses: The PAST software will be used for the analysis of one-way analysis of variance (ANOVA).

Results and Disscution

Research Activities

37 soil core samples from mangroves and saltmarshes (N=45) were collected from various Noakhali islands, including Hatiya, Nijhumdip, Domar Char, Shahapara Char, Bendir Char, and Jaglar Char, as well as Char Monpura, Char Alin, Char Pataliya, Sarsa Char, Char Paliya, Dhal Char, Char Nizam, and Char Kukrimukri. The remaining study area, such as Sandwip, Borguna, and Potuakhali, where soil core samples from saltmarshes and mangroves will be taken this year (Figure 01).

Figure 02: Soil core sampling process of blue carbon ecosystem in the deltaic coast of Bangladesh (Hatiya, Noakhali)

Soil core samples storing for further organic carbon analysis

Soil core samples have been stored in the EOCD Lab, BORI. It is important to store mangrove and saltmarsh soil core samples at 4°C to preserve their organic matter content and prevent degradation (figure 03). The stored soil cores will likely be used for various analyses, including carbon content, isotopic composition, and other relevant parameters.

Figure 03: Soil core samples stored at 4°C temperature

Figure 05: Samples drying at 60° C by Incubator

Figure 04: Sectioning the soil core samples

Sectioning the soil core samples

The sections of the soil core samples have been completed in EOCD Lab. This is an important step in the process of estimating the amount of carbon stored in these ecosystems. The sections of soil core samples (pieces of soil core = 2 cm) have been dried by the oven (figure 05). Bulk density of the core samples are analyzing in the Lab.

Grinding of soil core samples

Grinding soil core samples is an essential step in preparing them for blue carbon analysis (figure 06). Blue carbon analysis measures the amount of carbon stored in coastal ecosystems, such as mangroves and saltmarshes. Grinding the samples increases their surface area, making them easier to analyze for organic matter content, which is an indicator of carbon storage.

Figure 06: Grinding of soil core samples are working in the EOCD lab

Loss of Ignition (LOI%) process (measuring organic carbon) is depended on available electricity in the lab (the soil samples will be burned in 550 o C for 4h). This process is going on in the lab.

Results: This is a two years R&D project. We collected the soil core samples (N=37) from the deltaic coast of Bangladesh (50% of the study area) and we will collect remain part of the soil core sample this year. So, after the collection of the samples and analysis of samples, we will present our R&D results next year.

Output of the research project

The output of the research project on Carbon Sequestration Capacity of Tidal Marshes and Mangroves Soil and their Response to Climate Change in the Deltaic Central Coast of Bangladesh will be:

• An estimate of the present status of soil carbon stock. This will provide valuable information on the amount of carbon stored in these ecosystems, which can be used to assess their potential to mitigate climate change.

• A mapping of the soil carbon stocks. This will provide a spatial overview of the distribution of carbon in these ecosystems, which can be used to identify areas with high carbon stocks and to target conservation efforts.

• An investigation of the contribution of mangroves and salt marshes to climate change mitigation. This will help to understand the role that these ecosystems play in absorbing carbon from the atmosphere, and how they can be managed to maximize their carbon storage potential.

• An investigation of the changes pattern of tidal salt marshes and mangroves ecosystem. This will help to understand the factors that are driving changes in these ecosystems, and how these changes may affect their carbon storage potential.

Conclusion:

This research project will provide valuable information on the carbon storage potential of tidal marshes and mangroves in Bangladesh and how they are responding to climate change. This information will be used to develop recommendations for their management and conservation, and to contribute to the global understanding of the role of coastal ecosystems in climate change mitigation.

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Assessing the microplastic distribution in water, sediment and fish species in the Sundarbans Reserve Forest (SRF), western coast of Bangladesh

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Abstract

The present study, considered as one of the pioneering microplastics (MPs) particles (particles size ≤5mm) research, measured the abundance and spatial distribution of microplastic pollution in the Sundarbans Reserved Forest (SRF). Surface water and bottom sediments samples were collected from (20 bottom sediments and 20 surface water) 20 different locations. The fish sample were collected from local fishing boat to ensure the fish sample must be same area where sediment and water sample were collected. The sampling was conducted during November 2022. During the study period, a total 410 microplastics (Bottom sediment MPs-67, Surface water MPs-236 and Fish MPs-107) particles were recorded from the study area. To prepare the samples for analysis, a digestion process with 30% H2O2 was employed to remove organic matter. Density separation using ZnCl2 (~1.5 g cm−3) allowed microplastics to float for examination. The extracted particles were then scrutinized under a stereo microscope, and their characteristics, including shape, size, and color, were quantified and categorized. The study reveals higher microplastic pollution in the eastern Sundarbans Reserve Forest, specifically in the Pasur and Shibsha rivers, attributed to human activities such as overfishing, tourism, the dry fish industry, marine vessel movement, port activity, and unplanned settlements. Results indicated the ubiquitous presence of microplastics throughout the study area, potentially linked to anthropogenic activities. The comprehensive data generated by this research offers valuable insights into the abundance and spatial distribution of microplastic pollution in the remote forest areas of Bangladesh.

Keywords: Microplastics, surface water, bottom sediments, fish species, mangrove.

Introduction

Marine plastic litters is a rising environmental problem worldwide (NOAA, 2014). The National Academy of Sciences, USA, defines marine plastic litter as "solid materials of human origin that are discarded at sea or reach the sea through waterways or domestic and industrial outfall." Two primary sources of marine litter include sea-borne and land-based sources such as industrial wastes and litter resulting from human activity on the beach (UNEP, 2005). According to the Department of Commerce (US) and the US Navy, approximately 80% of litter is reported to be washed off the land, blown by winds, or intentionally dumped from the shore (The Ocean Conservancy, 2005). Market demand for plastic products is expected to increase, with projections indicating production levels reaching around 600 million tonnes by 2025 and exceeding one billion tonnes by 2050 (Lusher et al., 2017). Plastic items undergo degradation into increasingly smaller microplastic fragments, below 5 mm in diameter, due to ultraviolet (UV) radiation, oxidation, and mechanical forces (Barnes et al., 2009; Cole et al., 2011). Because of their size, microplastics are accessible and ingested by a broad range of organisms, potentially threatening ecosystems and human health (Lusher et al., 2015; Vethaak et al., 2016). Rapid development in Bangladesh over the last few decades has not been paralleled by adequate environmental awareness and waste management. The 710 km long coastline of Bangladesh encompasses diverse ecosystems and is broadly divided into three distinct regions: the eastern, central, and western regions. The western region, known as the Sundarbans (Sundarbans Reserve Forest, SRF), is predominantly covered with dense mangrove forests featuring deeply scoured tidal channels on the tidal plain, overlaying the abandoned Ganges delta (Ahsan, 2013). The quality of the western region has significantly declined due to factors such as heavy tourist activity, extensive marine vehicle transportation, overfishing, and overpopulation. Additionally, the riverine system carries a substantial amount of plastic debris that becomes trapped in the mangrove ecosystem, disturbing the development of mangrove tillers and initiating ecological instability. Extensive usage of plastic fishing gears contributes to potential microplastic contamination, posing a serious threat to coastal ecosystems and possibly endangering marine organisms and humans through the transfer of plastic pollutants in the food chain (Zhang et al., 2020). While recent research has documented the presence, distribution, and concentration of microplastics in shore sediments and marine fish organs in the coastal region of Bangladesh, there is limited quantitative information regarding marine plastic pollution in river estuaries and mangrove ecosystems

(Hossain et al., 2019; Nahian, 2020; Rahman et al., 2020; Kumar et al., 2022). This study addresses a critical gap in research by focusing on microplastic contamination in the coastal region of the Sundarbans, specifically in the Sundarbans Reserve Forest (SRF). The investigation encompasses bottom sediment, surface water, and fish species, providing a comprehensive analysis of microplastics in this unique ecosystem. This study is the inaugural investigation into microplastics in the Sundarbans Reserve Forest coastal area, exploring their presence, quantity, characteristics, and distribution in marine sediments, surface water, and the digestive organs of associated fish.

Materials and methods

Study area

The spatial distribution, types, and characteristics encompassing color, shape, and size of microplastics in surface water and bottom sediments were examined across 20 selectively chosen locations within the Sundarbans Reserve Forest (SRF). The study area stretches between the Baleswar River in the east and the Harinbanga in the west, positioned on the western coast of Bangladesh, adjacent to the Bay of Bengal. Sample collection occurred within the geographical coordinates of latitude 21° 30″ to 22° 30′ 00″ North and longitude 89° 00′ 00″ to 90° 00′ 00″ East, covering a total area of approximately 10,000 km². Bottom sediment samples were collected from 20 distinct locations within the SRF, with each sampling site positioned perpendicularly to the shoreline and situated 0.5 km offshore. Concurrently, surface water samples were gathered from the same geographical area as the bottom sediment samples. Additionally, fish samples were procured from local fishing boats to ensure alignment with the specific locations where sediment and water samples were collected.

Figure 01: Sampling localities for assessing plasticpollution at different locations of Sundarbans.

Sample Collection and Analysis:

In order to gather data on microplastic pollution, a total of 200 fish samples representing 17 species were collected from local fishing boats within the Sundarbans. Simultaneously, surface water and bottom sediment samples were obtained from the same locations. The calculation of river surface water microplastic abundance was accomplished by towing a manta net (300 mm mesh size), and the collection of river bottom sediment was performed using a Van Veen grab sampler. Microplastic particles were assayed from the gastro-intestinal track and gills of the collected fish, as well as from river surface water and bottom sediment. The microplastics extraction procedure from fish sample showed in figure 02. The organic materials of the collected samples were subjected to digestion using H2O2 (30%, V/V), and microplastic extraction was conducted through density separation methods utilizing ZnCl2 solution (1.5 g/cm3) (Avio, et al. 2015; Su, et al.2019; Hossain et al.2019). The documentation of each sample location was carried out using the Garmin GPS system, facilitating a comprehensive assessment of microplastic presence and abundance within different environmental compartments of the Sundarbans. Upon analysis, the identified microplastics were categorized into five distinct morphotypes: films, fragments, expanded polystyrene (EPS), foams, and fibers/lines. Additionally, microplastics were further classified based on their colors, which included transparent - white, gray - black, green -light green, red - orange, blue -light blue and yellow-pale yellow (Nahian et al., 2023). This detailed classification provided valuable information about the diversity and composition of microplastics present in the Sundarbans ecosystem. Microplastics were also categorized into two primary shape groups. The first group included films, foams, and fragments, while the second group comprised fibers, lines, and other miscellaneous shapes. The distribution of these morphological groups was found to be non-uniform within the Sundarbans rivers, with films, foam, fibers, and fragment debris predominantly found in downstream areas of the river system. This observation suggests potential pathways of microplastic transport within the ecosystem.

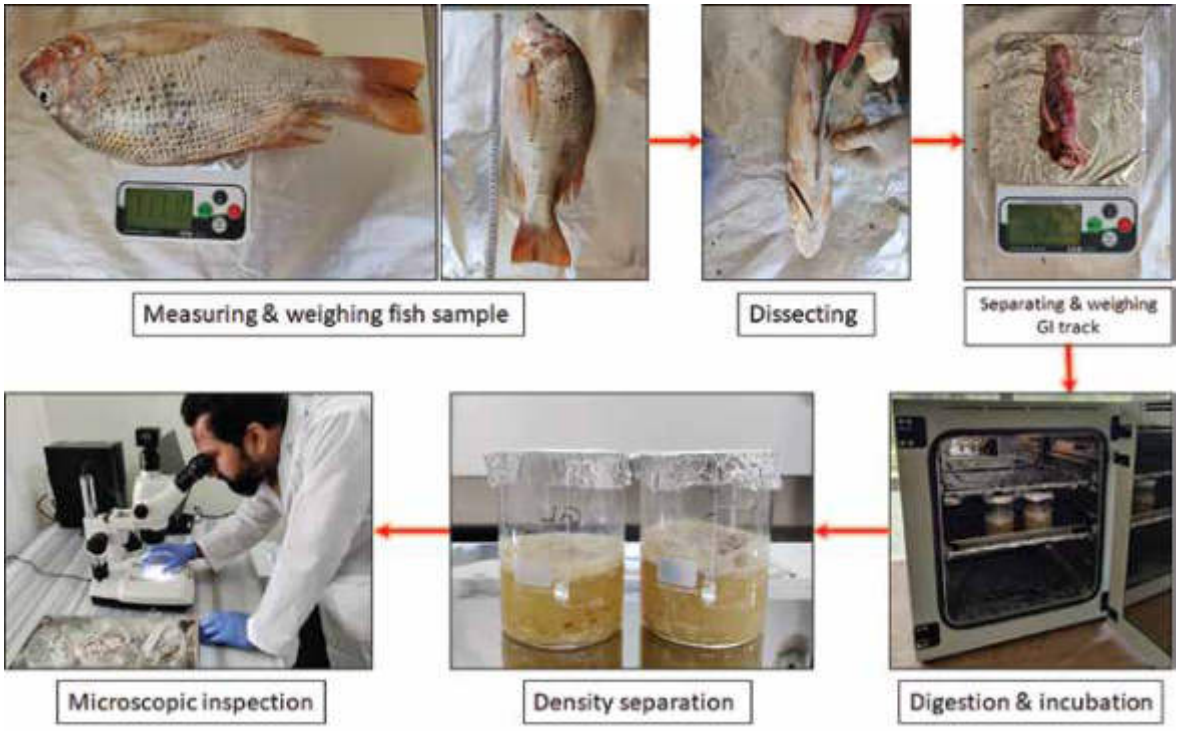

Figure 2: Microplastic analysis from fish sample.

Result and Discussions:

Abundance and distribution of microplastics (MPs):

Bottom sediments:

The Sundarbans Reserve Forest (SRF) is vital for wildlife migration, serving as crucial spawning and feeding grounds for millions of fish and bird species. However, the threat of ingested microplastics, both physically and toxicologically, poses a significant risk to the integrity of this coastal ecosystem. This is the first study to report microplastic abundances in benthic sediments of the SRF tidal river system. These plastic particles degrade slowly, releasing harmful plasticizers and can move through various levels of the food chain. The collected microplastics are categorized based on their size, shape, and color. Different researchers may use varied classifications, but in this study, microplastics were categorized into five classes based on geometrical shape: Expanded Polystyrene (EPS), Foams, Fragments, Films, and Line/Fiber.

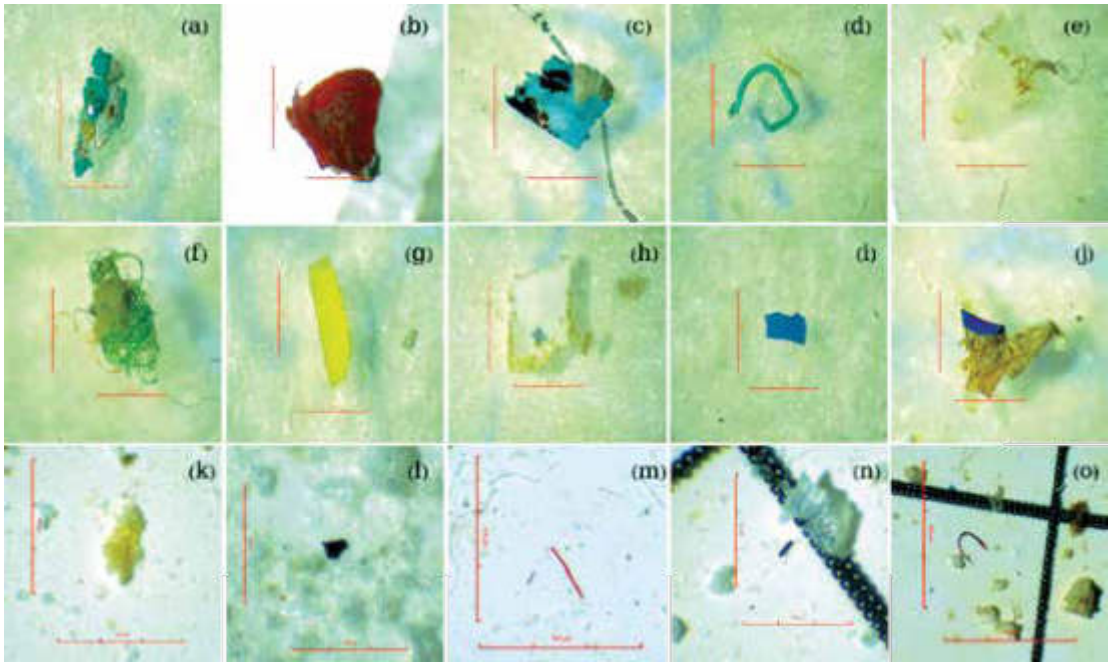

Figure 3: Photograph of plastics retrieved from study area (a-e) Surface water (f-j) Bottom Sediments and (k - o) Fish sample.

Although there is no standardized protocol, the morphological information from microplastic samples can offer insights into their potential sources. In this study, 20 bottom sediment samples were obtained, in which the majority of samples are caly sediments and few sample are sandy clay sediments. Throughout the study period, microplastics were found in every bottom sediment sample across all sampling sites in SRF tidal river system, with concentrations ranging from 1 to 07 plastic particles/kg of dry sediments. During 20 samplings, a total of 67 microplastic debris pieces were collected and divided into categories: Fragments (28%), EPS (6%), Foam (6%), Line/Fibers (30%), and Films (30%). Size-wise abundance and percentage distribution of plastic items, such as fragments, fibers, filaments, foam, and EPS, in shore sediments were illustrated. The color-wise mean abundance of plastics on all sampling stations followed the order: transparent-white (25%), blue-light blue (17%), green-light green (12%), red-orange (11%), yellow-pale yellow (9%), and grey-black (8%). The color of the collected plastic particles exhibited significant variability. This morphological information from the microplastic samples can be used to indicate their potential origins. For example, primary microplastics usually resin plastics which comes from industrial effluent or accidental leakage from ship. Line/fiber usually originates from fishing lines, clothing, or other textiles, while filaments mainly originate from plastic bags or wrapping materials. EPS and Foam type plastic comes from fishing related activity because fishermen extensively use EPS and foam type materials to float their nets. During the study period microplastics were found in every bottom sediment sample in all the sampling sites.

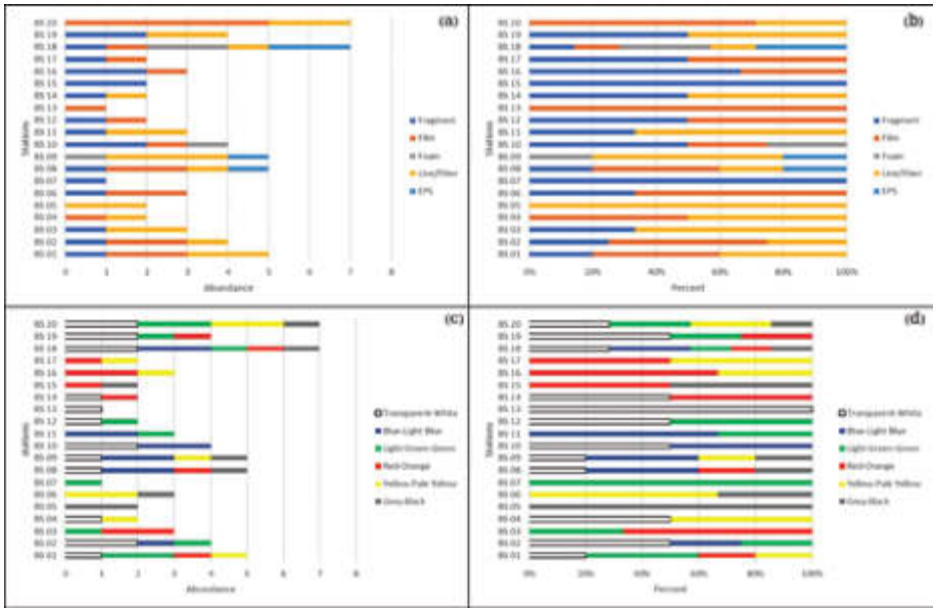

Figure 4: Abundance and proportion of various shape (fragments, films, lines/fibers, EPS and foams) of microplastics along the bottom sediment (a,b) and (c,d) color distribution of microplastics collected from the study area.

Surface water:

In this study, 20 surface water samples were obtained, in which all the samples were found contaminated by microplastic debris. The microplastic abundance in the surface water ranged from 0 to ~1 items/m3 of water. Total 236 items of microplastic recorded from 20 surface water samples. Generally, the microplastic abundance in the surface water were higher in the mouth of the tributaries and estuary. Deferent concentrations of microplastics can be attributed to a variety of factors, such as hydrological conditions, surroundings around the water and the properties of deferent plastics (Horton et al. 2017). Sorted plastic pieces collected from the field into five different categories (fragments, films, foam, line/fibers and EPS) and counted their abundance. Most of the retrieved plastic pieces were lines/fibers (for a total of 56 items) which accounted for 24%. The others plastic particles were: films (for a total of 53 items, 22%), fragments (for a total of 51 items, 22%), (Foam, for a total of 40 items, 17%), expanded polystyrene (EPS, for a total of 40 items, 17%). Data on size-wise abundance and percentage of plastic Items in every surface water sample and distribution of plastic items (e.g. fragments, line/fibers, films, foam and EPS) from all water sample is shown in (Figure 05 a & b). In this study because of rare and inconsistent occurrences, other plastic shapes such as beads, micro beads, scrubbers were not accounted. The color of the collected plastic particles from the studied sediments varied greatly (Figure 05 c & d). Color-wise mean abundance of plastics on all sampling station of coastal surface water followed the order, transparent – white (53 items, 22%), blue-light blue (32 items, 14%), green-light green (26 items, 11%), red-orange (47 items, 20%), yellow-pale yellow (44 items, 19%) and grey-black (34 items, 14%). According to the results most dominant microplastics found lines/fibers and films plastic particles which usually comes from fishing related items. Films usually comes from cement bags and polyethene sheets are most popular and widely used in fish market, local bazar, and dry fish processing area. Fibres were coming from garments and cloths. Main source of line is plastic ropes, fishing nets and fishing line.

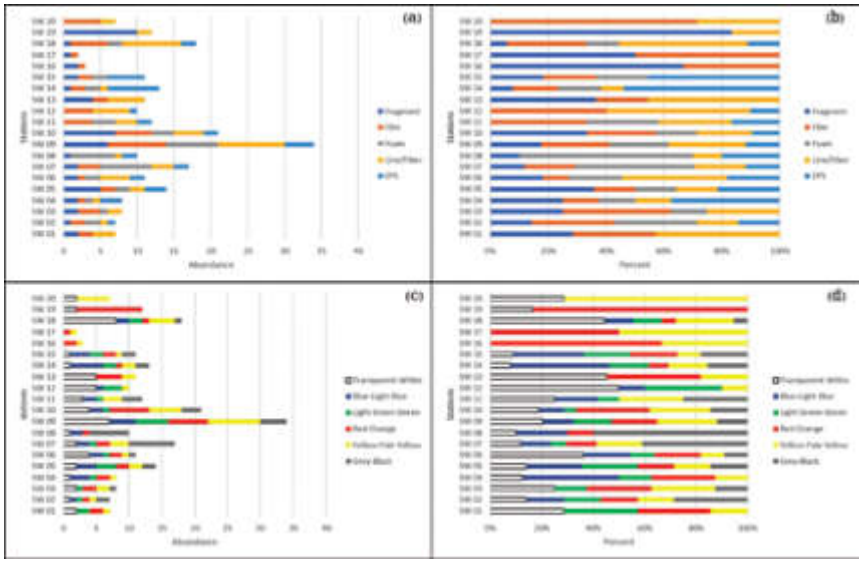

Figure 05: Abundance and proportion of various shape (fragments, films, lines, EPS and foams) of microplastics in the surface water samples (a,b) and (c,d) color distribution of microplastics collected from the study area.

Microplastics in Fish Organs:

Microplastics were detected in both the gills and gastrointestinal tracts of the local Sundarbans fish. Notably, demersal fish species were found to contain higher concentrations of microplastics compared to other fish species. This finding raises concerns about the potential bioaccumulation of microplastics in the food web and its implications for the health of fish populations and human consumers. Total as many as 107 micro plastic particles were recovered from the gills rack (GR) and gastrointestinal tract (GIT) of all fish species. Only three type/shapes of microplastics were found in fish samples, including fragments, lines/fibers and foams. Morphotypes of microplastic were varied in diverse fish species. The fiber was the most abundant forms of microplastic observed in fish species. The proportions of microplastics were lines/fibers (for a total of 88 items, 82%) and the others plastic particles were: fragments (for a total of 10 items, 09%), and foams, for a total of 09 items, 09%). The color of the retrieved microplastics were classified into six categories: transparent – white (14 items, 13%), blue-light blue (32 items, 30%), green-light green (05 items, 05%), red-orange (35 items, 33%), yellow-pale yellow (07 items, 06%) and grey-black (14 items, 13%). (Figure 6, c & d). The abundance of microplastics in fish gastrointestinal tracts and gill racks may be linked to their habitats and surroundings (Baalkhuyur et al., 2018). Van Cauwenberghe et al., 2015 and Wang et al., 2019a reported that sediments are recognized as a microplastic sink, low-density microplastics can become denser than seawater through processes like biofilm formation, the biofouling process, or by wrapping with marine animal feces. This increases the contact and ingestion risk for demersal species, leading to significantly higher concentrations of microplastics in demersal compared to pelagic species (Zhu et al., 2019). In this study, Greenback mullet, Spotted scat, Goatee croaker, and Goby demonstrated a higher abundance of microplastics, potentially influenced by their habitat and dietary preferences.

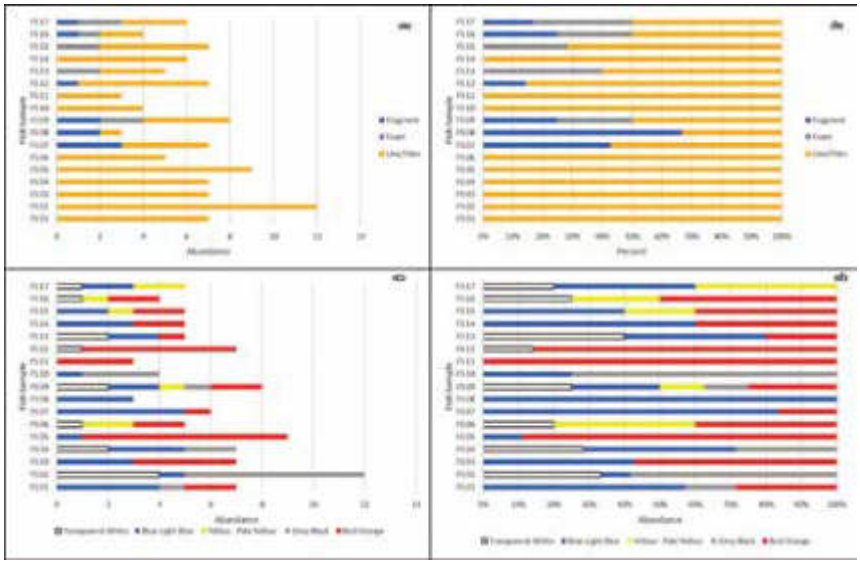

Figure 6: Abundance and proportion of various shape (fragments, foams andlines/fibers) and color distribution of microplastics in the fish samples (a,b) and (c,d) were retrieved from the study area.

Microplastic Pollution Distribution:

The study findings indicated that the eastern part of the Sundarbans Reserve Forest is more heavily polluted with microplastics than the western part, with the Pasur and Shibsha rivers being identified as particularly impacted areas. Human activities, including overfishing, tourism, the dry fish industry, marine vessel movement, port activity, and unplanned settlements, were identified as significant sources of microplastic pollution in the region. Based on the retrieved microplastic pollution data, a comprehensive GIS-based "microplastic pollution map" of the Sundarbans Reserve Forest was generated. This map serves as a valuable tool for policymakers and environmental authorities to implement effective pollution control measures in the region. By identifying hotspots and sources of microplastic pollution, this map aids in targeted conservation efforts and the protection of the unique and ecologically sensitive Sundarbans ecosystem.

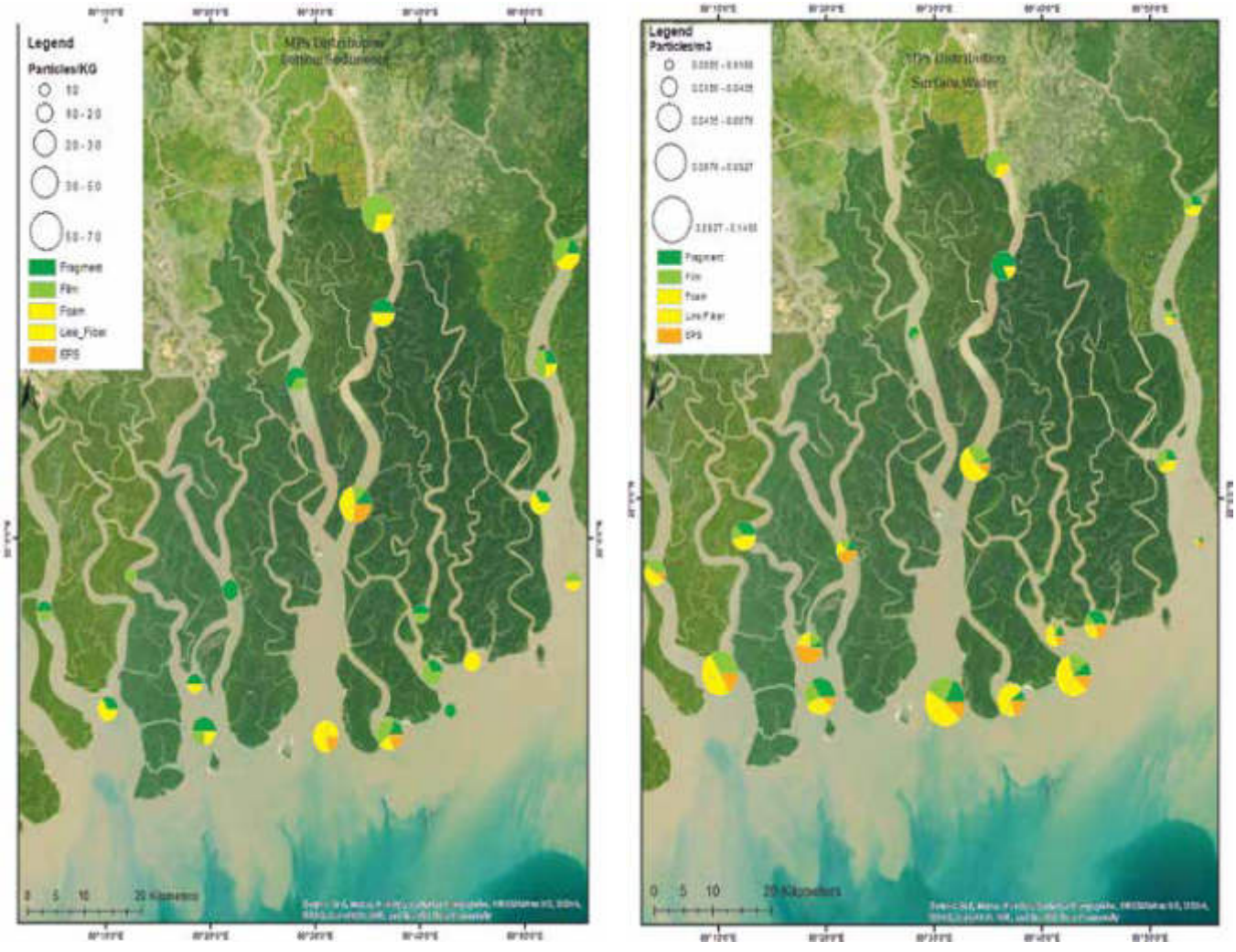

Figure 07: Distribution of microplastics based on their groups (a) Bottom Sediment and (b) Surface Water

Conclusion:

This pioneering study has provided crucial insights into the spatial distribution and characteristics of microplastics in the Sundarbans Reserve Forest, Bangladesh. Through the comprehensive analysis of surface water, bottom sediments, and fish samples collected from 20 different locations, a total of 410 microplastics were recorded during the November 2022 sampling period. The concentration of microplastics was notably higher in the eastern part of the Sundarbans, particularly in the Pasur and Shibsha rivers. Human activities, including overfishing, tourism, the dry fish industry, marine vessel movement, port activity, and unplanned settlements, were identified as major contributors to microplastic pollution in the region. Microplastic pollution levels in Sundarbans Reserve Forest (SRF), area exhibited significant variation, decreasing in the order of surface water > fish > sediment. The distribution of microplastics was influenced by factors such as geological location, pollution load from tributaries, wind direction, surface current, tidal influence, and sedimentary budget. The study serves as a vital baseline for future research, conservation efforts, and policy formulation aimed at safeguarding the pristine ecosystem of the Sundarbans from the impacts of plastic pollution.

Acknowledgement:
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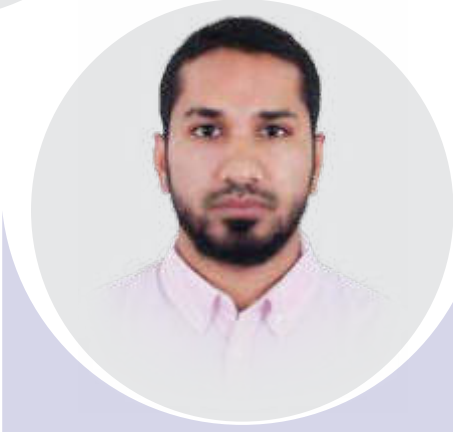

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7

CHAPTER

OCEANOGRAPHIC DATA CENTER

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.

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 & 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

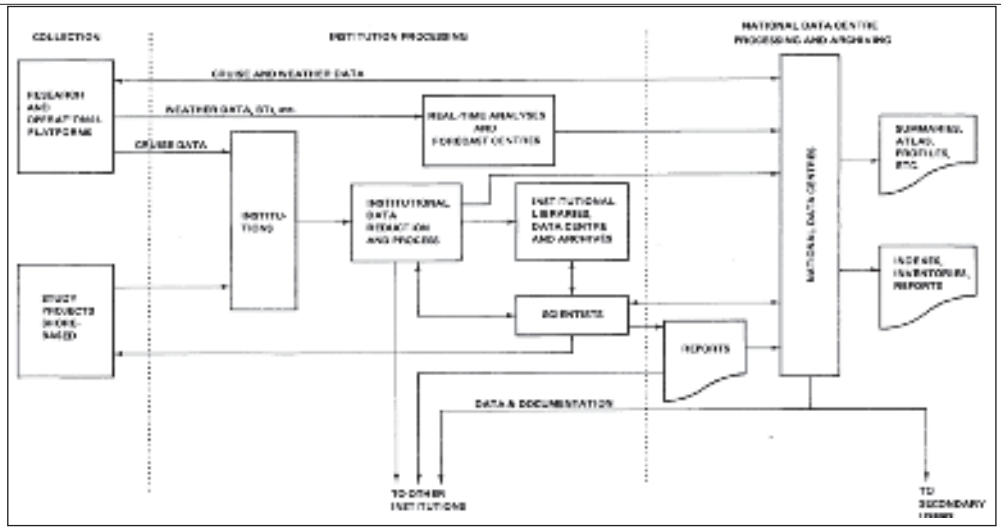
Atmospheric and oceanographic data may be archived in several different computer forms: character format, native format, packed binary or in one of several “standard” scientific data formats. Users of datasets must be aware of how the data are stored. There are different methods for storing both character 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.

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RESEARCH PROJECTS OF 2023-2024 FY

SL	Title of Research Projects	Principal & Associate Investigators
01	Winter Stratification, Frontal Zone Identification and Coastal Current Detection in the Eastern Coast of Bangladesh	Principal: Rupak Loodh, SO, Physical and Space Oceanography Division Associate: Siraj Uddin Md. Babar Chowdhury, SO, Physical and Space Oceanography Division
02	Investigation of Sedimentation and Mineralogy of the Seafloor Deposits along the Central Coastal-marine Area of Bangladesh	Principal: Md. Zakaria, SSO, Geological Oceanography Division Associate: Mohammad Mozammel Hossain Khan, SO, Geological Oceanography Division Mst. Tania Islam, SO, Oceanographic Data Center
03	Assessing Coastline Erosion Protection Measures via an In-depth Examination of Sedimentary Processes along the South-eastern Coast of Bangladesh	Principal: Mohammad Mozammel Hossain Khan, SO, Geological Oceanography Division Associate: Md. Zakaria, SSO, Geological Oceanography Division Mst. Tania Islam, SO, Oceanographic Data Center Syntheia Towhidy, SO, Biological Oceanography Division
04	Status and Impact of Oil-Grease in the Water & Sediment of Central Coastal Region of Bangladesh.	Principal: Abu Sharif Md. Mahbub-E-kibria, SSO, Environmental Oceanography and Climate Division Associate: Md. Tarikul Islam, SSO, Chemical Oceanography Division Siraj Uddin Md. Babar Chowdhury, SO, Physical and Space Oceanography Division Mohammad Mozammel Hossain Khan, SO, Geological Oceanography Division Showmitra Chowdhury, SO, Biological Oceanography Division
05	Carbon Sequestration Capacity of Tidal Marshes and Mangroves Soil and their Response to Climate Change in the Deltaic Central Coast of Bangladesh	Principal: Mir Kashem, SO, Environmental Oceanography and Climate Division Associate: Sultan Al Nahian, SO, Environmental Oceanography and Climate Division Md. Zakaria, SSO, Geological Oceanography Division Seema Rani, SSO, Biological Oceanography Division Syntheia Towhidy, SO, Biological Oceanography Division Bipasha Sur, SO, Biological Oceanography Division Md. Alamgir Hossain, SO, Environmental Oceanography and Climate Division
06	Micro-plastic Contamination Assessment in Marine Fish Species from the Central and Northeastern Coastal Regions of Bangladesh.	Principal: Sultan Al Nahian, SO, Environmental Oceanography and Climate Division Associate: Mir Kashem, SO, Environmental Oceanography and Climate Division Abu Sharif Md. Mahbub-E-kibria, SSO, Environmental Oceanography and Climate Division Ahsan Habib Nayan, SO, Environmental Oceanography and Climate Division Md. Tarikul Islam, SSO, Chemical Oceanography Division
07	Distribution pattern of pollutants and pollution sources along the coastline of Cox's Bazar district in Bangladesh	Principal: Md. Hasanat Arefin, SO, Environmental Oceanography and Climate Division Associate: Abu Sharif Md. Mahbub-E-kibria, SSO, Environmental Oceanography and Climate Division Mir Kashem, SO, Environmental Oceanography and Climate Division Sultan Al Nahian, SO, Environmental Oceanography and Climate Division Md. Alamgir Hossain, SO, Environmental Oceanography and Climate Division
08	Occurrences of Micro-plastics over the Marine Fisheries Resources according to their Marine Food Chain in the South East Coast of Bangladesh	Principal: Ahsan Habib Nayan, SO, Environmental Oceanography and Climate Division Associate: Md. Simul Bhuyan, SO, Biological Oceanography Division Bipasha Sur, SO, Biological Oceanography Division
09	Exploration of Coral resources of the Bay of Bengal	Principal: Md. Hashibul Islam, PSO, Chemical Oceanography Division Associate: Md. Hanif Biswas, SO, Biological Oceanography Division Md. Tarikul Islam, SSO, Chemical Oceanography Division Ahsan Habib Nayan, SO, Environmental Oceanography and Climate Division
10	Biochemical Composition, Occurrence & Distribution Pattern of Commercially Important Marine Crabs of Bangladesh	Principal: Md. Tarikul Islam, SSO, Chemical Oceanography Division Associate: Abdullah Al Mamun Siddiqui, SSO, Biological Oceanography Division Seema Rani, SSO, Biological Oceanography Division Bipasha Sur, SO, Biological Oceanography Division
11	Phylogenetic identification and biochemical composition of 10 commercial seaweeds of Bangladesh	Principal: Abu Sayeed Muhammad Sharif, SSO, Biological Oceanography Division Associate: Md. Hanif Biswas, SO, Biological Oceanography Division
12	Investigation of jellyfish resources and their potential as blue foods and high-value bio-products	Principal: Abdullah Al Mamun Siddiqui, SSO, Biological Oceanography Division Associate: Showmitra Chowdhury, SO, Biological Oceanography Division Sultan Al Nahian, SO, Environmental Oceanography and Climate Division Md. Tarikul Islam, SSO, Chemical Oceanography Division Ahsan Habib Nayan, SO, Environmental Oceanography and Climate Division Syntheia Towhidy, SO, Biological Oceanography Division
13	Present status of potential non-conventional marine species and their contribution in the blue economy of Bangladesh	Principal: Seema Rani, SSO, Biological Oceanography Division Associate: Abdullah Al Mamun Siddiqui, SSO, Biological Oceanography Division Md. Simul Bhuyan, SO, Biological Oceanography Division Bipasha Sur, SO, Biological Oceanography Division Ahsan Habib Nayan, SO, Environmental Oceanography and Climate Division
14	Assessment of bacterial diversity and antibiotic sensitivity pattern in marine microbial community after anthropogenic perturbation in the water of south-eastern coast of Bangladesh	Principal: Bipasha Sur, SO, Biological Oceanography Division Associate: Seema Rani, SSO, Biological Oceanography Division Mir Kashem, SO, Environmental Oceanography and Climate Division Md. Hanif Biswas, SO, Biological Oceanography Division
15	Variability of chlorophyll-a and phytoplankton community structure with tides in response to physico-chemical parameters of estuarine water of Cox's Bazar, Bangladesh	Principal: Syntheia Towhidy, SO, Biological Oceanography Division Associate: Seema Rani, SSO, Biological Oceanography Division Md. Hashibul Islam, PSO, Chemical Oceanography Division Rupak Loodh, SO, Physical and Space Oceanography Division Bipasha Sur, SO, Biological Oceanography Division

8 CHAPTER

BLUE ECONOMY

PLANS OF BORI FOR BLUE ECONOMY

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.

Bangladesh Oceanographic Research Institute's Short-term, Mid-term and Long-term plans for the development of Blue Economy (From 2018 to 2028)

Terms	Plan	Program Description	Time Period (FY)	Total Budget	Budget Source	Progress (Up to July 2022)	Required Element
Short Term	Identification of geologically important sites and potential resources present in the coastal area by collecting geological baseline data of southern part of the eastern coast.	The coastal area of Bangladesh is divided into 3 zones: East, Central and West. Among these three zones, collect and analyze sediment and sea water samples from the coastal and nearshore areas of the eastern area (part from Cox's Bazar to St. Martin's Island) and identify existing resources by determining geological parameters.	Short term (2 years) 2018-2019 to 2019-2020	40 lac	Revenue Budget (Special Allocation)	According to the research results, significant amount of heavy minerals up to 8-18% was found in Cox's Bazar sea area. A technical report has been sent mentioning the results. Progress: 100%. The results have already been published in the institute's yearbook. Research submitted for publication in journals.	
	Determination of Baseline Data related to Biological Oceanography.	Collecting and identifying seaweed samples from the shores of Martin's Island. Illustrated taxonomic booklet "Marine algae (Seaweed) of Bay of Saint Martin's Island, Bangladesh" is to be published.	Sshort term (2 years) 2018-2019 to 2019-2020	50 Lac	Revenue Budget (Special Allocation)	During the fiscal years 2018-19 and 2019-20, cruises were conducted and samples were collected by undertaking R&D projects in this regard. 72 species have already been identified by analyzing collected seaweed samples. Illustrated taxonomic booklet "Marine algae (Seaweed) of Bay of St. Martin's Island, Bangladesh" is in progress. 40 species have already been fully profiled. Progress: 97%. Documentation is in progress for printing.	
	Quantification of zooplankton of Bay of Bengal and publish Book.	Collecting Zooplankton samples from the coast of Bay of Bengal to deep sea area to identify it. Publication of taxonomic book with photographs.	Short term (2 years) 2018-2019 to 2019-2020	20 Lac	Revenue Budget (Special Allocation)	BORI scientists collected samples of zooplankton from deep sea jontly with Fisheries Research Institute using RV Dr. Fritjof Nansen ship of Norway. Zooplankton has been identified by analyzing these samples of Bay of Bengal. Publication of illustrated taxonomic book is in progress. Progress: 90%	
	Aquaculture	Identifying different areas to determine the location for aquaculture (cage culture) and to carry out a pilot culture.	Short term (2 years) 2018-2019 to 2019-2020	20 Lac	Revenue Budget (Special Allocation)	The plan is being implemented as a medium term plan.	
	Baseline Data enrichment related Chemical Oceanography.	Enrichment of Baseline data related to chemical oceanography in the coastal and nearshore areas of the eastern part of Bangladesh	Short term (2 years) 2018-2019 to 2019-2020	50 Lac	Revenue Budget (Special Allocation)	Research has been completed in the 2019-20 FY. Progress is 100%. Publication of result is in progress.	

	Reduce pollution of coastal areas.	Prevention of plastic and garbage pollution in the eastern 250 km coastal area of Bangladesh's 710 km long beaches. Formulate and implement Marine Litter Action Plan. Practical implementation of domestic and international laws and policies to prevent pollution of the marine environment of Bangladesh and to protect marine environment in a sustainable manner.	Short term (2 years) 2018-2019 to 2019-2020	20 Lac	Revenue Budget (Special Allocation)	A pollution assessment map has been prepared for the area from St. Martin Island to Maheshkhali Island. Progress: 100%. Result publication is in progress.	
	Experimental data collection and regular updating activities for the proposed Oceanographic Data Centre.	To inform about future conditions by collecting and analyzing meteorological data of coastal areas.	Short term (2 years) 2018-2019 to 2019-2020	10 Lac	Revenue Budget (Special Allocation)	Data collection and data analysis work has been completed. Report preparation is in progress. Two studies have already been published in international journals. Research findings have been presented at international seminars. Progress: 100%	
		To start real time data collection of sea by installing at least one data buoy (Data Buoy) through pilot project in Rejukhal area adjacent to Cox's Bazar Marine Drive Road.	Short term (2 years) 2018-2019 to 2019-2020	30 Lac	Revenue Budget (Special Allocation)	Specifications and estimates for procurement of related equipment in FY 2019-20 have been completed. Equipment could not be collected on time due to COVID-19 situation. BORI's technical committee permission for procurement of equipment was not obtained.	Approval for Buoy installation equipment.
	Marine affairs related skilled manpower development with sea related awarness program.	Initiatives will be taken to develop and implement a comprehensive roadmap to create national and international opportunities for training and workshops of scientists to create skilled manpower. Initiatives will be taken to create and implement a complete roadmap for public awareness activities on ocean issues. This will also help to improve the tourism sector.	Short term (2 years) 2018-2019 to 2019-2020	100 Lac	Revenue Budget (Special Allocation)	12 scientists working at BORI underwent 15 days training at NIO, India. Director General of BORI participated in the oceanography workshop of the Third Institute of Oceanography of China and received assurances about providing training to BORI scientists at the said institute in China. 3 scientists trained on remote sensing. 5 officers received training from NOAMI. Moreover 15 officers have completed 2 months non-cadre basic training at National Development and Training Academy. Proposals for signing MoUs have already been received from 3 universities of the country. The proposal is being presented approval.	Signing MoUs with experienced and skilled countries in oceanographic research.
Mid Term	Establish marine aquarium	Establishment of a research oriented modern marine aquarium in Bangladesh Oceanographic Research Institute area.	Mid term (4 years) 2018-2019 to 2021-2022	39,577 crore	Annual Development Program (ADP Budget)	PEC meeting was held in Planning Commission on 25/03/2018. As per the decision of the PEC meeting the reconstituted DPP has been sent. DPP sent back on 7th April 2022 with some observations from Planning Commission. As per the observations /opinions of the Planning Commission, permission to acquire the land has been obtained. Accordingly, the work of reorganizing the DPP is underway.	Approval of DPP.

	Bangladesh Oceanographic Research Institute (2nd Phase) Project Undertaking.	Development of physical infrastructure and other facilities of Bangladesh Oceanographic Research Institute, construction of work shop, installation of ocean observation system, research vessel (Research Vessel) and collection of laboratory scientific equipment and other equipment.	Mid term (4 years) 2018-2019 to 2021-2022	750 crore	Annual Development Program (ADP Budget)	The project titled Bangladesh Oceanographic Research Institute (2nd Phase) at an estimated cost of Tk 44394.00 lac; Approved in ECNEC meeting held on 05 April 2022 for implementation from April, 2022 to March, 2025. Project implementation is in progress.	DPP approval.
	Determination of Base Line Data related to physical and space oceanographic.	Collecting Base Line Data related to all physical parameters (such as wave data, tide data, current data and other temperature, pressure, salinity, depth, etc.) of the coastal and nearshore areas of the 3 coastal zones of the Bay of Bengal.	Mid term (5 years) 2018-2019 to 2022-2023	200 Lac	Revenue Budget (Special Allocation)	The physical parameters of most of the nearshore areas of the east coast have been determined in 2 zones of the coastal area. In FY 2021-22, samples were collected from the remaining area up to Kutubdia. Already 70% research activities have been completed. A research proposal has been submitted for FY 2022-2023 for the remaining work.	Installation of at least 1 tide gauge in coastal areas.
	Determination of biochemical composition of non-conventional animals.	To determine the biochemical composition of various non-conventional (unconventional) animals found in the coastal areas of Bangladesh, such as snails, oysters, crabs kuchia, etc.	Mid term (5 years) 2018-2019 to 2022-2023	100 Lac	Revenue Budget (Special Allocation)	In the financial year 2019-20 and 2020-21, non-traditional marine invertebrates (oysters) and marine invertebrates (Marine Invertibrate) have been cultivated in Rejukhal, an area near BORI. Progress: 65%. Testing is in progress for the remaining works.	
	To identify geologically important areas and potential resources present in coastal marine areas by collecting geological oceanographic base line data of the eastern coast.	Coastal Area All geological parameters (such as mineralogical data, sediment characteristics, geological maps, tectonic movements, erosion and deposition, base line data related to precious minerals) of the eastern area (from Feni to Saint Martin) coastal and nearshore areas within the three zones. Base Line Data Collection.	Midterm (5 years) 2018-2019 to 2022-2023	80 Lac	Revenue Budget (Special Allocation)	Among the three sea areas, half of the eastern sea area (about 5000 sq km) has been sampled. Progress is 70%. Research proposals have been submitted for FY 2022-2023 for the remaining 30% of the work.	Arranging a research vessel or boat.
	Preparation of list of marine bio-diversity and valuable organisms by determining Base Line Data related to Biological Oceanography.	Bay of Bengal St. By collecting samples of seaweed from the coast of Martin's Island, analyze the biochemical composition and determine the amount of agar and carrageenan.	Midterm (5 years) 2018-2019 to 2022-2023	80 Lac	Revenue Budget (Special Allocation)	A research project proposal has been approved by BORI in the financial year 2019-20 to carry out research activities in this regard. Out of 100 identified seaweeds, out of 20 commercially important seaweeds, 6 seaweeds are being researched on economic use and cultivation methods. Agar and carrageenan have already been produced from seaweed. Progress: 70%. A research proposal has been submitted for FY 2022-2023 for the remaining work.	Taking analytical services from BCSIR/ BAEC.

	Aquaculture	Undertake and implement the pilot project of aqua culture (Cage Culture) at designated places.	Mid term (5 years) 2018-2019 to 2022-2023	200 Lac	Revenue Budget (Special Allocation)	Plans are underway to take up a project from the research sector of BORI.	Necessary to take technical consultation services in this regard.
	Identifying the area of oil spill in the sea and determining the harmful of the oil spill.	Assessing the impact of Oil Spill on Eastern and Central Coastal and Nearshore areas within 3 coastal zones.	Mid term (5 years) 2018-2019 to 2022-2023	100 Lac	Revenue Budget (Special Allocation)	Research activities have been taken up in the financial year 2021-22. The work of the eastern area has been completed. Progress: 50%. A research proposal has been submitted for FY 2022-2023 for the remaining work.	
	Public awareness activities on oceans including creating skilled manpower on oceans.	To undertake public awareness activities to protect forest and aquatic resources of coastal areas. As a result, the tourism sector will develop along with the environment.	Mid term (5 years) 2018-2019 to 2022-2023	100 Lac	Revenue Budget (Special Allocation)	Training is being given to scientists and officers of the institute. A training program has already been organized at India's National Institute of Oceanography (NIO), Goa. In view of the proposal from Geological Society of Malaysia to monitor and train the operations of the Oceanography Data Center, there have been fruitful discussions with the Malaysian institution NAHRIM and other institutions regarding training. The training calendar for the fiscal year 2022-2023 has been prepared.	Development of cooperation by signing memorandum of understanding with countries skilled in oceanographic research.
Long Term	Determine the physical and space oceanographic Base Line Data to determine sea water quality, productivity and potential presence of fish.	Creating a local algorithm (Local Algorithm) through chlorophyll and other physical data, through which it will be possible to determine the quality of sea water, productivity and possible presence of fish from satellite images.	Long term (above 5 years) 2018-2019 to 2027-2028	500 Lac	Revenue Budget (Special Allocation)	A plan of action has been taken in this regard. Implementation of long-term activities in this regard is also ongoing through short-term activities. Progress: 35%	Collecting Satellite Image.
	Determination of Base Line Data related to Geological Oceanography.	Base regarding geological parameters of coastal and nearshore areas of Bangladesh (3 zones) (such as mineralogical data, sediment characteristics, geological maps, tectonic movements, erosion and deposition, sub-surface core data collection and base line data related to precious minerals) To identify the existing mineral resources in the area by collecting Line Data.	Long term (above 5 years) 2018-2019 to 2027-2028	500 Lac	Revenue Budget (Special Allocation)	Long-term activities are also ongoing in the short-term activities. The work on the east coast area will be completed in FY 2022-23. Progress: 35%	Use of NAVY/ DoF vessels may be required.
	Bayes line data enrichment related to chemical and biological oceanography of port areas.	Monitoring the actual situation of ballast water management of Chittagong sea port and Mongla sea port and taking timely and sustainable measures to identify various invasive species and stop their entry.	Long term (above 5 years) 2018-2019 to 2027-2028	100 Lac	Revenue Budget (Special Allocation)	A plan has been adopted to take action in this regard.	Assistance & approval from Chittagong Port & Mongla Sea Port.

	Conducting magnetic survey.	Conducting magnetic survey in territorial sea and EEZ area of Bay of Bengal and identifying economic mineral (Iron bearing Mineral resource) area. It will be possible to detect important economic minerals including magnetic minerals.	Long term (above 5 years) 2018-2019 to 2027-2028	1000 Lac	Revenue Budget (Special Allocation)	The project titled Bangladesh Oceanographic Research Institute (2nd Phase) at an estimated cost of Tk 44394.00 lac; Approved in ECNEC meeting held on 05 April 2022 for implementation from April, 2022 to March, 2025. The project will collect related equipment. Project implementation is in progress.	Collecting marine magneto-meters
	Carry out gravity survey.	Collecting economic and scientific data, determining geoid and geological history through gravity survey in Territorial Sea and EEZ area of Bay of Bengal. Moreover, it is believed that there is a possibility of getting gas hydrate in the EEZ area of Bangladesh. In this case gravity survey is required to identify the possibility initially.	Long term (above 5 years) 2018-2019 to 2027-2028	1000 Lac	Revenue Budget (Special Allocation)		
	Determination of Base Line Data related to Biological Oceanography.	Coral rehabilitation and production in the St. Martin area; Which will improve the biodiversity index of that area. Will develop fishery resources. If the program is successful, it will be widely expanded. As a result coral sighting tourism will expand.	Long term (above 5 years) 2018-2019 to 2027-2028	100 Lac	Revenue Budget (Special Allocation)	Long term activities are being carried out in short term activities. Progress: 30%	
	Establishment of Oceanographic Data Center.	Development of marine information and technology including development and data enrichment.	Long term (above 5 years) 2018-2019 to 2027-2028	4000 Lac	Annual Development Program (ADP Budget)	The project titled Bangladesh Oceanographic Research Institute (2nd Phase) at an estimated cost of Tk 44394.00 lac; Approved in ECNEC meeting held on 05 April 2022 for implementation from April, 20 22 to March, 2025. Data center with ocean observation system will be established in the said project. Project implementation is in progress.	
		Preparing ocean observation system for setting up data buoys at different places of the sea and doing ocean monitoring (Real time ocean monitoring) by setting up at least 8 data buoys.	Long term (above 5 years) 2018-2019 to 2027-2028	200 Lac	Annual Development Program (ADP) budget		
	Undertake public awareness activities.	According to the roadmap of public awareness activities, 50% of the population of coastal areas will be covered under the said activities.	Long term (above 5 years) 2018-2019 to 2027-2028	500 Lac	Revenue Budget (Special Allocation)	As part of public awareness work, a billboard has been put up in Himchhari area of Cox's Bazar. 2 digital displays have been installed at the main gate of the institute and in front of the administration building.	

Activities of Bangladesh Oceanographic Research Institute (BORI) to Implement the Blue Economy Development Plan Adopted by the Maritime Affairs Unit (MAU) of the Ministry of Foreign Affairs (MoFA)

Action Plan	Initiative	Current progress
Development of Mariculture	Identification of suitable areas for Mariculture	Physical, chemical and biological parameters, water quality, nutrients, chlorophyll etc. have already been measured in the coastal area from Saint Martin's Island to Kutubdia Island to identify suitable areas for mariculture. Data is being analyzed to identify suitable areas and initiatives are being taken to survey other areas.
Development of Marine tourism	Setting up a world-class marine aquarium in Cox's Bazar	A PEC meeting was held in the Planning Commission on 25/03/2018 in view of sending the project proposal. As per the decision of PEC meeting, the reconstituted DPP has been sent to the Planning Commission. DPP sent back on 7 April 2022 with some observations. As per the observations of the Planning Commission, the work of restructuring the DPP is in progress.
	Dolphin and whale sightings, identification of their habitats and annual time periods of presence	Initiatives have been taken to take action in this regard.
	Declaration of Marine Eco-park to protect the existence of corals	Taxonomic study of corals and coral restoration work is ongoing to protect the integrity of corals. Coral Identification has already been completed.
Offshore Energy, Renewable Energy and Blue Biotechnology research and development	Ensuring food and nutrition	Modern methods of farming of sea snails, oysters (green mussel), and crabs are being researched to ensure food and nutrition.
	Establishment of marine based industries	Commercial ingredients have already been extracted from seaweed for setting up marine-based industries. Plans are being taken to arrange for commercial production of these components.
	Production of cosmetics from marine resources	Agar and carrageenan have already been produced from seaweed. Research activities for the production of alginate are ongoing.

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.

Action plan of Bangladesh Oceanographic Research Institute According to Election Manifesto-2018 (5 Year Plan)

Election Manifesto No. and Subject	Identified priority activities/action plans adopted	target	Cumulative Achievement (%) (February 2019 – July 2022)
3.22 Sea Conquest: Blue-Economy-Opening Horizons of Development	Identification of geologically important sites and potential resources in the eastern coastal area of the Bay of Bengal (from Feni to St. Martin Island)	Determination of potential heavy mineral and light mineral sand content by collection and analysis of sediment samples from the East Coastal area (from the core up to 20 km inland) by June, 2022.	Sediment sample collection and analysis completed from St. Martin Island to Kutubdia (up to 20 km offshore). Overall 75% of the work has been completed. Research proposals have been submitted for completion of the remaining 25% of the work in FY 2022-23.
	To determine the productivity of marine fisheries resources and the potential presence of fishes by determining the physical parameters of the east coastal sea area.	Up-welling, marine stratification and spatio-temporal status by collecting and analyzing physical data of water in the eastern coastal sea area (up to 20 km inland from the coast) by June, 2022. To determine the productivity of marine fisheries and the potential presence of fish.	Sample collection and analysis of sea areas adjacent to St. Martin Island and Maheshkhali Island has been completed. Sampling of the area up to Kutubdia has been completed. Overall 75% of the work has been completed. Research proposals have been submitted for completion of the remaining 25% of the work in FY 2022-23.
	Monitoring the extent of ocean acidification	Determination and monitoring of pH values in coastal areas. Setting up of pH monitoring stations by 2022.	Data is currently being collected through surveys. 70% work completed. Research proposals have been submitted for completion of the remaining 30% of the work in FY 2022-23.
	Determining the biochemical composition of various non-conventional animals found in the coastal areas of Bangladesh, such as snails, oysters, crabs, kuchia, etc.	By the year 2022, to determine the biochemical composition of four species of snails, oysters, crabs and Kuchia in the eastern coastal sea area and to develop simple farming methods and field tests.	A project for cultivation of unconventional marine invertebrates (oysters) and marine invertebrates has been taken up in Rejukhal area near BORI. 60% of project activities have been completed. Field survey is going on to complete the remaining 40% of the work.
	Preparation of a taxonomic inventory of the seaweeds and corals of the East Coast area and St. Martin Island.	Publication of taxonomic book on seaweed of St. Martin's Island within 2022.	97% completion of book preparation of seaweed list. 70% of total work completed. Preparation of taxonomic list of corals is in progress.
	Collection and Publication of Marine Phytoplankton and Zooplankton Specimens.	Samples were collected by BORI scientists using RV Dr. Fridtjof Nansen research ship of Norway from deep-sea in association with Fisheries Research Institute. The samples will be analyzed and the booklet of Marine Phytoplankton and Zooplankton will be published.	By analyzing these samples of Bay of Bengal, 70% of the zooplankton identification work has been completed. The remaining 30% work will be completed in FY 2022-23. Phytoplankton identification is also underway.
3.23 Climate Change and Environmental Conservation	Mapping the sources and causes of environmental pollution along the coast	Mapping the sources and causes of environmental pollution along the coastal area of Bay of Bengal, Bangladesh.	Mapping of St. Martin area has been completed. The work in the area from Teknaf to Maheshkhali has been completed. 70% of total work completed. Research proposal is submitted in FY 2022-23 after completion of remaining 30% work.
	Assessment of coastal climate change and future scenarios	Collection of weather data from 1948 to present day from 16 coastal meteorological stations and installation of data buoys to assess ocean influence.	Two parameters namely rainfall and temperature data were obtained and analysis was done. Overall 70% work has been completed. For the remaining 30% of the work, data is collected directly from the BMD. Data analysis is in progress.

9 CHAPTER

BORI ADMINISTRATION

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.

Human Resource

SI	Approved Post	Appointed Manpower				Total	Progress
		1st Class	2nd Class	3rd Class	Outsourcing		
1	1st phase =137 (2015-2017 fiscal years)	18	24	12	49	103	Completed
2	2nd phase =31 (2017-2019 fiscal years)	17	17	4	14	52	Completed
3	3rd phase =55 (2019-2021 fiscal years)	18	-	-	-	18	Completed

Trainings

To motivate and build up skillful human resources Bangladesh Oceanographic Research Institute (BORI) emphasizes on customized training programs and developed different training modules.

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, UV-Vis Spectrophotometer Operational Training, HPLC Operational Training, Training on Microscope etc.

(c) Software Training

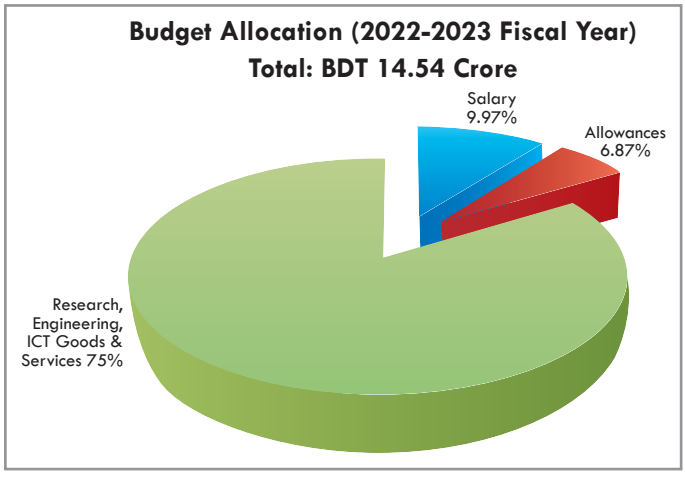
It also arranges regular training programs for researchers and engineers like basic software: FORTRAN, Java, C/C++, MATLAB and Pythons etc., analytical & application software: R, SPSS, Python, GIS Basics, GIS Advance and some other customized software designed for laboratory equipment.

ACCOUNTS AND 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.

Budget

The overall outline of the financial costs of BORI for the last 2022-2023 fiscal's year's is given below.



Audit

Bangladesh Oceanographic Research Institute has an internal auditing system. The auditor 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 vessels, development works and maintenance service purposes. Engineering division is responsible for valuable utility services, development planning, maintenance of buildings and vessels, renovation and construction works for various tasks to the scientific efforts for strengthening and expanding research and development activities in BORI.

Development Planning

Design and planning for 32-meter research vessel & self-sustained pontoon for ship mooring.

Design and planning for 200 m long jetty for berthing research vessel and speed boats

Plan for six storied 100 seat international hostel cum training center.

Plan for three storied Engineering Workshop building cum transport pool.

Plan for vertical extension of two storied officers and staff building up to three storied building.

Design for biological culture unit.

Plan for a 100m research vessel in near future.

Develop an uninterrupted freshwater supply system.

Construct a mosque in the BORI campus.

General Services/Maintenance Works

Civil Works

Plumbing Works

New Construction of Buildings

Hill protection & Guide Wall Maintenance

Electrical & Electronic Repair/Maintenance

Sub-station Maintenance inside Institute Campus.

Electric power management and solar system.

Other Responsibilities

Annual procurement management along with the administrative division.

Supporting scientists for acquiring required research equipment along with the administrative division.

Enhancing the Marine Instrumentation capacity.

Planning to develop underwater marine robots.

Engineering Workshop to assist scientists and for other domestic engineering services.

Assisting Administrative division to arrange training/seminar/workshop.

Assisting Information Management Division with proper co-ordination.

Recent Activities

Implement BORI (2nd Phase) Project approved in April 2022 by ECNEC.

Preparation of Development Project Proposal (DPP) along with the administrative division.

Assisting administration through procurement activities, quality assurance and other necessary activities.

Utilities like uninterrupted electricity, water supply and sewerage management etc. and liable for repairing of pumps, valves, generators, machineries and lab equipment.

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.

Research Fleet Services (In Near Future)

Assess and execute all the necessary works of repairing and maintenance for ship, boats, jetty/mooring facilities.

Estimate the annual budget for ship, boats and jetty repairing and maintenance, voyages & fleet staffs.

Co-ordinate the vessel operation team, BORI scientists and administration during voyages.

Plan for voyages with BORI R&D Wing.

Prepare vessel for voyages ensuring fuel, freshwater, fooding and other requirements.

INFORMATION MANAGEMENT DIVISION (IMD)

Ict Cell

The goal of the cell is to offer a centralized computer facility that includes hardware maintenance, software installation, networking, computer troubleshooting, and internet service. The cell also looks after the Institute's e-nothi, d-nothi, email service, social media, and website management. In order to ensure alignment with the organization's overarching goal, the ICT Cell manages IT and communication development activities at all levels.

In order to support the Institute's aims for research, education, and administration, the ICT cell's mission is to give value via leadership in the creation and implementation of cutting-edge computing and information technology solutions.

Activities of ICT Division of BORI

- Develop Ideas to digitalize the manual system and develop the system by an efficient vendor with proper monitoring
- Providing internet services and quick maintenance in office, officers' dormitory, club building, DG Banglo, officers' quarter, and Rest House
- All types of software installation including operating system
- Software/Hardware troubleshooting.
- Arrange and manage all types of online/offline seminars, workshops, training, and meeting.
- All programs photography and collection photos.
- To ensure maximum use of need-based state-of-the-art of technology.
- Monitor and ensure round-the-clock Internet and Telephone facility.
- Monitor, Maintenance, and Troubleshoot BORI website, Servers, Workstations, Routers, Network switches, and all other IT accessories.
- Needful IT support for CCTV system maintenance.
- Provide support for the PABX system.
- Keep track of IT assets.
- Assist scientific officers to process data using programming language, big data set analysis & making meaningful insight, etc.
- Monitor e-filing activities on a regular basis. Organize in-house training on e-filing.
- Prepare tender documents for procurement, publish the tender on the E-GP website, and complete the whole procedure in a timely manner.
- Maintaining E-Haziaa for all employees of the institute, taking the report on a daily basis, and backup the E-Hazira database daily.

CCTV Surveillance System

The whole area of the Institute campus has been brought under CCTV coverage system by installing 47 cameras in different areas of the campus.

PABX System

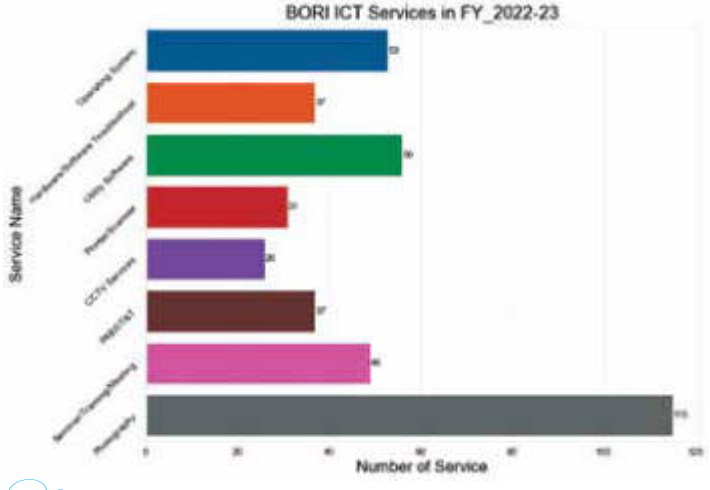
A central PABX system has been established to smooth communication to accelerate research and administrative work. It has 120 active lines.

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, international conferences remotely. Important government officials such as Ministry Office are communicated by using Video Conferencing.

Computer Training Lab

BORI has developed a computer training lab, and the ICT cell is in charge of all the facilities. Ten (10) students can utilize one of the lab's ten computers at once, each of which has a LAN network connection. Throughout the year, several sorts of IT-related training, including Microsoft Office Training, Data Analysis with Python, Data Analysis with MATLAB, R, FORTRAN, ARCGIS, and many other types of training, are conducted at the lab.



Core Activities Done by ICT Cell in FY 2022-23

ICT incorporates a variety of technological advancements used to maintain engagement and information. Information and communication technology (ICT) is a broad category of technological tools and resources used in BORI to

create, distribute, acquire, and maintain IT-related accessories. In the last fiscal year, Operating systems have been installed 53 times, utility software has been installed 56 times, printers & scanners have been worked 31 times, hardware and software troubleshoots have been done 37 times, CCTV cameras have were done 26 times, and PABX/T&T work has been done 37 times. More than 50 seminars, workshops, training, ocean literacy sessions and meetings have been given direct support from ICT, Photography and photographs of more than 115 programs have been saved. In addition, fingerprints, social media, and websites have been regularly updated and managed, and numerous internet-related works have been done.

Future Plan of ICT cell

- Design and develop a central Local area Network for the whole institute.
- Launching automation/ an attendant/entrance service in institute building and all laboratories with a punch card/face detection system.
- Implement Active directory, Applaud action, and File server by creating a domain network to monitor and provide any types of IT support to any workstation centrally.
- User-friendly and efficient web/Desktop application for office's day-to-day activities depends on users' requirement to reduce bulk use of paper.

Library Cell

The Library is an important organ in supporting develop high-quality quality research, research and, outreach programs. Keeping up with modern technology, Bangladesh Oceanographic Research Institute (BORI) has a Library with rich a collection of books and, journals. Every year more than hundreds of new books are added to the library depending on the needs of various research purposes. Network, 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, staff, 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.

OFFICERS

Md. Roni Abbas Hawlader
Assistant Director (Admin)

B.Com. (Accounting)
M.Com. (Accounting)

Sectoral Interest:
Office Management
Accounting System
MIS, Budgeting

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E-mail : ad.admin@bori.gov.bd

Md. Abdur Rouf Talokder
Assistant Engineer

B.Sc. (Naval Architecture & Marine Engineering)
M. Eng. (Naval Architecture & Marine Engineering)

Sectoral Interest:
Offshore Structure
Research Vessel
Underwater Robotics
Marine Instrumentation

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E-mail : abdurrouf@bori.gov.bd

Dr. Fatema Rahman
Medical Officer

MBBS (International Medical College & Hospital, DU)
PGF (Doctor's world wide, England)

Research Interest:
Passionate to discover the
wonders of aquatic world
with local diving
Mammals in Sea

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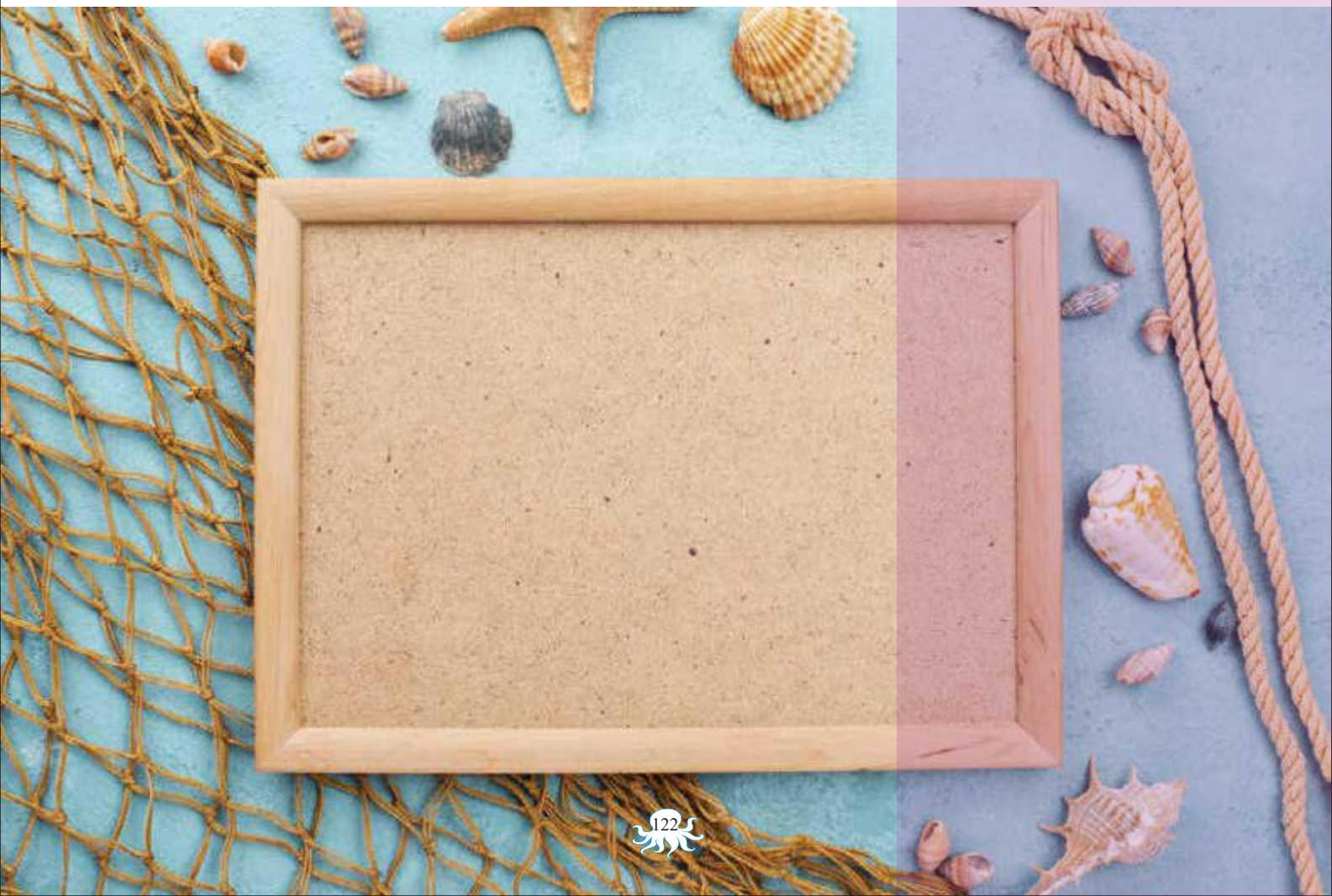
WORLD OCEAN DAY 2023

BORI Celebrated 'World Ocean Day 2023' on 08 June at Cox's Bazar. Honorable Minister, Ministry of Science and Technology, Architect Yeafesh Osman was the Chief guest on the Occasion.

CHAPTER 10

VOYAGES OF EXPLORATION



HONORABLE MINISTER

ARECHITECT YEAFESH OSMAN
MINISTRY OF SCIENCE & TECHNOLOGY AT BORI

Architect Yeafesh Osman, Hon'ble Minister, Ministry of Science & Technology visited BORI laboratories on June 2023.

Honorable Minister visited BORI

Honorable Minister in a meeting BORI Scientists

Honorable Minister visited innovation display of BORI

Honorable Minister Planting Trees at BORI

HONORABLE SENIOR SECRETARY

MR. ZIAUL HASAN ndc
MINISTRY OF SCIENCE & TECHNOLOGY AT BORI

Honorable Principal Coordinator (SDGs), Prime Minister's Office, Mr. Md. Akhter Hossain & Mr. Ziaul Hasan ndc, Honorable Senior Secretary, Ministry of Science & Technology visited BORI on June 2023.

Honorable Principal Coordinator received crest from BORI

Honorable Principal Coordinator & Senior Secretary visited BORI

Honorable Principal Coordinator planted tree at BORI

Honorable Senior Secretary planted tree at BORI

NATIONAL DAYS

BORI observed 47th martyrdom anniversary of Father of the Nation Bangabandhu Sheikh Mujibur Rahman and the National Mourning Day on 15 August 2022.

BORI observed the great victory day by arranging different programs, a discussion meeting was organized in the seminar room of BORI on 16 December 2022.

Father of the Nation Bangabandhu Sheikh Mujibur Rahman's birthday and National Children's Day celebrated on 17 March 2023 at BORI.

BORI organized rally to pay a humble tribute to all language martyrs and celebrates the International Mother Language day early in the morning of 21 Feb 2023.

A discussion program & prize-giving ceremony was organized by BORI on Sheikh Russel Day on 18 October 2022. DG, BORI was present as the chief guest.

On the occasion of the celebration of the Great Independence and National Day 2023 on March 26, a Discussion meeting was organized by the BORI.

TRAINING SEMINAR

Training on 'AMMS-2.0'

Training on 'Service Delivery Commitment'

Seminar on 'Ocean Education & Research'

Training on 'GRS Software'

Training on '4th Industrial Revolution'

BORI VISIT

Cox's Bazar Development Authority (CDA) visited BORI

Students from Jagannath University visited BORI

Students from Khulna University visited BORI

Students from Maritime University visited BORI

A Team from Bangladesh Navy visited BORI

Students from Haji Mohammad Mohsin College Chottogram visited BORI

Students from Haji Shafiq Islamia Dakil Madrasha visited BORI

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

1st Class Officers of BORI- 29 August, 2022 (2nd Recruitment of BORI)

Contact Address
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Cox's Bazar-4730, Bangladesh. www.bori.gov.bd