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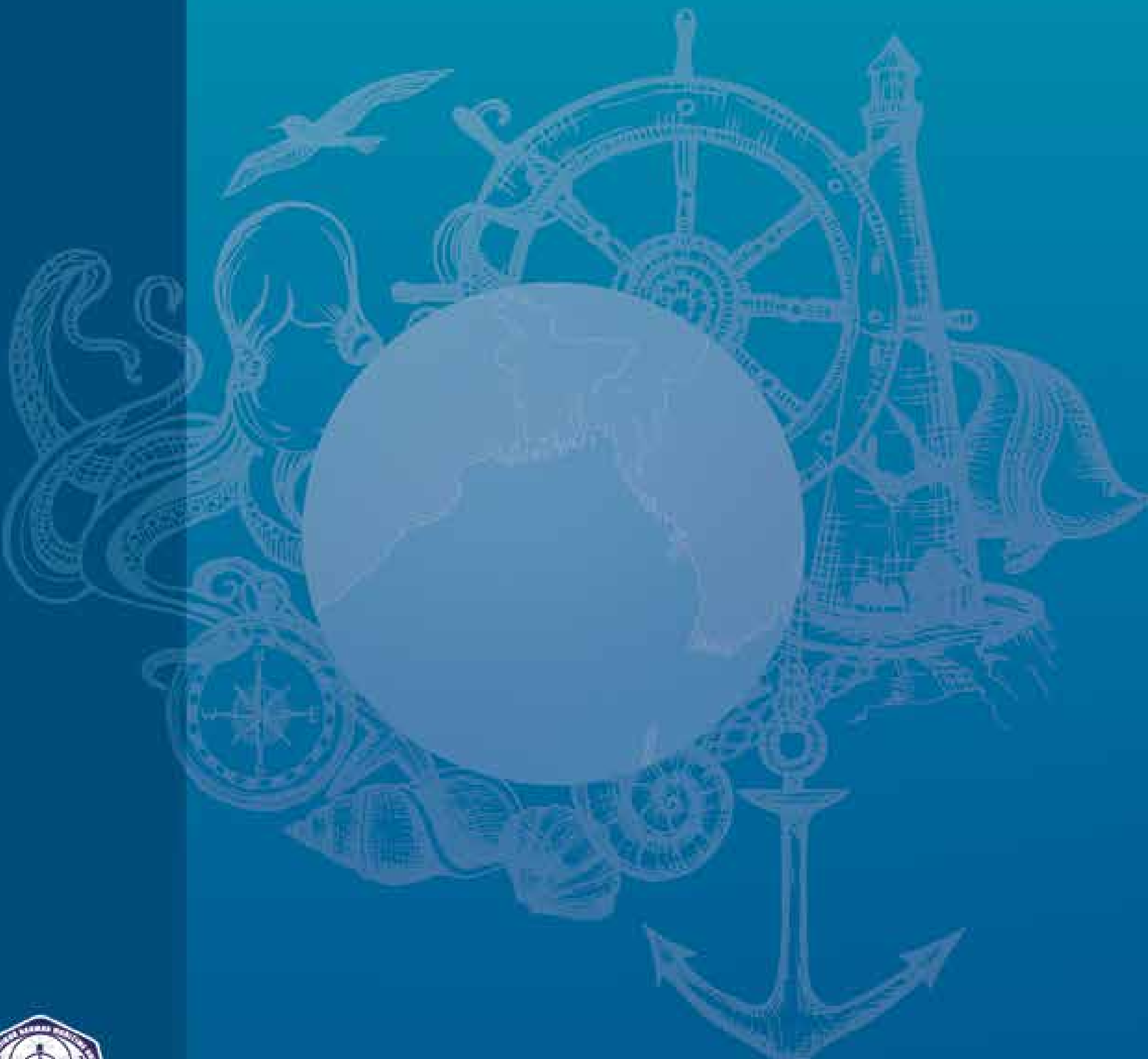

Bangabandhu Sheikh Mujibur Rahman Maritime University, Bangladesh

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"This volume of Bangladesh Maritime Journal is dedicated to the honour of the Father of the Nation Bangabandhu Sheikh Mujibur Rahman on his birth centenary celebration."

## MESSAGE FROM THE CHIEF ADVISER

I am delighted to be a part of the new multidisciplinary, peer-reviewed journal that publishes original research in the 'Maritime Domain' yearly. I am proud that we are publishing this journal in the 100th birth year of the Father of the Nation Bangabandhu Sheikh Mujibur Rahman which is being celebrated as 'Mujib Shoto Borsho 2020'. For the last few years, Bangladesh Maritime Journal has been a beacon of 'Maritime Research' that maintains a high level of ethical integrity, ensuring consistency and scientific rigour in each of its research articles. My desire for Bangladesh Maritime Journal is to continue to excel and insightfully build for the future to provide the greatest value for sharing outstanding science.

There has been a growing appreciation that the world's Oceans and Seas require more in-depth attention and coordinated action. In Bangladesh, certain maritime activities were not well coordinated. It is high time that we establish a platform for sustainable development of Bangladesh through 'Maritime Vision'. Under the visionary leadership of the Hon'ble Prime Minister Sheikh Hasina, Bangladesh today has a huge maritime area of 118,813 sq. km. The country is moving towards achieving Vision 2041' to become a happy, prosperous and developed Bangladesh. With that aim in view, Bangladesh Maritime Journal provides scope for sharing knowledge in maritime issues, challenges, prospects and technology so as to nurture our objectives of 'Blue Economy'.

I hope Bangladesh Maritime Journal will become the primary platform for maritime professionals, researchers, technologists, academicians, policymakers and stakeholders to share findings and publish all aspects of maritime science and technology. I sincerely hope that all professionals will eagerly access Bangladesh Maritime Journal, as both contributors and readers, for the insightful and stimulating science that will shape our future and lead the way towards realizing the dream of 'Maritime Bangladesh'.

In that view, I wish to see the Editorial Team continue to expand their horizon even beyond our frontiers so that we are enlightened more with the knowledge and experiences of the reputed academicians and professionals at the global level. I express my deep satisfaction for the good works of the Chief Editor, Reviewers and the Editorial Board, who have really made great efforts in publishing this important journal.

**Rear Admiral M Khaled Iqbal,** BSP, ndc, psc
Vice-Chancellor
Bangabandhu Sheikh Mujibur Rahman Maritime University, Bangladesh

**EDITOR'S NOTE**

Bangabandhu Sheikh Mujibur Rahman Maritime University, Bangladesh is a premier maritime university of Bangladesh, whose motto is to achieve maritime excellence, through sharpening the storm of intellectual passion within the maritime community. The BMJ is one of such works that truly embodies the qualitative products of students and faculties of BSMRMU as well as other maritime researchers. It contains original research works dealing with theory and practice of maritime science and studies. The journal seeks to foster the exchange of new ideas and information. The scope of this journal covers a full range of research, analysis, design, operation and support. The constantly growing list of maritime specialised areas is included within the scope. This ranges from the technology and policy to strategic maritime issues.

It is hoped that the articles published in this volume will contribute largely to the research on maritime issues and benefit the maritime communities both at home and abroad. The standard of the articles was evaluated on technical quality, relevance and importance of materials, the interest of readers and timeliness through peer review. Independent experts have provided the author with critical commentary and suggestions to improve their final papers prior to publication. The authors had to certify that submitted manuscripts had not been published previously or submitted for publication elsewhere, and did not violate any security, proprietary or copyright restrictions.

The Editorial would not be complete if we do not record our gratitude to the Chief Adviser, Rear Admiral M Khaled Iqbal, Vice-Chancellor, BSMRMU, whose invaluable guidance was always with the Editorial Board. We forward our deepest appreciation to the distinguished reviewers for their hard work and relentless support. We also thank the Advisory Board for their valuable guidance and support. Despite all efforts, toils and sincerity, unintentional errors in whatever form may not be unlikely in the appearance of the Journal. We fervently beseech the readers to pardon us of such unnoticed slights. Comments on the journal, articles as well as editorial policy are welcome and will be considered. We hope that the journal will prove its worth to a reader with an investigative mind, an intellectual zeal, assiduous learning and academic yearnings.

**Commodore M Ziauddin Alamgir,** (L), NGP, fdc, psc, (retd), BN
Dean, FET and Chief Editor, BMJ

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# Ocean Governance for Sustainable Maritime Development in the Bay of Bengal

Rear Admiral M Khaled Iqbal[1]

***Abstract***

*The human civilisation is indebted to the oceans for serving mankind as a major source of food, minerals and energy linking economies around the world. The oceans serve as an engine for global economic growth and highways for seaborne international trade giving access to global markets. But there has been a growing appreciation that the world's oceans require more caring attention and integrated response. There is a progressive degradation of ocean health caused by IUU fishing, marine pollution and unplanned coastal development. However, in recent years, few developing countries have looked to the ocean as a new economic frontier and developed growth policies based on the concept of the Blue Economy. It is aimed at enhancing livelihoods for the poor, creating employment opportunities and reducing poverty.*

*A Blue Economy roadmap is essential to provide an integrated approach to ocean-based sustainable development, which brings together economy, environment and society being closely linked with the UN Sustainable Development Goals 2030 (SDGs). Making the transition to a Blue Economy would entail fundamental and systemic changes in the policy-regulatory-management-governance framework using the tools of an ecosystem-based Marine Spatial Planning (MSP).*

*Today the littoral countries of the Bay of Bengal are showing huge trends of economic development due to their increasing importance on the ocean-based economy. But our development patterns are often undermined and diminished due to lack of appropriate ocean governance measures whereas various policies are either poorly implemented or lacks supervision. So, a regionally integrated management and governance system is the demand of the day in order to ensure sustainable maritime development in the Bay of Bengal region.*

*In this context, the paper endeavours to analyse how the Bay of Bengal region is responding to the challenges of ocean governance and harvest Blue Economy benefits from the ocean. In fact, the challenges are many, but a properly planned Blue Economy and Ocean Policy can bring to the developing countries of this region substantial benefits of economic and social development in the years ahead.*

**Keywords:** Ocean Governance, Marine Spatial Planning, Blue Economy

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## Introduction

The oceans are the most important sources of many invaluable resources and they have big contributions to maintain the climate and biodiversity. The oceans are also engines for global economic growth and key sources of food security. Oceans contribute to poverty eradication by creating sustainable livelihoods, provide food and minerals and continue to support all life today by recycling nutrients and regulating global climate and weather patterns. International shipping and ports provide crucial linkages to global supply chains and are essential to gain access to global markets serving as highways for seaborne international trade.

But there has been a growing appreciation that the world's oceans require more caring attention and coordinated action. The progressive degradation of ocean health is caused by several human drivers like Illegal, Unregistered and Unregulated (IUU) Fishing, land-based and ship-borne marine pollution and unplanned coastal development. It is frequently observed that ocean resources are excessively overexploited. The nation should also be careful about the fact that all the marine-related issues are inter-connected because they may share a common space. Ocean governance is the integrated conduct of the policy, actions and affairs regarding the world's oceans for sustainable use of coastal and marine resources reducing the risk of irreversible damage to our marine eco-systems. However, in recent years, few developing countries have started formulating economic growth policies based on the concept of the Blue Economy. But making the transition to a Blue Economy would entail fundamental and systemic changes in their policy-regulatory-management-governance framework.

It is time for the developing countries of the Bay of Bengal to draft an Ocean Policy vision by charting a course towards a blue horizon and formulate a framework for achieving sustainable development.

## Strategic Importance of the Bay of Bengal (BoB)

The vast maritime-littoral space of the Indian Ocean is of immense geopolitical, geoeconomic and geostrategic significance, where economics and security have always influenced the historical and contemporary discourse in the region. About two-thirds of the world's seaborne trade in oil, 50 per cent of world's seaborne container traffic, one-third of bulk cargo and the world's highest tonnage in the seaborne transportation of goods, reportedly involving some 100,000 ships per year, transit through the Indian Ocean and its adjacent waterways. Historically, the Bay of Bengal region has played a pivotal role as a maritime highway to the greater Indian Ocean where trade, commerce and cultures were intertwined for centuries. Today, due to geostrategic and geoeconomic factors, it emerges as one of the most significant regions in the Indo-Pacific region. The BoB is an important bridge connecting the Pacific and Indian Oceans. This enables South Asia to be connected with South East and East Asia. The Bay of Bengal also forms crucial entry points to India's North-East and Nepal. Bhutan and Kunming of China. The Bay of Bengal is also confronted with common maritime security issues like human and drug trafficking and other cross-boundary issues, whereas its vicinity to the so-called maritime silk route squarely puts a further strategic focus on this region.

## Challenges of Blue Economy

The oceans, with a current estimated asset value of USD 24 trillion and annual value addition of USD 2.5 trillion, would continue to offer significant economic benefits for the coastal states. But the developing countries have to overcome challenges like unsustainable extraction marine resources, destruction of marine and coastal habitats, climate change, sea-level rise and marine pollution.

**IUU Fishing.** A major challenge is unsustainable fisheries due to IUU fishing. Statistics show that the proportion of marine fish stocks estimated to be underexploited or moderately exploited declined from 40% in the mid-1970s to 15% in 2008, and the proportion of overexploited, depleted or recovering stocks, increased from 10% in 1974 to 32% in 2008.

**Ocean Acidification.** A newly emerging issue like Ocean Acidification resulted in a 26% increase in the acidity of the Ocean affecting carbon accretion in coral reefs causing net decreases in global coral reef coverage and associated species.

**Blue Carbon.** Several key coastal habitats such as mangroves, salt marshes and seagrass meadows, also known as Blue Carbon, fix carbon at a much higher rate per unit area than terrestrial forest ecosystems. But mangroves have been reduced to 30-50% of their historical cover and 29% of seagrass habitats are estimated to have been lost in the last 150 years.

## Blue Economy and Sustainable Maritime Development

The Blue Economy is a developing world initiative relevant to all coastal states and countries with an interest in sustainable maritime development. It is aimed at enhancing livelihoods for the poor, creating employment opportunities and reducing poverty. Blue Economy was first prominently addressed during the Rio+20 UN Sustainable Development Conference in 2012. The National Maritime Foundation, an active Indian think tank, has adopted the following definition of the Blue Economy: "Marine-based economic development that leads to improved human wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities". However, a global definition devised by the Economist Intelligence Unit (2015) is "A sustainable ocean economy emerges when economic activity is in balance with the long-term capacity of ocean ecosystems and remain resilient and healthy". However, the difference between "ocean economy" and "Blue Economy" is that the former provides no measure or indication of sustainability. But the Blue Economy concept promotes the sustainable development of the ocean economy.

## Prospects and Potentials of Blue Economy

A brief overview of the state of various maritime sectors and industries would give us a clear indication of the enormous prospects and potentials of the Blue Economy:

**a. Marine Fisheries.** The volume of fish traded by developing countries is estimated at USD 25 billion making it their largest trading item whereas 1 billion people in developing countries depend on seafood for their primary source of protein. There are about 475 species of fish found in EEZ of Bangladesh compared to 250 sweet water species.

**b. Aquaculture.** Integrated multi-tropic offshore aquaculture is the fastest-growing global food sector, now providing 47% of the fish for human consumption.

**c. Marine Biotechnology.** One of the fastest emerging high-technology sectors in Blue Economy is marine biotechnology with a market of an estimated USD 4.6 billion by 2017. It has wide-ranging applications in industrial sectors including pharmaceuticals, cosmetics, nutritional supplements, enzymes and agro-chemicals.

**d. Offshore Energy and Deep-Sea Mining.** The largest chunk of developing countries' ocean economy can be sourced from offshore energy exploration and mining. The seabed currently provides 32% of the global supply of hydrocarbons, up from 20% in 1980.

**e. Marine Tourism and Leisure.** Globally, coastal and marine tourism represents 5% of world GDP. The increasing involvement of local communities in the value chain can contribute to the development of local economies and poverty reduction.

**f. Shipping, Port and Maritime Logistics.** About 80% of global trade by volume and over 70% by value, is carried by sea and handled by ports worldwide. Smart and deep-water ports, efficient shipping and logistics industries will be instrumental for the development of the Blue Economy.

**g. Shipbuilding, Marine Manufacturing and Ship Recycling.** Marine manufacturing consists of construction, repair and maintenance of boats, ships, fishing vessels, yachts, floating structures and other marine technology which is an important sector of the Blue Economy. Shipbreaking or ship recycling is also another growing industry in developing countries.

**h. Marine Renewable Energy.** Renewable energy enjoys almost 22% share of the global energy mix. There are various forms of marine renewable energy: (1) offshore solar energy, (2) offshore wind energy, (3) wave energy, (4) tidal energy, (5) ocean thermal energy, (6) salinity gradient, (7) ocean current energy, and (8) energy from marine biomass.

## Ocean Governance in the Bay of Bengal

As discussed earlier, the Bay of Bengal has tremendous economic and strategic significance. Additionally, the importance of ensuring maritime security is increasingly recognised by all the states in the Bay of Bengal to deal with both traditional and non-traditional threats. The Hon'ble Prime Minister of Bangladesh Sheikh Hasina has expressed that a peaceful and prosperous ocean realm of the Bay of Bengal through the integrated and cooperative partnership would determine the future development and economic growth of Bangladesh.

## Steps Taken by Bangladesh for Sustainable Maritime Development

This is a very important time for Bangladesh when we are witnessing unprecedented economic growth and remarkable development in social and economic indicators with substantial investment in regional connectivity, seaports, special economic zones, coastal industries, energy clusters and offshore oil and gas exploration. As a major Blue Economy initiative, Bangladesh Delta Plan 2100 for the next century has been prepared by the govt which would focus on sustainable delta management, integrated water resources management, long term land reclamation and adaptation to climate change etc. Besides, Vision 2041, a long-term perspective plan for a developed Bangladesh, has identified Blue Economy as one of the essential drivers for sustainable development. Moreover, the goals of SDG 2030, especially SDG Target 14 i.e. Life Below Water is being implemented with various maritime development agenda in Bangladesh.

However, in the past, certain maritime activities were not coordinated and thereby suffered from duplication of efforts whereas some maritime sectors were totally ignored. Various maritime industries were neither controlled nor their performance was supervised. However, in the recent years under the leadership of our Hon'ble PM Sheikh Hasina, Bangladesh has peacefully resolved the long-standing maritime boundary disputes with neighbours: India and Myanmar gaining a huge sea area of 1,18,813 sq km.

The government has formed an independent Blue Economy Cell to ensure proper coordination of Blue Economy activities among all govt and private sector maritime stake holders in the country. Moreover, Bangladesh Ocean Research Institute has been established whereas Bangabandhu Sheikh Mujibur Rahman Maritime University with specialised Maritime Faculties has been set up in 2013 for maritime higher education and research.

However, the researcher like to reiterate on the three voluntary commitments made by Bangladesh during UN Ocean Conference in June 2017 in New York. First one is to declare 5% of marine areas as Marine Protected Area (MPA) of about 7,500 sq km by 2020 (Target 14.2). Mentionable that the Sundarbans which is one of the largest mangrove ecosystems in the world is a declared World Heritage Site. Next is to effectively regulate IUU fishing and destructive fishing practices in marine areas (Target 14.4). The third commitment is to prevent and significantly reduce marine pollution of all kinds, particularly from land-based pollution (Target 14.1).

## Port-led Development

In the present economic context of the globe, a port is not only a corridor for export and import rather it can lead to the overall development of a nation. Therefore, the vision of port-led economic development is followed by many to reduce logistics cost and contribute to economic growth by establishing economic corridors, Special Economic Zones (SEZs), port-based industries, deep seaports, Energy Clusters, FSRU (Floating Storage Regasification Unit) etc. However, following the examples of Shenzhen Port of China and Sagarmala Project of India, the logistics-intensive industries, efficient port, seamless connectivity and requisite skill base would be necessary.

## Maritime Crime and Security Management

We also believe that sustainable Blue Economy is not possible without ensuring maritime security, preventing piracy, human trafficking, smuggling and all kinds of terrorism in the maritime areas. Given the current global and regional security environment, a comprehensive maritime security structure needs to be formed recognising the Bay of Bengal as a common security space.

## Ocean Policy for Sustainable Maritime Development

The approach for an Ocean Policy has to be inter-disciplinary with historians, lawyers, economists and political scientists working with engineers, biologists, chemists and physicists on common ocean interests. In case of Bangladesh, the overall vision of the Ocean Policy should be to ensure a healthy sustainable ocean; nurtured, understood and harnessed wisely for the benefit of all to achieve vision 2021, vision 2041 and the Delta plan 2100. The main elements of Ocean Policy would be as follows:

**a**. Conservation of Marine Biological Diversity

**b**.Regional Marine Planning

**c.** Maintenance of Ecosystem Integrity

**d.** Multiple Ocean Use

**e.** Marine Protected Areas

## Way Ahead

The way forward for the regional countries would be to chart a roadmap at the national and regional level through proper policy formulation and implementation. Some suggested options are as follows:

**a. Develop Ocean Account and Monitor Progress.** Develop systems to measure and monitor the performance of the ocean economy, work out the statistics of the ocean's natural capital, develop an "ocean account" and identify the country's ocean economy industries.

**b. Coordinated Policy Directives.** A coordinated policy planning process with common objectives and information sharing will be essential for all relevant public agencies under a Ministerial level watchdog for better coordination.

**c. Capacity Building.** Capacity-building needs to be planned in regard to governance and institutional framework, academic and research institutions, managerial–technical–technological capabilities and qualified skills.

**d. Priority Sectors.** Each country should weigh the relative importance of various sectors of the Blue Economy and prioritise sectors based on its domestic needs and demands of the global market.

**e. Marine Spatial Planning.** Marine Spatial Planning process can be developed to provide a judicious response for resolving conflicts and multiple ocean uses.

**f. Ocean Policy.** It has become imperative to put in place a comprehensive Ocean Policy based on a shared regional vision for integrated ocean planning and management.

**g. Collaboration and Partnership.** The Blue Economy makes its strongest gains when it adopts a holistic strategy anchored in partnership integrating regional policy and governance frameworks.

**h. Public-Private Partnership.** The private sector must play a key role in the Blue Economy as a way to enhance capacity building**.**

**j. Maritime Education and Skill.** The promotion of higher maritime education at the university level is important to create maritime experts in the country.

**k. Support of the International Community.** The ocean is universal and needs regional collaboration for technical assistance, technology transfer and capacity building.

## Concluding Remarks

To conclude, the challenges to implementing Blue Economy are many, but it stands to bring the people of developing countries substantial benefits of development and general wellbeing in the years ahead. Now is the time to marshal the data, political will and financial resources to put the developing countries on the blue path and design global and regional partnership towards the achievement of ocean governance and sustainable maritime development.

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# Ship Registration System of Bangladesh: An Assessment

Md. Mostafa Aziz Shaheen[1], M Ziauddin Alamgir[2] and Dewan Mazharul Islam[3]

***Abstract***

*Registration offers a flag to a vessel providing access to high sea and ports worldwide. Many countries pursued aggressive registration policy allowing non-citizens with flexible tax and fee structure resulting in a significant amount of revenue earning by becoming the desired destination for ship registration worldwide. Despite ample opportunities, Bangladesh could not tap the potentials of ship registry to boost up her economic growth through fleet expansion. This paper aims at identifying challenges of ship registration in Bangladesh and put forward strategies for their mitigation to get optimum output in the registration market. This study revealed a complicated ship registration process in Bangladesh relying on national register with nationality as a determining factor for registry resulting in sluggish growth of ship registration. The underlying causes are the rigid legal frame, inadequate institutional architecture, huge tax burden, insufficient incentive. Therefore, this study recommends flexibility in a legal frame to introduce hybrid registries, reformation of Mercantile Marine Office, automation of registration process, rationalisation of the tax regime and investment facilitation through incentives.*

**Keywords:** Ship Registration, National Register, Hybrid Registries, Tax Regime.

## Introduction

Shipping has been the backbone of international trade since time immemorial. With the progression of seaborne trade, ship registration has become one of the prerequisites of the ship's operation. Like every person or enterprise, nationality is attributed to a vessel flying the flag of a state.

Ship registration ensures freedom of navigation on the high seas, through territorial

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waters and to enter ports. It brings a vessel within the legal regime on national law and international convention (UK Chamber of Shipping, 2012). Registration process generates revenue, annual tonnage fees and also creates employment opportunities for nationals (Phang and Toh, 1994).

In general, ships are registered in any of the forms among closed, open and hybrid registration (Rogers, 2010). At the beginning of 2019, there are 96,295 vessels trading in the global merchant fleet with a combination of a total of 1.97 billion deadweight tonnage (DWT). More than 70% of the commercial fleet is registered under the Flag of Convenience (FOC) commonly known as the open registry. In terms of tonnage, more than 40% of world fleet registered in three major open registry flags: Panama, Liberia and Marshall Island. These countries are mostly small island developing States, such as the Marshall Islands and the least developed countries, such as Liberia (UNCTAD, 2019).

Panama and Liberia possess aggressive policy to promote ship registration applying FOC. Revenue generated from Liberian International Ship and Corporate Registry (LISCR), the world's 2nd largest open registry, was accounted for 25% of the Liberian national income (Sharife, 2011). Since Panama Flag runs over 19% of total tonnage in the world today, compared to only 13% belongs to Liberia; the income from open registry services of Panama is even much larger (ISL, 2017). In 1969, even in Asia, the establishment of Singapore as a flag of convenience state solved employment for Singaporean nationals. Recruiting Singaporean crew in Singapore registered vessel enjoys a significant refund in annual tonnage tax (Phang and Toh, 1994). Furthermore, financial incentives plus Singapore's reputation as a politically stable and a worldwide network of consular services contributed to her exceptional growth as a shipping registry. Shipping tonnage has grown from 0.02 million gross tons in 1966 when the registry was first established to 88 million gross tons in 2016 (Phang and Toh 1993).

Bangladesh is historically a maritime nation having 710 km coastline along the Bay of Bengal (Shemon, 2017). After the maritime boundary settlement with Myanmar (March 14, 2012) and India (July 07, 2014), the country focuses on prospects of the Blue Economy and aspires to be a middle-income country by 2021 and developed economy by 2041. (CRI, 2014) It can be mentioned that Bangladesh has already fulfilled the criteria of a developing country. Bangladesh is being included in the 'white list' of the International Maritime Organisation (STCW, 2018). The state holds the availability of potential seafarers and its immense population to produce within the shipping market. Presently, Bangladesh applies a national registration system. As a state party of the United Nations Convention on the Law of the Sea 1982 (UNCLOS III), countries adopted 'Merchant Shipping Ordinance, 1983. This ordinance defines the process and conditions of ship registration under the Bangladesh flag. The country also enacted 'Bangladesh Flag (protection) Ordinance, 1982 (Alam and Zakaria, 2016). With existing law and policy, only 46 ships have been registered under the Bangladesh flag (GSO, Bangladesh 2019). In contrary, flags like Panama, Liberia and Singapore had registries of 7860, 3496 and 3433 vessels respectively in 2019 (UNCTAD, 2019). These ships are not sufficient for existing trade and finance. Moreover, Bangladesh, with a large coastline, enough manpower, enlisted in IMO white list and its upward trade growth, has the potential to expand market and beneficiary in the ship registry industry. Though the country has a huge potentiality, due to the national ship registration policy, Bangladesh flag can't capture the opportunities of expanding her fleet compared to other flag registers.

With this backdrop, the purpose of this paper is to assess the existing ship registry policy of Bangladesh with a view to recommending a way out for its improvement.

This research analyses the ship registration policy in Bangladesh. The data were collected from both primary and secondary sources for this assessment process. The primary data were collected through interviews with the officials of Mercantile Marine Office (MMO), Government Shipping Office (GSO), Department of Shipping (DoS), shipping companies, people engaged in Maritime Education and Training (MET), some other resource persons related to this sector in Bangladesh. The secondary data were obtained from official websites, annual reports, published books, journals and articles, shipping statistics, and market review. In addition, various shipping laws and amendments of Bangladesh have been discussed throughout the research. The statistical data is presented by diagrams, charts, table etc.

## Overview

Shipping is a global platform, volatile, capital intensive and complex in nature. Bangladesh is not apart from it. Since the liberation war, the number of vessels under the Bangladesh flag travelled in a small circle. In the last decade, several business groups uphold Bangladesh flags in the ocean through their own cargo. A number of Bangladeshi business groups (Basundhara, Kabir, Meghna, Crown, Akij etc.) mostly possess bulk carrier based on their industrial cargo (cement clinker, steel billet, sugar etc.). After the freight market recession in 2008, the growth of the Bangladesh flagged fleet was expanding. In 2014, there were 72 vessels in the Bangladesh flagged fleet. But the expansion did not sustain for long and now, Bangladesh flag register has been surviving with only 46 ships (Figure 1) Out of 46 vessels, there are 40 bulk carriers, 06 tankers (GSO, 2019).

It is evident that the Bangladesh flag register could not advance much. According to Chowdhury, president of Bangladesh Oceangoing Shipowners' Association (BOGSOA) "if a businessman buys a vessel worth USD 20 million, he needs to pay another USD 7.0 million as taxes, which is a big burden for the industry." (Islam, 2018) Owners highlighted the high import cost of vessels, high operating costs and the presence of withholding tax as the main reasons for the lack of investment (Parvez, 2018). In the meantime, most of the vessels of Bangladesh Shipping Corporation (BSC) were more than 25 years old. Due to high maintenance and operation cost, BSC scraped those vessels at different times. Concurrently, BSC failed to invest in procuring new vessel at that moment. It is a matter of hope that BSC has already procured 6 new vessels of different types and a new procurement plan of 24 vessels is under process (BSC website). At the same time, the legal framework of vessel registration does not permit a foreign investor to hold more than 49% of the total share. Also due to complex and paper-based registration process, ship owners face difficulty and time-consuming in registering ships under the Bangladesh

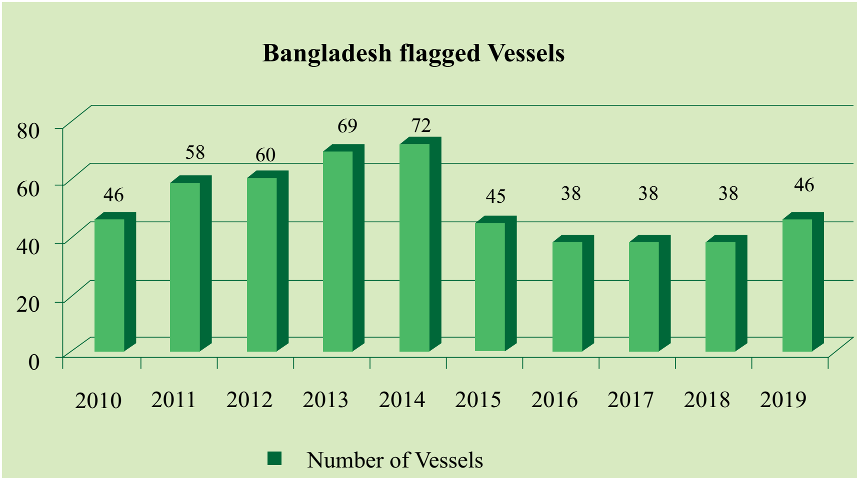


*Figure 1: Statistics of Bangladesh flag registered vessels*
*(Source: Authors, based on the data from MMD and GSO)*

flag. This study has brought out relevant issues involved in vessel registration under the Bangladesh flag. These are discussed subsequently.

## Issues Involved in Vessel Registration in Bangladesh

The major issues involved in vessel registration under Bangladesh flag are Legal Frame, The registration process, Tax and Fee, Incentive and Investment. These are subsequently discussed below: -

### Legal Frame

Article 91 of the United Nations Convention on the Law of the Sea (UNCLOS) reads:

> *"Every state shall fix the conditions for the grant of its nationality to ships, for the registration of ships in its territory, and for the right to fly its flag. Ships have the nationality of the state whose flag they are entitled to fly. There must exist a genuine link between the state and the ship.*
>
> *Every state shall issue to ships to which it has granted the right to fly its flag documents to that effect."*

The oceangoing vessels in Bangladesh are registered, surveyed, inspected under the guidelines of the Bangladesh Merchant Shipping Ordinance, 1983(BMSO). According to BMSO, Director General (DG) of Department of Shipping (DoS) is the Registrar General of Bangladesh ships. Presently, Principal Officer is in charge of Mercantile Marine Office (MMO), at Chattogram port and acts as the Registrar of Bangladesh ships. Part II of this ordinance discusses 'Registration and Nationality' applied to all seagoing Bangladesh ships exceeding fifteen tons net and fitted with mechanical means of propulsion, but shall not apply to ships registered under any law for the time being in force for the registration of inland ships plying on inland water.

Under clause 3 of chapter 1 defines Bangladesh ships and the condition of her ownership.

> *"Bangladesh ship" means a ship belonging to a statutory corporation or a ship acquired and owned by a foreign national or company and leased out to the government or a citizen of Bangladesh or a Bangladeshi company under such an agreement that the ownership of the ship shall be transferred after a specified period of time to the government or such citizen or company in accordance with the terms of the agreement or a ship owned wholly by persons each of whom is:*
>
> *(a) A citizen of Bangladesh, or*
>
> *(b) A company which fulfils the following conditions, namely:*
>
> *(i) The principal place of business of the company is in Bangladesh,*
>
> *(ii) shares representing more than 50% of the share capital of the company or shares carrying more than 50% of the total voting power of the company are held by citizens of Bangladesh,*
>
> *(iii) The majority of the directors of the company are citizens of Bangladesh,*
>
> *(iv) Either the Chairman or the Managing Director of the Board of Directors of the company is a citizen of Bangladesh.*

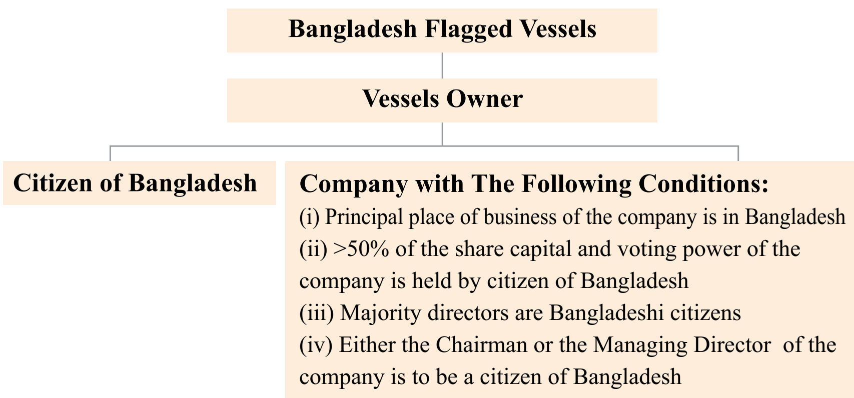


*Figure 2: Conditions of Bangladesh flagged vessels' ownership*

*(Source: Authors, based on data from BMSO, 1983)*

Under clause 17 of chapter 1 defines foreign going ship and clause 44 defines the sea-going vessel.

> *"Foreign going ship" means a ship employed in trading between any port or place in Bangladesh and any other port or place outside Bangladesh, but does not include a coasting ship or a home trade ship.*

*"Seagoing", in relation to a vessel, means a vessel proceeding to the sea beyond such limits as may be specified by the government by notification in the official gazette.*

Bangladeshi flag vessel registration requires to fulfil the following conditions:

**a)** Vessel age should not be over 25 years (if the vessel is imported) (Import policy order, 2015-2018)

**b)** Vessel to be verified under Bangladesh recognised classification society

**c)** Vessel to be surveyed by a Surveyor or by any Surveyor of a Classification Society duly authorised by the Government of Bangladesh and complied with maritime legislation such as IMO convention, SOLAS, MARPOL etc.

**d)** The vessel should specify the ship's tonnage and build, deliver certificate and such other descriptive identity ascertained in the prescribed manner to register.

## The Registration Process of Bangladesh

The Registration Process is the significant aspect of a ship by which she is documented and provided with the nationality of a state. The nationality permits a ship to trade and navigate worldwide as it is the evidence of ownership of the vessel. Documentation is a complex procedure with so many steps under a flag state by which it exercises regulatory control over the vessel. Flag state requires inspecting it periodically. This involves certification of the equipment, the crew of a vessel and complete documentation. In Bangladesh, a vessel is surveyed by a flag state surveyor in most cases, otherwise, it endorses the document surveyed by the assigned classification society inspector.

Registering a vessel under Bangladesh flag requires to submit an application by the shipowner authorised agent to the Principal Officer, MMO in the prescribed form for provisional registration with appropriate documents. On perusal of documents submitted with the application, Principal Officer will issue provisional Continuous Synopsis Record (CSR), provisional Safety Equipment Certificate (SEC), and provisional Safety Radio Certificate (SRC). Subsequently, vessel owners/agents will obtain Call Sign, Radio Station License from (BTRC) with the submission of necessary documents provided by MMO. Upon collection of call sign and radio station license, Bangladesh Telecommunications Company Ltd. (BTCL) will issue Maritime Mobile Service Identity (MMSI) number and Department of Shipping will issue Minimum Safe Manning Document (MSMD). The Principal Officer will issue the provisional Certificate on receipt of necessary MMSI and station license documents from the applicant. After issuance of the provisional certificate, flag state surveyor or approved classification society surveyor will inspect the vessel physically and conduct a survey in compliance with maritime legislation including ratified IMO convention. Upon satisfactory report of the surveyor, full submission of all documents, payment of tax to National Board of Revenue (NBR), registration and others fees, the vessel will be provided final registration by Register of the Bangladesh Ships. On completion of the registration under Bangladesh flag, the Registrar shall grant a certificate of registry in the prescribed form containing the particulars of the respective ship as entered in the register book and the name of her maiden master.

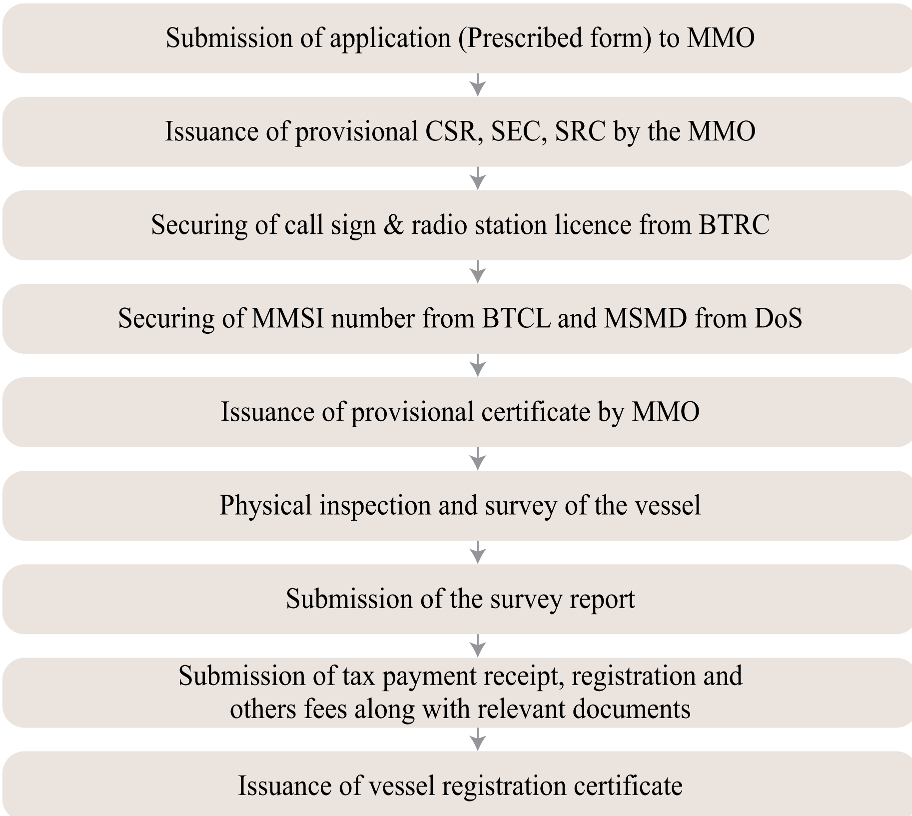


*Figure 3: Vessel registration process under Bangladesh Flag*

*Source: Authors, based on data from MMO, Chattogram*

**Tax and Fee**

Taxation and other charges are the most vital factors for shipowners in choosing a flag. Top-ranked ship registers choose their flags in a flexible tax regime that offers competitive registration fee. In Bangladesh, ship owners are subject to several taxations from vessel import to profit gain. A tax regime that exists now in Bangladesh is as follows:

**Import Duty**

Chapter 89 of the Bangladesh Customs Tariff (BCT) states that cruise ships, excursion boats and similar vessels principally designed for the transport of persons, ferry-boats of all kinds, tankers, refrigerated vessels, other vessels for the transport of goods and other vessels for the transport of both persons and goods including warships and lifeboats other than rowing boats are subject to import duty on the particular description are follows:

**a)** 25% import duty for vessels with a capacity not exceeding 3,000 DWT for registration in Bangladesh operating in oceans for at least 3 consecutive years

**b)** 10% import duty for vessels with a capacity exceeding 3,000 DWT but not exceeding 5000 DWT for registration in Bangladesh operating in the oceans for at least 3 consecutive years

**c)** 0% import duty for vessels with a capacity exceeding 5000 DWT for registration in Bangladesh operating in the oceans for at least 3 consecutive years (BCT, 2017-18)

**Value Added Tax (VAT)**

VAT at 15% is payable in case of import of ocean-going vessels as per Value Added Tax Act, 1991. It needs to be mentioned that exemption from payment of VAT is available if the vessel fulfils the following criteria:

a) Vessels should be more than 5,000 DWT and a vessel has to be registered in Bangladesh

b) Vessels should not be older than 22 years and must be used for carrying freights for at least five years, during which the vessels cannot be sold or transferred

c) Double hull/ double bottom vessel

d) Every year submission of Proceed Realisation Certificate (PRC) from bank to the local VAT office as a proof of their foreign currency earnings

e) 70% manpower for the vessels should be hired from Bangladeshi citizens (Shaheen, 2019)

**Income Tax at Source**

According to Section 53AA of Income Tax Ordinance, 1984 embodied in Income Tax Manual, 1984, a resident engaged in shipping business is subject to income tax at source. Section 53AA requires the commissioner of customs or any other authority duly authorised in this behalf, to collect tax at the 5% of total freight received or receivable in or out of Bangladesh before granting port clearance to a ship owned or chartered by a resident assessee. In case of services rendered between two or more foreign countries income tax at source would be 3% of total freight received or receivable.

**Corporate Tax**

Para (Kha) of Finance act, 2017 stated that as a non-listed company, shipping companies are subject to 35% tax on company income.

**Advance Income Tax (AIT) From Dividend**

Above all, according to section 54 of Income Tax Ordinance, 1984, shipowners' income is subject to payment of 10% Advance Income Tax (AIT) from the dividend in addition to VAT, others tax and fees.

**Other Fees**

In the Bangladesh flag register, there are several fees applicable for registering a vessel such as registration fee, certification fee, VAT, maritime training fee, registration

Table 1: List of taxes of ship operation in Bangladesh

| Level of Tax | Type of Tax | Description | Statutory Rate |
|---|---|---|---|
| Import | Import Duty (3.3.1) | All kinds of vessel | 0-25% |
| | VAT (3.3.2) | Imported vessel | 15% |
| | AIT | Imported vessel | 5% |
| Operation | Income tax at source (3.3.3) | Total freight received or receivable from a vessel | 5% (for in or out of Bangladesh)<br>3% (for two or more foreign countries) |
| Profit | Corporate Tax (3.3.4) | Company income | 35% |
| | Advance Income Tax (AIT) from dividend (3.3.5) | Based on vessel owner/director's income | 10% |

*Source: Authors, based on different tax regulation of Bangladesh*

supervision fee and other fees. Most of the vessel fee is based on the GT except the supervision fee which is based on contracted price.

Table 2: Comparison of registration fees between Bangladesh and Panama.

| VESSEL SPECIFICATIONS | | | |
|---|---|---|---|
| **Building year** | | 2006 | |
| **Type** | | Bulk Carrier | |
| **Gross Tonnage (GRT)** | | 32,379 | |
| **Net Tonnage (NRT)** | | 19,353 | |
| **Vessel (Contracted price)** | | TK.924,000,000 (assumption) | |
| **Cost of Registration (Bangladesh)** | | **Cost of Registration (Panama)** | |
| **Type of Fee** | **BDT.** | **Type of Fee** | **US$** |
| **Provisional Registration**<br>(for collecting MMSI, Call Sign and Station Licence) | 4000 | **Registry fee**<br>**($ 0.10 per GRT up to a max fee of $ 6,500)** | $6500 |
| **Provisional CSR**<br>(for collecting MMSI, Call Sign and Station Licence) | 4000 | **Annual Tax**<br>**($0.10 per NRT)** | $1935 |
| **Provisional SEC**<br>(for collecting MMSI, Call Sign and Station Licence) | 4000 | **Annual Consular fee**<br>**(More than 15,000 GRT)** | $3000 |
| **Provisional SRC**<br>(for collecting MMSI, Call Sign and Station Licence) | 4000 | **Annual Inspection fee**<br>**(More than 15,000 GRT)** | $1200 |
| **Final Registration**<br>**(More than 15000 GT)** | 175000 | **Annual Investigation fee**<br>**(More than 10,000 GRT)** | $500 |
| **VAT 15%**<br>**(On Final Registration)** | 26250 | **+3% of net tonnage** | $581 |
| **Maritime Tanning**<br>**(Gross ton×1.2)** | 38855 | **Sub-Total**<br>**(Second-hand vessel)** | $13716/<br>TK.1152144 |
| **Carving and Marking Note** | 1000 | **-A discount of 60% for a new building** | -$8229.60 |
| **Registration Cover Fee** | 1000 | **Total**<br>**(USD 1 =BDT 84)** | **$5486.40/**<br>**BDT.460858** |
| **Registration Supervision Fee**<br>**(0.1% on contracted price)** | 924000 | | |
| **Total** | **BDT. 1182105** | | |

*Source: Authors, based on the data from MMO, Chattogram (Bangladesh Part), Consulate General of Panama in New York and Toronto (Panama part)*

**Incentive**

The incentive scheme is the driver for most of the flag registers. Incentive modules have been developed on the basis of different aspects. Included in incentive mechanism are refund, discount/rebate, reimbursement on fee and tax etc. For instance, the Singapore Registry of Ships (SRS) facilitates the shipowner with Block Transfer Scheme (BTS), Green Ship Programme (GSP) and Annual Administrative Fee (AAF) scheme. Currently, incentive and discount schemes are widely practised at the world ship registry market. Eligibility for incentives is determined on the basis of:

**a)** Age of vessel

**b)** Multiple vessels registered

**c)** A large volume of gross tonnage registered

**d)** Port state control performance

**e)** Recruiting citizen of flag state on board

**f)** Vessel practising green ship movement

Presently, the vessels registered under the Bangladesh flag register do not enjoy any incentive. However, the underlying reason for registering a vessel in Bangladesh is the Flag Vessel (Protection) Ordinance, 1982. Clause 3 of the ordinance states that at least 40% (at present 50% proposed) of the sea-borne cargoes relating to the foreign trade of Bangladesh shall be carried by Bangladesh flag vessel.

**Investment**

Investment in the vessel of a country is one of the major influencing substances of expanding fleet under any flag register. In Bangladesh, two types of vessel owning company exist at present such as state-owned and private-owned. Bangladesh Shipping Corporation (BSC) is the only state-owned shipping company. Since 2018, BSC was the owner of only 2 ships. In ship acquisition, BSC got loan assistance from different friendly countries. Of late, with the financial assistance from China EXIM Bank, BSC will get USD184.5 million for procuring 6 new vessels from China. These include three bulk carriers and three tankers, each having 39000 DWT capacity.

On the other hand, several business groups from different shipping companies are the private entities of Bangladesh flag vessel. No other significant foreign investment has found in vessel owning under the Bangladesh flag. List of the business group owned vessel in Bangladesh flag are as follows:

**a)** Kabir Group of Industries

**b)** Bashundhara Group

**c)** Akij Group

**d)** Chowdhury Group (Crown Navigation)

**e)** MJL Bangladesh Limited

**f)** Meghna Group of Industries

**g)** BSA Group

## Impact of Prevailing Registration System in Bangladesh

Impact of present ship registration in Bangladesh includes reduction of vessel number, uncaptured freight, unemployment of seaman, revenue earning. These are subsequently discussed.

### Number of Ship

Bangladesh is a maritime nation with a long historical background on shipping. As a maritime nation, a number of ocean-going vessels are always standing below a hundred. Moreover, state-owned BSC is only having eight ships. The prominent business groups including Abul Khair Group closed their ship operation with five ships in 2016. Meanwhile, the neighbouring country like India is having with 5.34% growth in term of DWT on the period of 2016–2017 (UNCTAD, 2017). Meanwhile, the growth of the Bangladesh flag vessel is not significant. The more alarming news is that existing ship-owners are presently registering their fleet under foreign flag mostly in open register. From several interviews with Bangladeshi shipping experts, it was found that business group like Meghna group, registered almost all of their vessel in the Marshall Islands, Akij Group owns 10 ships, out of these, 2 ships are registered in Panama flag. Also, another business giant, Basundhara group is having half of their vessels flying Tuvalu flag.

### Freight

In the fiscal year (FY) of 2016-2017, the total import-export volume handled by both Chattogram and Mongla port was around 81 million metric tons. In the same FY, more than 3,700 vessels handled by both the ports. Meanwhile, the country's foreign trade volume was USD 77,000 million. As freight charge, the country spent a minimum USD 7,700 million at the average 10% rate for carrying goods. (Uddin, 2018) Given the provision of 40% (at present 50% proposed) of international seaborne cargos for Bangladesh-flagged vessel, local oceangoing vessels could not tap the opportunity of the market due to a dearth of vessels. The number of Bangladesh-flagged oceangoing vessels sharply declined to 38 in 2017 from 72 in 2014 (MMD, 2017). The national flag-carrying vessels operated by local oceangoing ship operators earned only on an average USD 150 million a year by carrying less than 5 per cent of the total export-import goods, claimed BOGSOA vice-president. According to local vessel operators, the rest of the freight charge, generated from the country's booming exports and imports, goes to foreign vessel operators in the absence of investment in the sector (Uddin, 2018).

### Recruitment

Due to her geographical location, Bangladesh has ample opportunities to increase its share in the maritime labour market. A healthy national fleet is of utmost importance for the seafarers' employment perspective (Kabir, 2014). A total of approximately 10,205 registered officers and 3,849 registered ratings are there in Bangladesh. It was observed that Bangladeshi seafarers had the opportunity to serve in the national flag vessels which could equip them with sufficient skills and experience to be employed in foreign companies where the remuneration is much higher compared to the Bangladeshi flag vessel. Due to shrinking fleet of Bangladeshi flag vessel, Bangladeshi seafarers face the high unemployment rate and the placement of the fresh cadet is obstructed (GSO, 2018)

### Revenue Earning

Taxation, registration and other fees are the key drivers for any state to allow a vessel flying the national flag of that state. Tax and fee structures have a significant impact on the revenue earning of flag States. Ship-owners will be interested to register a ship in Bangladesh once they find a flexible tax regime compared with other flag registers. What prompts ship-owners to consider vessel registration in a state is the cost-benefit ratio. A country to be considered for registration must be contemplated in the light of ship-owners' benefits from competition amongst registers. Open registers offer flexibility in terms of tax and fees. Rochdale Report figured out that registry fee and an annual fee, based on tonnage, are normally the charges claimed on most open registers (Rogers, 2010). The open register has experienced exponential growth in fleet size and registered tonnage thereby contributing a sizable amount of revenue to the country's economy. For instance, in Panama, 20% of its GDP accounts for the maritime sector. (Icaza et al., 2012). Liberian shipping registry accounts for 30% to 70% of Liberia's government revenue (Sharife, 2011). Due to taxation at several stages and registration complexity, local entrepreneurs do not find this area worthy of investment. In Bangladesh, the Board of Revenue received only BDT 160 crore from the sector in last 3 years while MMO collected revenue without tax nearly BDT 30 crore from all types of vessels including foreign going vessels in FY 2017-18. It appears that there remains ample scope to substantially increase revenue earning from the sector if there are flexible tax and fee structures.

## Challenges of Present Ship Registration System in Bangladesh

The challenges militating against prevailing ship registration for enhanced capacity building in Bangladesh include the rigid legal frame and institutional architecture, complicated registration process, huge tax, inadequate incentive and insufficient investment. These are subsequently discussed at some length.

### Rigid Legal Frame and Intuitional Architecture

According to BMSO, ship acquired and owned by a foreign national or company requires to be leased out to the government or a Bangladeshi citizen/company with an agreement to transfer the ownership of the ship after a specified period of time to the government/ Bangladeshi citizen or company. Within this regulation, the Bangladesh flag register allows a maximum of 49% of the foreign share for owning a vessel. Moreover, the Chairman/Managing Director, majority of director of the shipping company must be the citizen of Bangladesh. With this provision, the foreign investors will be deprived of taking a decision as there is inadequate voting power. Besides, there is no prominent shipping company in Bangladesh who is a competitor of reputed shipping company like Maersk, MSC, COSCO, NYK etc. As a result, within this regulation, vessel registration under the

Bangladesh flag will not be attractive to the foreign investor. MMO is the only authority for the purpose of oceangoing vessel registration in Bangladesh. Presently, the number of employees at MMO are eight in total including three surveyors. It is quite difficult to survey all the vessels under the Bangladesh flag with these limited surveyors. For a vessel positioned in a foreign port poses a huge challenge to conduct a survey within scheduled time resulting in undue delay at the port without commercial operation. For these, owners have to bear additional fixed operation cost for that inordinate delay. Therefore, rigid legal frame and intuitional architecture is indeed an impediment to the fleet expansion of the Bangladesh flag register, thereby impinging negatively on her capacity building.

**Complicated Registration Process**

For registering a vessel, ship-owner/appointed agent has to face several offices in Bangladesh such as MMO, BTRC, BTCL, NBR etc. There is no automation and simplified service for registering a vessel. Paper-based documentation and process to complete vessel registration. Moreover, there is no simplified guideline/booklet provided in MMO official website. There is no other maritime consular office or authorised agent/inspector overseas to conduct a survey and other processes. Several prominent vessel registers like Panama, Liberia, and Singapore simplified their process and provides guideline in their website. According to the Singapore Registry of Ships (SRS) website, the procedure for registering a ship with the SRS is quick and easy, requiring only 5 major steps (Figure 4). Furthermore, significant investment in advanced information technologies makes the renowned ship register a unique value-added partner for quality ship-owners and ship managers. The top registers also set up a worldwide network and maintain full-service regional offices strategically located in the major maritime centres of the world.


*Figure 4: Summary of the steps for registering a vessel in Singapore*

*Source: Authors, based on the data from MPA, Singapore*

## Huge Tax

Huge tax burden poses a challenge for the shipping companies in Bangladesh. At present, taxation at three levels is required for a ship to operate in Bangladesh. For registering a vessel and make it operational, owners have to pay tax during vessel import, vessel operation and on the profit generated from shipping operation. Local industry experts highlight that importing a vessel, the buyer has to pay 5% AIT, 15% VAT and some other taxes, which altogether stands at nearly 27% immediate tax incidence on this high-capital-intensive business. Owners are also subject to payment of tax on freight received from shipping operation. Additionally, they are required to pay 35% corporate tax and personal income tax respectively on the profit earned. For example, if a shipping company makes a net profit of BDT 10 lacs in a year, it can retain only BDT 6.5 lacs to be distributed among directors (owners) after deducting corporate tax of 35%. Again, the individual owner is liable to pay 10% individual income tax from the profit which amounts to BDT 65,000. In the end, ship-owner retains BDT 5, 85,000 only although net profit was BDT 10 lacs. In the open registries, when non-nationals owners are allowed to fly the flag of the state registered usually exempted from payment of any tax. The main source of government revenue for shipping is not the tax on import, income tax or corporate tax but the ship registry fees, annual tonnage tax and other fees (Stephens, 2001). Another distinctive feature of the open registry is that the access to the registry is quite easy. The ship-owner has to pay a registration fee and subsequently annual fee, based on tonnage for the duration that the vessel is entered into the register. Moreover, a shipowner may also request the flag-state authorities a guarantee from future taxation relief or tax exemption (Balyk and Lyudmyla, 2006).

Table 3: Sampling of zero tax regime of some of the popular open registers

| Tax / Country | Income tax | Capital gains tax | Inheritance tax |
|---|---|---|---|
| Panama | Exempt | Exempt | Exempt |
| Marshall Islands | Exempt | Exempt | Exempt |
| Cyprus | Exempt | Exempt | Exempt |
| Malta | Exempt | Exempt | Exempt |

*Source: (Reus Diaz, 2012)*

## Inadequate Incentive

The incentive package is another driver of a flag state to attract the ship owners for the registry. Incentives such as a discount on vessel registration fee and refund on tonnage tax for the observance of good practice in safety management and pollution prevention prompt owners to register more vessels which opens up opportunities for employment of the citizen of flag register. Increased number of registration upswing the flag state image in addition to revenue increase and employment generation. For instance, initially in 1969, Singapore registry provided 50% refund on the annual tonnage tax while recruiting at least 25% Singaporeans on board. By these, Singapore solves the unemployment problem within five years. Singapore economy had been facing a labour shortage for most of the last four decades and required the importation of sizeable foreign workforce (Phang and Toh, 1994). With the Green Ship Programme (GSP), Singapore-flagged ships encourage to reduce carbon dioxide and Sulphur oxides (SOx) emissions. Vessels that adopt green technology and use liquefied natural gas (LNG) as alternative fuel enjoy a reduction of initial registration fees up to 75% and a rebate on the annual tonnage tax up to 50% (MPA, 2018). Panamanian Law 57/2008 on the merchant marine establishes a set of discounts that can be granted to vessels that are newly built, vessels registered in the Merchant Marine within five years from the date of the laying down of the keel. These incentives are also directed to vessels that have not been detained for any Port State Control (PSC) inspection within a span of 24 months. Such policies can improve the performance of the Panamanian flagged fleet and reduce the number of detained individual ships (Piniella et al., 2016). Incentives that exists in Bangladesh is not enough to encourage ship-owners to register their vessel in Bangladesh. In the recession period of 2015-2016, Bangladeshi owners demolish most of the vessels due to low freight rate. Even when the recession is over, several shipping companies still registered their vessel in oversea due to high tax. As a result, sharp declination of vessels was observed during 2016-2017. In this backdrop, the incentive scheme can be an option for promoting Bangladesh flag register. However, the government of Bangladesh exempted VAT for more than 5000 DWT while import a vessel. With this provision, 'MT. Omera Legacy', a 107,091 DWT vessel got VAT emption on import.

### Insufficient Investment

Investment on the vessels can enlarge the fleet of a flag state. Most of the successful flag register are promoting by major vessel owning nation. Greek ship-owners boost Marshall Island registry. Republic of the Marshall Islands' ship registry (RMI) enjoys a considerable growth fleet with an average annual growth rate of 11.9 % since 2013. At the start of 2017, the Greek-owned fleet consists of 856 RMI flagged vessels totalling 63 million DWT. Besides Greece, mainly the U.S. (23 million DWT), Korean (21 million DWT) and German (12 million DWT) ship-owners use the flag of the Marshall Islands (ISL, 2017). In the Bangladesh flag register, most of the vessels are bulk carriers (mainly operated by industrial shipping). Due to flag registration policy, no foreign shipping company registered any vessel in Bangladesh. Also, no significant foreign investment found in ship owning (except BSC). Due to the high-interest rate, local banks could not support the ship-owner effectively. As a result, the country could not tap the opportunity of the Bangladesh flag registry. Bangladesh flag registry could not collect a significant amount of revenue from the registry market. Furthermore, more than 95% of the freight transferred to overseas.

## Findings

The journey of shipping in Bangladesh can be traced back in ancient times. After 1971, Bangladesh flag is patronised by state-owned BSC. Gradually, private ship-owners entered the market in different phases. The study finds

- MMO of the DoS remains as the only authority dealing with vessel registration.
- To be eligible as a Bangladesh-flagged ship, it must comply with some conditions so as to empower Bangladeshi citizens with more than 50% of voting power in decision making.
- Foreign citizens are also allowed to hold share on vessel ownership or solely own a vessel which is a subject to the fulfilment of stringent conditions to hold permanent ownership.
- It is worth to mention that existing manual registration process is mostly based on papers involving several steps at different offices instead of Information Technology (IT) based automated service.
- Owners are required to pay both taxes and fees separately to different authorities at different stages in the absence of a one-stop service.
- Most of the taxes and fees are based on the ship's price rather than based on GT and NT.
- The incentive provided by the Bangladesh flag register is not sufficient to drive investment in ship owning resulting in insufficient vessels to cater to the demand and compelling reliance on the foreign-flagged vessel.
- Increased reliance on foreign-flagged vessels is a roadblock to revenue growth and the scope for recruitment in the sector.

## Policy Implications

### Flexible Legal Frame and Institutional Capacity Building

Vessel registration plays a pivotal role in the documentation of a vessel. It also contributes to revenue earning, employment generation and economic activities of a state. Ship-owners tend to avoid the complexity of the national legislative process. In order to achieve the required growth in Bangladesh-flagged vessels, there should be a smoother registration policy suitable for both citizen and non-citizen of Bangladesh. Alongside the existing registration system in Bangladesh, a second register need to be introduced to attract non-Bangladeshi citizens to register their vessels in Bangladesh in order to earn more revenue and employment generation. To operationalise the second register in Bangladesh, owners of the foreign vessels need to set up their corporate offices in Bangladesh. Again, in the existing registration system, the provision should be to increase the share of non-citizens from 49% to 70% or 80% so as to attract more foreign investment in the sector while keeping ownership of Bangladeshi nationals. Additionally, this will help to develop expertise in ship management and chartering companies. As a result, Bangladesh will be able to retain freight money and bring foreign cargo freight in the country.

To cater to hybrid registration that consists of both closed and open registration and the consequent increase of Bangladesh-flagged vessel, existing institutional architecture needs to be reformed. Besides, the expansion of MMO with skilled manpower is a prerequisite. Establishment of maritime consular offices in major reputed port cities (For example, Singapore, Fujairah, Rotterdam, Hong Kong, Japan, Durban, Santos, Vancouver etc.) will facilitate vessel registration service and survey facility in overseas. Vessel inspection services may be outsourced from qualified surveyors abroad enlisted with MMO.

**Automation of the Registration Process**

A vessel owner/ operator has to keep himself busy with vessel operation, chartering, crewing, port dealing etc. in addition to keep registration to a flag state. Procrastination in registration caused by a complex procedure frustrates a vessel owner to register a vessel in any flag state. Simplification of the procedure together with automation of the registration process may prompt vessel owners for registry in any flag state. Application (in a prescribed form) for registration should be made available on the website of MMO so that a vessel owner or operator may submit an online application. Upon receiving the application, MMO will ask for necessary documents which the vessel owner is required to submit via email to all offices concerned including disclosure of the name, address and nationality of every shareholder, and the number of shares held. Then the applicant is required to pay due taxes and fees. To give comfort to vessel owners or operators, one-stop service needs to be introduced to procure Call Sign, MMSI, and Station License, thereby making issuance of provisional registry certificate possible within 3-4 days. For conduction of the survey, MMO will ask for a convenient port and date. Then survey can be conducted by own nautical surveyor or authorised flag state inspector. Upon a satisfactory report from the surveyor, Register of Bangladesh-flagged ships will provide a vessel registration certificate. The whole of the registration process and required documents should be available on the official website to guide those interested for vessel registration.

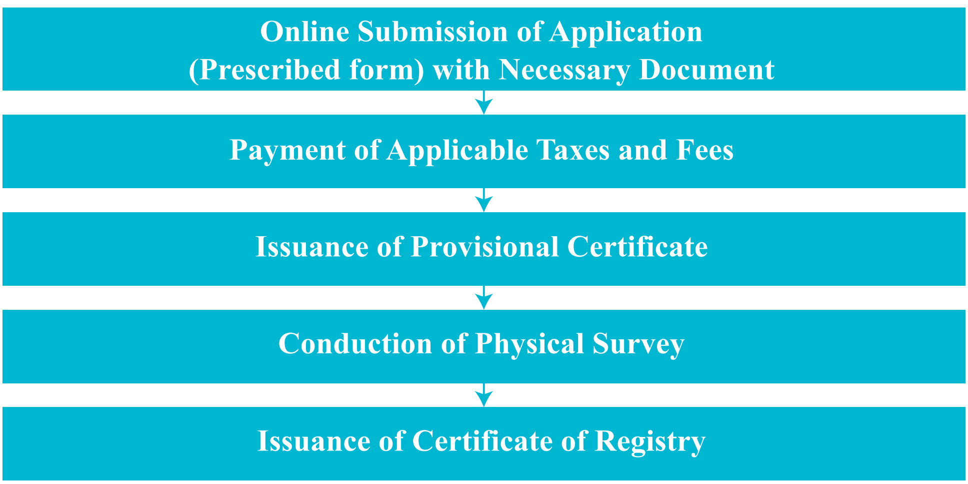


*Figure 5: Simplified registration process (proposed)*

*Source: Compiled by the authors*

## Easing Tax Structure and Fees

Ship-owners always prefer flag state where they get more flexibility and economic gains. In Bangladesh, tax is determined on the basis of imported price and fees are based on both vessel size and import price. Had the taxes and fees were determined solely on the basis of vessel size or tonnage instead of the imported price that would be more transparent and straighter forward. Again, taxes and fees are required to pay at different stages which could be a one-off event so that one may compare applicable taxes and fees with ship registers of other flag states. Taxes and fees in connection with vessel registration and operation should be made available on the website to the convenience of stakeholders. Panama model offers a good example to be followed where all the taxes and fees such as registration fee, annual tax, annual consular fee, annual inspection fee, annual investigation fee are based on GRT and NRT. Except for registry fee, all the recurring taxes and fees need to be paid every year to continue vessel operation.

Table 4: Proposed taxes and fees structure for vessel operation.

| | **Taxes and Fees for Vessel Operation** | |
|---|---|---|
| Serial No | Type of Fees | Statutory Rate |
| 1. | Registry fee | (USD 0.10 per GRT up to a maximum fee of USD 6,500) |
| 2. | Annual Tax | (USD 0.10 per NRT) |
| 3. | Annual Consular fee | (More than 15,000 GRT, USD 3000) |
| 4. | Annual Inspection fee | (More than 15,000 GRT, USD 1200) |
| 5. | Annual Investigation fee | (More than 10,000 GRT, USD 500) |
| 6. | +Net Tonnage | USD 0.03 per NRT |
| | **Sub-Total** | ******* |

*Source: Authors, based on the data from consulate Panama*

## Incentive Mechanism

Incentive scheme encourages ship-owners in order to promote good safety management, recruitment and business expansion. Most of the ship-owners trade on a reputation for quality. The registration of ships under a flag (such as those on the Paris MoU and Tokyo MoU "white list") that is recognised as upholding safety standards and being well run is an important element of a quality reputation. To ensure this, the Bangladesh flag register can introduce a set of discount schemes as follows:

**a)** For new-built vessel, a discount of 60% on the total registration fee for the first year as a new-built vessel has the low port state control (PSC) detention rate.

**b)** If a shipping company wants to register fleets with 5–50 vessels may receive discounts from 20% up to 65% on registry fees.

**c)** Vessel with comprising of at least 75% Bangladeshi seafarer may enjoy a 50% refund on the annual tonnage tax.

**d)** These incentives are also directed to vessels that have not been detained for any PSC inspection within a 24 months period.

Aforementioned incentives can improve the performance of the Bangladesh flagged fleet and reduce the number of detained individual ships as well as increase flag image.

### Investment Facilitation

Effective investment facilitation on vessel purchase can enlarge the growth in a number of vessels and registered tonnage. Bilateral agreement and ship financing are of utmost importance to attract effective investment.

Bangladesh flag register can sign bilateral agreements with major ship owning nations (i.e. Greece, Japan, China, Germany, Republic of Korea etc.) by providing special services and economic benefits. Agreements may also be signed with reputed and giant shipping companies (i.e. Maersk, Mediterranean Shipping Company, CMA-CGM, Hapag Lloyd, Evergreen, Overseas Container Line, Hamburg-Süd, Yang Ming, United Arab Shipping Company, Nippon Yusen Kaisha etc.) with the provision of quality services.

The bank that finances the purchase of a ship may stipulate a group of acceptable flags under one of which it must be registered. Clearly, it will wish to ensure that the ship against which the mortgage is secured, operated and maintained with a high standard is registered in a jurisdiction where it is confident that a mortgage governed by the laws of that jurisdiction is good security and thus it can enforce payment. For the purpose of ship financing, agreements can be signed with highly ranked worldwide credit institutions so that the market finds ample support in the Bangladesh flag register through the ship mortgage. Moreover, the government may consider loans on softer terms through local banks and financial institutions in order to encourage entrepreneurs of the shipping sector.

## Conclusion

Ship registration is evidenced to the world by the flying of the flag and ship's papers (documentation). The flag of a vessel is also the visible evidence of nationality. (Rogers, 2010) Nowadays, the shipping market focuses not only its prime job of cargo carriage but also emphasises from a commercial and strategic view. Ship-owner tends to transfer their vessel registration in a state where they get flexibly and commercially rewarding. With this in mind, major vessel registers arrange business-friendly policy and flexible fee structure to attract ship-owners, thereby, holding a remarkable share of vessel registry market in terms of vessel number and deadweight tonnage. Since independence, an insignificant number of vessels travelled under the Bangladesh flag. Moreover, it could not seize the opportunity of their local seaborne cargo share as the majority of the freights are transferred to foreign vessel operator depriving the country of revenue earnings, employment generation and business opportunities. The limited capacity of MMO, high taxes at several stages, complexity in the registration process and inadequate policy support have reduced the number of Bangladesh-flagged vessels. Reforming institutional architecture, simplifying the registration process, investment-friendly tax regime and providing policy support can go a long way to boost the shipping sector with a reasonable number of Bangladesh-flagged vessels.

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# Wave Energy Harnessing for Marine Propulsion- An Approach Towards Energy Efficient Shipping

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Mohammad Saidee Hasan[3]

***Abstract***

*The quest for clean sources of energy is still too far from the challenge faced by the modern world of the 21st century. An increasing amount of industrialisation is continuously resulting in a gradual depletion of fossil fuel and extensive damage to the environment. The shipping sector, one of the biggest and ever-expanding industries of the world, almost exclusively uses fossil fuels to meet its energy needs. Due to the nature of this industry, there is always availability of waves at sea which can be harnessed and utilised as a source of energy though it hasn't been utilised yet in vast canvas. Wave energy can be considered as a robust form of energy and an effective alternative to fossil fuel if it can be properly harnessed. This study focused on how energy could be produced from ocean waves and could be used efficiently in the propulsion system. Methodology revealed here is basically to show the viability of the application of Wave Energy Converter (WEC) technologies in a vessel while at anchorage and port, since the application of WEC during sailing of a vessel hasn't still been proved as an efficient option because of vessel size associated with additional drag resistance. Aim of this paper is to elucidate mathematically if the harnessing is possible at anchorage time and additionally describes the theoretical prospect of mass implementation possibility at the port to affirm energy-efficient shipping. The outcome of this research could lead to an energy-efficient and economical propulsion system with the utilisation of a renewable energy source as well as a reduction in carbon dioxide emissions.*

**Keywords:** Emission Reduction, Energy Efficient Shipping, Renewable Energy, Wave Energy Conversion

## Introduction

The shipping industry is the backbone of the global economy. Approximately 90% of the tonnage of all traded goods is transported by ships as estimated by the International Chamber

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of Shipping. The total marine fleet of the shipping world altogether consumes between 250 to 325 million tons of fuel annually [The International Maritime Organization(IMO) estimates that between 2007 and 2012] and it is blamed for approximately 2.8% of annual global greenhouse gas emissions. More stringent regulations and measures are enforced by MARPOL (The International Convention for the Prevention of Pollution from Ships) to throttle down carbon dioxide emissions 20% by 2020, 50% by 2050. In addition, rising of bunker fuel prices in a global volatile market and low freight rates opt-out another reason for the shipping company to find the best alternative way to reduce dependency on fuel. As more than 70% of the earth's surface is covered by ocean, it is theoretically estimated that the ocean holds energy resources about four times the global electricity demand (Nielsen, 2012). In this context, the energy-efficient shipping idea incorporated with renewable energy comes to focus.

Solar, wind and wave are the basic forms of renewable energy. Among these, the wave has the high-density energy form. As a renewable source of energy, wave energy has significant advantages over other renewable sources of energies (Clément et al. 2002). While solar energy intensity is typically 0.1–0.3 $kW/m^2$ in a horizontal surface, converted to an average power flow intensity of 2-3 $kW/m^2$, wave energy in the vertical plane is perpendicular to wave propagation (Falnes 2007). Wave power devices can generate power up to 90% of the time compared to 20~30% for wind and solar power devices (Polinder and Scuotto 2005). Most importantly, it has limited negative environmental impact in use. Table 1 indicates a comparative analysis of effective power obtained from renewable sources of energies.

Table 1. Comparison of effective power obtained from renewable sources (Nat, Sommer, 2013)

| Source | Available energy in Northern scenario ( North sea ) | Available energy in Southern scenario (Mediterranean ) | The energy at best condition |
|---|---|---|---|
| Sun | 23 kW | 45 kW | 55 kW |
| Wind | 48 kW | 37 kW | 67 kW |
| Waves | 106 kW | 18 kW | 319 kW |
| Total | 113 kW | 26 kW | 331 kW |

As seawater is about 850 times heavier than air, it contains a lot of energy while in motion. However, power per length of a wave crest, [W/m], is a fair measure of the energy contained in waves where in comparison to the energy flux of wind and solar energy are presented in the unit of [$W/m^2$].For this study, a worldwide shipping route, composed of 496 points using great circle navigation is considered for calculating average energy flux for a given amount of time. (Af, Klinteberg,2009). From below table-2, the estimated result is pretty evident that the average energy flux of wave along this route varies between 10 kW/m and 50 kW/m with a yearly average of 26 kW/m.

Table 2: Average monthly energy flux along the worldwide route during January-December 2007 (Af, Klinteberg, 2009)

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Avg. in Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wave energy flux (kW/m) | 49 | 49 | 34 | 28 | 15 | 12 | 12 | 11 | 15 | 21 | 29 | 41 | 26 |

With an estimated average energy flux of J = 26 kW/m, a ship following the worldwide route will be exposed to an energy of roughly 4 MW on average. This vast pull of energy can save large amounts of fuel if properly exploited and utilised in the propulsion system.

To conduct the methodology,

- Few data are required.
  - Data of the vessel in anchorage and port
  - The data of wave period and height at that certain location
  - Data of WEC to be applied in the vessel
- Primary data is collected from MarEng Shafiul Bari, working as a Fourth Engineer in MV Great Royal by an interview.
- Secondary data were obtained from books, journals, the Internet, and other relevant articles.
- The equation to calculate the power generated by WEC technology supplied to vessel is studied from a book 'Marine Renewable Energy Handbook' edited by Bernard, Multon.

To validate the study,

- It is needed to calculate how much average wave power is available in Kutubdia all over the year
- How much power can be captured in WEC
- How much power can be contributed to the ship's power main

So, accumulating all the data, this study will show how to gain a positive output mathematically to ascertain the viability of implementing WEC technology in the vessels.

## Wave Formation and Wave Anatomy

Wave energy is basically another concentrated form of solar energy, which is produced by wind flow over the surface of the ocean. When the sunray strikes the atmosphere, it becomes hotter. As a result of the temperature differences created in the atmosphere, the air moves from hotter regions to cooler regions, thus making wind energy to flow. Waves can also be created from landslides, gravitational attraction, and other earth movements i.e. tectonic movement.

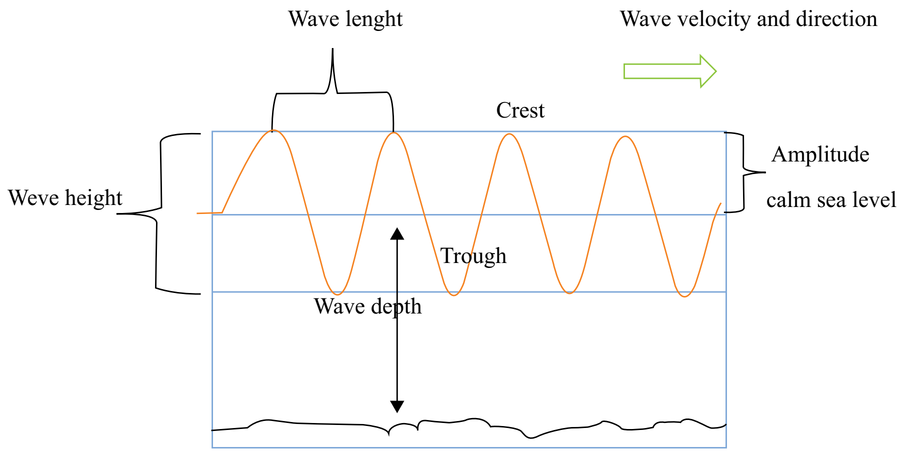


*Figure 1: Wave anatomy*

### Wave Energy Conversion Device and Technology

There are many technologies being invented to capture energy from ocean waves. These technologies include converting wave to electricity and converting wave to useful propulsive thrust. Among those, some technologies can be feasible to be implemented in vessels.

Different types of WEC are available in the world. Basically, they can be categorised into three types:

**a) Wave activating body-** extracts power from up and down motion of the waves, which depends upon the design and building characteristics. Different types of Wave Activating Body are there.

- Attenuator (Pelamis)
- Point absorber
- Bulge wave converter
- Oscillating wave surge converter

**b) Oscillating water column-** extracts power from the vertical oscillating motion of wave and converts to air pressure.

**c) Wave capturing overtopping device -** extracts power from the flow of water-assisted by wave and gravity

Besides, there are some other technologies available like Hydrofoil/ thrust generating foil technology and WITT (Whatever Input to Torsion Transfer) technology. Basically, these technologies can be implemented in vessels in three ways: during sailing, at port and port operation and at anchorage.

## Wave Energy and Wave Power Formula

The power of a wave is determined by the "Wave Power Equation". Wave power is defined by the flow of energy through a vertical surface perpendicular to the direction of its propagation. It could, therefore, be expressed in $Wm^{-2}$. However, this is not the usual usage, and it is preferable to quantify wave power in $Wm^{-1}$ (watts per metre of wave front).

To calculate the flow of energy, it is necessary to find out the mechanical energy of a vertical column of water and then multiply with the speed of the wave. The mechanical energy of a water column is the sum of its potential and kinetic energy. For loss-free propagation of the wave, both of them are equally written as follows in the case of a wave with sinusoidal formation:

$$< Ek\ (t) > = < Ep\ (t) > = Em/2 = (\rho wgH^2)/16$$

Where,

$\rho_w$ = Density of seawater (1,025 kg/m³)

$E_k$ = Kinetic energy of water column

$E_p$ = potential energy of water column

g = gravity

H = wave height

$E_{m=}$ mechanical energy of water column

When the depth of the water is infinite, the group speed, $v_g$ (i.e. speed of energy propagation) is written:

$$Vg(T) = gT/4\pi$$

Where $T$ is the period of the sinusoidal wave.

So, the power per metre of the wave front of a sinusoidal wave is therefore equal to:

$$Pw = E_m v_g = H^2T \approx 980\ H^2T\ (W.\ m^{-1})$$

It is the simple equation of ideal wave power avoiding complexity. This equation is valid for unidirectional and uniform sinusoidal waves.

## Hydrodynamic Performance of Wave Energy Converters

How much power can be captured by WEC technology from available wave power can be calculated from the hydrodynamic efficiency of WEC technology. In case of capturing energy from waves to a WEC technology, the ratio of power absorbed by WEC to the wave energy flux (wave power per meter length of wavefront) is defined as capture ratio, $B_w$.

$$\text{So, } B_w = Pabs/Pw$$

This relation is homogeneous to a given length. It may be interpreted as the wave-front width of wave energy absorbed by the system. From the definition, it is found that hydrodynamic performance is the ratio of capture width to relevant dimension,

$$\eta = B_w / B$$

$$\text{or,} \eta = Pabs / (Pw \times B)$$

So, power absorbed by a WEC can be written as follows:

$$Pabs = Pw \times B \times \eta$$

Where,

Pabs = Wave power absorbed by the WEC

Pw = Wave power per meter length wave front

η = Hydrodynamic performance of wave energy converters

B = Size or dimension of WEC device (can be length or width, depends on which principle the wave energy converter works. Such as for Pelamis, it is the length.)

If power take-off efficiency is €, then electricity supplied to ship from WEC device is,

$$Ptotal = Pabs \times €$$

## Findings and Result

In this section, it can be calculated mathematically to find out how much power can finally be contributed to the ship's power main. For this process, a vessel named MV Great Royal is considered here for a period of 26 June 2018 to 13 July 2018 at Kutubdia anchorage, Bangladesh. Since the purpose of this research is to study the viability of WEC technology while the vessel is standstill, the duration of the vessel at anchorage is only to be considered. For better understanding, all the specifications of the vessel are provided below:

Table 3: Particulars of the vessel considered for the study (Interviewed by the authors)

| **Ships' name and details** | **Location of anchorage** | **Time at anchorage In Kutubdia** | **Average generator load** | **Average fuel consumption** |
|---|---|---|---|---|
| MV. Great Royal<br>Gross Tonnage: 23,263 MT<br>Deadweight: 42,174 MT<br>Length Overall x Breadth Extreme: 180m × 31m | Kutubdia | 26 June 2018 to 13 July 2018 | 360 kW | 2.8 Tons/day |

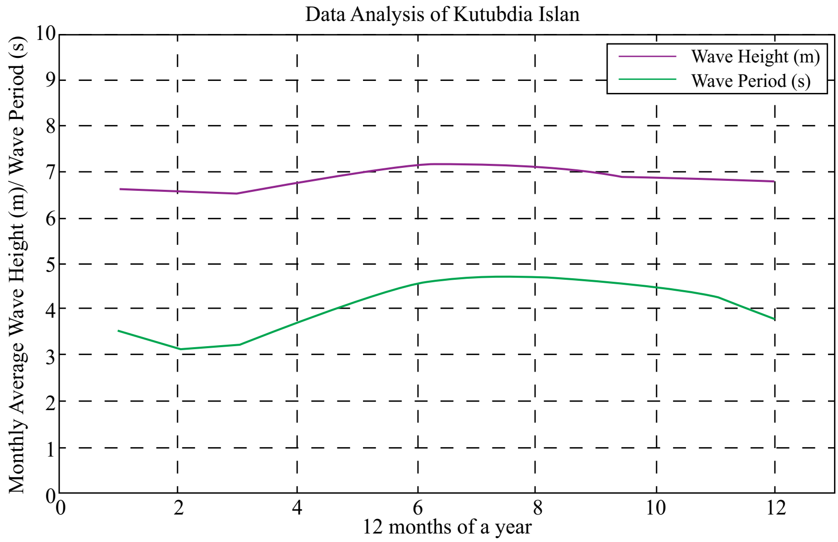


*Figure 2: Wave height and period at Kutubdia round the year (Samrat, Rahaman, Mamun,Adib, Badhan,Ahmed, 2014)*

From Figure 2, it can be obtained that from June to July in Kutubdia, average wave height and wave period is 7.2 m and 4.7 s. So, theoretically how much wave power is available at that time at sea, can be gained roughly by the following formula:

$$Pw = Emvg = \rho wg2/32\pi \text{ H2T} \approx 980 \text{ H2T (W. m-1)}$$

So, wave power per metre length of the wavefront is, $980\times (7.2)^2\times 4.7 \text{ W.m}^{-1}$

$$= 238775.04 \text{ W.m}^{-1}$$

$$= 238.77 \text{ kW.m}^{-1}$$

Here, a small size WEC is considered for easy handling and carrying out of operation. Large or medium size WEC can be applied in a vessel for more power, but ship personnel may face difficulties while installing on seawater surface.

From the equation of power absorbed by WEC, power absorbed by a small heaving buoy (size of 5 m) such as a small point absorber can be easily found out in such condition with the values of B and η obtained from table 4.

$$P_{abs} = P_w \times B\times \eta$$

$$= 238.77\times 5\times 0.09 \text{ kW}$$

$$= 107.44 \text{ kW}$$

If this power is converted to electricity with minimum power take-off efficiency € = 30%, the amount of power supplied to ship is,

$$P = (107.44\times 0.3) \text{ kW}$$

$$= 32.23 \text{ kW}$$

If 5 number of small size point absorber heaving small buoy can be used while ship anchoring, total power supplied to the ships' power main is,

$$P_{total} = (32.23\times5)$$
$$= 161.15 \text{ kW or } 161 \text{ Kw}$$

So, generator load can be reduced by 161 kW, from 360 kW to 199 kW saving fuel about (2.8/360) × 161 tons

= 1.25 tons roughly.

Table 4: A list of hydrodynamic performance of different types of WEC. (Multon Bernard, 2012:348)

| Category | Sub-category | Average hydrodynamic performance | Min. | Max. | Typical Size | Reference dimension |
|---|---|---|---|---|---|---|
| Oscillating water column | | 33% | 20% | 45% | 30m | Width |
| Overtopping system | | 13% | 4% | 23% | 300m | Width |
| System driven by the waves | Small heaving buoy | 9% | 3% | 14% | 5m | Width |
| | Large heaving buoy | 29% | 19% | 42% | 20m | Width |
| | Bottom fixed oscillating flaps system | 41% | 25% | 65% | 20m | Width |
| | Floating oscillating flaps system | 20% | 14% | 36% | 25m | Width |
| | Floating system combining surge/ heave/ pitch | 17% | 6% | 27% | 30m | Width |
| | Heave/ yaw | 6% | 5% | 7% | 150m | Length |

For port, multiple arrays of WEC technology can be implemented in deep seaport or seaport. But this won't be effective if the water depth is less than 30-40 metres, as large size WEC technology unable to work efficiently in shallow water. As Bangladesh has gradual slopping down of continental shelf to the seabed, it is not possible to find enough depth in Kutubdia or Chattogram port or even Payra port for implementing WEC technology. But apart from Bangladesh, it is possible to find enough depth for successfully implementing WEC technology in other geographical port locations all over the world. In such kind of geographic locations, commercial installation of robust size WEC technology, for example, Wave Dragon, Oyster, Pelamis can contribute to a huge amount of electricity in port, which can be used for cold ironing (supplying shore power to ship). From table 5, we can notice that a large size wave dragon can have a power rating of 7000 kW/ single unit. So, theoretically, 2 units of wave dragon can supply (2 × 7000) = 14,000 kW = 1.4 MW, which can annually supply about 12264 MW of electricity to shore.

Table 5: Capacity of different types of WEC (Wave Energy Converters)(Rusu, Egen, 2013)

| Device | Power per Unit (kW) | Movement | Depth (m) | Size |
|---|---|---|---|---|
| Oceantec | 500 | heave | 30–50 | medium |
| Pelamis | 750 | surge & heave | 50–70 | medium |
| P P Converter | 3620 | heave | deep | large |
| Wave Dragon | 7000 | Overtopping | 30–50 | large |
| Seabased | 15 | heave | 30–50 | small |
| Aqua Buoy | 250 | heave | >50 | small |
| AWS (Archimedes Wave Swing) | 2320 | heave | 40-100 | Medium |
| Langlee | 1665 | Oscillating flaps | deep | Medium |
| OE Buoy | 2800 | Oscillating column | Deep | Medium |
| Wavebob | 1000 | Heave | deep | Medium |

## Discussion

### The power saved per day over anytime of the year:

It is calculated by the equation described above in methodology. This discussion is valid for any ship staying at Kutubdia anchorage with 5 number of small size point absorbers heaving small buoy.

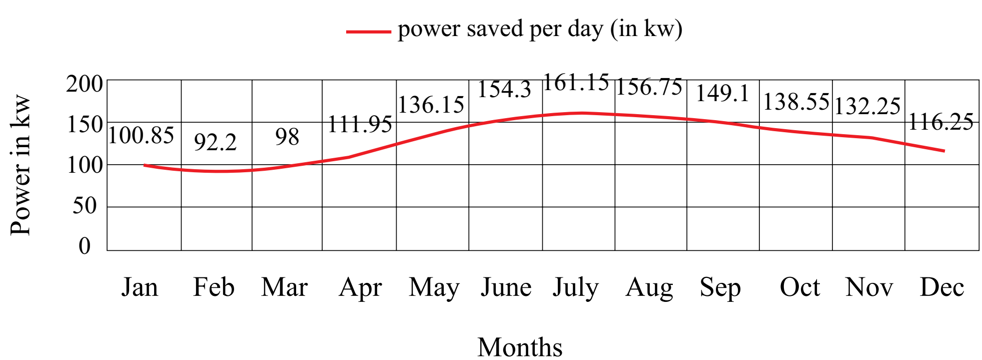


*Figure 3: Power saved per day throughout the year*

**Reduction of $CO_2$ emission**

It is estimated that specific $CO_2$ emission of HFO (Heavy Fuel Oil) is 3.11 kg $CO_2$/kg fuel.

So, $CO_2$ reduced = fuel saved × specific $CO_2$ emission

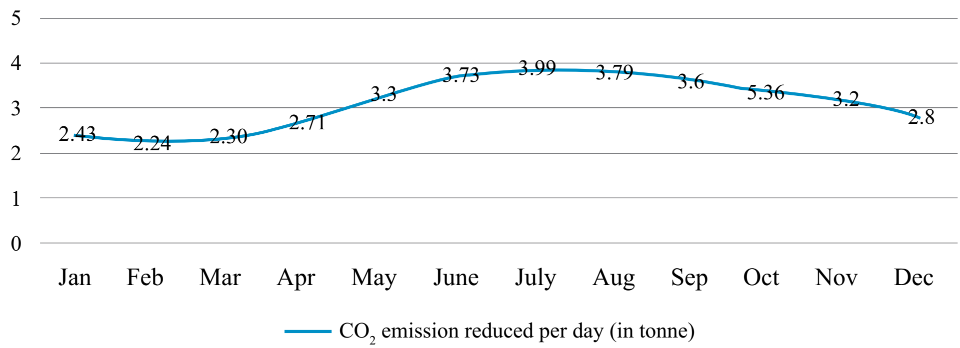


*Figure 4: $CO_2$ emission reduced per day throughout the year.*

**Cost Analysis**

**Fuel saved**

Amount of fuel saved is calculated by taking into account the average fuel consumption per kilowatt power production of that vessel mentioned, i.e.

Fuel saved = power saved per day× (2.8/360)

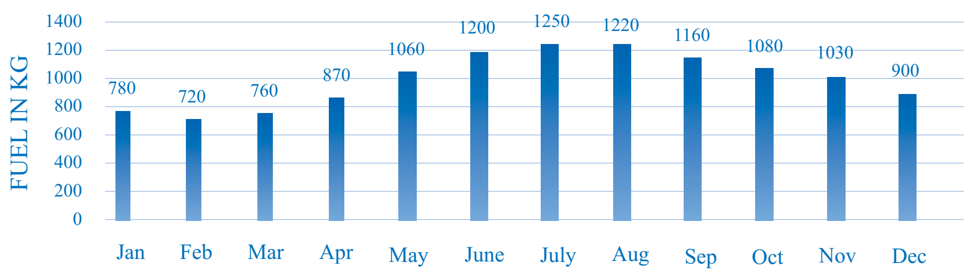


*Figure 5: Fuel saved per day around the year in KG.*

**Cost saved**

According to the world market, global bunker price is 489 USD per MT (Metric Ton)

So, Cost saved = (fuel saved × price).

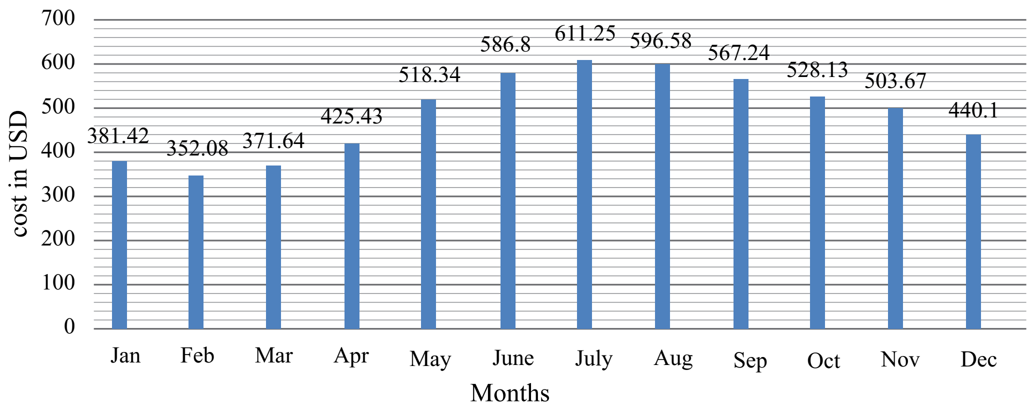


*Figure 6: Cost saved per day around the year*

Here, the smallest WEC is considered with the least efficiency of power uptake, so power production is less. If to consider medium or large WEC, then power production would be more undoubtedly. Other WEC technologies such as Anaconda Bulge wave converter technology seemed promising, could be proved viable in a ship, but lack of data and unconfirmed information didn't assist to carry out the calculation.

The small heaving point absorber type WEC is considered regardless of the depth of installation in the sea. It is demanded by the manufacturer that a single unit point absorber, Aqua Buoy of 6m diameter with 50 m depth can generate 250 kW depending on sea state. In that case, instead of installing 5 units, only a single unit Aqua Buoy type WEC can contribute enough to reduce fuel consumption of that vessel.

As some geographic location, such as Bangladesh doesn't have enough depth in the seabed, so apart from WEC technology, other tidal energy conversion technology can be proposed. High torrent characteristics of Karnaphuli River in Bangladesh may also permit this. But as tidal energy is beyond this study domain, this concept is not focused here. Other ports and deep seaports area over the world having enough depth could be proved as a worthy example of the energy-efficient port to ensure an energy-efficient propulsion system in shipping all over the world.

The cost of implementing WEC technologies may be expensive in the short term but can give a long-term cost-efficient return for the shipping company as well as significantly contribute to the emission reduction and a better shipping environment.

## Conclusion

Though a propulsion system completely based on wave energy is yet to be implemented, wave energy has a lot more to contribute to the shipping sector. While fossil fuel is nearly running out, at the same time adverse effect on global climate urges for energy efficiency in the shipping industry. To ensure this, wave energy has been proved a better option of having more advantages than other green energy sources such as wind and solar, due to its higher energy density and easy availability. In the context of exploiting and utilising wave energy in seagoing vessels while sailing, frictional drag effect and wave resistance of WEC devices, slow speed functioning of devices, a slower speed of the vessel and less effectiveness of these technologies in larger ships etc. result in drawbacks and not fulfilling requirements. Only WITT WEC seems promising. Hence, authors went for evaluating the concept of feasibilities of wave energy technologies to near shore, port, harbour, deep seawater ports and vessels while anchoring, which theoretically seems satisfying their aims by significantly reducing fuel consumptions and $CO_2$ emissions and saving cost. These benefits may vary due to different place, condition and state of the sea.

Though all of these wave technologies are not commercially viable yet, testing of their prototypes proved good working. This study can pave a long and effective way in better and cost-efficient designing of these technologies, which could make it possible to easily and economically fit in vessels in vast prospect. In the near future, this research will surely enlighten higher efficient power benefits making a great step in the way of ensuring viable and energy-efficient shipping all over the world.

**Recommendation and future work:**

Since wave energy idea, as a green energy source is still in fledgling condition, less work has been conducted on wave energy research and application on seagoing vessels. Below are a few recommendations from authors to conduct further research in this regard.

- For ensuring the viability of wave energy while the vessel is at sea, more thorough research is required on advanced fluid dynamics and wave resistance effect on the ship.
- Lot more works can be done on WITT WEC system for making it viable in the ship at sea.
- Lots of future works are to be conducted and ensure whether existing wave energy harnessing solutions are viable or not. There are far more works to be done in this field for developing and designing more efficient and suited WEC device for fitting in the vessel.
- Frictional drag effect of wave energy converters is to be vastly calculated whether they make any drawbacks or not.
- There is a vast scope of doing hard works and research for commercially and profitably implementation of large WEC technologies at near shore and port.
- Further research can be conducted in the field of designing and developing WEC technologies which are feasible to work in shallow water such as Bangladesh seabed area.

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# Does SST Explain the Seasonal Variability of Chlorophyll in the Upper Indian Ocean?

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and Subrata Sarker[3]

***Abstract***

*Quantitative analyses of chlorophyll concentration in relation to Sea Surface Temperature (SST) can explain the spatiotemporal distribution of phytoplankton in oceans. In this study, the response of chlorophyll in the Bay of Bengal (BoB) and the Arabian Sea (AS) to seasonal SST was investigated using remotely sensed Moderate Resolution Imaging Spectroradiometer (MODIS) data. MODIS SST data were validated with in-situ data derived from the World Ocean Database. Thus, satellite-based SST estimates were more reliable for BoB than that of AS. In general, SST was comparatively high in BoB; the lowest 27.88° C recorded in January and the highest 30.33° C in April. In contrast, maximum SST in AS was 29.82° C in May and minimum 26.66° C recorded in January. The chlorophyll concentration in BoB was minimum (0.31 mg m-3) in April and maximum (0.46 mg m-3) in September. While the chlorophyllin AS was minimum (0.34 mg m-3) in April and maximum (1.18 mg m-3) in September. These results suggest a significant negative association between SST and chlorophyll in BoB and AS that can explain 32% variability of chlorophyllin both areas. Other than SST, a large number of biotic and abiotic factors, such as nutrient availability, presence of sunlight, mixing layer depth, grazing etc. affect the seasonal variation of chlorophyll. Nevertheless, this study will provide useful information to understand the phytoplankton dynamics in tropical seas.*

**Keywords:** Phytoplankton, Temperature, Dynamics, Bay of Bengal, Arabian Sea.

## Introduction

Oceans, which occupy ~72% of the earth's surface, play an important role in the climatic conditions of adjacent land areas. The information about ocean waters, its nutrients and circulation dynamics along the coast have paramount importance in understanding the ocean processes. The physical and biological processes are closely coupled and vary

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over a wide range of time and space scales (Hutchings et al., 1995; Smith, 1995; Hickey, 1998 and Mackas et al., 2006).In the ocean, physical, chemical, and biological processes are linked in an intimate manner (Tang et al., 2002). Oceanic features influence ocean dynamics and its interaction with the atmosphere. The biological processes in world oceans are mainly controlled by the presence of phytoplankton, which forms the base of the food chain. The presence of phytoplankton is also known to affect the sea surface temperature (SST) by interception of short radiation absorption and thereby increasing SST (Sathyendranath et al.,1991). The influence of phytoplankton on the colour of sea has been studied for decades. It is well understood that chlorophyll concentration and the photosynthetic pigments in phytoplankton absorb relatively more blue and red light than green and the spectrum of backscattered sunlight or colour of the ocean water progressively shifts from deep blue to green as the concentration of phytoplankton increases (Yentsch, 1960).

To assess the seasonal variability of chlorophyll and temperature, and their relationship in the open ocean, cruise data were used for the Arabian Sea (AS) (Chaturvedi et al., 2000), but laboratory study suggests that enrichment in $CO_2$, SST and exposure to higher mean radiances have a great influence on the growth of ocean biota. The north-eastern part of AS is one of the high productive zones, while the southern part of Bay of Bengal (BoB) is not that productive compared to the Ganges-Brahmaputra delta in the northern BoB (Chauhan et al., 2001). The continental shelf in AS is much shallower compared to the shelf in southern BoB (Dey and Singh, 2003). In northern AS, the rate of phytoplankton cell division is controlled by nutrient availability rather than light, while light inhibition of photosynthesis near the surface is negligible (Tang et al., 2002). The boundary and open ocean processes of AS are influenced by upwelling during summer and cooling in winter that brings in a high amount of nutrients into the upper ocean enhancing primary productivity, and ultimately the fisheries (Madhupratap et al., 2001). A conspicuous surface salinity gradient could be seen from the northeast Bay to the north-central AS (Shenoi et al., 2002). For the freshwater balance of the north Indian Ocean, an efficient conduit for the export of low salinity water from BoB was observed (Jensen, 2001). This low salinity water eventually finds its way into the southeastern AS and plays an important role on the formation of a mini warm pool during the pre-monsoon months (Rao and Sivakumar, 1999; Shenoi et al., 1999).

The optical properties of oceans are of fundamental interest in oceanographic studies. Their variability is largely determined by variations in the ecology and biological response to physical and chemical environments. This study aims to characterise and interpret the spatial and temporal variability of chlorophyll and SST in AS and BoB, by coupling US NASA Ocean Colour Web (OCWEB) and World Ocean Database 2009 (WOD09). Specifically, to compare two regional thermal and bio-optical fronts in satellite imagery, examine chlorophyll and SST variability, and describe the role of SST on chlorophyll in the tropical seas of the Indian Ocean.

## Materials and Methods

### Study Area

This study was carried out in BoB and AS belonging to the northern Indian Ocean (Figure 1). The Indian Ocean is the third largest oceanic divisions in the world, and bounds the waters along the west of Africa, east of Malay Peninsula, Sunda Islands, Australia, south of the Southern Ocean and north of Asia including the Indian peninsula, which is the region of interest. The Indian peninsula is known to have unusual climate variability due to the monsoon wind system. The northeast monsoon blows from October to April/ December to July and the southeast monsoon blows from May to October. The Indian Ocean current system is largely influenced by the Indian monsoon current. During winter, currents blow towards the westward near the Indonesian Archipelago to AS. However, during summer, the direction of currents reverses, going toward BoB.

### Data Source and Data Processing

For the analysis of seasonal variability of SST and chlorophyll concentration in BoB and AS, Moderate Resolution Imaging Spectroradiometer (MODIS) data with 4 km resolution

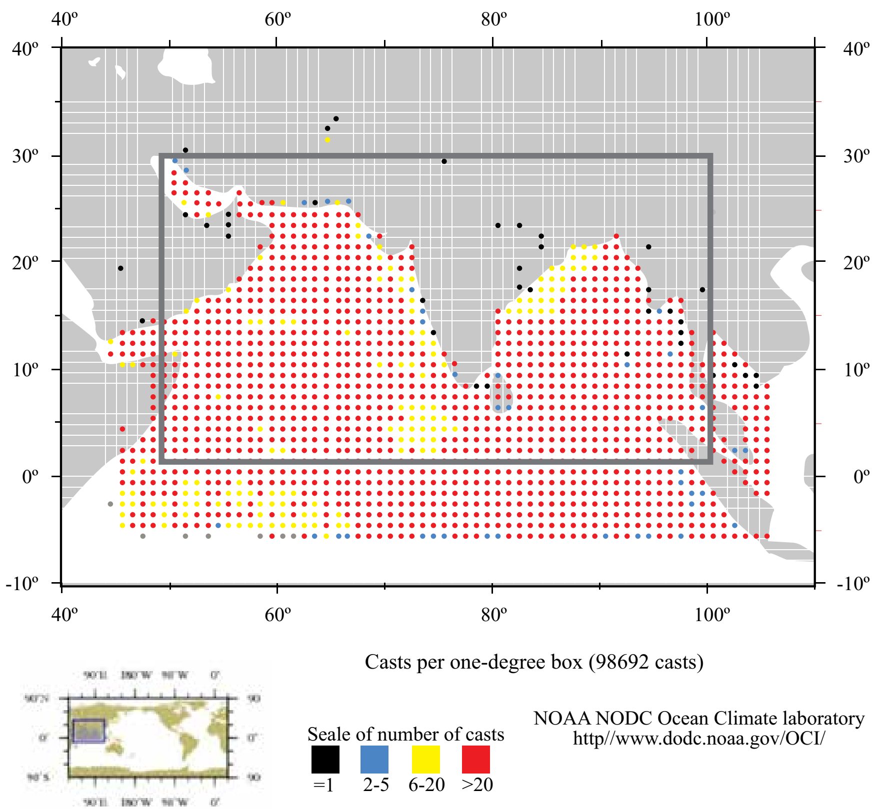


*Figure 1.The geographical location of the northern Indian Ocean.*

were used. The Ocean Colour Web (OCWEB) sensor onboard aqua-MODIS satellite has been a boon to the scientific community involved in the analysis and characterisation of chlorophyll concentration and SST in the oceans. The level-2 files are spatially averaged into level-3 daily binned files using the 12 bin programme developed by the Ocean Biology Processing Group (OBPG) and the daily files are further composited into weekly, monthly, annual, seasonal and climatological time periods using the 13 bin code (replaced time bin). For binning we followed Campbell et al., (1995). The bin products are then used to generate mapped products for chlorophyll-a concentration and SST on 4 km equirectangular projection. These image products are in Standard Mapped Image (SMI) format. They are produced using the smigen programme. The climatological binned and mapped products are produced in the refined processing stream.

The present study has made use of aqua MODIS monthly climatology data from OCWEB for the period 2002 - 2011 over AS and BoB region to understand the variability in chlorophyll and SST pattern. Atmospherically, radiometrically and geometrically corrected monthly chlorophyll images have been analysed. These are the level-3 global gridded product with 4 km resolution distributed by NASA (http://oceancolor.gsfc.nasa.gov/). All of the data products from MODIS are stored in the Hierarchical Data Format (HDF). From the global chlorophyll and SST images for AS and BoB has been extracted using Saga GIS software. To validate the satellite data, the archived field data were collected from WOD09 for SST for the same time as MODIS data were collected. These data were visualised in Ocean Data View (ODV).

## Results

In this study, a 20-year data set of seasonal SST and chlorophyll concentrations in BoB and AS were examined. The satellite data were validated with observed data obtained from the World Ocean Database. The monthly mean data were prepared and presented. Regression and correlation analyses were carried out for all relationships in order to describe the interactions between SST and chlorophyll.

### Variability in SST

Comparison of observed data with satellite-derived SST showed that satellite data can explain 87% and 41% ($p<0.001$ and $p<0.05$) variation in observed SST data in BoB and AS respectively. SST of BoB was found relatively higher than that of AS throughout the year (Figure 2). December to February is characterised by low SST with the lowest (27.88° C) in January (Figures - 3 and 4). April and May are characterised by high temperature with the highest value of 30.33° C in April. A secondary peak in SST was observed in October and November in the BoB. Similar to BoB, in the AS, the primary and secondary peak in SST were observed from April to May and October to November respectively. Maximum SST was found 29.82°C in May and the minimum temperature was found 26.66°C in January.

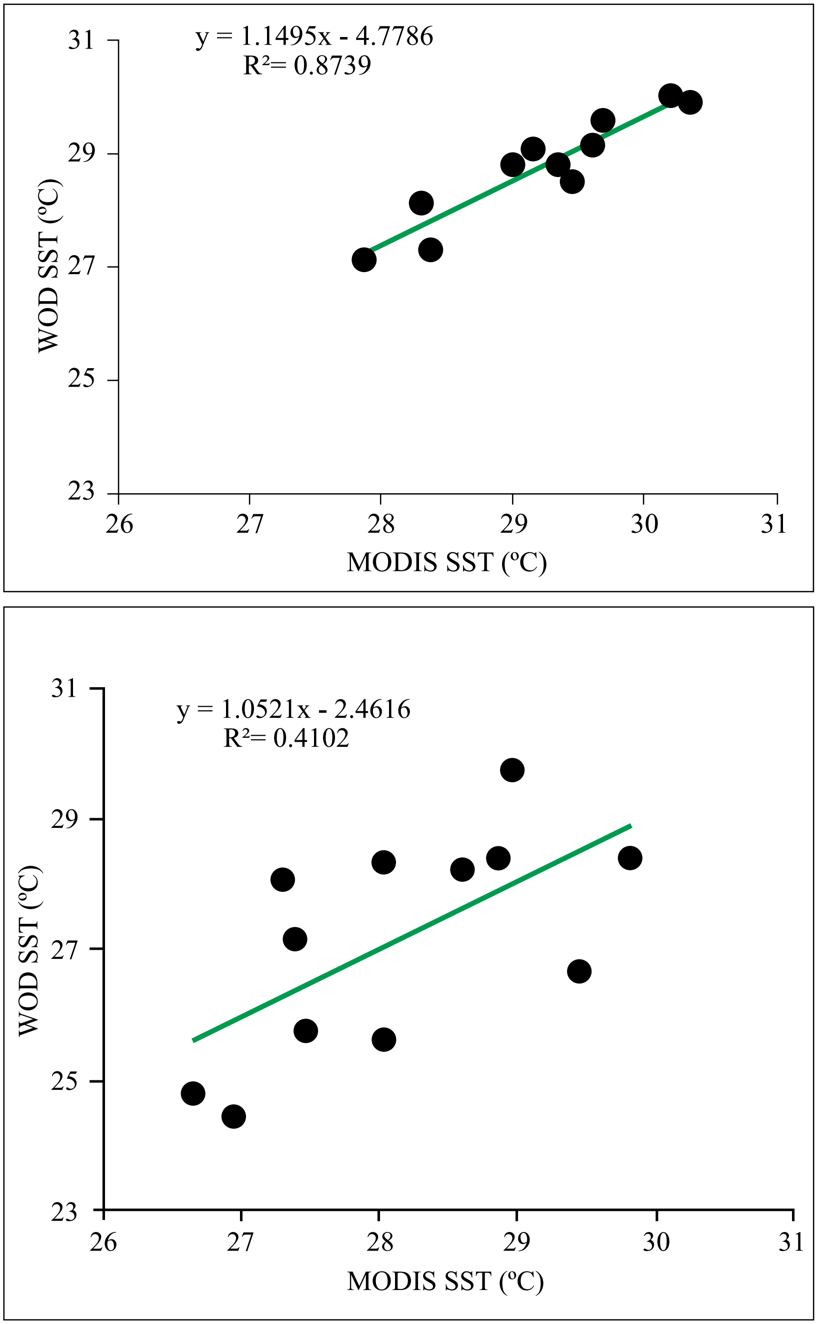


*Figure 2. Validation of satellite-derived SST data with WOD data for the Bay of Bengal (top) and the Arabian Sea (bottom)*

**Variability in Chlorophyll Concentrations**

Chlorophyll data are not sufficiently available for the northern Indian Ocean in the World

Ocean Database. Therefore, in this study, a comparison of satellite-derived chlorophyll data with observed data was not possible. Seasonal chlorophyll concentrations in the BoB did not show significant variation (Figures 4 and 5). The lowest chlorophyll concentration was found 0.31 mg m-3 in April and the maximum was found 0.46 mg m-3 in September in the BoB. Seasonal chlorophyll concentrations declined from January to May and then increased from the end of May to end of August. From the September to end of December, chlorophyll concentrations did not show any significant variations. In contrast to BoB, a significant seasonal variation in chlorophyll concentrations in the AS was observed. A peak in chlorophyll concentration was found in September (1.18 mg m-3) while the lowest value was found in April (0.34 mg m-3). Chlorophyll concentrations increases from January to end of February, then decline until the end of April and again increase from June to September. From October to December are characterised by low chlorophyll concentrations.

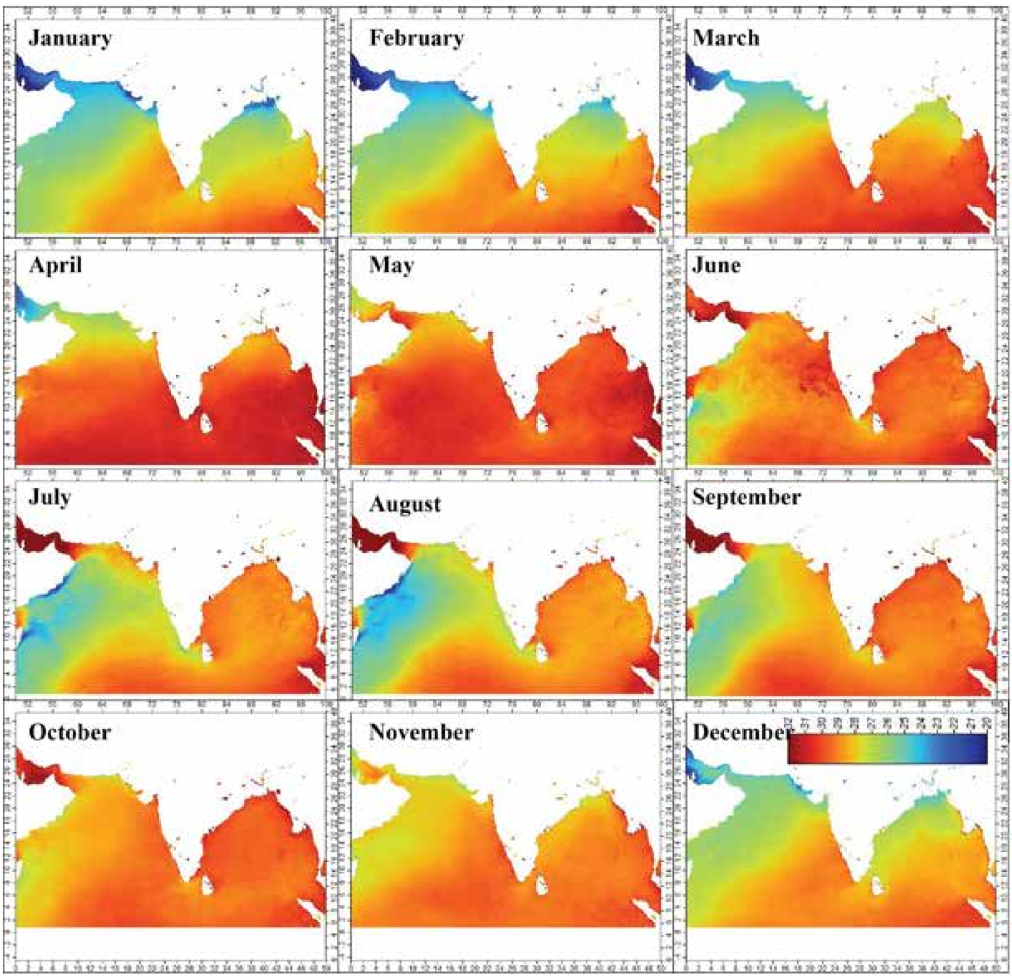


*Figure3. Seasonal spatial distribution of SST in the northern Indian Ocean*

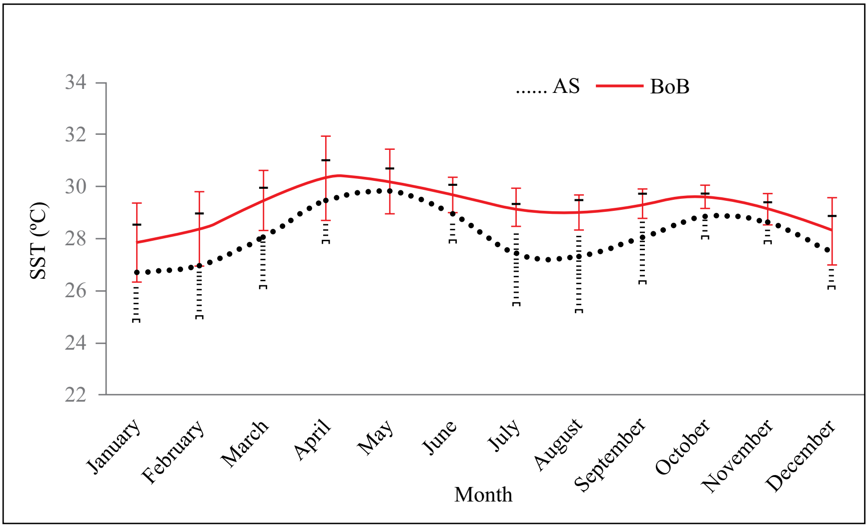


*Figure 4. Seasonal variation of SST in the Bay of Bengal and the Arabian Sea*

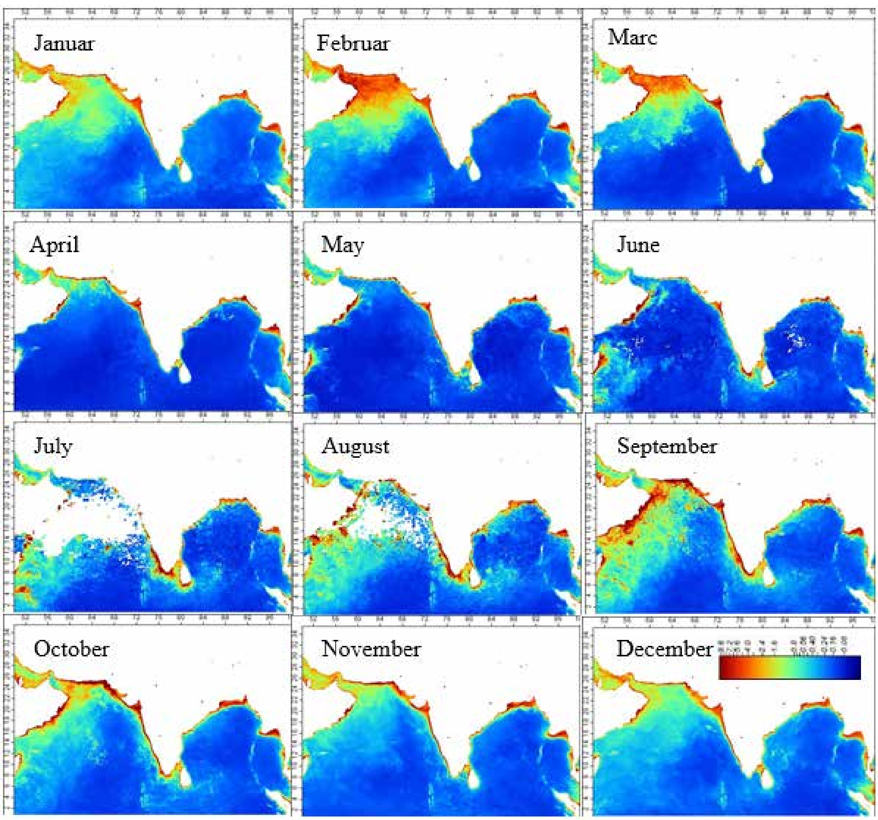


*Figure 5. Seasonal spatial distribution of chlorophyll concentrations in the northern Indian Ocean*

**Relationship Between SST and Chlorophyll**

To examine if the SST can explain the seasonal variation in chlorophyll concentrations in the BoB and AS, a linear regression analysis was performed (Figure 6). It showed that for both BoB and AS, SST is a significant predictor of chlorophyll distribution. In both cases, SST can explain 32% variation in chlorophyll concentrations. Interestingly, we observed a significant negative association between SST and chlorophyll concentrations. During March to June, SST was higher than the seasonal mean and chlorophyll was lower than the average in the BoB (Figure 6). During January, February and from August to December it was vice versa. In the AS, from January to February SST was lower than the average value while the chlorophyll was higher than the average (Figure 7). From April to June SST was lower than the average value and chlorophyll was higher. During August to December, SST was low but chlorophyll concentrations were higher than the seasonal average. The anomaly of SST and chlorophyll in BoB and in ASis shown in figure 8. Findings show that in BoB chlorophyll shows positive anomaly from July to March while negative anomaly was observed from April to June. Reverse condition in SST anomaly was observed in BoB. A similar pattern in SST and chlorophyll anomalies was observed in AS. However, the magnitude in SST and chlorophyll anomalies varies significantly betweenBoB and AS.

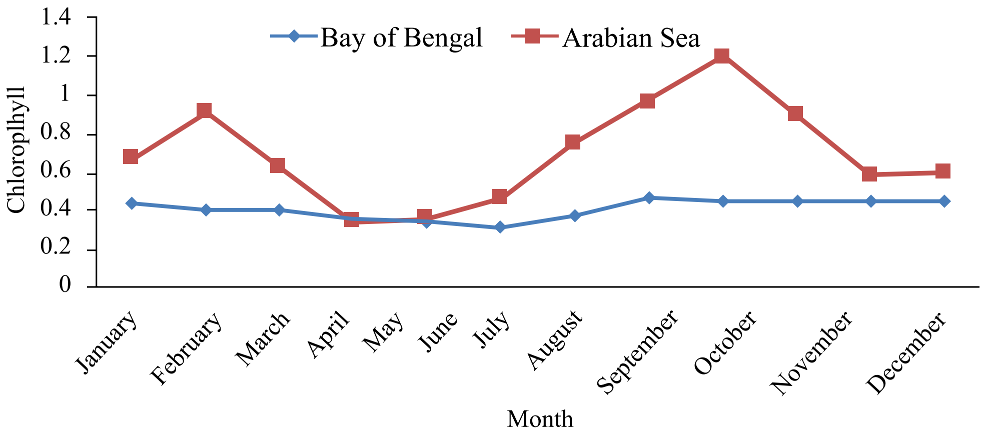


*Figure 6. Seasonal variation of chlorophyll in the Bay of Bengal and the Arabian Sea*

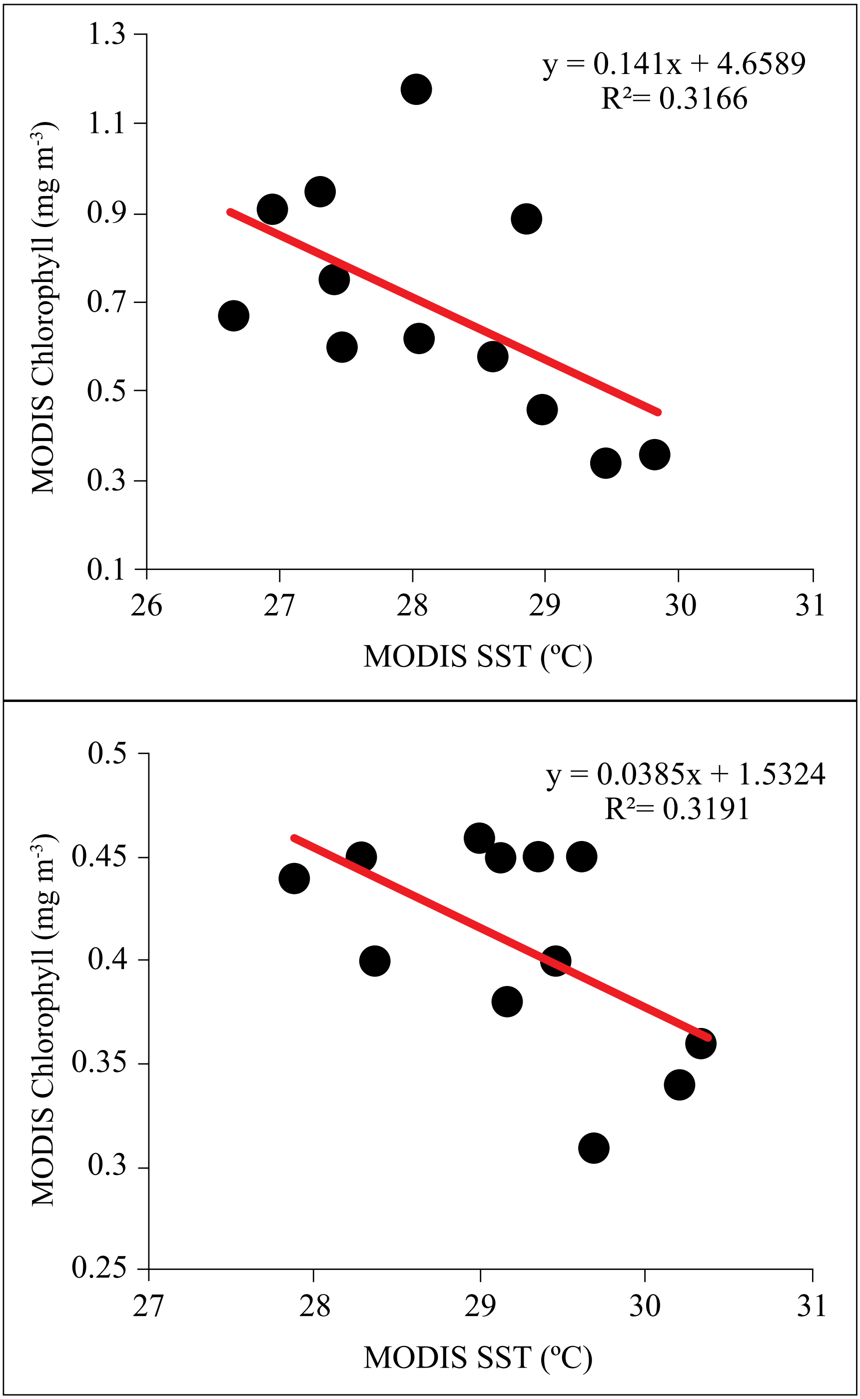


*Figure 7. Relationship between SST and chlorophyll in the Bay of Bengal (top) and in the Arabian Sea (bottom)*

## Discussion

This study aimed to examine the role of seasonal SST in explaining the variation in chlorophyll concentrations in tropical seas. We selected the BoB and AS of the northern Indian Ocean as our area of interest. Variability in long-term seasonal chlorophyll concentrations and SST in the BoB and the AS were studied using satellite-derived data. Here we used seasonal MODIS data on chlorophyll and SST from 2000 to 2011. MODIS SST data were validated with the World Ocean Database derived in-situ data. Findings showed that satellite data provide more reliable SST for the BoB than for the AS. Sea surface temperature was found higher in BoB than the AS. In BoB, the lowest SST was found 27.88° C in January and the highest value 30.33° C was found in April. Maximum SST was found 29.82° C in May and the minimum was found 26.66° C in January in the AS. The lowest chlorophyll concentration was found 0.31 mg m-3 in April and the maximum was found 0.46 mg m-3 in September in the BoB.

Remotely sensed SST explains oceanic environment suitable for enhanced production. Our current analyses showed the difference in a monthly pattern in the AS and the BoB. In the dry season (January-February-march) SST was found low where high SST was observed in April-May. In the months of June-July-August (wet season) SST was found declining due to rain. After that, it was increasing during September-October. Monthly and spatial variability of AS and BoB from remote sensing MODIS derived SST images are seen of three distinct months and from in situ WOD derived in-situ SST images are seen of the same month. We observed almost the same pattern of SST in both types of data sets. Winter cooling of surface water has been reported the lowest SST 25°C in the northern Indian Ocean in January (Murthy et al., 1992). SST increased in April-May and also in September-October in this region (Sarangi et al., 2008) and the same pattern of SST was found in this study.

High values of chlorophyll were measured by MODIS in the region of AS compared to BoB. Although, some uncertain values of chlorophyll were found in the nearest coastal region of both areas. Four distinct months were identified through observing twelve months of chlorophyll concentration from MODIS data. In the northern AS chlorophyll concentration was found higher in January to March compared to other regions due to low SST in the same months. AS water leads cool water which initiates convective mixing and injection of nutrients into the sea surface which is responsible for the higher chlorophyll concentrations in the northern AS in January to March (Kumar & Prasad, 1996). This mixing of water indicates upwelling areas leading to highly productive zone and thus the development of the localised ecosystem. The average monthly basis chlorophyll showed a peak in January during 1998-2000 in the northeast AS (Chaturvedi, 2005). Chlorophyll values were high in November and declined after January and remained constant from December onwards (Chaturvedi, 2005). In this study, it was declining January to June with little values where September to December Chlorophyll concentration was found as same as 0.45 mg m-3 in BoB.

Phytoplankton productivity and biomass in the world ocean are limited by nutrients (i.e. N, P, Si, Fe) concentrations (Chisholm and Morel, 1991) and/or the mean light level, which is modulated by vertical mixing and seasonal variability in daily insolation (Siegel et al., 2002). The relationship between temperature and chlorophyll has been emphasised by previous studies (Bailleulet al., 2007). In this study, BoB and AS showed an inverse relationship between chlorophyll and SST with an R2 value 0.319 for BoB and 0.316 for AS. Barnard et al. (1997) observed the distribution of chlorophyll and SST are inversely correlated. The enhanced chlorophyll concentration in winter is that Wyrtki jets and wind stirring are responsible for bringing up the mixed layer of rich nutrients to the surface and the enrichment of the mixed layer through cool thermocline water. This cooling event is responsible for the increase in surface chlorophyll concentrations (Vinayachandran and Saji, 2008). Strutton et al. (2015) evaluated this hypothesis using moored chlorophyll observations and modelled results and found credence to the hypothesis. It is well established that mixing of deeper water with the surface water causes a decrease in SST and supplies nutrients to the upper layers which enhances the productivity and hence the high surface chlorophyll concentrations (Prakash and Ramesh, 2007). Based on the direction of winds, they could trigger upwelling or downwelling signal. Since the dominant wind direction in the equatorial Indian Ocean is westerly, it normally triggers downwelling Kelvin signal and, therefore, reduces the chlorophyll concentrations during summer (Kumar et al., 2016).

## Conclusion

In conclusion, the results demonstrated the monthly climatological variability and inter-relationship of the Chlorophyll and SST in BoB and AS. The SST plays an important role in Chlorophyll concentration and its variability. The lower chlorophyll concentration has been found in BoB compared to those in AS. The higher chlorophyll concentration in AS is attributed to the vertical mixing of its water and upwelling of water, rich in nutrients, whereas chlorophyll concentration and productivity in BoB are low. Monthly variability in chlorophyll and SST shows an inverse relationship in both regions. And the variability in chlorophyll also shows an inverse relationship in BoB and AS. The persistent co-occurrence of colour and thermal features indicate the close coupling between the physical and biological parameters. Chlorophyll features appear to be well defined and contain more information compared to SST features. The application of chlorophyll and SST would be useful to improve the methodology for exploring living marine resources.

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# Shipbuilding: A Gateway for Bangladesh to Achieve Economic Solvency

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***Abstract***

*Bangladesh has been ranked 41st among the world's largest economies in 2019 as well as become the second biggest economy in South Asia. As a maritime nation, the country focuses on prospects of Blue Economy and aspires to be a middle-income country by 2021 and developed economy by 2041. To achieve this goal the shipbuilding industry can be the perfect alternative. Being a nation next to the sea, she has a long heritage of building ocean-going ships. With the recent success of the shipbuilders of Bangladesh, it is crystal clear that this industry has more potentials to impact the national economy. The study was mainly a descriptive research. Data were mainly collected from secondary sources. Some primary data were also collected from experts and policymakers through unstructured interviews. The study revealed that Bangladesh has a great potentiality in this sector. Bangladesh is emerging as a shipbuilding nation. In the last decade by exporting more than a hundred ships, Bangladesh earned a lot of foreign currency. The shipbuilding industry of Bangladesh has a great scope in the international market for building small ocean-going vessel although there are some obstacles and challenges that are hindering the proper growth of this industry. The study provided valuable guidance for the government of Bangladesh to make a clear policy regarding the expansion of the shipbuilding industry to attain economic solvency. It is expected that this study would contribute to improving policy, further research and advance the frontier of the knowledge.*

**Keywords:** Shipbuilding, Economic Solvency.

## Introduction

Bangladesh has been bearing the flag of a shipbuilding nation from ancient time. The ships built in Chattogram were of high quality and had been preferred by the Turkish

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army, British army and so on. The history of shipbuilding in Bangladesh can be found in the writings of famous travellers like Ibn Battuta and Caesar Frederick. Due to the riverine geography of Bangladesh, a big part of trade and commerce is being conducted through shipping. Consequently, the economy of this country is greatly depended on shipping. Shipping and shipbuilding are inextricably related to each other.

In Bangladesh, the GDP growth used to be made on the basis of three main sectors – agriculture, industry and services. In FY 2017-18, the contribution of the industrial sector is 33.71% and the growth rate of the industrial sector is 11.91%.

Shipbuilding industry is under the industry sector. After RMG, the shipbuilding industry is the second largest sector in the percentage contribution to GDP. From 2008-2012 Bangladesh exported ferries, cargo vessels and ocean-going multipurpose vessels worth more than USD 500 million. (Ethirajan 2012)

The shipbuilding industry has the highest multipliers effect on the national economy, it can earn a huge amount of foreign currency by exporting ships, and it can create job opportunities, provide support to build backward linkage industries and it can help to upheld the GDP of a country.

## Global Perspective

In 2018, China consolidated its top position with a 43.1% market share (Morrison, 2019). Chinese shipyards, from being mere shipbuilders in the 1990s, are today the industry leaders. In the last three decades, the Chinese shipbuilding industry has transformed from a 'basic ship producer' to an industry, focusing on 'high technology' and 'support equipment'. This has allowed them to dominate the world market in both commercial and naval shipbuilding segments. 70% of Chinese ships are being exported to 91 countries and regions, including countries like Greece, Norway, US, UK, Japan, South Korea, and Germany (Nitin Agarwala, R.D. Chaudhary, 2019). This enormous growth has been aptly supported by a judicious mix of public and private enterprises in the field of science, technology, and innovation. The Chinese economy is growing day by day and in 2018, they were the largest economy of the world and the Chinese shipbuilding industry has a great contribution to this achievement.

## Regional Perspective

Our neighbouring country India initiated a master plan to bring India to the level of China in terms of shipbuilding gross tonnage capacity by the year 2015. About 15 new conglomerates have initiated the development of large scale shipbuilding projects in India with an estimated investment of 60,000 crores rupees, and the coastal state governments from Gujarat to West Bengal are luring the investors, offering lands at throw-away prices and other state incentives (Ahmed, 2008).

The government of India recently formed a consultative committee to determine whether to extend the 30% federal cash subsidy against export which expired recently after five years of continuation. India will have a cost disadvantage of 30-55% compared to China if the ongoing federal subsidy is removed (Ahmed, 2008). The state government of Gujarat most recently went one step ahead by announcing that it will reimburse stamp duty on land registration for the shipbuilders and it will provide the capital fund with 5% interest subsidy for five years. The Indian government are working hard to flourish its shipbuilding industry and the target is to surpass China in terms of shipbuilding production (Ahmed, 2008).

### National Perspective

In recent years, the fast-growing shipbuilding industry in Bangladesh has emerged as a significant means of export diversification. In a short period of time, this high-potential industry has made a good reputation in the global competitive market (Islam, 2018).

Bangladesh's introduction to the shipbuilding market was back in the late 2000s. Initially, a few small boats had exported to Mozambique and a few others to the Maldives, but the major turning point came when Bangladeshi shipyards started receiving orders from Europe. Vessels called multi-purpose cargo ships were ordered by German and Danish buyers. From 2008, upon exporting these ships to Europe, Bangladesh came to be recognised as a shipbuilding nation (Islam, 2018).

Even the government of Bangladesh recognised shipbuilding as a major industry for export diversification. This industry was declared as the "thrust sector" due to its potential in the export business. Presently, Bangladesh is contributing 0.84% of the global shipbuilding market (Ship Building Sector, 2019).

### Objective

In the last decade by exporting more than a hundred ships, Bangladesh has emerged as a shipbuilding nation. The shipbuilding industry of Bangladesh has a great scope in the international market for building small ocean-going vessels.

The objective of the study is to discover the potential of the shipbuilding industry in Bangladesh to achieve economic solvency. At the same time, the challenges this industry is facing currently and the opportunities it will have in future if nurtured have also been depicted here.

## Methodology

This study is a descriptive and explanatory research. The research is mostly based on secondary sources of information. For the secondary data, literature related to the topic from different databases, websites and other available sources were collected. A systematic review of the collected literature was done in detail.

Primary information has also been collected through unstructured face to face interview and telephonic interview with few shipbuilders, top bankers and some government officials in Dhaka.

## Literature Review

(Shemon, 2017) In his work "Problems and Prospects of Bangladesh's Shipping Industry: A Comparative Overview" mostly highlighted on an overall picture of this industry which has been depicted by identifying the actual shipbuilding practice in both public and private sector.

(Zakaria et al, 2010) In his work "Study on some competitive parameters for shipbuilding industry in Bangladesh" mainly focuses on some crucial competitive factors like labour skill, labour availability, labour man-hour, labour cost and productivity for local shipbuilding which are the inherent part for the expansion of this industry. The analysis also focuses on the existing access to the resources like materials, knowledge and capital for shipbuilding. Comparison of these parameters with other nations has been made qualitatively and quantitatively to find the level of our shipbuilding.

(P.G. Patil et al, 2018) In their work "Toward a Blue Economy: A pathway for Bangladesh's sustainable growth", they tried to synthesise the current theory and practice of the Blue Economy concept to govern economic activity linked to the ocean, and to provide a framework for the government of Bangladesh to analyse its potential. Through the report, they offer a conceptual framework to guide policy-makers in Bangladesh in proposing specific reforms, by illustrating the economic activities of the ocean economy together with the underlying natural capital, as well as other types of capital.

The existing literatures analysed the prospects, challenges, the suitability of Bangladesh to develop the shipbuilding industry and the Blue Economy for sustainable growth. But none of these works of literature discussed how this shipbuilding industry can be a gateway for Bangladesh to achieve economic solvency.

## An Overview of Shipbuilding Industry in Bangladesh

During the first half of the 19th century, the shipyards at Chattogram used to build ships up to 1000 DWT (Yousuf, 2014). Later, due to the incapability to cope up with the modern shipbuilding technology, Bangladesh had fallen behind. Fortunately, this industry has once again been revived with the initiative of a few businessmen. Yet it is a small step compared to giant shipbuilding economies such as China, Japan and South Korea.

Shipbuilding industry of Bangladesh will continue to grow because the country has several advantages over its rivals. Bangladesh already stepped into the international arena. In recent times, local shipyards can design and fabricate ship up to 3500 DWT to fulfil the demand of the local market. All inland and coastal ships are being built by local shipyards and the number of vessels built per year counts an average of 250. Bangladeshi shipbuilders meet country's internal demand, the value of local shipbuilding is about USD 1 billion per year (Uddin, 2017). Recently, few local shipyards have attained the capacity to manufacture 10,000 DWT ships and shipyards like Ananda Shipyard and Slipways Ltd. (ASSL), Western Marine Shipyard Ltd. (WMSL) and HS has started to export ships from 2008 and day by day the number of exported ships is increasing.

Present (2018) capacity of Bangladesh is 0.84% of global shipbuilding production (Ship Building Sector, 2019). Bangladeshi shipyards concentrate on building medium-sized vessels within 12000 DWT capacity. From 2008-2012 Bangladesh exported ferries, cargo vessels and ocean-going multi-purpose vessels worth more than USD 500 million (Yousuf, 2014). Ships exported to the following countries- Germany, Finland, Pakistan, Denmark, Tanzania, New Zealand, Kenya, India, Uganda, UAE Norway, Ecuador, Gambia, Mozambique, and Maldives.

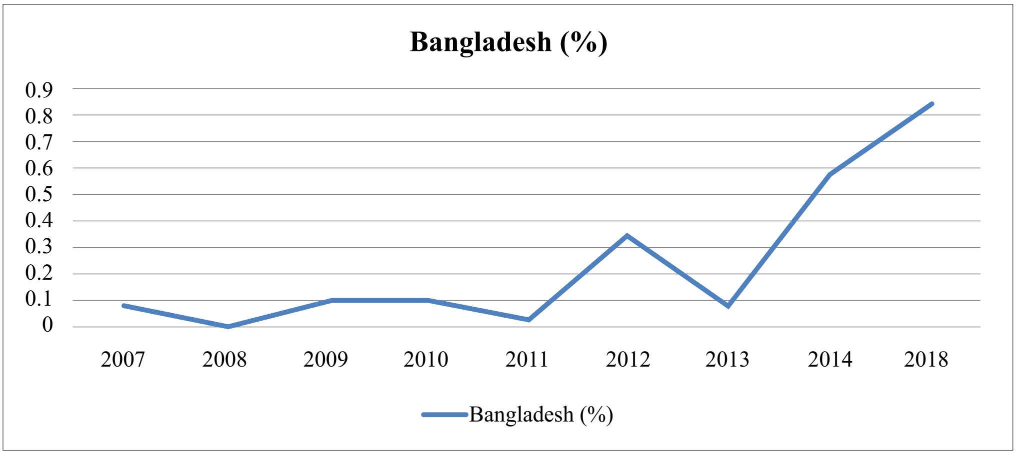



*Figure 01- World shipbuilding market shared by Bangladesh*
*Source: Bangladesh shipyard statistics, 2014 (Compiled by Author).*

From the above figure, it is clear that the shipbuilding market is volatile in character and it is same for Bangladesh as well. In spite of the current recession in the world economy, the shipbuilding industry in Bangladesh is booming from 2013. This positive sign indicates the potentiality of this industry.

After garments, the shipbuilding industry is the second largest sector in the percentage contribution to GDP. Contribution of the industrial sector to national GDP is 32.42% and in the fiscal year 2017-18, the growth rate of the industrial sector was 11.99%. Average growth of the shipbuilding industry is 8%.

Export earnings from the thriving shipbuilding industry of Bangladesh have reached a year on year growth of 456.88% in the first half (h1) of the fiscal year 2017-18 (Uddin, 2017). Figure 02 shows that from FY 2012-13 to FY 2016-17, the export earnings from this promising industry had been constantly increasing.

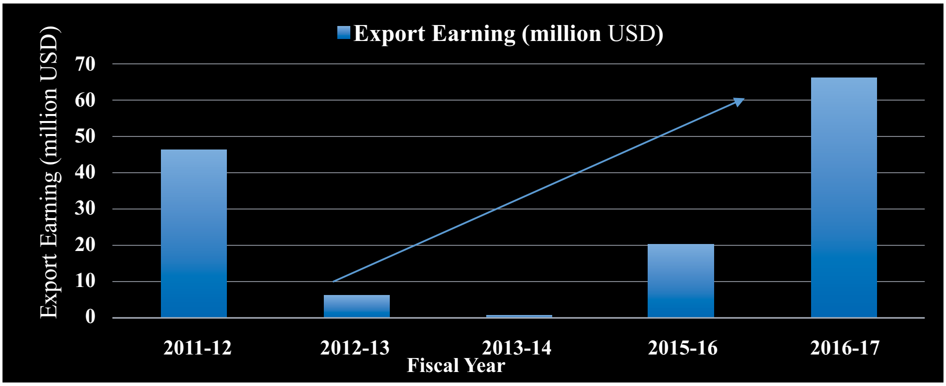



*Figure 02- Export earnings of Bangladesh in the shipbuilding industry from the fiscal year 2011-12 to 2016-17(Yusuf, 2014):*

**Prospects of Bangladesh's Shipbuilding Industry:**

Around USD 650.83 billion will be spent on the procurement of new ships in the year 2026 across the globe (Uddin, 2017). There is a demand for small vessels with capacity 3000-15000 DWT (Parvez, 2008). As the leading shipbuilders like China, Japan and South Korea are fully booked for building super-ships and specialised water vessels for the next ten years, Bangladesh is in a strategic position to take advantage of the increasing demand for smaller ships in the international market. Our expertise in domestic shipbuilding has become an advantage for us while positioning us in the international market. Global shipbuilding market size is USD1600 billion. Meanwhile, the market for small ocean-faring vessels would grow to USD 400 billion annually and Bangladesh has a great chance to fetch 1% of shipbuilding market which worth USD 4 billion annually (Ship Building Sector, 2019). In the year 2019 the total GDP of Bangladesh was USD 314.656 billion (IMF, 2019) and with the promising USD 4 billion annual revenue from the shipbuilding industry, the GDP will be enriched which will help to achieve economic solvency.

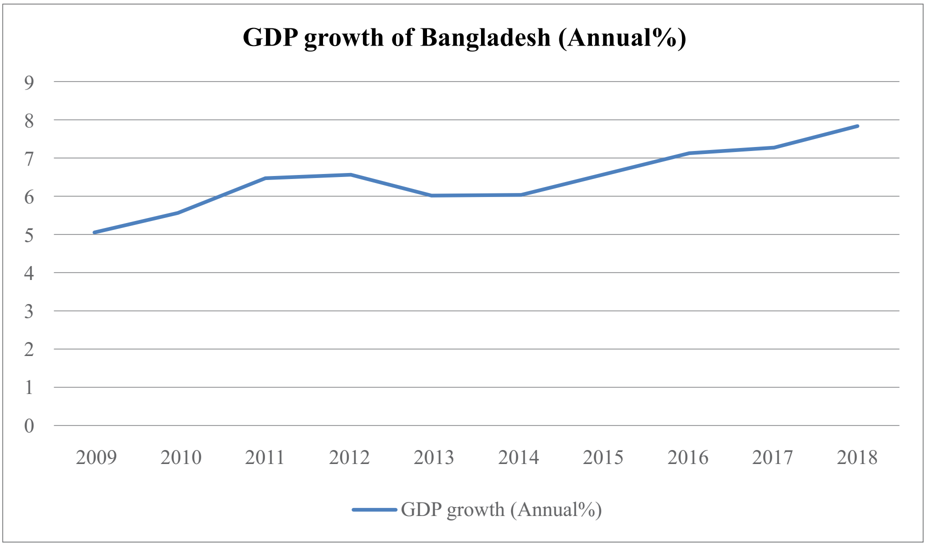
## Achieving Economic Solvency through Shipbuilding Industry

### Contribution of Shipbuilding Industry to Real GDP

Real GDP is the best single measure of the average standard of living in a country. Gross domestic product is the market value of all finished goods and services produced within a country in a year. And the largest product which has been produced in our country is the ship. The shipbuilding industry is a capital-intensive industry. From 2008-2012 Bangladesh exported ferries, cargo vessels and ocean-going multi-purpose vessels worth more than USD 500 million (Uddin, 2017). Shipbuilding is the second largest sector in the percentage contribution to GDP. During the recession period, the real GDP and GDP per capita falls around the world. But the shipbuilding industry was booming at that time and helped Bangladesh to uphold her GDP (Parvez, 2008).

The economic growth rate of Bangladesh has been depicted by the following table and it is increasing. If we take a close look at the table, it is obvious that from the last decade, the average growth rate reached a level of 6.5% (Source: WDI).

Table 01- GDP growth of Bangladesh from 2009-2018. (Source: WDI).




Nearly 80% of the total GDP comes from the Garments industry. Such a large contribution from a single industry is not the sign of a sustainable economy. In general, the high level of growth rate indicates the potential development of many sectors which have scopes to grow more than the present level. The shipbuilding industry in Bangladesh is one of the sectors where entrepreneurs have shown the feasibility that they can add 1% growth in our economy subject to getting facilities and other services from government and financial sectors (WMSL, 2019).

### Economic Multiplier Effects

Shipbuilding has one of the highest economic multiplier effects among all industries, especially in employment and investment which leads to sustainable economic growth. And the technological benefits are outstanding for any developing country like Bangladesh.

### Creating Employment Opportunity

Shipbuilding industry is a labour-intensive industry. Small shipyards specialise in vessels below about 10,000 DWT have a workforce of at least 1,000 employees (Stopford, 2009). There are 10,000 of operations going on in a shipyard. There are 124 shipyards around the country and more than 250,000 skilled and semi-skilled workers are employed in the shipbuilding industry of Bangladesh (Shemon, 2017). If we look at the below chart, we can see that the labour cost consists of 47% of the total cost of a merchant ship's building cost. So, it is deducible that the shipbuilding industry will create more jobs and employment opportunity for the people of Bangladesh through which GDP per capita will increase.

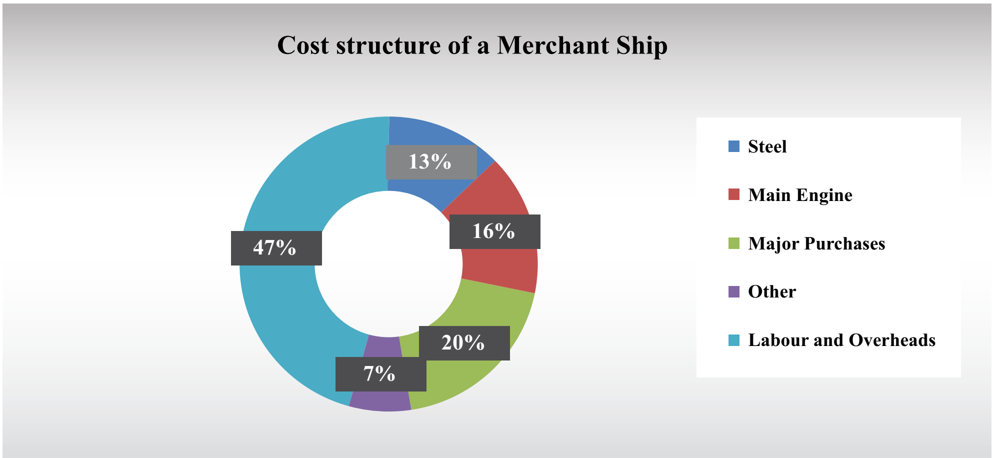



*Figure 03- Cost structure of a Merchant Ship (Stopford, 2009)*

### Development of Backward Linkage Industries

A ship is made out of thousands of individual elements, and shipbuilding will not only create huge employment opportunities but will also help to establish many subsidiary outsourcing/backward linkages. Presently, around 90% of the machinery, parts and other tools are imported for shipbuilding. The good news is few companies have been entered into the supply chain of the shipbuilding industry by producing marine cable (BRB Cable, 2019), marine paint (Roxy Paints, 2019) and furniture.

### Enhancing Value Addition

The consequent domestic value addition in shipbuilding for export will eventually rise to 45-50% from the current 25-30% in no time if we can establish the backward linkage industry appropriately (Zakaria, 2019). Local shipbuilders of Bangladesh have suggested setting up of more backward linkage industries to help them add more value to the country's growing shipbuilding sector for increasing its competitiveness in the global market.

### Earning Foreign Currency by Exporting Ships

Imagine the take home foreign currency amount per year for the government from just 10 shipyards, each contracted to deliver vessels worth USD 60-80 million to the foreign buyers (Ahmed, 2008). The potential of earning considerable foreign currency aside, the shipbuilding industry, if allowed to develop, will generate unprecedented skill development in the heavy engineering fields whether for a simple technician or an engineer.

### Attracting Foreign Direct Investment

The Vietnamese government, in recent years, has pumped millions of dollars into the country's special shipbuilding zone/area infrastructure development plan and arranged 400 million euros as grant from European Economic Community (EEC) in 2004 for an association of about 20 Vietnamese shipyards to transform themselves to international standard by developing modern shipyard infrastructure and by acquiring technical know-how from abroad (Ahmed, 2008). From there on, there was no turning back for Vietnam. The government of Bangladesh, following the example of Vietnam, can be successful in developing its shipbuilding capacity and can even attract foreign direct investments in this sector from Norway and Germany with a package of government-sponsored incentives.

## Challenges

### Unskilled Labour and Less Productivity

In Bangladesh, actual MH/CGT (which is internationally accepted potential measure of productivity) for steel in a local shipyard for the export-quality ship is six times higher than the international standard of MH/CGT value and for a local vessel, it is 1.5 times higher than international standard (Shemon, 2017).

It is estimated that, the relative productivity of shipbuilding labour of Bangladesh is 11.4 and which is one of lowest among neighbouring countries, which indicates that we have a very cheap labour cost and at the same time it is less productive and unskilled. These two things are posing great challenges in the way to achieve economic solvency.

### Weak Financial Back up

The higher cost of investment is the main challenge of this sector. As the shipbuilding industry requires huge capital, Bangladeshi shipbuilders need to have a large capital, and that is a major source of competitive disadvantage for Bangladeshi builders. Bangladeshi shipbuilders can get a loan at an interest rate of 12% whereas their Chinese counterparts can acquire loan at, on an average, 6% interest rate (Uddin, 2017). Bangladesh is lagging behind because of weak financial back up. In addition to this, shipyard owners have to pay import duty on raw materials aimed at ship construction in the country, which is contrary to the industrial policy.

### Less Incentive for Export

Export incentives for shipbuilding are very less in Bangladesh. Now the sector gets a 5% incentive on export. Assessing the present market circumstances, the experts from various Bangladeshi Shipyards agreed that the sector will be benefitted, if it is increased to 15%. Our neighbouring country India provides nearly 25% incentives to this sector.

### Competitors Around the World

All of Bangladesh's competitors like India, Indonesia, Philippines and Vietnam mentioned below have cheaper and quicker access to their own steel and other components for shipbuilding as well as heavy doses of government subsidies and other policy support. Our main competitors India and Vietnam governments are providing interest-free loan for a period of up to 20 years. As a result, Bangladesh is lagging behind in term of production as well as her share in the international shipbuilding market. The following figure shows the shipbuilding productivity of India, Bangladesh and Indonesia in terms of gross tonnage.

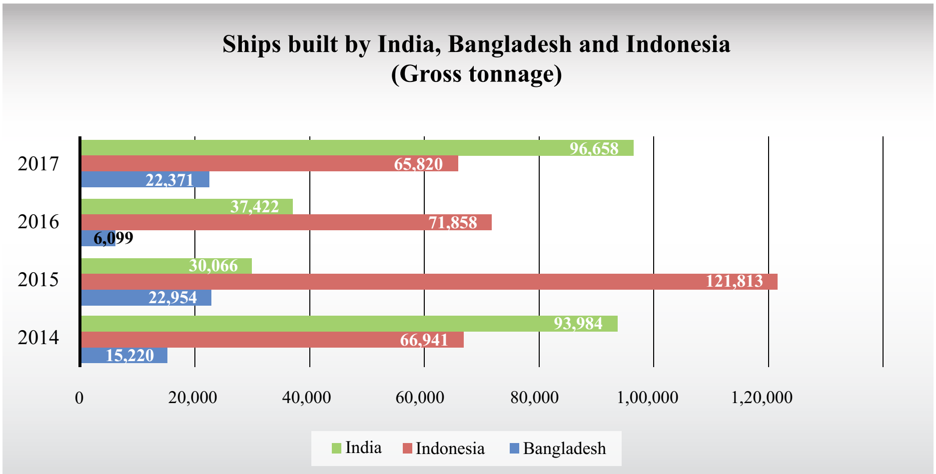



*Figure 04: Ships built by India, Bangladesh and Indonesia (Gross tonnage).*

## Conclusion

In the fiscal year 2019, the GDP of Bangladesh was USD 314 billion. In terms of GDP Bangladesh is now the 43rd largest economy in the world. If we can overtake 23 countries in the next 23 years, we'll have the 20th largest GDP in the world by 2041. The 20th largest GDP means we are a developed nation. Shipbuilding industry can contribute to attaining this achievement. The current shipping boom has provided a unique opportunity for the entry of Bangladesh in the international arena and we can't afford to lose this opportunity. Already Bangladesh has made her maiden journey into the world of international shipbuilding and heavy engineering. The industry is in its infancy, there are considerable bottlenecks to be removed, which need immediate government attention.

## Recommendation and Policy Guidelines

The rising labour cost in China, India and Indonesia (main competitors of Bangladesh for smaller ships) will create an opportunity for Bangladesh to remain competitive. The assentation for Bangladesh to remain competitive with cheap labour alone will not sustain unless we develop our technical skill with foreign help or technology transfer backed by fiscal incentives. The following recommendations may help the government to make better policy to develop the shipbuilding industry in Bangladesh.

### Transform Unskilled Labour into Skilled and Productive Labour

Bangladesh has the advantage of having very cheap labour but it is less productive compared to the competitors around the world like India, Vietnam, Indonesia, and so on. As this shipbuilding industry is a labour-intensive heavy engineering industry, we need to utilise our human resources more efficiently to improve productivity. An intensive TNA (Training Need Analysis) should be conducted in the shipbuilding industry to identify the specific skills required for the development of manpower. Collaboration among the training institutions and universities is a must. BUET, MIST, BSMRMU and other technical institutions must be informed regarding the skills required in the shipbuilding industry so that they can incorporate those skills into their students who will join the industry. Moreover, special emphasis should be put on the skill requirement of the labours (welders, mechanics, fitters, painters, finishers, etc.). The training institutions must design their courses in such a way so that they can incorporate necessary skills for the labours. Moreover, the shipyards authority needs to change their strategy by setting up a target bar for the workers as well as providing incentives to encourage them.

### Long Term Financial Back up

From the signing of a contract to the expiration of guarantee period, total payment procedure of a ship is very lengthy. The following figure can demonstrate the scenario more clearly. For this drawback, the shipbuilding industry needs long-term financial back up with a minimum interest rate to grab more orders from the international market. In this case, most of the bank in Bangladesh reject to provide loan to the shipbuilders as they are not used to wait for the return for such a long period or they agree to give a loan at a very high-interest rate. To solve this, Bangladesh Bank, the central bank of Bangladesh, can directly provide loan to this shipyard owners as it does to various banks with a less interest rate for a convenient time.

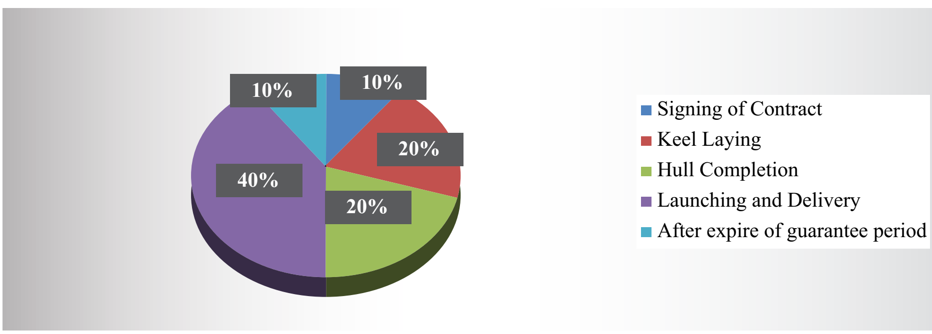



*Figure 05: Typical pattern of shipyard stage payments (Stopford, 2009).*
*Source: Maritime economics Book, Martin Stopford.*

### Public Private Partnership

The highly prospective shipbuilding industry is projected to earn USD 4 billion by exporting ships within the next five years. The need for building the capacity of the industry by providing soft loan and a tax rebate for further development must be emphasised. Public Private Partnership (PPP) is proposed for building state-of-the-art dockyards and shipyards to harness Blue Economy and to get a lower rate in bank interest. It facilitates sovereign bank guarantee facility, performance guarantee and creating a fund for the development of the sector.

### Single Digit Interest Rate

The shipbuilding industry is a capital-intensive industry. Shipyards require long-term easy loans with single-digit interests for its high social and economic value addition. To become competitive with other shipbuilding nations such as India, Korea, China and Vietnam it is the demand of Bangladeshi shipbuilders to the government to slash the interest rate on bank loan to 6 to 7% from present 13 to 14%.

### Incentive in Export

In Bangladesh, currently, the shipbuilding sector is getting a 5% incentive on export. To promote this emerging industry at such primary level, the government may provide at least 15% cash incentive on export to offset various constraints in the sector.

### Focus on the Small and Medium Sea-going Vessels

According to our study, a highly lucrative market has emerged for Bangladesh to produce small and medium seagoing vessels as the industry leaders like China and South Korea are after larger container ships and tankers. Bangladesh can emerge as a surprise competitor in the small to medium ocean-going vessels market segment. The overseas buyers have been testing the strength of the country's not-so-organised shipyards with stray orders. It is indeed gratifying that our manufacturers are now planning to go in a big way in this hitherto uncharted territory. Observers believe that this is a sector which has all the potential to flourish. Bangladesh can emerge as a market leader in the small and medium sea-going vessels segment if the backward linkage industry can be made strong.

### Promotion of the Shipbuilding Industry

The government can organise shipbuilding exhibition in Bangladesh to introduce the competent, cost-effective and competitive shipbuilding industry of Bangladesh as well as to support the local shipyards in participating international exhibition abroad to secure foreign shipbuilding orders.

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# Drivers of Revenue Generation in the Blue Economy of Bangladesh: A Case Study on the Chattogram Sea Port

Fakir Tajul Islam[1]

***Abstract***

*Blue Economy is a blessing for an emerging economy like Bangladesh. After achieving a new maritime boundary, it becomes more significant for economic development utilising ocean resources. Considering this phenomenon, this paper aims to find out the drivers of revenues in the context of the Blue Economy of Bangladesh. The study has confined itself to the Chattogram Sea Port and its operations. Itis based on historical data ranges from 2009 to 2018. The methods of research analysis were descriptive statistical tools, tabular and graphical analysis. The study has found out that the Chattogram Sea Port (CSP) has been contributing to the Blue Economy of Bangladesh. The major drivers of revenue generation are living resources, minerals, energy and transport and trade at the seaports.CSP generates most of its revenues from the export-import, containersand vessel management. Expenditure control can also enhance the revenue of CSP. Proper planning and policies can expedite the growth of the Blue Economy in Bangladesh. The effort should be balanced between proper planning and effective execution.*

**Keywords:** Blue Economy, Revenue Generation, Chattogram Sea Port, Bangladesh.

## Introduction

The emergence of the Blue Economy advances the efficient management of ocean resources, which is also known as the blue research of an economy (Chowdhury, 2019). Blue Economy is a set of policies to enhance the sustainable development of ocean resources. This concept strengthens the economic growth by accelerating the aggregate natural capital and by conserving the ecological balance also (World Bank 2018). The core of the "Blue Economy" concept is ensuring the socio-economic development with cautions of environment degradation, as an emerging economy in South Asia, Bangladesh can focus on its Blue Economy with more emphasis on it. The new maritime boundary, which is achieved recently, gives Bangladesh a broader area of Blue Economy which includes gas and oil reserves, tourism, shipbuilding etc. The shipbuilding industry has

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been growing moderately since the last decade. The coastal and marine tourism is expected to grow by 9% every year. Moreover, new potential industries in the Blue Economy have been recognised for generating revenue and for enlarging the economy of Bangladesh. Bangladesh has a very lucrative geographic location where West meets Asia, and it is in the middle of a region that will build a prominent economy to generate USD 100 trillion by 2030 (Roy, 2017). Despite having a blessing of the sea waterways and panorama of Blue Economy, the country may face different types of obstacles. To overcome all the obstacles, every economy must secure its revenue and retain it for further development. This study focuses on those drivers of revenue generation in the Blue Economy of Bangladesh. The coastal and marine activities mostly surrounded around the Chattogram Sea Port (CSP), which signifies the setting the case on this port to conduct this study.

## Literature Review

Blue Economy is a very recent concept to explore. Varieties of research were done on different aspects of the Blue Economy. According to the findings of the Blue Economy concept paper (2012), the total area of our blue planet covered by the ocean is 72% and it holds 95% of the total biosphere. The life started in the ocean has contributed in a variety of ways in human life and in the economy as well. Similar to the 'Green Economy', the Blue Economy model aims at the improvement of human wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities (Chowdhury, 2019). In Bangladesh, this sector is not analysed intensely for generating useful findings and directives for strengthening economic development. Hossain(2001) found that coastal and marine environments are becoming significant for economic development with social status improvement. He also added that the ocean economy will contribute to the strategic objectives of Bangladesh's economic policies. But Bangladesh has that efficient workforce, relevant knowledge and supportive technology to bring the maximum benefits and favourable outcome from Blue Economy and for best utilisation of deep-sea resources (Roy, 2017).

European Commission (2019) studied on EU Blue Economy practices. Their study revealed that the Blue Economy has several sectors and sub-sectors for doing business and for generating revenue. The following table shows that six established sectors in the Blue Economy along with the respective sub-sectors.

These sectors of Blue Economy in Bangladesh are still under development or in some cases neglected by the authorities. In this study, the port activities are emphasised, which is a major concern in developing the Blue Economy in Bangladesh in a sustainable manner. Blue Economy has gained significance in the post-2015 Sustainable Development Goals (SDGs) declared by the United Nations. The goal 14 of SDGs, the United Nations says, "Conserve and sustainablyuse the oceans, seas and marine resources for sustainable development." Furthermore, the government of Bangladesh has been trying to advance its status of a middle-income country by 2021 and to become a developed country by 2041. It is analysed and opined that to achieve these SDGs and to make the dreams to be true, Bangladesh has to focus heavily on Blue Economy, by targeting the entire coastal

Table 1: The six established sectors in the Blue Economy and their subsectors

| Sectors | Sub-sectors |
|---|---|
| **Coastal tourism** | Accommodation, Transport, and Other expenditures |
| **Marine living resources** (Extraction and commercialisation of marine living resources) | Capture fisheries<br>Aquaculture sector<br>Processing and distribution |
| **Marine non-living resources** (Marine extraction of minerals, oil, and gas) | Extraction of crude petroleum, natural gas, marine aggregates<br>Support activities for petroleum, natural gas extraction |
| **Port activities** (Ports, warehousing and construction of water projects) | Warehousing and storage<br>Cargo handling<br>Construction of water project |
| **Shipbuilding and repair** | The building of ships and floating structures<br>The building of pleasure and sporting boats<br>Marine machinery and equipment<br>Repair and maintenance of ships and boats |
| **Maritime transport** | Sea and coastal passenger water transport<br>Sea and coastal freight transport<br>Renting and leasing of water transport equipment |

*Source: European Commission (2019).*

belt of Indian Ocean (Roy, 2017). In a study by OECD (2016), a variety of industry dynamics were explored and evaluated to find out the changes and evolution of the ocean economy in 2030. That report explored the different aspects of the prospects of the ocean economy in the world. It was identified that there are few emerging industries to generate revenue in the ocean economy. The following table shows that findings along with the established industries in the ocean economy:

Table 2: Selected ocean-based industries

| **Established industries** | **Emerging industries** |
|---|---|
| Capture fisheries; Seafood processing; Shipping; Ports; Shipbuilding and repair; Offshore oil and gas (shallow water); Marine manufacturing and construction; Marine and coastal tourism; Marine business services; Marine research and development and education; dredging | Marine aquaculture; Deep and ultra-deep-water oil and gas; Offshore wind energy; Ocean renewable energy; Marine and seabed mining; Maritime safety and surveillance; Marine biotechnology |

*Source: OECD (2016)*

The size of Blue Economy is very promising, as it is valued at around USD 1.5 trillion per year, covering 80% of worldwide trading. 350 million jobs are strongly linked with fisheries. Aquaculture is the fastest-growing business in the world which supplies about 50% fish for human consumption. In addition to that, Blue Economy also entails many promising sectors including renewable energy, aquaculture, seabed extractive activities and marine biotechnology and bioprospecting (Chowdhury, 2019). A Blue Economy aims for a balance between economic opportunities and the environmental limitations of using the ocean to generate wealth (World Bank, 2018).

As reviewed in the earlier works of literature, there are many sectors in a Blue Economy.

These sectors are available in Bangladesh but are not researched for further development and for identifying the new sectors as stated in the OECD (2016) research. Besides, the six established sectors in the Blue Economy and their subsectors as identified by the European Commission (2019) are not explored well in Bangladesh by scholars and researchers.

## Research Methodology

This study incorporates historical and secondary data for analysis and evaluation of the drivers of revenue generation for the CSP as a part of the blue economy of Bangladesh. Descriptive statistics, tabular analysis and graphical trend analysis are the tools for preparing the analysis and the research findings of the study. Descriptive statisticsare used to present the current scenario of the blue economy in Bangladesh. The study has confined itself to the CSP and its operations. This study is based on historical study ranges from 2009 to 2018.

In this study, the drivers for revenue generation in the Blue Economy of Bangladesh are mainly export and import operations as well as revenues from containers and vessels. Apart from these functions, CSP may increase its revenue by reducing its expenses, so the expenditure accounts are also beinga driving factor for income generation. The data used in this studyaremainly collected from different websites and research articles. The CSP statistical record and other studies of different international agencies were found very useful for the study.

## Research Findings and Analysis

CSP is one of the oldest ports in the region. In this part of the study, the drivers for revenue generation for CSP are identified along with the global practices and potentiality of sources.The higher revenue generated by the CSP was BDT 2,661.76 crore in 2017-18 fiscal years. It is noticed that the minimum revenue was BDT 1,529.92 crore. Considering the number of containers and vessels, the maximum figure is 2,705,909 (containers),

Table 3: Descriptive statistics of drivers of revenue generation at CSP

| | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| Total Revenue of CSP | 1529.92 | 2661.76 | 1958.58 | 437.30 |
| Operating Expenses | 469.04 | 1117.87 | 752.7329 | 259.48979 |
| Admin & Gen. Expenses | 181.18 | 288.45 | 238.8543 | 44.73 |
| Import (MT) | 36,184,936 | 78,050,447 | 52,605,436.85 | 15,667,952 |
| Export (MT) | 4,716,374 | 6,997,465 | 5,804,747.85 | 839,440 |
| Container (TUEs) | 1,343,408 | 2,705,909 | 1,945,645.85 | 510,028 |
| Vessels | 2265 | 3664 | 2754 | 497 |

*Source: Author’s own calculation*

3,664 (vessels). Besides the income-generating sector, expenses are also important to increase revenue. In the following table, the descriptive statistics show the minimum and maximum value observed in the last seven years.

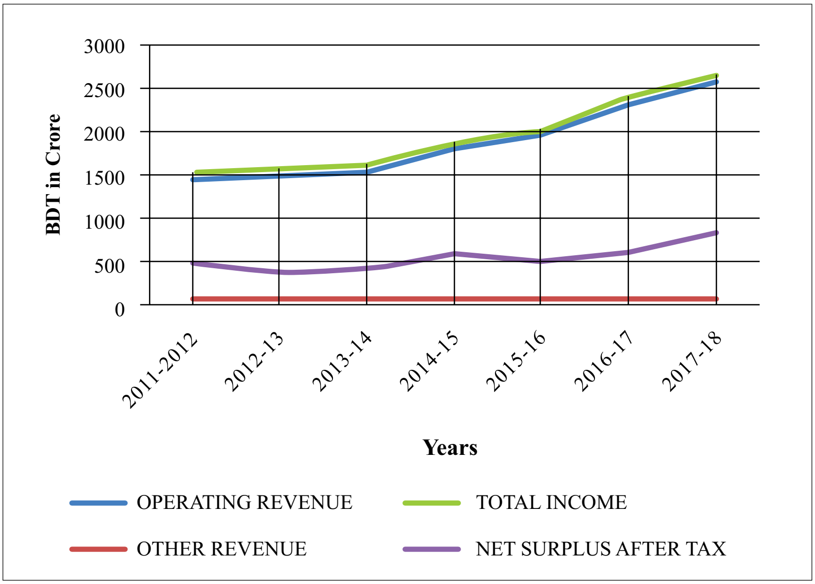


*Figure 1: Revenues of CSP in the last five years (CPA, 2019)*

The revenue of this port has been increasing since the fiscal year 2011-12. In the following figure, the trend of the revenues is shown. The trend of net surplus after tax is also upward

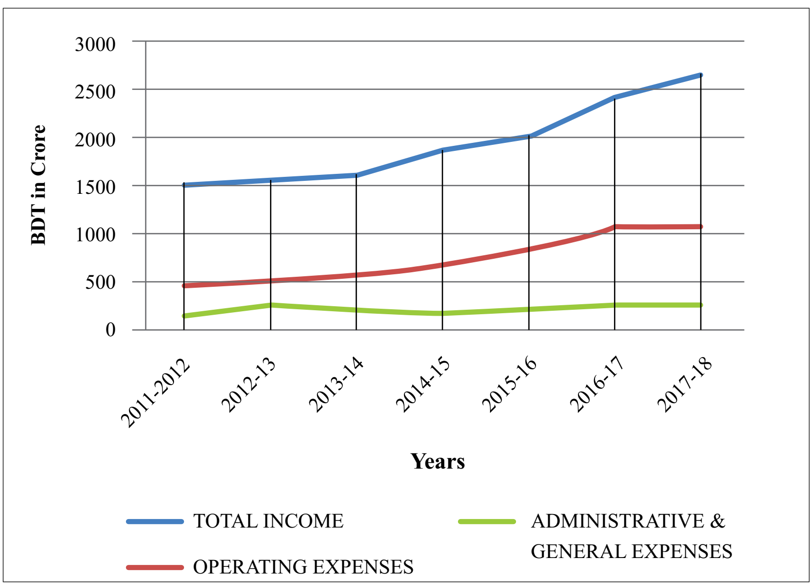


*Figure 2: Income and expenditures of CSP (CPA, 2019)*

moving and growing over the last seven years. Operating expenses and administrative and general expenses are the major drivers for boosting revenue.

If the expenses can be reduced, it will augment the revenue. The CSP has three major types of expenses which are operational expenses, administrative and general expenses. These expenses can be minimised by employing skilled and trained employees. Currently,

Table 4: Export, Import and other income sources of CSP

| | Import (MT) | Export(MT) | Container (TUES) | Vessels |
|---|---|---|---|---|
| 2011-12 | 36184936 | 4716374 | 1343408 | 2265 |
| 2012-13 | 38312028 | 5059640 | 1468713 | 2318 |
| 2013-14 | 41960170 | 5338377 | 1625509 | 2498 |
| 2014-15 | 48941406 | 5839986 | 1867062 | 2566 |
| 2015-16 | 58324786 | 5971634 | 2189439 | 2875 |
| 2016-17 | 66464285 | 6709759 | 2419481 | 3092 |
| 2017-18 | 78050447 | 6997465 | 2705909 | 3664 |

*Source: CSP annual report (2019)*

the scope of training facilities and frequency of skill development programmes are not adequate to expedite the growth of seaport operations in Bangladesh.

In the following table, the amount of import and export in metric tons (MT) handled by

Table 5: Annual gross value added from Bangladesh's Blue Economy

| Ocean economy industry/service (Nominal USD Millions) | 2009-10 | 2010-11 | 2011-12 | 2012-13 | 2013-14 | 2014-15 |
|---|---|---|---|---|---|---|
| Marine capture fisheries | 664.00 | 777.00 | 786.23 | 907.49 | 1,037.49 | 1,167.79 |
| Marine aquaculture andshellfishfarming (shrimps and crabs) | 78.65 | 92.48 | 99.76 | 122.05 | 144.99 | 163.20 |
| Sea salt production | 123.20 | 124.11 | 145.51 | 184.35 | 195.45 | 197.88 |
| Crude petroleum extraction | 22.42 | 23.65 | 23.69 | 25.16 | 26.40 | 30.55 |
| Natural gas (liquid) extraction | 971.13 | 948.62 | 919.94 | 986.25 | 1,041.87 | 1,174.58 |
| Maritime freight transportation | 307.90 | 319.55 | 295.81 | 300.33 | 327.15 | 375.58 |
| Maritime passenger transportation | 617.61 | 659.27 | 606.66 | 663.14 | 720.69 | 788.35 |
| Port and harbor operations | 104.95 | 103.29 | 135.57 | 145.32 | 172.37 | 202.17 |
| Shipbuilding and repairing | 110.32 | 114.77 | 106.68 | 109.58 | 108.59 | 387.06 |
| Ship breaking | 127.39 | 130.80 | 134.27 | 136.83 | 138.31 | 138.21 |

*Sources: World Bank (2018).*

the CSP, is summarised. The table-4 shows also the container and vessel numbers which are also the source of revenue for the port. These are the very important driver of revenue, and also a major source of supplying raw material for the businesses in Bangladesh. A high level of engagement of seaport operations is prevailing in the import and export management through containers and vessels.The export operation of the seaport enhances the economy by bringing more foreign currency which is very crucial for uplifting the economic growth in Bangladesh. Besides, the import can inject raw material for faster business operation and its growth.

In the last few years, Bangladesh has found a variety of sectors of Blue Economy, which may add to the national income. Most of the income of the Blue Economy usually comes from the ports in Bangladesh. The most important and biggest port of Bangladesh is Chattogram Sea Port (CSP). In the following table, the annual gross value added by the Blue Economy for the year 2009 to 2015 is shown.

The major contribution of Blue Economy sectors comes from natural gas (liquid) extraction and marine capture of fisheries. From 2009 to 2015, most revenues in the form of value addition come from these two major sectors of Blue Economy.

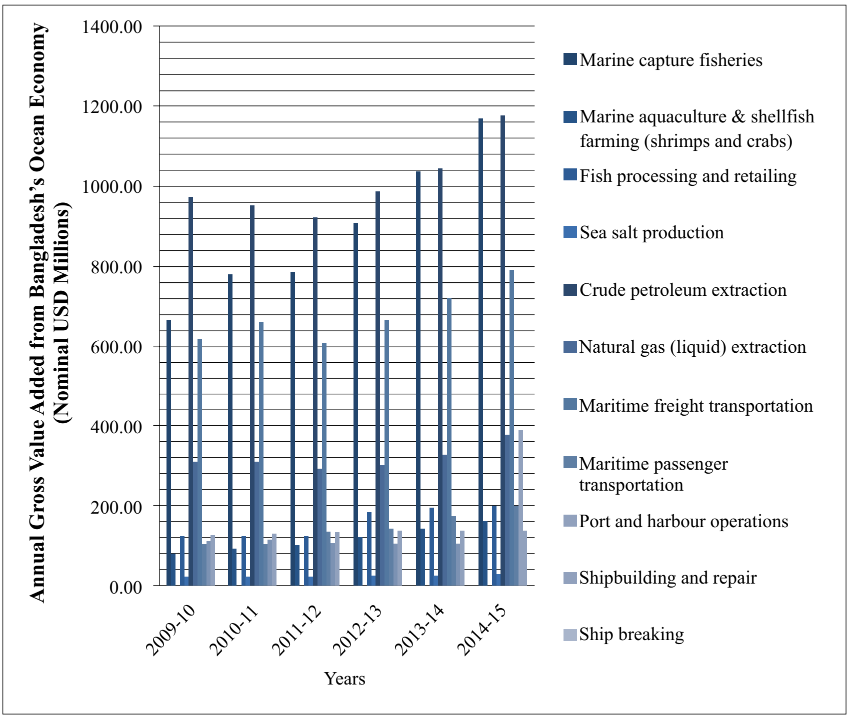


*Figure 3: Annual Gross Value Added from Bangladesh's Ocean Economy (World Bank 2018)*

The above figure shows the sectors of the ocean economy in Bangladesh. Natural gas (liquid) extraction and marine capture of fisheries sectors are always the top contributors for value addition in Bangladesh's Blue Economy. Besides these two sectors, maritime passenger transportation, shipbuilding, and repairing, maritime freight transportation are also encouraging. Apart from these sectors, marine aquaculture, marine biotechnology, maritime safety and surveillance may become more promising and revenue-generating sectors in the Blue Economy of Bangladesh.

## Recommendations on Revenue-generating Drivers at CSP

As it is found in the research findings and analysis of this study, there are few promising areas for generating revenue from the sea port's operation. The recommendations on these issues are as follows:

- There are varieties of operating expenses that reduce the profitability of the seaport operation. The management should be more efficient to reduce the expenses. The efficiency can be availed by training and other skill development programmes.
- In a Blue Economy, the major contribution comes from natural gas (liquid) extraction and marine capture of fisheries. These sectors should be empowered along with other promising sectors like marine living resources, maritime transport etc.

## Conclusion

This research could be expanded to other areas of the Blue Economy of Bangladesh, though the data for analysis were not readily available. So, it will be more resourceful if the scope of the study widens by doing further research. As analysed and evaluated in the previous sections, CSP has a few regular sectors for revenue generation, such as maritime passenger transportation, maritime freight transportation, export-import of goods and commodities, etc. There are few other potential sectors that may become a major driver of revenue in the Blue Economy. Candidates to that are marine aquaculture, marine biotechnology, maritime safety and surveillance etc. Bangladesh should work on enhancing the service of its industries based on maritime resources whichwill eventually be contributed to the Blue Economy. To increase the revenue and to get the highest benefit of the Blue Economy, the government and private sector should work together. This effort may enforce rules and regulations for the effective use of ocean resources in Bangladesh. Expenditure control can also enhance the revenue of CSP. Proper planning and policies can expedite the growth of the Blue Economy in Bangladesh. The effort should balance between proper planning and effective execution.

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# Mapping and GIS Analysis of Small Water Reservoirs in the Hills of the Halda River Watershed

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***Abstract***

*The aim of this research is to the discovery of small water reservoirs in the Halda river watershed, analysing their geometric and geographic parameters like area, neighbourhood distance, elevation wise distribution, tortuosity, perimeter and also mapping these small water reservoirs. Through this research work, a total of 593 reservoirs is identified and mapped. The total area of those reservoirs is 6,124,117 m$^2$ (6.12 km$^2$) which cover almost 0.36% of total Halda watershed area and 0.56% of upland (>20 m elevation) area. The average area of these reservoirs found around 10327 m$^2$. The minimum and maximum area of these small reservoirs found around 180 m$^2$ and 115007 m$^2$ respectively. The neighbourhood distance also calculated. The highest occurring distance among reservoirs is around 830 m. The maximum and minimum distance is around 3391 and 44 m respectively. The total number of the neighbourhood is found 1595 under 3400 m cut off distance. The average elevation is found 30.74 m. Elevation wise distribution shows that most of the reservoirs are located in the hill tracts of Halda river watershed which commonly known as upland area. Tortuosity of reservoirs is calculated. From the descriptive statistics, the average tortuosity of studied reservoirs is around 7. Most of the small reservoirs have 250 m to 500 m perimeters. Their average perimeter is calculated as 696.17 m. For the first time, the reservoir map and their relative neighbourhood graph of Halda river watershed are generated through this research.*

**Keywords:** Mapping, Small Reservoir, Watershed, Halda River, Relative Neighbourhood Graph (RNG), Area, Tortuosity, Elevation.

## Introduction

Halda is a major tributary of Karnaphuli river and one of the main rivers of Chattogram district. It is the third main river of Chattogram after the Karnaphuli and the Sangu (Kabir

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et al. 2013). Halda River is originated from the Badnatali Hills range in Ramgarh Upazila in the Chattogram Hill Tracts and flows through Fatikchhari, Hathazari, Raozan Upazilla and Chattogram city, and finally falls into the Karnaphuli river (Akter and Ali, 2012). The main water source of this river is its tributaries. The length of the Halda river is 110 km with its headwaters and without headwaters, it is 100 km (Chowdhury, 2015). Halda river watershed lies within longitudes 91°48′–91°53′E and latitudes 22°24′–22°54′N. It consists of an area of 1,682.92 km$^2$ where land covers 1670.59 km$^2$ and water area covers 12.33 km$^2$.

The topography of Halda river watershed comprises of agricultural land, hills, upland, plain land, water areas (ponds, reservoirs, stream, tributaries), build-up area (towns and village) etc. Reservoirs are scattered in all of the watershed areas, especially in the upland area. These reservoirs are difficult to reach because of their location in the hilly area. There is no reliable and quality data on these reservoirs especially about their area, location, shapes etc. Source of water in these reservoirs is mainly rainfall especially the runoff water from hills. In the rainy season, the water level in these reservoirs rises with the increase of rainfall and they slightly expand their area horizontally. These small reservoirs can be classified as rain dominated system. The hilly region of Halda river watershed is well forested. The evaporation and transpiration rate in that area is also greatly depended on these small reservoirs. These small reservoirs increase the soil moisture and they are important for their aquatic resources. In this study, all the small water reservoirs existing in the Halda river watershed were mapped and their different geometric and geographic parameters were analysed. This study will also indirectly help in estimating the role of these small water reservoirs in the hydrologic cycle of Halda river watershed. Since the evaluation of watershed and to prepare a management strategy need quality measurement of land cover use parameters (Butt et al, 2015), so the study of these reservoirs was important.

## Methodology

The major part of this research work was on-screen digitising of small reservoirs over a high resolution satellite image of Google Earth. Google earth application is used for on-screen digitising. A series of connected vertices (polygon geometry) is used for enclosing the shape of these small reservoirs. To create the exact curvy shape of these small reservoirs, vertices are dropped homogenously around the boundary of the reservoirs. A single polygon is created for every small reservoir. Then all polygons are saved in Keyhole Markup Language (KML) format. The watershed boundary was used from Halda river basin map (Chowdhury, 2015) and within this area, all the small reservoirs of the watershed were digitised. For better image quality during the digitisation of reservoirs, the image of different years and times were compared and the best image was used. To confirm some of the confusing small reservoirs, ground-truthing was done. After digitisation, QGIS 2.8.1 version software was used to analyse different parameters of these small reservoirs. The parameters that were calculated for these small reservoirs were area, neighbouring distance, elevation, tortuosity and perimeter. After that, exploratory data analysis was done in Microsoft Excel and descriptive statistics were generated for every parameter. To generate a map of these small reservoirs and also for generating Relative Neighbourhood Graph (RNG), QGIS and Arc GIS 10.1 software version were used. In RNG map, the cut off distance were 3400 m that means reservoirs having distance more than 3400 m among them has no neighbouring relation.

## Result andDiscussion

Descriptive statistics were generated on data of every parameter of small water reservoirs (Table 1). Total five parameters were analysed. Descriptive statistics revealed the mean, median, mode, sum, count, minimum and maximum value of selected parameters.

Table 1: descriptive statistics data for Reservoirs in Halda river watershed:

| Statistical Parameters | Area(m2) | Neighbour's distance(m) | Elevation(m) | Tortuosity | Perimeter(m) |
|---|---|---|---|---|---|
| **Mean** | 10327.34 | 1208.52 | 30.74 | 7.03 | 696.17 |
| **Median** | 5782.96 | 1048.98 | 26 | 6.22 | 472.39 |
| **Mode** | N/A | 829.67 | 20 | 4.65 | 254.30 |
| **Minimum** | 180.93 | 44.67 | 5 | 3.68 | 62.03 |
| **Maximum** | 115007.43 | 3391.59 | 95 | 20.92 | 4858.48 |
| **Sum** | 6124117.37 | 1927592 | 18229 | 4173.3 | 412831.32 |
| **Count** | 593 | 1595 | 593 | 593 | 593 |

### Reservoir Area

From the descriptive statistics (Table 1) the mean area of reservoirs is estimated at around 10,328 $m^2$. The median most reservoirs are nearly 5,783 $m^2$. In the study area, the minimum area of studied reservoirs was 180.93 $m^2$ and the maximum was 115,007.43

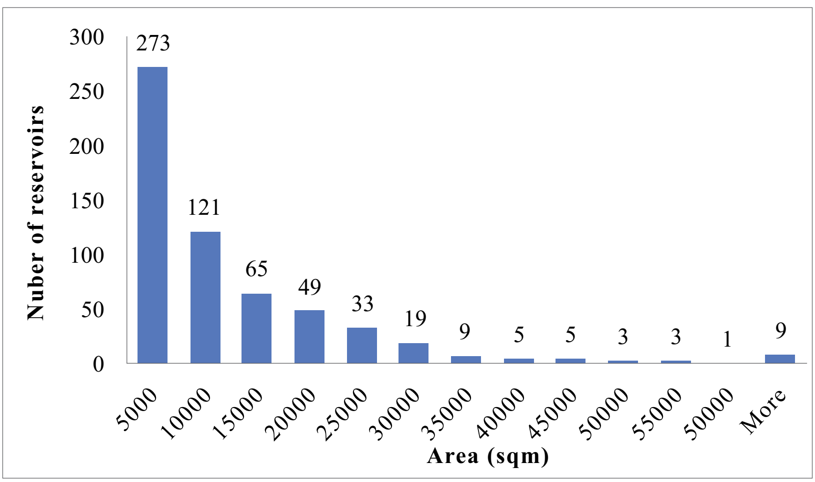


*Fig. 1: Frequency of reservoirs according to their area.*

m$^2$. The total area occupied by the studied reservoirs was 6,124,117.37 m$^2$. The total area of Halda watershed is 1,682.92 km$^2$. Reservoirs occupied 0.36% of total watershed area and 0.56% of upland (>20 m elevation) area. The total number of studied reservoirs is 593.

The bar diagram (Fig. 1) showing that the highest number of reservoirs cover 5000 m$^2$ and 9 reservoirs cover more than 60000 m$^2$.

The cumulative percentage graph (Fig. 2) is showing that 90% reservoirs are less than 30,000 m$^2$ and the median area is about 5,782 m$^2$.

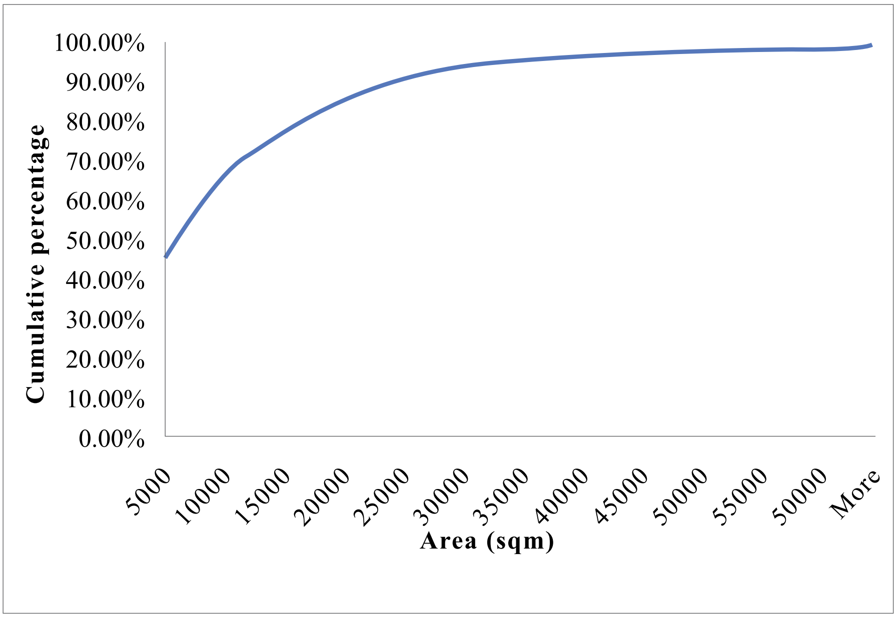


*Fig. 2: Cumulative percentage of reservoirs according to their area.*

**The Neighbouring Distance Among Reservoirs**

According to descriptive statistics (Table 1) the average distance among neighbouring reservoirs was around 1,209 m. The highest occurring distance among reservoirs was 830 m. The minimum distance among reservoirs was 44.67 m and the maximum was 3,391.59 m because 3,400 m were set as the cut off distance.

The frequency graph (Fig. 3) shows that the highest number of reservoirs (270) has around 700 m neighbourhood distance among them. The lowest number of reservoirs (10) has less than 100 m neighbourhood distance among them.

The cumulative percentage graph (Fig. 4) is showing that more than 75% reservoirs are in between 2,000 m neighbourhood distance and the median neighbourhood distance is around 1,048 m.

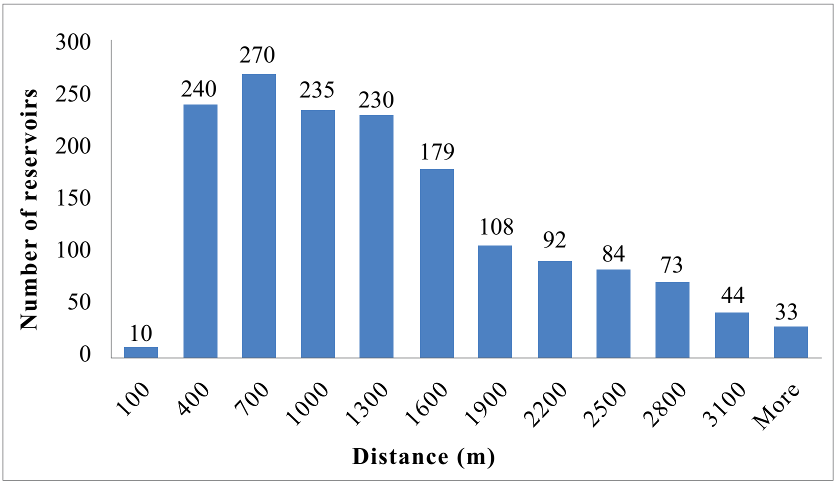


*Fig. 3:Frequency of reservoirs according to their distance.*

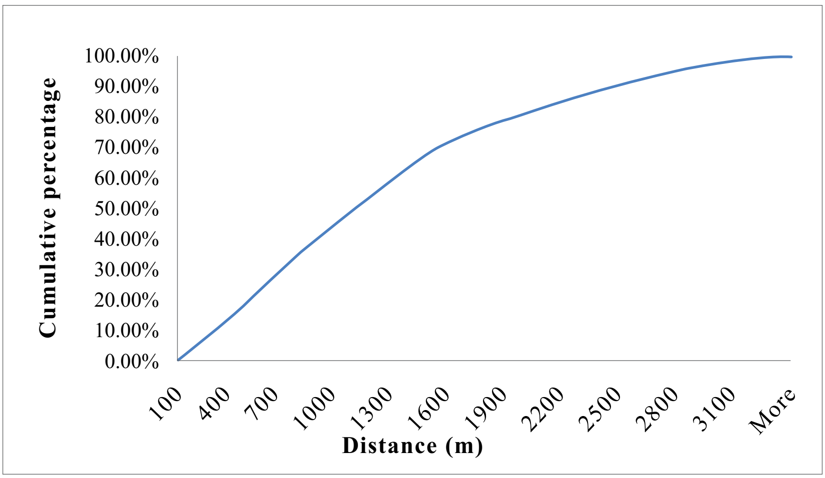


*Fig. 4:Cumulative percentage of reservoirs according to their distance*

## Elevation Wise Distribution of Reservoirs

According to the descriptive statistics (Table 1), the average elevation (elevation from the sea level) of the reservoirs is around 31 m. The median most reservoirs are nearly 26 m elevation. The minimum elevation of reservoirs is 5 m and the maximum elevation is 95 m. Elevation wise distribution shows that most of the reservoirs located in the hill track which commonly known as non-valley area. Hilly region of the watershed is well forested while the plains are broad and fertile, suitable for cultivation.

From frequency distribution (Fig. 5), the highest number of reservoirs (168) falls in elevation class of 20-30 m. Most of the reservoirs lie between elevation-class of 10-40 m. Only one reservoir lies between 90-100 m elevation class.

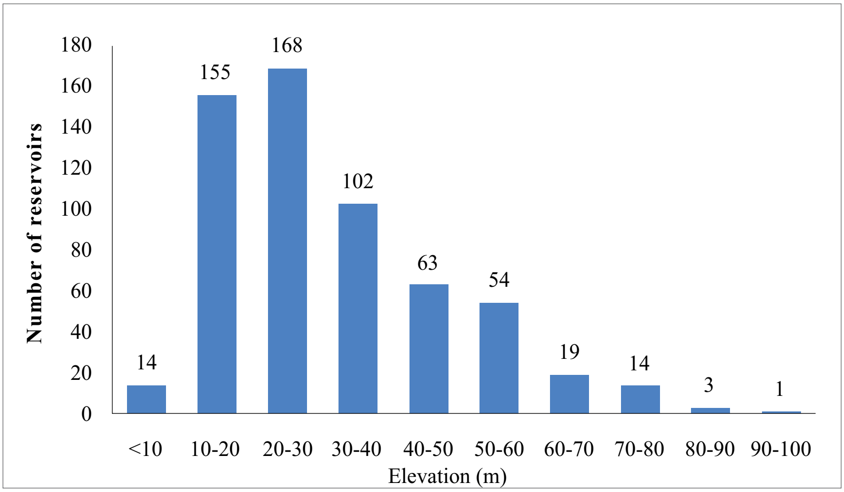


*Fig. 5:Distribution of reservoirs at different elevation*

The cumulative graph (Fig. 6) shows that about 80% of reservoirs are located between 10-40 m elevation classes. The median elevation of the reservoir is 26 m.

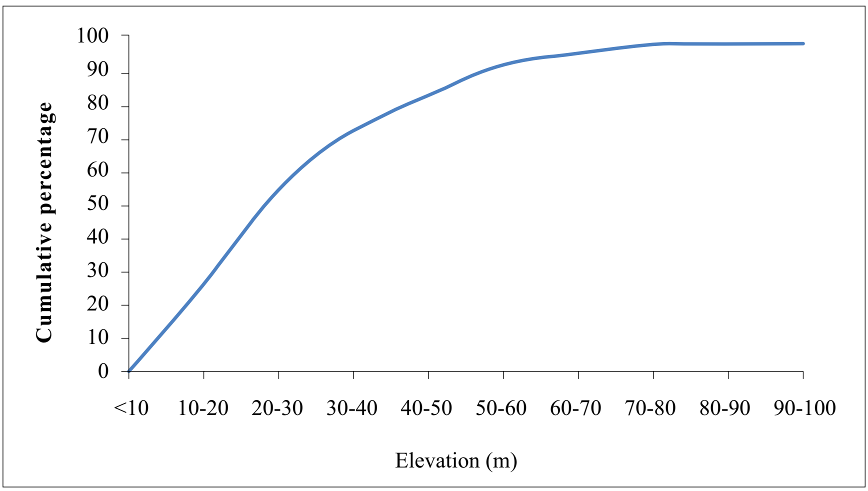


*Fig. 6:Cumulative percentage of reservoirs according to their elevation*

## Tortuosity of Reservoirs

Tortuosity of a reservoir denotes that how much curvy the boundary of the reservoir is. From the descriptive statistics, the mean tortuosity of studied reservoirs is around 7 per unit area. The median tortuosity of the reservoir is 6.22 per unit area. The dominant tortuosity of reservoirs is around 5 unit per area. The minimum tortuosity of the studied reservoirs is about 4 and the maximum is around 21 unit per area.

According to the bar diagram (Fig. 7), the highest number of reservoirs tortuosity has 6 per unit area and the lowest number of reservoirs tortuosity has 20 unit per area.

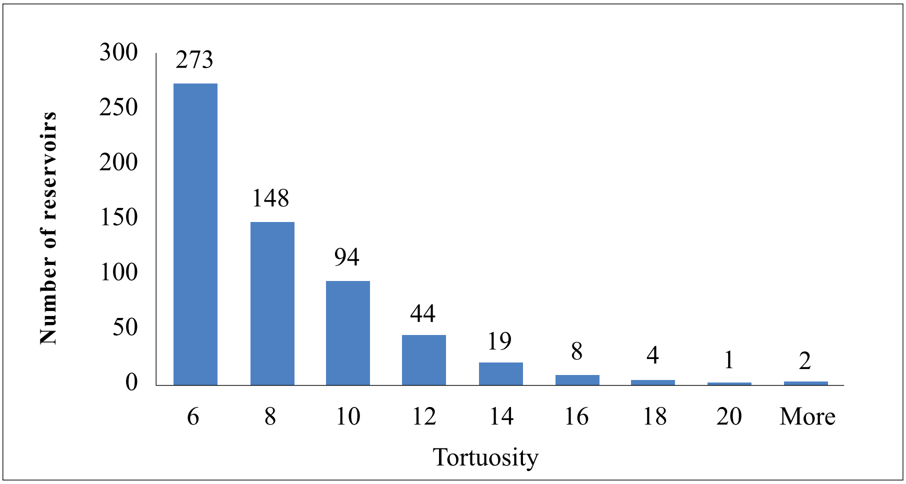


*Fig. 7:Frequency of reservoirs according to their tortuosity.*

The cumulative percentage graph (Fig. 8) showing that 90% of the reservoirs' tortuosity is less than 10 per unit area and the median tortuosity is about 6 per unit area.

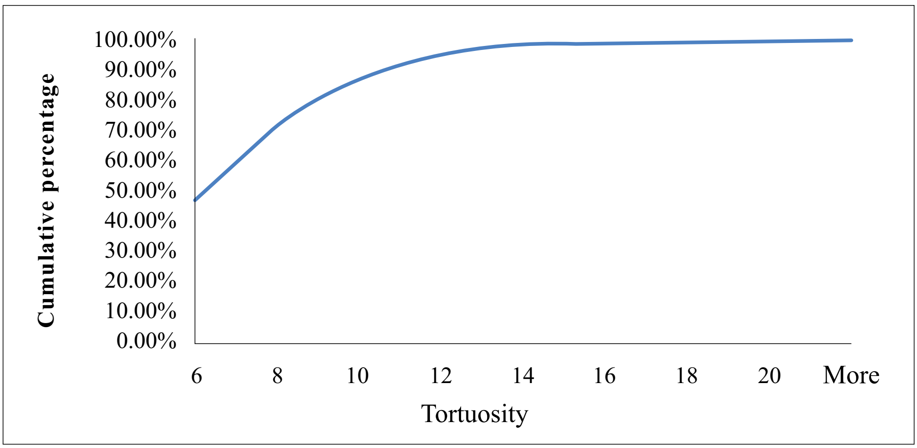


*Fig. 8:Cumulative percentage of reservoirs according to their tortuosity*

## The Perimeter of Reservoirs

According to descriptive statistics (Table 1), the average perimeter of reservoirs is estimated at around 697 m. The middlemost perimeter of reservoirs is closely 473 m. From the descriptive statistics, the minimum perimeter of reservoirs was 62.03 m and the maximum was 4,858.48 m. These studied reservoirs have a total 412,831.325 m boundary line.

From the bar Diagram (Fig. 9), the highest number of reservoirs (211) cover 500 m perimeter and the 17 reservoirs' perimeters are more than 2500 m.

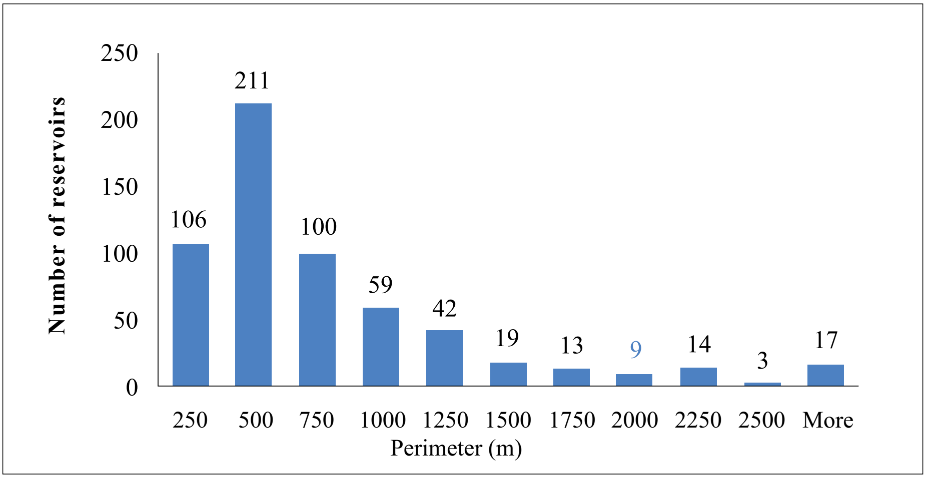


*Fig. 9:Cumulative percentage of reservoirs according to their Perimeter*

The cumulative percentage graph (Fig. 10) above is showing that 95% reservoirs are less than 1,300 meters and the median perimeter is about 473 meter.

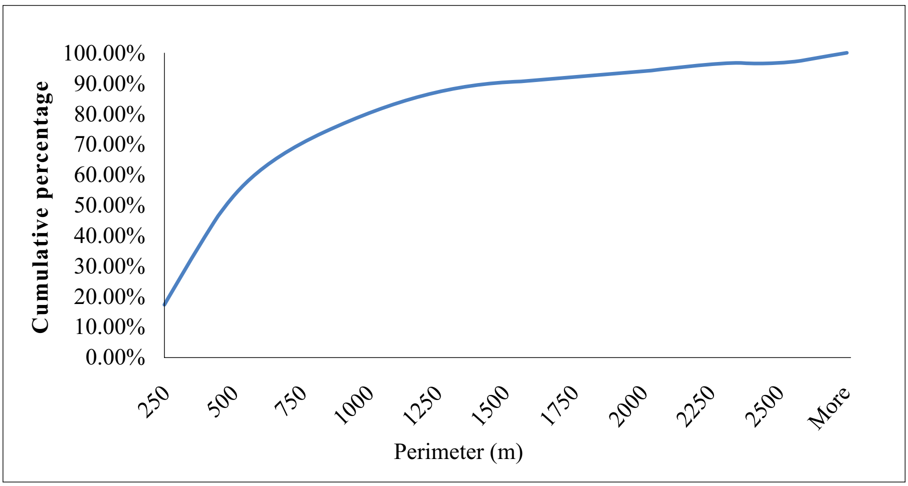


*Fig. 10:Cumulative percentage of reservoirs according to their perimeter*

## Maps

Two maps of small water reservoirs are produced through this research work. First one is the small water reservoir map (Fig. 12) and the second one is the Relative Neighbourhood Graph (RNG) of reservoirs (Fig. 13). These two maps show the distribution of reservoirs in the Halda river watershed and their neighbouring distance.

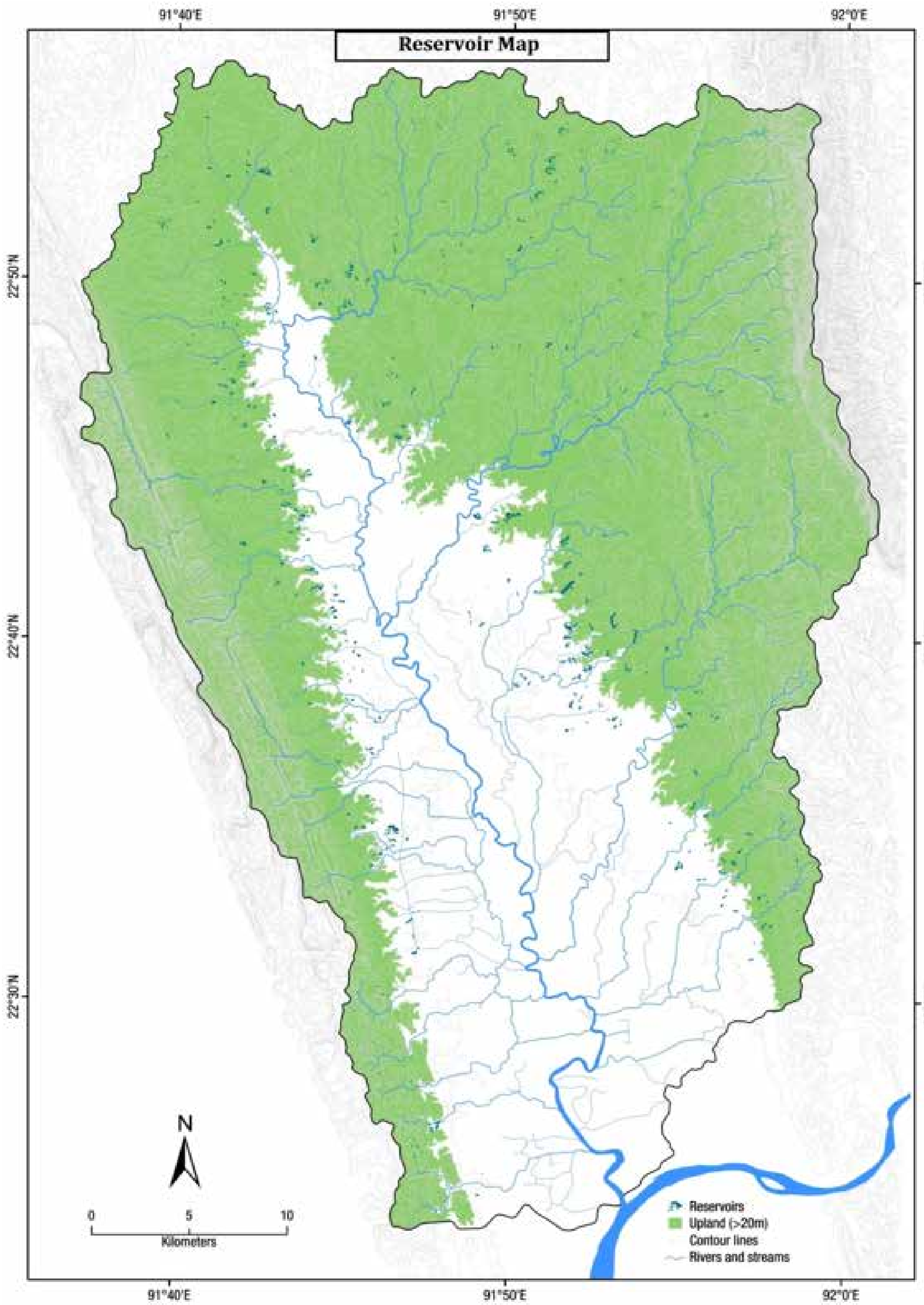


*Fig. 11:Map of all reservoirs in the Halda river watershed*

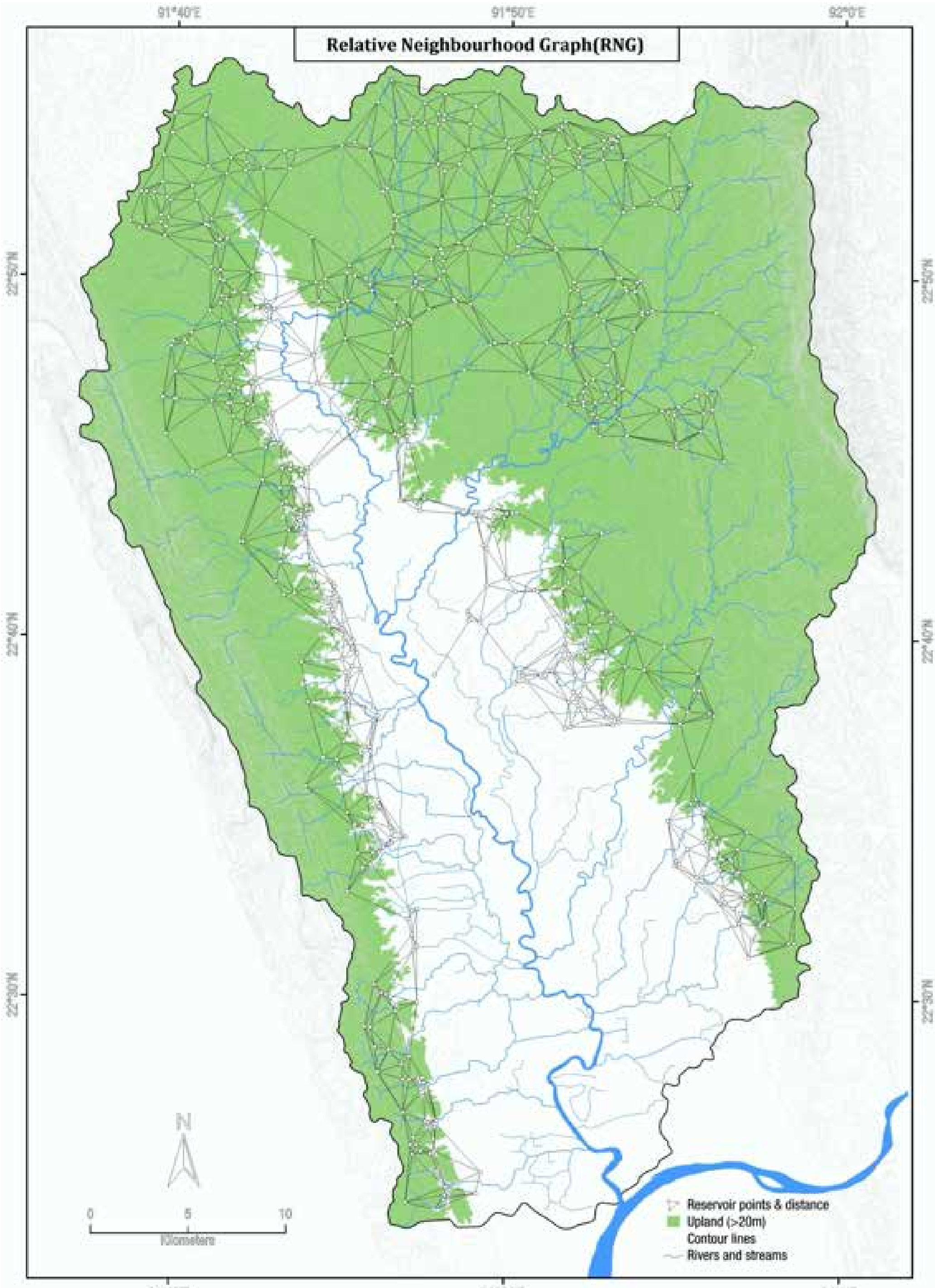


*Fig. 12:RNG Map of reservoirs in the Halda river watershed*

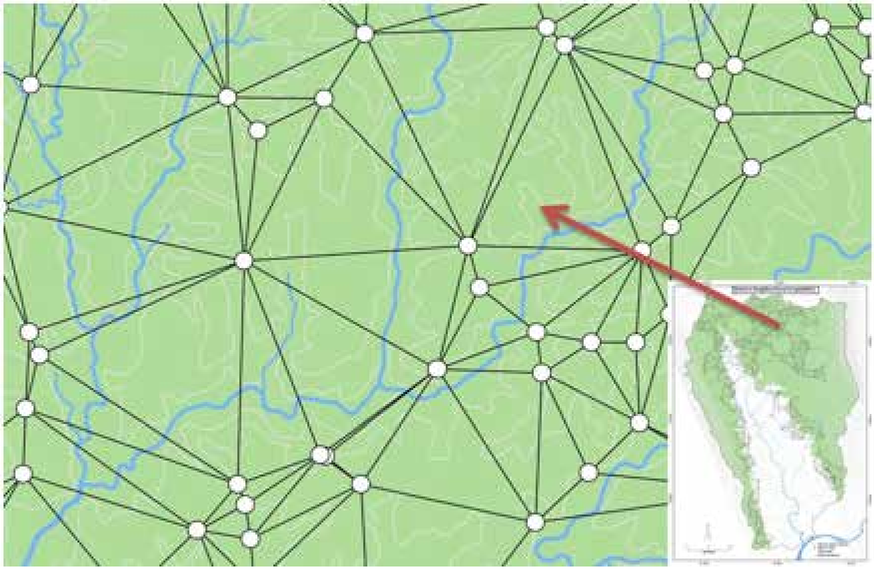

*Fig. 13: Zoomed view of RNG graph*

## Conclusion

The result gathered from the study can be useful for management and planning for watershed and conservation of reservoirs. Total research work and data analysis have been done by using GIS and statistical software. Digitisation of small water reservoirs was done in the Oceanic and Atmospheric Data Analysis Laboratory (OADAL) of the Institute of Marine Sciences, University of Chittagong. Special thanks to Google for their freely available high-resolution satellite images. On behalf of all authors, the corresponding author states that there is no conflict of interest.

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# Seasonality of Stratification Along the Offshore Area of the Northern Bay of Bengal

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***Abstract***

*One of the vital factors for understanding and investigating ocean dynamics is the stratification of the water column. Argo profiling floats for the period of January 2011 to September 2017 and World Ocean Data (WOD) for the same region were taken to comprehensively study temperature-salinity distribution from which to calculate the sigma-t (density). The average density increased sharply from around 20 m to 180 m depth. It is obvious that the northern Bay of Bengal (BoB) is much cooler than the southern bay. Additionally, the southern BoB is denser than the northern BoB. The strong seasonal cycle of temperature and salinity was noticed which eventually controls the comparatively fresher water in the north and saltier water to the south. Furthermore, the static stability parameter of the water column was used to understand the processes affecting the stratification. The more the water is stable, the more the stratification of water is observed. Vertical stability was undulated in the upper 200 m and between 300-500 m depth. It was also found to be varied with strong south-west monsoon and north-east monsoon. Summer monsoon showed much stable than the winter monsoon because of the river runoff. Perhaps, the less dense water floating in the surface in summer could create the layer much stratified by inhibiting the subsurface nutrient to come upward and the opposite pattern was seen in winter monsoon. In spring and fall, southern BoB stability was stronger than northern. The study revealed that both of the available open-source datasets are very useful and precise to each other.*

**Keywords:** Stratification, sigma-t, Argo, Stability Parameter, Northern Bay of Bengal

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## Introduction

Water column stratification in the global ocean occurs mostly due to differences in densities between two layers. Stratification of seas is forced not only by solar heating at the surface but also by coastal freshwater run-off or by an excess of precipitation over evaporation (Longhurst 2007) and also by Sea Surface Temperature (SST), Sea Surface Salinity (SSS) to some extent. BoB being in the tropical region and severely affected by precipitation and river runoff, studying water stratification in this bay is highly challenging considering the fact that fewer studies are performed in the northern part of the bay. Development of fronts between stratified and non-stratified regions of the shelf are contributed by multiple processes; most important, perhaps, is vertical shear within the tidal streams, together with the effect of baroclinic eddies of semidiurnal frequency. The oceans occupy three-fourths of the earth's surface and are a vast reservoir of living and nonliving resources. They, directly and indirectly, provide foods and livelihoods to millions of people of the coastal states and elsewhere. Developing countries earn considerable revenue through the exploitation and marketing of marine living resources and other biological resources which might be affected and altered by the process of seasonal variation in stratification. One of the largest bays in the world, the Bay of Bengal (BoB) with a semi-enclosed basin with waters flowing straight out of the Himalayas through the Bengal region. The bay is roughly triangular (Vinayachandran, Murty, and Ramesh Babu 2002). It is bordered by India, Myanmar, Sri Lanka, Indonesia. Countries dependent on BoB straddle both South Asia and Southeast Asia. The BoB occupies an area of 2,172,000 square kilometres (Hussain et al. 2017)

Biological productivity in the northern BoB is one of the highest among all the oceans (Arun Kumar, Babu, and Shukla 2015; Gauns et al. 2005). Despite being in the monsoon belt, BoB comes under the influence of semi-annual seasonality due to the differential heating and cooling of the land and sea. In winter monsoon (November to February), winds are weakly (~5 m/s) blowing from the northeast. Cool and dry continental air is brought to the BoB by this wind. In contrast, during the summer monsoon (June to September), strong (~10 m/s) southwest winds bring humid maritime air into the BoB (Ramage 1971). The winds are still north-easterly during the winter monsoon when the current along the western boundary reverses and flows northward. This is called East Indian Coastal Current (EICC), which peaks during March-April (spring inter-monsoon) when the winds are weak and possess anti-cyclonic curls (Shetye et al. 1991). The excessive river runoff (1.625 X 1012 $m^3y^{-1}$) into the BoB (Subramanian 1993) and rainfall leads to a positive water balance (P–E=0. 8m $y^{-1}$) (Balachandran et al. 2008). Runoff from the Indian rivers to the BoB play a critical role in the process of monsoon intensification by creating and sustaining low salinity layer on the top of the BoB (Rajamani et al. 2006). The massive freshwater influxes result in strong vertical stratification, which impedes the vertical transfer of nutrients to the surface, leading to low biological production. Based on the monsoon (arrival and retrieval) and its associated environmental characteristics, the northern Indian Ocean experiences variations in seasonality. The four seasons addressed are as follows:

**Spring inter-monsoon (March to May):** The water column becomes more stabilised by thermal stratification. Hot weather prevails with occasional violent local storms accompanied by violent winds, torrential rain, etc.

**Summer monsoon (June to August):** Characterised by south-westerly winds and resultant heavy rainfall, the bulk of annual rainfall in India is received during these months.

**Fall inter-monsoon (September-October):** Intensity of rainfall becomes much less. Low-pressure zones are developed, which sometimes intensify into cyclonic storms. Generally, a season of transition.

**Winter monsoon (November to February):** A period when the sea surface loses heat to the atmosphere, consequently, the surface water becomes colder, bringing heavy rain, particularly in the northern regions of the BoB. (Babu et al. 2003; Murty et al. 1992)

BoB appears to be variable and also quite complex. The more the water would be stratified, the less the water would mix and less mixed water column would be less productive (less production of marine living resources) due to less nutrient upwelling from deeper water. Therefore, study of water column stratification is very important for the nation's economic growth. The area selected for this study is located in the BoB having geographic coordinates 85º to 95ºE longitude and from 18ºN to 21ºN latitude. As a basin situated in the monsoon regime, it is influenced by several oceanic processes with seasonal variability.

### Objectives

The prime objective of this study is to characterise the distribution of water column stratification of the northern BoB, however, other important goals of this study are:

- To know the seasonal variability of the stratification in Northern Bay of Bengal
- To determine the seasonality of the density of the Northern Bay of Bengal
- To compare the open-source data to the Argo profiling data in the Northern BoB

## Materials and Methods

### Study area

Bathymetry of the study area indicates that inside the black dashed line (Fig. 1), there are lower depth area, shelf-slope region, and depth increases rapidly after the shelf until 18°N. All the Argo profiling floats and in-situ measurements data from the World Ocean Database (WOD) were considered in the box. Because of the shallower depth, the Argo floats were not available from 20°N to the coast of Bangladesh. So, WOD datasets were only used in that case.

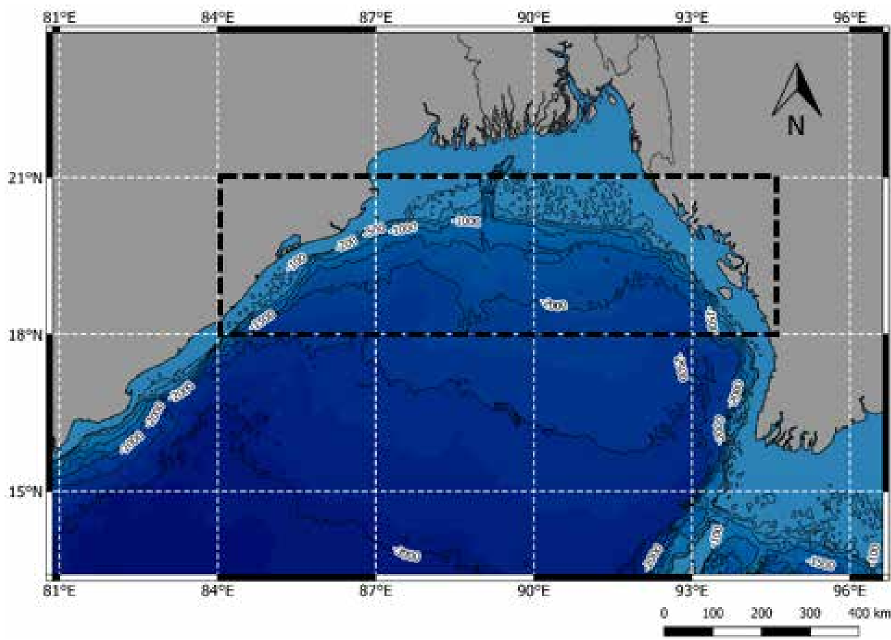


*Figure 1 Bathymetry of the northern BoB. The black dashed line is the area (18–21°N, 85°E–95°E) of this study.*

## Data Sources and Analyses

Temperature and salinity data for the present study were obtained from USGODAE website (https://www.usgodae.org/cgi-bin/argo_select.pl) of Argo profiling floats in BoB within the domain 18–21°N, 85°E–95°E from the period January 2011 to September 2017. The spatial distribution of the number of Argo-derived temperature-salinity profiles was taken in the delay mode. Note that, north of 21°N latitude, there are no Argo profiles and in BoB the number of profiles was extremely low. Another data source for this study would be, World Ocean Database (WOD), which builds on this record and includes updates and new data. The 40 standard depth levels used in previous versions of WOD are all among the 137 standard depth levels used in WOD13, to provide continuity. Open-source software package Ocean Data View (ODV) is used to read the WOD native format and display the data. Ocean Data View 4.5.7 has been updated to read the amended format. All the Argo profiles were in NetCDF format (.nc) and in the discrete grid. Therefore, the ODV software was used to visualise by interpolating with the built-in DIVA method. GEBCO 2014 bathymetry data was used to produce the location map by using QGIS software.

Visual observation of temperature, salinity, and density profiles in BOB indicated that temperature-based techniques have been used most frequently, owing to the ease of reliability. For regions with weaker haloclines, both the temperature and density-based techniques produce nearly equivalent results (Brainerd and Gregg 1995). However, density-based methods have more reliability for regions where upper ocean salinity changes are high and precipitation can stabilise the water column stratification (Brainerd and Gregg 1995; Lukas and Lindstrom 1991; S Levitus, (173), and 1982, n.d.).

In the present study, the water column stratification is defined as the density sharply increase from surface value and it's denoted by "E". Stability in the Ocean, just like in the atmosphere, there are three possible scenarios: E > 0, stable, E = 0, neutral, and E < 0, unstable water column. The temperature and salinity also further used to calculate the density for the computation of the static stability parameter as follow:

$$E = -1/\rho\ (\delta\rho/\delta z)$$

Where E is the static stability parameter ($m^{-1}$), ρ is the density ($kgm^{-3}$) of the water and z is the depth (m) (Pond and Pickard 1983). The density of seawater was calculated using the equation of state for seawater developed by Pond and Pickard (1983) from Argo and WOD temperature and salinity, while depth was calculated from pressure using in an equation by inputting latitude and pressure at the location. The temperature/salinity/density at 5 m depth is considered as surface or initial temperature/salinity/density.

## Results

### Sigma-t Distribution Profiles

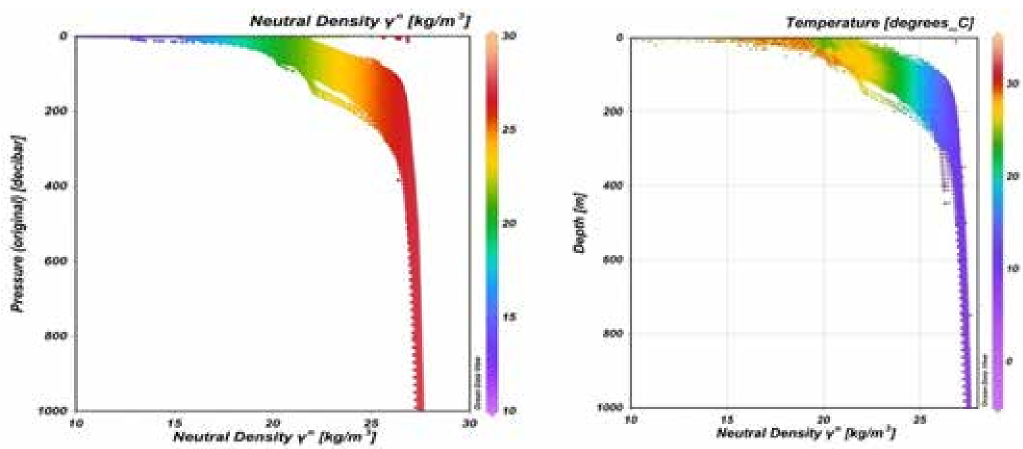


*Figure 2 Vertical sigma-t profiles from Argo data (left) and WOD data (right) from 2011 to 2017.*

During the seven years' study, all profiles were averaged without any seasonality and the averaged Vertical Sigma-t profile (VS-t) showed the presence of a typical profile with a large pycnocline in Fig. 2. Sigma-t increased sharply from 10 m to 180 m depth. Over the whole period of study of all seasons, the highest value of sigma-t was around 28 kg m-3 beyond the depth of around 200 m while the lowest was approximately 12 kg $m^{-3}$ near to the surface that can be seen in Fig. 2 (right). Surface Sigma-t (SS-t) distribution within the area 90ºE to 94ºE and 18ºN-20ºN is comparatively lower (14-16 kg $m^{-3}$) than the other part of the bay.

**Surface Sigma-t Distribution (SS-t)**

It was clear that the highest value of SS-t was around 20 $kgm^{-3}$ and the lowest is 12 kgm-3 that can be seen in Fig. 3 (right). SS-t distribution within the area 90ºE, 91ºE and 94ºE and 18ºN-20ºN is comparatively lower (14-16 $kgm^{-3}$) than the other part of the bay. Comparatively higher values of SS-t of around 18 $kgm^{-3}$ are found along the 91ºE, 92ºE and 93ºE longitude line. There are no Argo data after 20ºN to the northern part of the bay while the WOD has more data beyond the north of 20ºN latitude. The WOD data captures a similar pattern of Argo data for all SS-t distribution that can be seen in Fig. 3 (left). However, it is obvious that the northern BoB is much dense than the southern bay. During

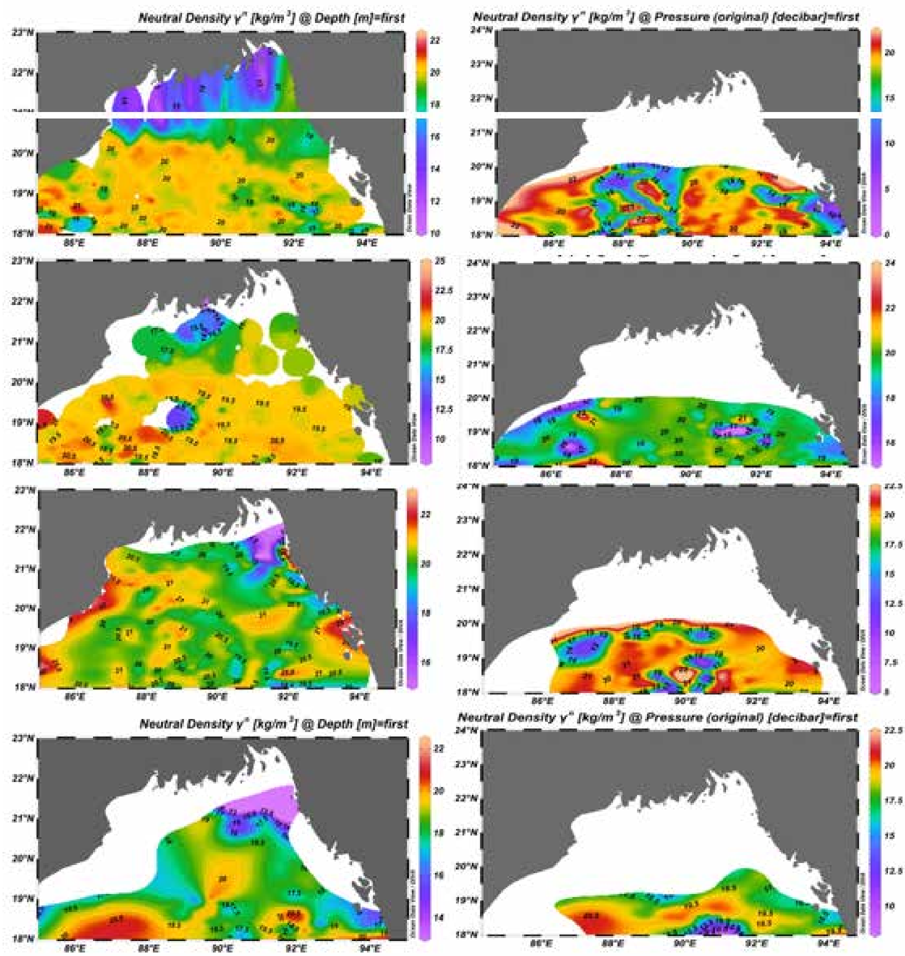


*Figure 3 Surface sigma-t distribution from WOD data (left) and Argo data (right), Summer, Spring inter-monsoon, Winter monsoon, Fall inter-monsoon respectively (top to bottom).*

all seasons, the density varies by 3-4 $kgm^{-3}$ from northern to the southern bay. Although, both datasets have revealed almost the similar pattern of SS-t, whereas the maximum values of WOD and Argo SS-t are 20 $kgm^{-3}$ and 20 $kgm^{-3}$ respectively.

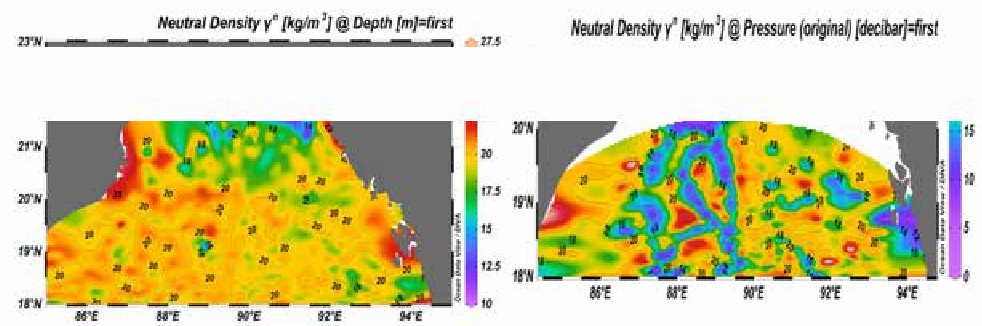


*Figure 4 All seasons averaged surface sigma-t distribution from WOD data (left) and Argo data (right).*

The above images illustrated the overall pattern of the surface density (SS-t) over the entire period of averaged values. Both of the datasets showed a similar density structure in the area of 18ºN -21ºN where the SS-t values ranged from 14-22 $kgm^{-3}$ (Fig-4). In the western BoB, the higher density observed while the northernmost and eastern bay is comparatively lower dense. The fresher water was found very close to the Bangladeshi coast.

**Latitude Average Vertical Sigma-t Structure (LAVS-t)**

During all monsoons, the highest value of latitude averaged vertical sigma-t structure (LAVS-t) near-surface is 21 $kgm^{-3}$ and the lowest value is 19$kgm^{-3}$ that can be seen in Fig. 5 (upper). The first unbroken contours 20.5 $kgm^{-3}$ is seen along approximately 40 metres' depth whereas contours are drawn 0.5 $kgm^{-3}$ intervals in this figure. LAVS-t contour line 20.5 $kgm^{-3}$ to contour line 26 $kgm^{-3}$ is distributed with a sharp change of density within the depth 40-160 metres that depth range can be defined as pycnocline.

After the depth of about 160 metres, density started to change slowly. If we look at both in upper and lower Fig. 5 around 91ºE longitudes, downward or down-welling tendency (with comparatively deeper 25 $kgm^{-3}$ contour line) can be seen there. Except that longitude line others area shows somehow horizontal pattern contour line with few concaves up or upwelling tendency. The WOD data captures the closely similar pattern of Argo data for the all-season LAVS-t distribution that can be seen in Fig. 5 (lower). Although both datasets have revealed almost the similar pattern of LAVS-t, whereas the minimum surface values of WOD and Argo data are 19.5 $kgm^{-3}$ and 19 $kgm^{-3}$ respectively.

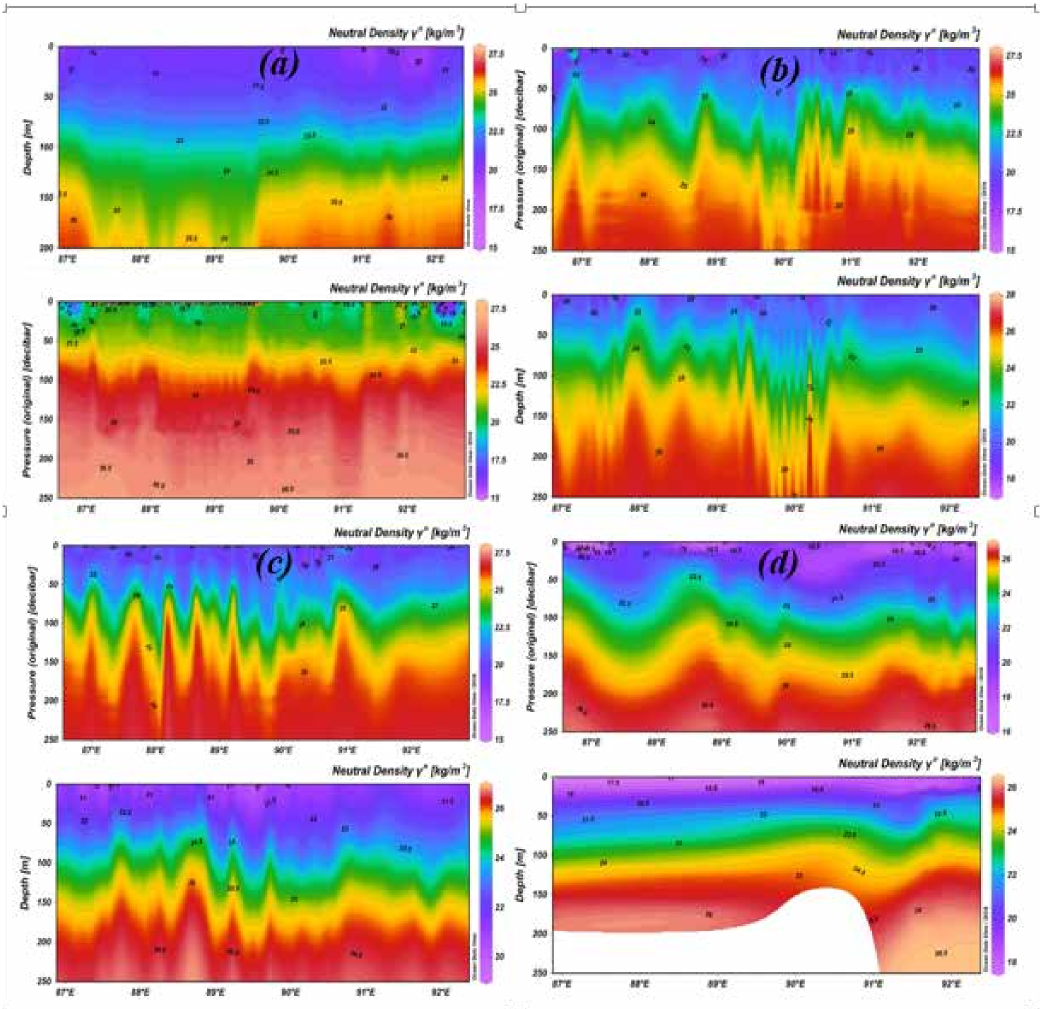


*Figure 5 Latitude average section plot for sigma-t of WOD (upper) and Argo (lower): (a) Winter monsoon, (b) Summer monsoon, (c) Spring inter-monsoon (d) Fall inter-monsoon.*

## Stability Distribution Profiles

Throughout the whole period of study, all profiles were averaged without any seasonality and the averaged Vertical Stability-Rp (VS-Rp) profile showed the changing tendency of stability from both Argo data and WOD data (see Fig. 6). Most of the data showed zero Rp whereas within the 200 m depth and between 200-400 m depth Rp ratio fluctuates intensively. After the depth of 400 m Stability, the ratio is almost constantly zero. The WOD data captures a similar pattern of Argo data for the study VS-Rp distribution that can be seen in Fig. 6.

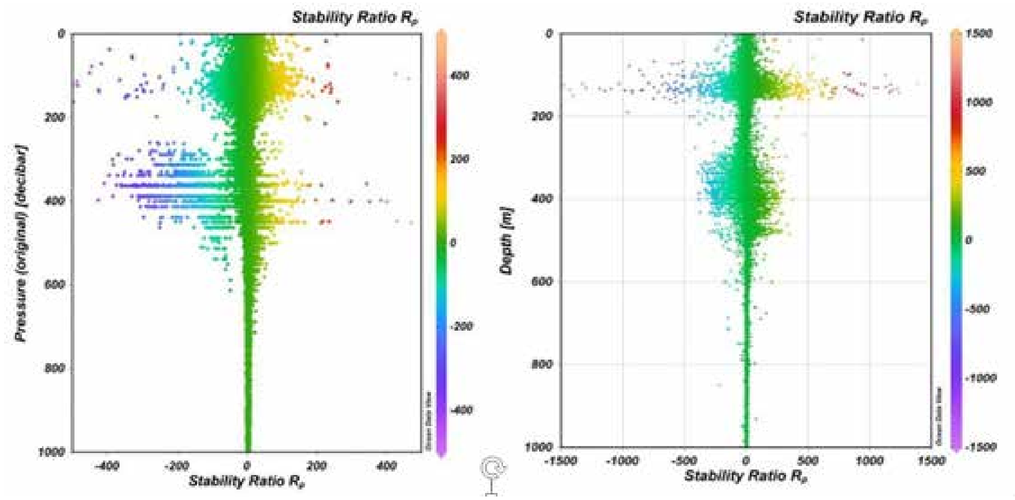


*Figure 6 Vertical stability Ratio-Rp from Argo (left) and WOD (right) from 2011 to 2017*

**Surface Stability-Ratio Distribution**

All through the seven years' study of all seasons, the highest value of stability is 40 and the lowest value is -10 that can be seen in Fig. 7 (right). Stability ratio distribution within the study area indicates a stable situation. There are no Argo data after 20ºN to the northern part of the bay while the WOD has more data beyond the north of 20ºN latitude. The WOD data captures a similar pattern of Argo data for them all season's stability distribution that can be seen in Fig. 7. However, it is noticeable that the northern BoB is much stable than the southern bay. Although, both datasets have revealed almost the similar pattern of stability, whereas the maximum values of WOD and Argo vary by 5 Rp.

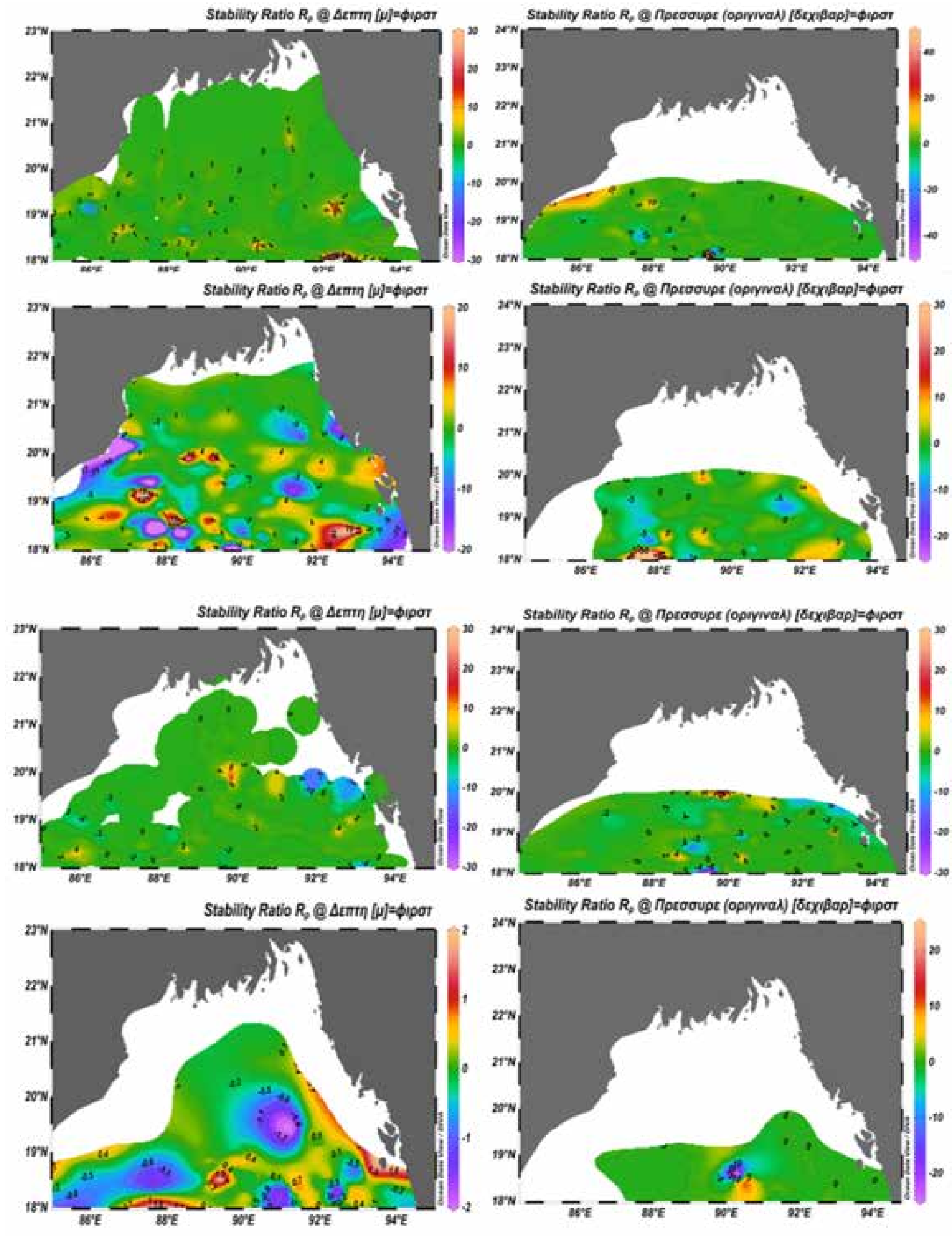

*Figure7 Surface sigma-t distribution from WOD (left) and Argo (right), Winter monsoon, Spring inter-monsoon, Summer monsoon, Fall inter-monsoon respectively (top to bottom)*

## Latitude Average Vertical Stability Ratio-Rp structure (LAVS)

For the period of the study of all seasons, the highest value of latitude averaged vertical stability structure (LAVS) near-surface is 0 that can be seen in the Fig. 8 and

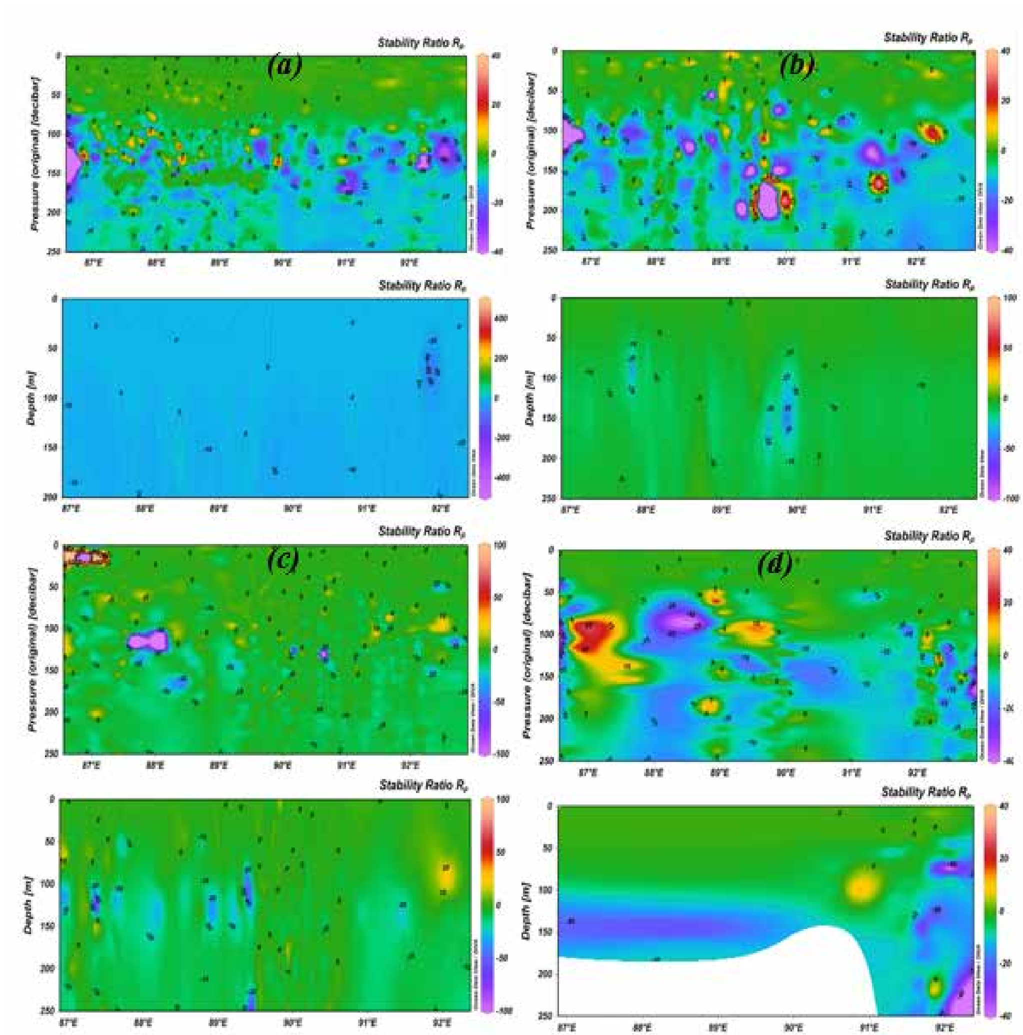


*Figure 8 Latitude average vertical sigma-t structure for WOD (upper) and Argo (lower): (a) Winter, (b) Spring, (c) Summer, and (d) Fall.*

means that water is stable near-surface. LAVS is distributed with a sharp change of stability within the depth 100-150 m that depth range can be defined as instability of water column. After the depth of about 150 m, water becomes more stable. The WOD data captures the closely similar pattern of Argo data for all seasons combined distribution except the instability extended more area in Fig. 8.

Table 1 Summary of all parameters with different sources of datasets

| SL | **Parameters** | Datasets | **Highest** | **Lowest** |
|---|---|---|---|---|
| **1.** | Surface Sigma-t distribution (SS-t) | Argo | 20 $kgm^{-3}$ | 12 $kgm^{-3}$ |
| | | WOD | 20 $kgm^{-3}$ | 10 $kgm^{-3}$ |
| **2.** | Latitude Average Vertical Sigma-t structure (LAVS-t) | Argo | 21 $kgm^{-3}$ | 19 $kgm^{-3}$ |
| | | WOD | 20.5 $kgm^{-3}$ | 19.5 $kgm^{-3}$ |
| **3.** | Surface Stability-Ratio distribution | Argo | 40 | -10 |
| | | WOD | 20 | -15 |
| **4.** | Latitude Average Vertical Stability Ratio- Rp Structure (LAVS) | Argo | 60 | 0 |
| | | WOD | 0 | 0 |

## Discussion

The BoB is traditionally considered to be a less productive bay. We have tried to find out the reasons for this in the northern bay during summer (June-August). Large rainfall and river water decrease salinity discharge along with the upper layers of the bay during summer, and SS-t was also warmer. This leads to a strongly stratified surface layer. The weaker winds over the BoB are unable to erode the strongly stratified surface layer, thereby restricting the turbulent wind-driven vertical mixing to a shallow depth of <20 m (Prasanna Kumar et al. 2002). During the spring inter-monsoon (March-May), strong stratification depleted nitrate concentration in the water column (60 m water column had <0.01µM) (Jyothibabu et al. 2006). During this period, dissolved oxygen concentrations in the surface waters (upper 50 m) of the Bay of Bengal were higher than in other seasons (Jyothibabu et al. 2008). During winter (November-February), there was a spatial decrease in temperature (4 °C), salinity (11 psu) and sigma-t (6 kg $m^{-3)}$ from south to north along the northern bay. The special difference of SS-t between WOD and Argo data was 21-22 kg $m^{-3}$ (Fig. 3). During the fall, there was a general decrease of sigma-t (7.5 kg $m^{-3}$) from south to north along the northern bay (Fig. 3). During boreal fall, a strong easterly anomaly arises near the equator, which triggers an equatorial Kelvin wave response and generates upwelling in the eastern equator meridional (Chowdhury et al. 2017). Vertical and surface seasonal static stability parameter (E, $m^{-1}$) was defined during winter, spring, summer and fall season for WOD and Argo data focusing the differences between them. Static stability was analysed to examine the stratification that could control the isotherm layer. In winter, southern bay stability was stronger than northern because of the temperature gradient from the south to north. In the upper 30 m, northern bay stability dominantly exceeded (5× 10-5 $m^{-1}$) the southern bay (Fig. 7). From upper 30 m to 100 m, southern bay stability (5× 10-5 $m^{-1}$) was stronger than northern (3× 10-5 $m^{-1}$) due to the subsurface temperature maximum which was stronger (more than 1.5°C) at high latitudes during the local winter season. A similar pattern of stability was seen in deeper than 100 m. The north-east winter monsoon was collapsed just after the winter which causes the southern bay stability stronger than northern bay in spring. In the upper 25 m, the northern bay was showed intermediate value which could be the reduced amount of freshwater present in the spring. In summer, northern bay stability was stronger than southern and highest compared to another season. In the upper 45 m, northern bay stability was dominantly exceeded (5× 10-5 $m^{-1}$) the southern. From upper 45 m to 80m, central bay stability (5× 10-5 $m^{-1}$) was stronger than northern (4× 10-5 $m^{-1}$), but southern bay (3× 10-5 $m^{-1}$) was seen as the lowest value. This phenomenon was mainly because of the huge amount of freshwater from the river runoff as well as rainfall which normally less dense and floated in the surface of the northern bay waters. Thus, this surface freshwater became much stratified during the summer. In the fall season, stability was showed a similar pattern like summer. Stability was showed a similar pattern in deeper than 100 m in almost all seasons (Fig. 8) (Chowdhury et al. 2017) because the deep water was not much affected by the surface stratified layer due to the temperature and salinity derived stratification.

## Conclusion

The present study focuses on the seasonal variability of stratification in the northern BoB. The energy required for mixing from Argo observations and WOD is analysed to understand the as seasonal variability of upper-ocean stratification from 2011 to 2017. Water column stratification is a phenomenon that occurs most prominently in the northern Bay of Bengal during inter-season. Higher heat flux could be one of the reasons for thermal stratification in the upper layer, especially during spring and fall season, followed the exchange of temperature with the deeper layer. During winter there was a spatial decrease in temperature, salinity and (6 $kgm^{-3}$) from south to north along the northern bay. Static stability was analysed to examine the stratification that could control the Isotherm layer. The southern bay was strongly stable than its northern counterpart during winter. Also, in the spring season, stability showed a similar pattern like winter. Conversely, in summer, northern bay stability was stronger than southern. Similarly, in the fall season, stability showed a similar pattern like summer. It is important to lay down spatial and temporal co-operation to set up immediate exploration and also to collect in-situ observation to analyse extensively the water column stratification and its seasonal variations etc. for further elaborate study.

## Acknowledgement

This research was possible due to the free availability of the temperature and salinity profiles data from Argo (http://www.usgodae.org/argo/argo.html) and WOD (https://www.nodc.noaa.gov/OC5/WOD/pr_wod.html). We are also grateful to the core group members of ODV and QGIS software.

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# Prevention of Grounding at Mongla Port with Virtual AIS

Md. Arif Mahmud[1] and Dewan Mazharul Islam[2]

***Abstract***

*About 90% of worldwide cargo transportation is performed by merchant ships. The trading is successfully completed only when the cargo is safely loaded, transported and safely delivered to the buyer. After loading vessels may navigate through channels, canals, rivers, bays, seas and oceans and carry the cargo to the destination. The navigation is done by ship's officers with the help of maps, charts and various navigation equipment available onboard. Ship's navigation is also helped from outside sources like the GPS satellites, communication satellites, lighthouses, light vessels, navigational buoys. By default, all systems must work perfectly otherwise ships may face trouble while underway. The Automatic Identification System (AIS) used by ships and ports for identification of ships. This can also be installed on light vessels and navigational buoys for identification with AIS equipment, RADAR (Radio Aid for Detection and Ranging) or ECDIS (Electronic Chart Display and Information System). Virtual AIS is a relatively new technology where no navigational buoys are placed on site but they can be detected by ships and this system will help the ships to navigate safely. Mongla Port is the second seaport of Bangladesh. It is situated in the Southern part of Khulna division and it is about 48 km south of Khulna city. Presently it has become a very busy port due to huge import of cement clinker, slag, gypsum, various fertilisers, coal, bulk edible oil, food grains, stone chips, heavy machinery and bulk LPG. Container and car carrier vessels also visit this port regularly. The introduction of Virtual AIS will help all the vessels to navigate safely throughout Pussur river, the risk of grounding will be minimised and hence there will not be any danger of oil pollution from grounded vessels and the ecological system of the Sundarbans will be preserved.*

**Keywords:** AIS, ECDIS, RADAR, Grounding, Virtual AIS, Buoys, Pilot.

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## Introduction

The Pussur river flows through the Sundarbans up to the Bay of Bengal and the Mongla port is situated on this river. Located in the delta of the three rivers, Ganges, Brahmaputra and Meghna, it is home to a significant portion of one of the world's largest contiguous blocks of mangrove forests and biodiversity (K. Mahadevia and M. Vikas, 2012). This port is mainly an anchorage port and many areas of this river are used for cargo work. There are few quays used by ocean-going vessels for container loading/unloading and LPG discharging. Few quays are also available for coastal vessels discharging imported Cement Clinker and Wheat.

For the identification of safer water, the whole river is marked with navigational buoys. They have specific colours and lights so that the vessels can identify them both in the day and at night. These buoys are fixed to the river bottom with anchors and the buoys float on the surface. Mongla port is a tidal port and sometimes the tides are very strong, especially during the rainy season. Strong tides can affect these floating buoys and shift their positions. The buoys are also shifted by cyclones and floods. Sometimes these buoys are damaged by cyclones and also due to contact with passing coastal or ocean-going vessels. Normally, the port authority transmits warning notices for shifted, damaged or unlit buoys. If a navigational buoy is shifted from its original position, ships can move near dangerous areas if not corrected the positions of buoys as required.

Virtual AIS is the solution to all these problems. If the transmitting stations are placed ashore secured and protected then it will always show the safe passage for the navigators. As the name suggests, this system uses a virtual means of navigation. It means the transmitting station is real and it will transmit real signals but the buoys are virtual. These virtual buoys will not be visible in the human eye but they will be detected well by RADAR, ECDIS and AIS and any vessel fitted with these equipment will be able to navigate safely through the Pussur river.

## Background

In the year 1950, Chalna Port was established on the banks of river Pussur. It was known as Chalna port but in 1954 the port was shifted about 18 km south to a new place named Mongla. The Mongla port is approximately 48 km south of Khulna city and about 130 km northwards from the Bay of Bengal. From the very beginning, Mongla port was used for exporting jute, jute products, frozen fish and frozen shrimps. The jetty facilities were very limited and the vessels used to complete their cargo operation mostly in the anchorage areas specified in the Pussur river. A number of mooring buoys were available for loading jute cargo directly from coastal vessels by ship's cranes. Sadly, with the invasion of plastic and polythene products, the demand for jute goods has fallen sharply and the export of jute and jute products from Bangladesh reached the bottom. Once a busy loading port remained almost inactive for many years.

The port was initially designed for ships with 8.5 m draft but the depth of water is reduced at many places, presently vessels are allowed to enter the port with a maximum draft of

8.0 m. All the vessels with import cargo must discharge their cargo at Chittagong during monsoon. In winter vessels with more draft anchor near the Fairway Buoy of Mongla Port in the Bay of Bengal. A number of small coastal vessels are engaged to load the cargo from the vessel to reduce her draft. Once the draft of the vessel is reduced to the permissible draft which is normally close to 8 m. Then the vessel will be allowed to enter inside the port. If the channel is dredged and the draft of the river is increased, deep-draft vessels will be able to enter the port directly.

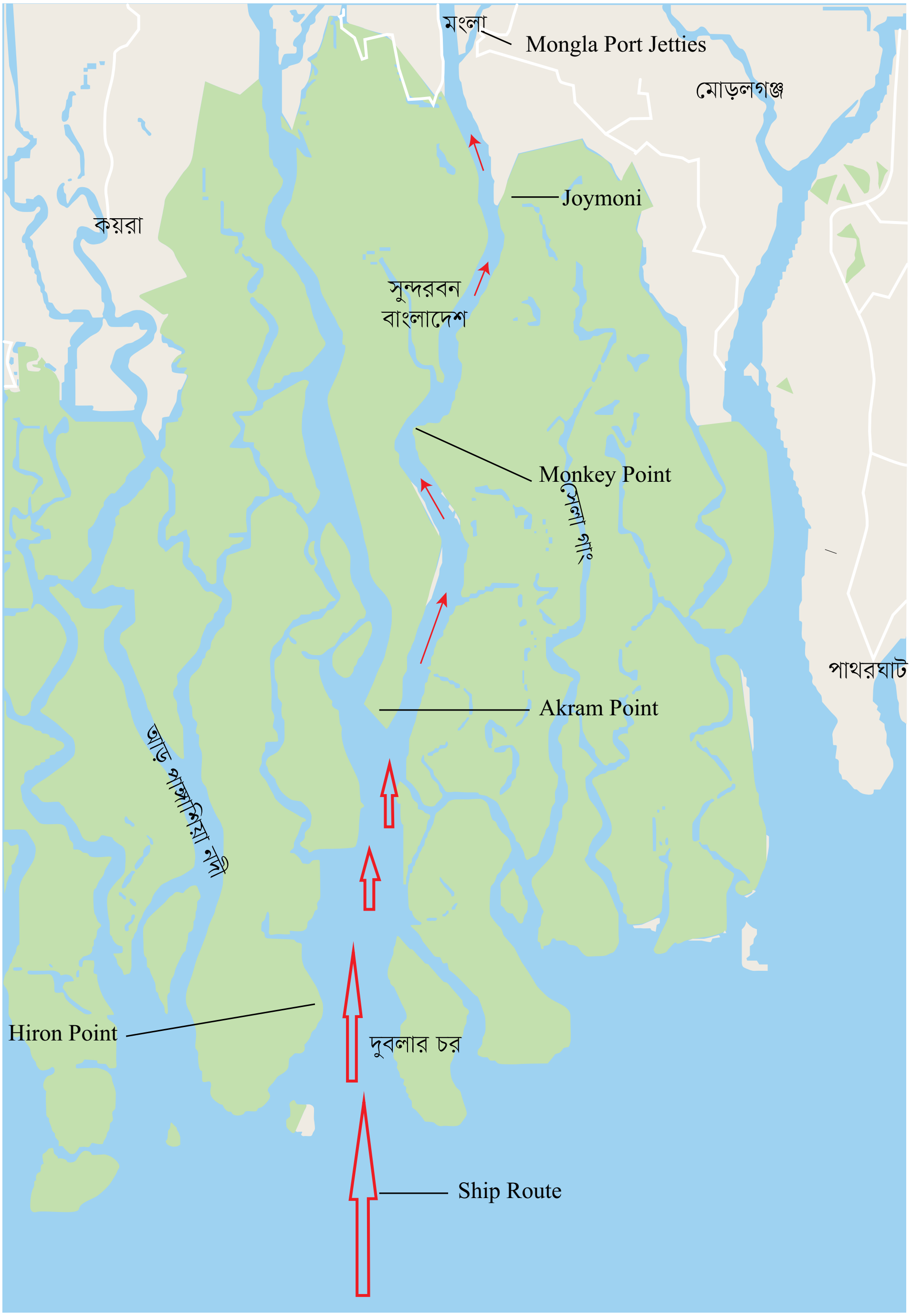
The vessels will move upstream through the Pussur river with the help of a pilot who is employed by the port and works as a local guide for the ship during navigation. The vessels must navigate on their own from the Bay of Bengal up to the Hiron Point to pick up the pilot. This passage from the Bay of Bengal up to Hiron Point consists of shallow-water patches, very strong tide, and sometimes misleading buoys. Some of the buoys are found to be out of position, unlit or damaged which are very dangerous for navigation if the updated status of each buoy is not known to the navigators.

The pilot guides the vessels up to a safe and available place in the Pussur river and drop anchor. The vessels normally maintain that position and arrange to discharge all their cargo in the coastal vessels. But the navigators are normally cautioned to keep sharp watch and check for anchor dragging and take immediate action, if necessary.

A total of 33 ships can berth in the Port (in quays, buoys, and anchorages) at a time. However, like other modern port of the world, the Mongla Port is keen to provide the highest port facilities, so that bigger draft ships can enter into the port-channel safely. (Motiur Rahman and Shahjahan Ali, 2018). The navigation channel from Fairway up to Hiron point is supposed to be marked with navigational buoys. As suggested by map and charts, buoys were placed along this channel but presently some buoys are missing, some are out of position, damaged or unlit. If all the buoys of a navigable channel maintain their specified positions and function properly, they will provide great help to the mariners for safe navigation.

The navigational buoys are big floating iron structure. They are kept in position with the help of anchors and chains which are laid on the river bottom. These buoys can be shifted by a strong tide, flood and cyclone. They can get damaged by cyclones and collisions. If a buoy is shifted, it will indicate a wrong way to the navigators and the ships may go in a dangerous area if a ship does not have up to date information about the buoys. If buoys are damaged, missing or unlit then they will not be able to show the safe way to the navigators.

## Map of Pussur river




*Picture no. 1: The shipping channel from Bay of Bengal towards Hiron Point and up to Mongla Port (Google Map, March 2019)*

## The Key Issue

Panama flagship 'MV Vinashin Iron' carrying 16,243 tons of urea fertiliser imported from China by Bangladesh Chemical Industries Corporation ran aground about 10 km away from Hiron Point near the Bay of Bengal on 2 September 2008. After receiving the information, Mongla Port Authority sent tugboat MV Shibsha to the spot but the ship could not be salvaged due to the ebb tide. "We are waiting for high tide to tug the ship in the river," said Capt Enam Ahmed, Harbour Master of Mongla Port Authority. The port authorities are monitoring the situation round-the-clock. (Source: The Daily Star, 04 September 2008).

Every year a number of ships go aground in the Pussur river. The most dangerous area is the length of the channel from the sea up to the Hiron Point. There are a number of causes for these accidents. The vessels have to go up to the Hiron Point to pick up the pilot on their own, the vessels have to cross the less depth areas in the highest possible tide. Sometimes the tide is very strong and vessels fail to navigate safely with a strong tide. As a result, vessels are drifted away from the safe water and pushed towards shallow water and if this type of movement is not controlled in proper time, vessels may end up getting aground. There are many wrecks in the Pussur river and these wrecks are causing siltation and making the channel shallower. Many places in the river need dredging.

The Pilot Boarding Station for Mongla Port is close to Hiron Point. The Pilots are local guides for vessels and they are employed by the port authority. From Hiron Point the pilots guide the vessels up to the port. From the Bay of Bengal up to the Hiron Point, which is about 46 km, the vessels are to navigate on their own and this is the most critical area of the Mongla Port. Over the years many vessels have been aground in this area and many ships have been abandoned as well.

During the Liberation War and thereafter, some local and foreign ships, (13 local and 5 foreign) sank at different reaches in the Pussur channel. Mongla Port Authority (MPA) has taken steps several times to remove the wrecks. The top portion of some wrecks have been removed but the bottom and sides of these wrecks still remain in the channel. MPA has difficulty in removing all the portions of the wrecks completely. Detail information of foreign wrecks are available in MPA. But information of local wrecks is not available. MPA only have the location of those local wrecks. For instance, one of the wrecks in the outer bar area (wreck ocean wave) causes siltation at its downstream. Thus, the existing navigation route at the downstream east side of the wreck is narrowing and swallowing and causes a threat to the existence of the route. (Md. Motiur Rahman and Md. Shahjahan Ali, 2018)

The passage from the Bay of Bengal up to the Hiron Point is supposed to be a buoyed channel. That means the total length of about 46 km of this passage is marked with green and red buoys. In normal circumstances, all the vessels can safely navigate through this channel and reach the destination. But there are many problems with the navigational buoys. The buoyed channel is currently not very safe because the buoys frequently get drifted by a strong tide, washed away by cyclones, sometimes hit and damaged by the coastal and ocean-going vessels. The buoys act as guidance to the mariners if they are in proper position and functioning correctly but if the buoys are out of position or missing and do not show the proper colour, top mark or light, it may cause the vessels to move into the shallow water areas. The rate of siltation is very high around Hiron Point due to geographical position and presence of numerous wrecks underwater. Frequent dredging is required in the Hiron Point area to maintain the depth of water.

The Port Authority frequently gives navigational warnings about the latest status of the navigational buoys especially from the sea up to the Hiron Point. If the buoys are shifted, drifted or damaged, the port authority always tries to rectify the problems soonest. The location of Hiron Point is very far from the Mongla Port and there is always a delay for all these repair works. Again, once all the buoys are repaired and put in the right places there is no guarantee that those will maintain respective positions. Because every year some cyclones pass over Bangladesh and there is every chance to get the buoys damaged or shifted by the wind and tidal surge of the cyclones.

## IMO Regulation

IMO regulation requires AIS to be fitted aboard all ships of 300 GT and upwards engaged on international voyages, cargo ships of 500 GT and upwards not engaged on international voyages and all passenger ships irrespective of size. The requirement became effective for all ships by 31 December 2004.

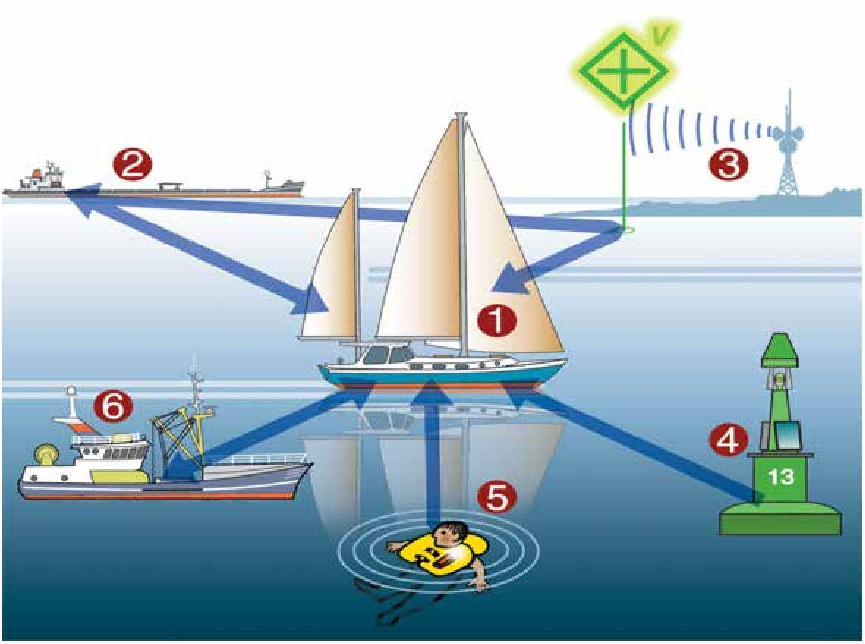
The regulation requires that AIS shall:

- Provide information - including the ship's identity, type, position, course, speed, navigational status, and other safety-related information - automatically to appropriately equipped shore stations, other ships and aircraft;
- Receive automatically such information from similarly fitted ships; • monitor and track ships;
- Exchange data with shore-based facilities.

(Source:http://www.imo.org/en/OurWork/Safety/Navigation/Pages/AIS.aspx)

## The Automatic Identification System (AIS)

AIS is a system of data exchange between ships that was made mandatory by the International Maritime Organisation (IMO) in 2004. AIS presents advantages for maritime transportation actors: improvements in safety, improvements in the management of fleets and navigation. Its distribution also presents numerous advantages in seaway management. However, the generalisation of AIS poses problems of confidentiality for ship-owners, indeed for safety. In effect, the data transmitted by AIS are available to all ships, port authority and traffic control stations (Arnaud Serry, 2016).




*Picture no. 2, the AIS network, (Picture Source, Duncan Kent, Sep 13, 2016, https://www.sailmagazine.com/)*

The Picture no.2 shows, how AIS spreads the news of a sailing boat's crew in water: the sailing boat's AIS transceiver (1) is exchanging information with a vessel (2) receiving signals from a land-based station serving as a virtual AtoN (Aids to Navigation) (3) receiving a signal from a green buoy of the navigation channel (4) displaying the distance and bearing to an MOB ( Man Over Board) via an AIS distress beacon (5) and calculating if it is on a collision course with a fishing boat (6).

As described before, the positions of buoys are always vulnerable. If the buoys are damaged or shifted then the AIS will totally ineffective. Moreover, the AIS can provide false information that may lead to the grounding of vessels. So, if the buoys do not maintain respective position then the AIS system will be very unreliable.

### Virtual AIS at Haldia Port

Years ago, the navigation towards Haldia Port was very unsafe. When Virtual AIS was introduced, the passage from the sea up to Haldia Port has proved to be very safe.

Vessel Traffic Management System (VTMS) is a radar surveillance system operating on radars at strategic locations connected through microwave data link and communication system. With a view to providing more effective and safer guidance to ship from the Sandheads to Haldia through radar surveillance, the Vessel Traffic Management System (VTMS) was taken up in the first phase from the Sandheads to Haldia. The system was operational in April 1996. Further, for the requirement of ISPS code and also for maintaining a back up to the VTMS system, a standalone VTS with Automatic Identification System (AIS) facility was established at the Saugar pilot station in May 2005. (Source: Kolkata Port Trust web site, 8 August 2019).

### Use of Virtual AIS to Avoid Grounding

Every year many accidents are caused due to missing, misplaced or unlit navigational buoys and all these problems can be very effectively and efficiently eliminated by using modern technology. The Virtual AIS, which is already in existence and used by many ports of the world, is really a virtual system. The vessels will observe navigation buoys in RADAR, ECDIS or in AIS very accurately and can safely navigate by using this new technology. Ships will observe the accurate position of virtual buoys on their screen, while in reality the buoys are not fixed in the river or channel. Rather a virtual system is operating from shore which will transmit electronic signals to ships and this will show accurate position of navigation buoys on ship's RADAR, ECDIS or AIS.  This system is very cheap in comparison to fixing real navigation buoys along the river.  The port authority can save a lot of money and time which they may spend for fixing and maintaining all those navigation buoys.

For the Virtual AIS system, first ground stations are established and signals transmitted by these ground stations in such a way that all the ships around will find virtual Aids to Navigation (AtoN) or buoys on their ECDIS, RADAR and AIS. Navigators are trained to sail with buoys when those are visible on RADAR, ECDIS and AIS. So, it will not cause any discomfort for navigators. All the buoys will show their accurate position and the navigators will efficiently find the navigable channel and also the no-go areas.


*Picture no. 3.  A shore station transmitting AIS signal and a sailing vessel will find a virtual AtoNon RADAR/ECDIS/AIS receiver and avoid a submerged rock very efficiently. (Source:Peter Nielsen, www.sailmagazine.com, June 12, 2012)*

## Implementation of Virtual AIS in the Pussur River to Avoid Grounding

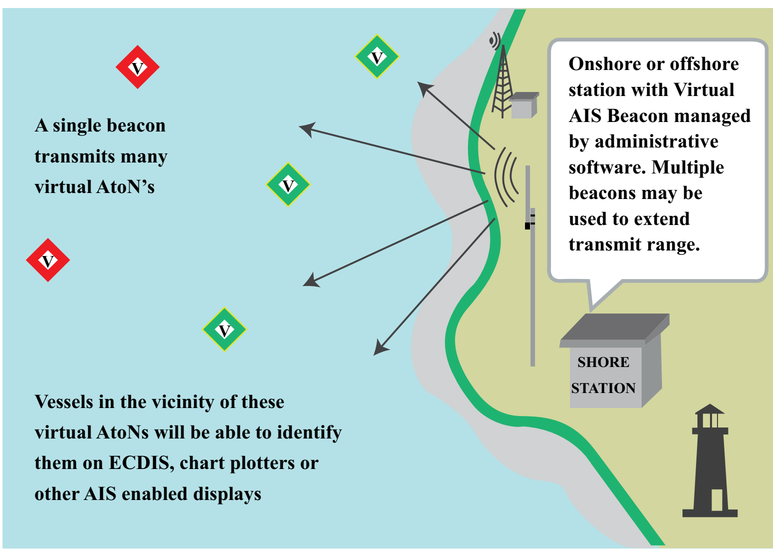
Multiple shore stations can be established along the Pussur river and ships can safely navigate by using Virtual Aids to Navigation (AtoN) or virtual buoys and safely navigate from the Bay of Bengal to the Mongla Port and vice-versa. One transmitter can generate 65 AtoNs. So only a few shore stations can cover the whole length of the Pussur river. Normally, the shore stations are fixed on land.

There is a manned harbour radio station for Mongla Port in the Hiron Point. The electricity is provided with the help of a generator. Moreover, solar panels can be fixed in this area as an alternative source of power. If a shore station is established and transmitter is fixed at Hiron Point, it can cover the dangerous area of the outer bar which is the place where the depth of water is very less, and ships go around frequently. Another transmitting station can be fixed at the Akram Point. With only two transmitting stations along the Pussur river, it is possible to maintain the virtual AIS coverage over the whole length of about 130 km of the river. All the ocean-going vessels have AIS, RADAR and ECDIS fitted and they can safely navigate from the sea up to Mongla Port jetty area.

If necessary, this system can be used in other rivers in Bangladesh. Coastal vessels with RADAR or AIS can utilise this system and perform safe navigation. When the coastal vessels use this system, they will always determine the safe navigable waterway and avoid going in dangerous areas. They will remain safe and will not cause any oil pollution.

## Requirements for Virtual AIS

A ground station with continuous power supply. The minimum height for the AIS antenna is only 7 m. AIS uses VHF transmitters.




*Picture no. 4, A ground station can transmit up to 65 virtual buoys or AtoNs, which can be detected by RADAR/ECDIS/AIS receivers. (Source: A. & Marine (THAI) Co., Ltd.)*

## AIS for Coastal Vessels

If AIS or virtual AIS buoys are fixed in the Pussur river and all other river routes of Bangladesh, it will be very beneficial for the coastal vessels. All the coastal vessels will be guided safely with the help of the AIS system. The coastal vessels will not be required to buy expensive AIS receivers. The AIS signals can be received by android mobile phones with the help of mobile apps like AIS Pilot, Easy AIS or my AIS which are available on the Google Play app store. So all the coastal vessels will be able to navigate safely through the rivers with AIS or a Virtual AIS system. Most of these apps work with internet connection but newly devised offline AIS apps are also available.

(Source:http://allbestapps.net/android/easyais , google play)

## Conclusion and Recommendations

Mongla port has a great possibility to flourish in this region. To achieve that the authorities need to plan and execute it effectively. If the river is dredged at the entrance (the Outer Bar) then many vessels will be able to enter the port directly. Presently many ships cannot enter the Mongla Port on arrival. Part of cargo has to be discharged either at Chattogram or at Mongla Fairway which is in the Bay of Bengal and suitable only in the winter season.

The news of any accidents or grounding has a very bad effect on the shipping market. The charter hire and the insurance premiums get increased for ships going to relatively dangerous areas. If a ship remains aground for some days the shipowner will claim money for those days. Either the charterer or the insurance company will pay for all the money. The port will also charge money if a pilot and tug are employed by the port. Fortunately, the bottom of the Pussur river is soft mud and the ships do not suffer any damage but after grounding a ship is normally surveyed by classification surveyors. All the above-mentioned coat will be added on the cargo and the poor people of the country will ultimately have to pay for all these accidents and grounding of ships at Mongla Port.

Virtual AIS is very easy to maintain and it is very cost-effective. One ground station can generate 65 buoys. The AIS operates with Very High Frequency (VHF) so the range will be about 30/40 km. One station can provide coverage upstream 30 km and downstream 30 km and it means a minimum of 60 km coverage can be provided by one ground station. The virtual AIS buoys will not get damaged by cyclones or by-passing ships and also they will not be drifted or shifted by cyclones or tide. The positions of buoys or Aids to Navigation (AtoN) can be added, removed or updated easily.

When the draft of the river will be enough and the navigation channel will be safe then Mongla port will be the first choice for ship owners. Because it is always safe to perform the cargo work in the river rather than doing it in the open sea.

It is recommended that,

**a.** The Virtual AIS may be established in the Mongla port and this system will help the vessels for safe navigation.

**b.** AIS system may be implemented in all other rivers which are used by coastal vessels as nowadays it is possible to receive AIS signal with android phones.

**c.** The shallow water areas of the Pussur river to be dredged as required and the draft to be maintained all over the river.

**d.** The old wrecks in the river to be removed soonest and make the river safe for navigation.

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# Maximum Sustainable Yield Estimate for Tiger Shrimp, Penaeus monodon off Bangladesh Coast Using Trawl Catch Log

Suman Barua*[1], Md. Abdullah Al Mamun[2], KM Shahriar Nazrul[3], Al Mamun[4] and Jewel Das[5]

***Abstract***

*Tiger shrimp, Penaeus monodon is the most economically important penaeid shrimp in Bangladesh for both culture and capture fishery. This study reveals an analytical stock assessment of tiger shrimp in Bangladesh marine waters after three decades of the inclusive survey. A time series of annual Catch Per Unit Effort (CPUE) was derived from commercial logbook data during the period from 1986 to 2017 and used as a tuning series for a Schaefer biomass model through MS-Excel and CMSY/BSM interfaces. The standing stock and harvest rate were estimated to be around 1250 t and 23% respectively. The estimated Maximum Sustainable Yield (MSY) reference points with 95% confidence interval are optimum biomass BMSY2360 t (1670-3320 t) and optimum fishing mortality Fmsy = 22% (16-31%). The average annual catch of last two decades 308 t, below estimated MSY of 527 t (388-717 t). Overall the stock is estimated to be at alarming state despite average annual catch lower than MSY for the last two decades. The enigma for this loophole likely to be lies indiscriminate exploitation of postlarvae (PL) from nature for coastal aquaculture and an extensive collection of brood shrimp for shrimp hatchery broodstock.*

**Keywords:** MSY, Tiger Shrimp, Bangladesh, SPM, Trawl Catch Log.

## Introduction

*Penaeus monodon* (Fabricius 1798) is the main commercial species among the penaeid shrimps and is commonly known as tiger shrimp in the Indo-Pacific region (Rao, 2013). It is known as 'Bagdachingri' in Bangladesh. Among the penaeid shrimps *P. monodon,*

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*P semisulcatus, P. indicus, P. merguiensis* are important contributors as larger shrimp in trawl catch (Mustafa, 2003). P. monodon is widely distributed in the Indian waters but forms a substantial component of the prawn landings from the sea and the estuaries of the east coast of India (Muhammed, 1970). It supports commercial fishery from the inception of the trawl industry, through their intensive exploitation is causing a decline in trawl catches. Extensive collection of postlarvae (PL) from the natural stock throughout the coastal area restrict recruitment to the industrial fishery which results in lowering of trawl catch (Khan et al., 2003). Consequently, catches of adult penaeid shrimps as broodstock for the coastal aquaculture industry have declined in terms of CPUE and size (Khan, 2010).

Each of the species of the Penaeus has peculiar latitudinal and longitudinal distribution pattern (Rao et al., 1993). The species of P. monodon spawn in the sea, but their larvae and postlarvae enter into backwaters and estuaries (Mohammed, 1970). In these ecosystems, they grow into juveniles (Rao, 1967; Subramaniam, 1987). After reaching the sub-adult stage, they migrate into inshore waters and further migrate into deeper waters for spawning on attaining maturity. Semi digested matter of the animals observed in the stomach contents of penaeid shrimps (Rao, 1988c). However, vegetable matter, large crustaceans, polychaetes, molluscs and fish as its food and is classified as an omnivore (Hall, 1962). All the species of the genus Penaeus are heterosexual and sexes can be distinguished by external characters (Rao et al., 1993).

Sustainable production model can provide guidance on stock status, MSY reference points and associated uncertainties (Cadrineet al. 1997). Surplus Production Models (SPMs) also known as biomass dynamic models (BDMs) are an important approach to the capture fisheries. Incredible work of various fisheries specialists has been accounted for production modelling (Schaefer, 1970; Fox, 1970; Hilborn & Walters, 1992). Generally, production models are based on the simple equation comprising of two or three parameters and population state and fishing activity could be described by a single variable (Laloe, 1994).

Much of the information available on the biology of the species but very few studies have been conducted on the population dynamics (Rao et al., 1993). Several researchers have studied the length-weight relationship of P. monodon following Thompson and Bell (1934) model (Rao et al.,1993; Lalita Devi, 1987, Khan et al., 2003). Barua et al. (2018) had assessed offshore shrimp stock of Bangladesh trawl catch using SPM. Some studied the P. monodon stock using SPM (Khan et al., 2003). However, there is no up-to-date published information available on stock assessment of P. monodon off the Bangladesh coast. The aim of the present study is to provide information on the stock status of P. monodon so that advice on reference points can be possible in order to drive optimum yields.

## Materials and Methods

### Data Collection

The time-series data (catch and effort) of Penaeus monodon of trawl catch log off the

Bangladesh coast from 1986 to 2017 (Table 1) were used into biomass pool for estimating reference points. The catch data were converted from headless weight to total weight using the conversion factor of 0.63 for tiger shrimp (Barua et al., 2018b), though they have been started to export of head-on tiger shrimp from 2012. There is minimal risk of under-reporting of shrimp catch because the majority of the catch of major shrimp species is exported (Barua et al., 2018b). Shrimp trawler engaged in fishing in the EEZ of Bangladesh beyond 40 metres depth contour (Fig. 1). Shrimp trawlers usually have 150-250 tons gross tonnage capacity including main engine power of 500-900 BHP. The maximum days of fishing per trip is 30 days. Every day usually completes 5-6 hauls for a period of 3-4 hours. Though, the fishing days and number of hauling fully depends upon weather and seaworthiness of the vessel itself (Uddin et al., 2012). The catch is expressed in metric tons (t), effort as the number of fishing days.

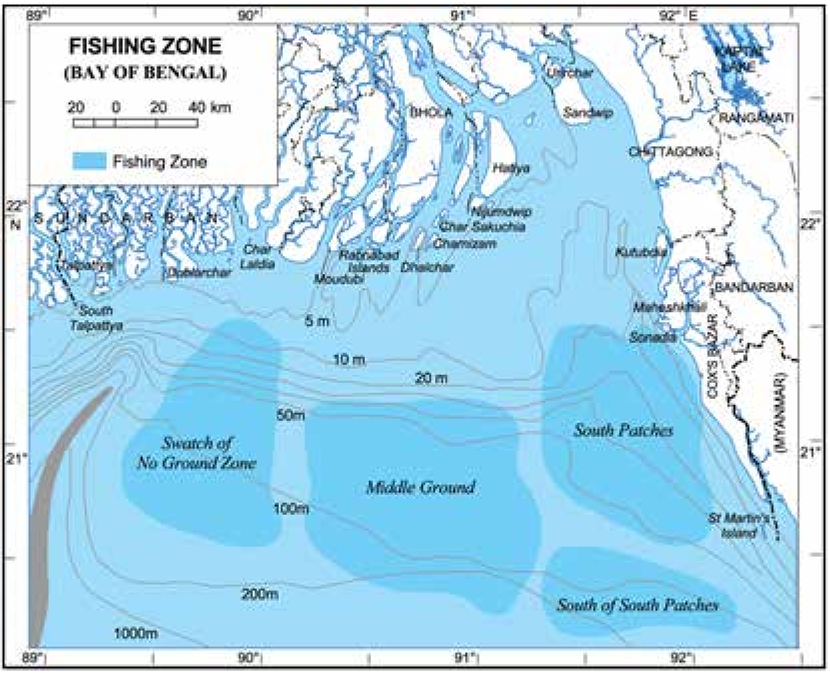


*Fig.1. Map showing trawl fishing zone in Bangladesh EEZ.*

## Stock Production Models

For this study, a Schaefer model was applied, which was based on the logistic population growth model.

The model is described as:

$B_{(t+1)}=B_t+rB_t(1-B_t/K)-C_t$ …………………………………… (i)

Where B is the biomass, t is the time (year), K is the carrying capacity, C is the catch

Table 1. The time-series data of P. monodon from trawler catch (Source: Marine Fisheries Office report).

| Year | Time (fishing day) | Catch (t) | CPUE (t/d) |
|---|---|---|---|
| 1986 | 6429 | 776.19 | 0.121 |
| 1987 | 6642 | 922.22 | 0.139 |
| 1988 | 7806 | 863.49 | 0.111 |
| 1989 | 7394 | 785.71 | 0.106 |
| 1990 | 5658 | 568.25 | 0.100 |
| 1991 | 5529 | 782.54 | 0.142 |
| 1992 | 6588 | 761.90 | 0.116 |
| 1993 | 7113 | 488.89 | 0.069 |
| 1994 | 6691 | 474.60 | 0.071 |
| 1995 | 6502 | 446.03 | 0.069 |
| 1996 | 6914 | 533.33 | 0.077 |
| 1997 | 7044 | 330.16 | 0.047 |
| 1998 | 7645 | 371.43 | 0.049 |
| 1999 | 7152 | 260.32 | 0.036 |
| 2000 | 7289 | 323.81 | 0.044 |
| 2001 | 6935 | 292.06 | 0.042 |
| 2002 | 7069 | 303.17 | 0.043 |
| 2003 | 7442 | 347.62 | 0.047 |
| 2004 | 7866 | 349.21 | 0.044 |
| 2005 | 7466 | 328.57 | 0.044 |
| 2006 | 5919 | 330.16 | 0.056 |
| 2007 | 5969 | 353.97 | 0.059 |
| 2008 | 5956 | 395.24 | 0.066 |
| 2009 | 4581 | 385.71 | 0.084 |
| 2010 | 4718 | 339.68 | 0.072 |
| 2011 | 4116 | 247.62 | 0.060 |
| 2012 | 4436 | 188.21 | 0.042 |
| 2013 | 4935 | 257.02 | 0.052 |
| 2014 | 4543 | 235.02 | 0.052 |
| 2015 | 4703 | 296.95 | 0.064 |
| 2016 | 4635 | 274.54 | 0.059 |
| 2017 | 5258 | 289.24 | 0.055 |

and r is the intrinsic rate of population increase. Mortality, age-structure, reproduction and tissue growth are all expressed by a simple parameter called the intrinsic rate of increase or intrinsic rate of production, r. In theory, r is fully observed at the lowest population level while the finite rate of population growth is the highest at the midpoint of K (Schaefer, 1954).

## MS-Excel

A non-equilibrium Schaefer surplus production model was fitted to the time-series input data. The initial biomass (B0), K and r for the stock was predicted at the beginning of the trend analysis. Then next year biomass was calculated by the following function:

*Biomass= max (B0+r* B0*(1- B0/K)-catch)*----------------------------------(ii)

The max function ensures that the stock biomass cannot go extinct when using the solver. The values of catch and survey indices (CPUE) above were used to estimate catchability (q) while altering r and K in order to establish the most suitable fittings between the observed and expected index for estimating these parameters. Sums of squared normal residual error (RSS) were then calculated. These estimated parameters were also transformed (loge) in order to calculate negative log likelihood (neglogL), using the following formula:

*neglogL=0.5*n*LN(2*PI())+n*LN(sigma)+RSS/(2*sigma^2)*--------------------(iii)

Where n was the number of years, LN was log natural, and sigma was the residue of error.

This was done to check the uncertainty of the model. Then, the solver was used to estimating the most reasonable output of desired parameters by targeting a minimum residual sum of square (RSS).

## The CMSY method

The Catch-MSY method (CMSY) as proposed here was inspired by the stock reduction analysis of Kimura and Tagart (1982) and Kimura et al., (1984). As input data, it requires a time series of removals, prior ranges of r and k, and possible ranges of relative stock sizes in the first and final years of the time series. It then uses the Schaefer production model to calculate annual biomasses for a given set of r and k parameters. As no prior distributions of r and k are available for most fish stocks, we randomly draw r-k pairs from a uniform prior distribution and then use a Bernoulli distribution as the likelihood function for accepting each r-k pair that has never collapsed the stock or exceeded carrying capacity and that results in a final relative biomass estimate that falls within the assumed range of depletion (Martell & Froese 2012).

## Derived Parameters

The estimated parameters *r, q* and *K* can be used to calculate management reference points such as *MSY*, Biomass that gives MSY ($B_{MSY}$), Fishingmortality at MSY($F_{MSY}$) as in:

*MSY = ( rK/4)*-----------------------------------------------*(iv)*

*B_MSY = ( K/2 )* ----------------------------------------------------*(v)*

*F_MSY= ( r/2 ) or ( MSY/B_MSY )* -----------------------------------------------------*(vi)*

## Results

The base parameters of the stock production model were quite similar irrespective of the interfaces used to assay. The intrinsic growth rate r, catchability coefficient q and carrying capacity K were estimated 0.447 (0.321-0.623), 0.0000467 (0.0000364-0.000060) and 3391 t (12039-26489 t) respectively. The bracketed value indicates a 95% confidence interval of estimated quantity (Table 2). The estimated MSY reference points with 95% confidence intervals are optimal biomass BMSY = 2360 t (1670–3320 t) and fishing mortality rate FMSY = 22% (16–31%). The average annual catch in this period is 289 t, less than the estimated MSY of 527 t (388-717 t) (Table 2).

Observed and expected index of tiger shrimp catch fitted to the CPUE used for tuning the SPM model (Fig. 2). The residue sum of square (RSS) was 1.10. The negative log-likelihood was -8.48, which is indicated the most likely precision between observed and expected fit.

The catch was far below from MSY reference point (527 t) for the last two decades although the catch was higher than MSY in the first decade of the study. The calculated biomass is 1250 t, which is far lower than the biomass reference point (2360 t) since last two and half decades. But, surprisingly the exploitation rate is above Fmsy reference point almost throughout the study period. Therefore, the relative biomass over relative effort indicates stock at an alarming state though catch has been showed far lower than MSY level for the last two decades (Fig. 3).

Table 2: Point estimates and 95% confidence intervals of estimated parameters, biomass in 2018 and reference points.

| Quantity | Estimate | 95% CI |
|---|---|---|
| $r$ | 0.447 | 0.321-0.623 |
| $K$ | 4720 | 3350-6650 |
| $q$ | 0.0000467 | 0.0000364-0.000060 |
| *Sigma* | 0.185 | 0.126-0.213 |
| *MSY* | 527 | 388-717 |
| $B_{MSY}$ | 2360 | 1670-3320 |
| $F_{MSY}$ | 0.224 | 0.160-0.312 |
| $F_{2017}$ | 0.232 | 0.186-0.327 |
| $B^{2018}$ | 1250 | 885-1550 |

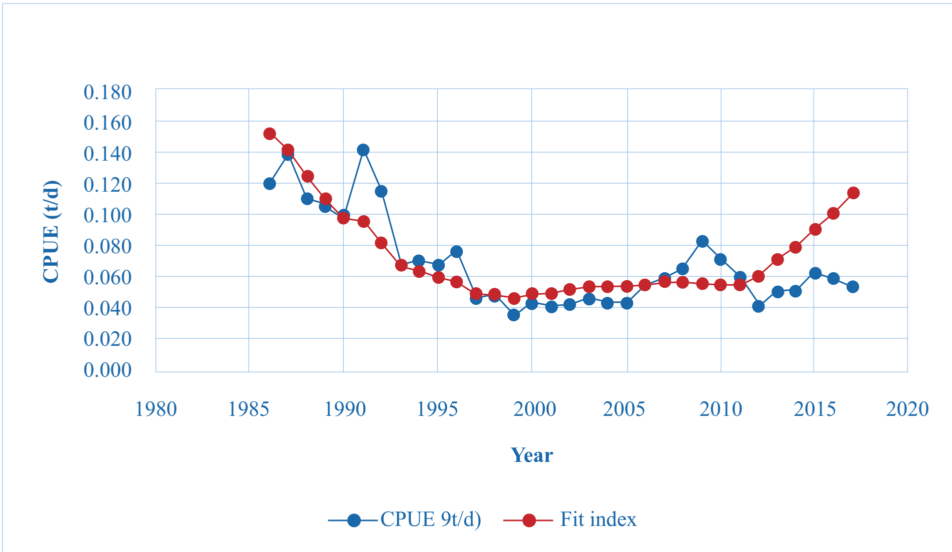


*Fig.2. Observed and expected index fit to the CPUE used for tuning the stock production model.*

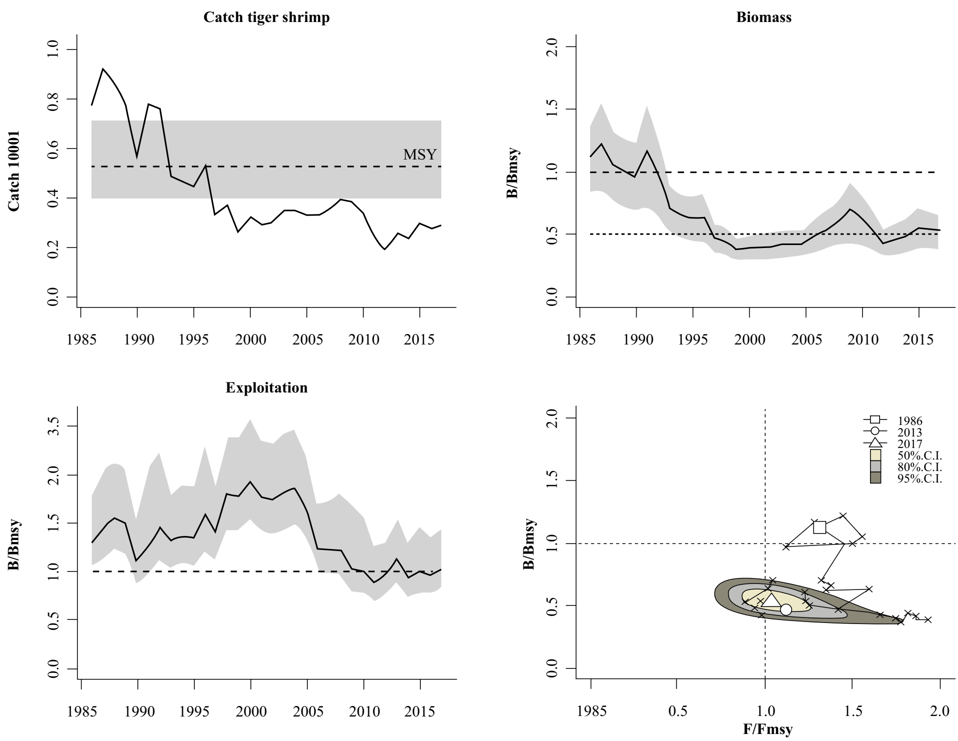


*Fig. 3: Results for management including stock status based on CMSY/BSM analysis for Tiger shrimp for the period from 1986 to 2017.*

## Discussion

The surplus production model is important in assessing the stock of aquatic species. Estimated reference points on biomass and harvest rule which are described here can be applied depends on reliable estimates of r and K. Most of the production models require a time series catch and effort data to provide dependable parameter estimates (Prager et al. 1996). In the case of less informative data to estimate parameters, independent data can be used to fix certain parameters. For instance, Prager (1993) fixed the value of r to provide guidance on MSY, but fixing r will determine the level of FMSY.

SPM has some assumptions. Practically, many of the assumptions are not met but this does not mean the method cannot be used. As long as it is used critically the model is a very powerful tool for initial assessment of a stock (Musick & Bonfill, 2004). In SPM, Maximum Sustainable Yield (MSY) is considered as a biological reference point on which sustainable exploitation goal can be achieved (Hilborn& Walters, 1992; Maunder et al., 2006; Musick&Bonfill, 2004 and Prager, 1994).

The present study provides information on reference point through SPM of P. monodon. The value of intrinsic growth rate, r obtained in the present study correspond to the findings of Komi et al. (2013), who studied r of P. monodon in the Andoni River, Nigeria (r = 0.87) and Barua et al. (2018), who assessed stock status of Bangladesh offshore shrimp including r = 0.76. The estimation of r, K and q from this study were 0.45, 4720 t and 0.0000467 respectively. Application of Verhulst equation and Pauly's model to the data on shrimp stock of Bangladesh from the year 1981-82 to 1997-98 by Ray & Khan (2003) resulted in r and K values of 1.33 and 11400 t respectively. The catchability coefficient of the present study is lower than the value of q (0.000097) estimated by Ray & Khan (2003).

The relative biomass over relative effort (Fig. 3) indicates stock at alarming state though catch has been showed lower than MSY level for the last two decades. The enigma of this loophole likely to be lies indiscriminate exploitation of post larvae from the coast (Khan et al., 2003; Quader 2010, DoF 2013) an extensive collection of brood shrimp from wild source for tiger shrimp hatchery (Khan, 2010).

## Conclusion

The stock of tiger shrimp is in an alarming state not due to commercial fishers but mostly due to lack of management strategy. For its rejuvenation, some steps are deemed necessary. First, an attempt has to be taken on stop collection of PL from the natural source (coast) and second, discourage collection of broodstock for shrimp hatchery from a wild source.

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**Notes for Contributors**

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