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Future importance of healthy oceans: Ecosystem functions and biodiversity, marine pollution, carbon sequestration, ecosystem goods and services

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1 INTRODUCTION

Earth's nickname "The Blue Planet" derives from the fact that oceans cover two-thirds of the surface of earth. Oceans, while relatively less explored than other natural resources, provide ecosystem services which are fundamental to the very existence of both terrestrial and aquatic biospheres on planet earth. Oceans act as a buffer to the changes in the composition of the atmosphere (Catling and Kasting, 2017; Gregor, 1985; Jickells, 2002; Sukumaran, 2000; Voss and Montoya, 2009), maintain the global thermal equilibrium (Faizal and Rafiuddin Ahmed, 2011; Wang et al., 2012), regulate of the hydrological cycle (Gröger et al., 2007), provide a sink for all forms of wastes from the anthrosphere (Goldberg, 1985; Holdgate and McIntosh, 1986; Peterson and Teal, 1986), mediate the formation of different kinds of sedimentary and metamorphic rocks, and serve as the world's largest pool of flora and fauna (Armbrust and Palumbi, 2015; Farrow, n.d.). Recently, we have started to understand the value of oceans as a sink of carbon dioxide (Ibánhez et al., 2016; Landschützer et al., 2016; Orr and Sarmiento, 1992; Quéré et al., 2003) and their importance in global warming. Also, the importance of oceans is recognized as never before because the value of fishery and seaweeds (Bouwman et al., 2011; Hehre and Meeuwig, 2016; Sweatman et al., 2016), salt and minerals (Loganathan et al., 2017; Shahmansouri et al., 2015), drinking water (Elimelech and Phillip, 2011; Ghaffour et al., 2013; Shannon et al., 2008), navigation (Fransoo and Lee, 2013; Lee and Song, 2017), petroleum resources including oils and gases under the sea bed and methane hydrate in the sea floor. In all, the sustainable future of mankind depends largely on the dramatic reduction of influx of pollutants into them and to maintain the biodiversity therein for sustenance of ecosystem services from them ("Classification of marine ecosystem services," 2016; Palumbi et al., 2009; Sultan, n.d.; United Nations, 2017). This importance is manifested from the declaration of sustainable development goals (SDGs) as Goal 14 explicitly call to "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" and outlined 7 main and 3 associated targets in order to attain the goal (Neumann et al., 2017; Vierros, 2017).

The Bay of Bengal large Marine ecosystem is the largest among the 66 large Marine ecosystems in the world (Coleman, 2008; NOAA et al., 2007; Sherman, 1991). This ecosystem provides food and nutrition to more than half a billion people while supporting the livelihood of several hundred million coastal population living along and in the vicinity of coastal zone of the marine ecosystem of the Bay of Bengal spreading over 8 countries including India, Bangladesh, Sri Lanka, Myanmar, Indonesia, Malaysia, Thailand and Maldives. The future development of these countries rests on the blue economy development in the region which again is dependent on the conservation of the marine and coastal ecosystem in the Bay of Bengal large marine ecosystem area. Accordingly, while all the countries need to take local initiatives to ensure the future health of this crucial ecosystem, regional cooperation and joining forces to work together is the only way to ensure the conservation of this ecosystem for the sustenance of ecosystem services to avail the potential offered by blue economy under threat of climate change (Verlaan, 2005; Vivekanandan et al., 2016).

This paper aims to review the current status of ecosystem and resource extraction in brief in order to come up with thoughts related to the future challenges in maintaining the health of the Marine and coastal ecosystems at the Bay of Bengal. In the beginning, a discussion has been included to contextualize the concept of healthy ocean in relation to Blue economy development and the importance as well as global and local challenges in keeping the Bay of Bengal healthy has been briefly introduced. Since the importance of any ecosystem is, in recent time, popularly expressed in terms of ecosystem services - a complete section has been dedicated to outline the ecosystem goods and services from the Bay of Bengal specifically by using the popular classification of ecosystem services under four categories - provisioning regulating, support and cultural services. The thematic section of this chapter highlighted the challenges current efforts and future interventions necessary to keep the Bay of Bengal large marine ecosystem healthy. In this section, future challenges related to the health of the Bay of Bengal including climate change, environmental pollution from different sources, biodiversity conservation, sediment movement. marine spatial planning and adoption of protected area concept to design marine reserve, fish sanctuary and ecological critical areas in the coastal zone were highlighted. This section included a schematic discussion on the importance and means of monitoring the help of the marine and coastal ecosystem at the Bay of Bengal which outlined the need for local and international collaboration in order to ensure adoption and management of an objective monitoring system for generation storage and analysis of data by devising a shared common platform under the leadership of Bangladesh to assist informed decision making regarding the Bay.

1.1 Healthy Oceans

1.1.1 Context

The health of oceans in the world are under the serious threat from a multitude of stressors including climate change environmental pollution, over exploitation of resources, enhanced marine transportation, reduction in the river discharges and changes in the sediment dynamics in rivers etc (Halpern et al., 2008). Climate change and related sea level rise along with the changed climatic extremes are posing the greatest threat to the ocean ecosystem especially in the Bay of Bengal large Marine ecosystem area (Bosello and De Cian, 2014; Greenberg et al., 2012; Weissenberger and Chouinard, 2015). Oceans are the largest sink of varied types of wastes and pollutants entering our environment from natural and anthropogenic sources (Bates and Peters, 2007; Heimburger et al., 2013; Krishnamurthy et al., 2007; Okubo et al., 2013; Zhang et al., 2004). These pollutants are entering into the oceanic system through transportation by and deposition from the atmosphere; with river discharges carrying contaminants from natural, municipal, industrial and agricultural sources; from the large number of marine vessels operating globally for different purposes; and from the exploration of resources from oceans and other activities like setting up of wind turbines, installation of underwater energy harvesting systems and laying out of global submarine internet communication network. Recently, for example, we became quite concerned about the entry of plastics into the ocean which are subsequently break down into microplastics and finally enter into the food chain creating a lot of issues related to the overall marine ecosystem. In this backdrop, it became quite important to act concertedly to ensure and healthy ecosystem in our oceans not only to conserve the biodiversity in the oceans but also to sustain the ecosystem services rendered by oceans which is very much crucial to the sustenance of our environment and the terrestrial life sustaining systems.

1.1.2 Importance

Healthy oceans are fundamental to the very existence of human civilization as they play crucial role in maintaining the global climate, the water cycle, atmospheric gases cycles including oxygen nitrogen and carbon dioxide cycles, in regulating global heat budget (Cullen, 1999; Gröger et al., 2007; Monteiro et al., 2010; Reed and Harrison, 2016). Besides, oceans are also linked to the sustainable flow of different consumable and economic resources including fishes, seaweeds, crabs, mollusks, algae, salt, petroleum, pearl etc (Baturin, 2000; Csirke and Garcia, 2009; Gonzalez, 2016; Seibold and Berger, 1996). Moreover, oceans are the main pathway for the global movement of merchandize which fuel world economy (Hoffmann et al., 2017). Conserving the oceans and its resources are fundamental to attain the lofty goal of converting the global economy into ocean and water based blue economy (Cressey, 2011). In addition, it is imperative to keep in mind that there are more resources in the oceans than we currently are aware of and without keeping the oceans healthy we shall miss exploring them (Cater and Cater, 2007; Gupta, 2017; Leary et al., 2009; Rajagopalan and Nihous, 2013). As the EEZ of Bangladesh is about the size of the country (KAŁDUŃSKI, 2015; Qiu and Gullett, 2017), the long term GDP growth of the country and equitable development depend on the productivity of Bay of Bengal which in terms depends on maintaining the bay in a healthy condition (Hussain et al., 2018; Rahman, 2017; Sarker et al., 2018). Maintaining the health of Bay of Bengal largely depends on understanding the threats to the ecosystem and biodiversity of the bay including climate change, overexploitation of resources, pollution and flow of pollutant containing sediments from municipal, industrial and agricultural sources. Special emphasis is needed to specially address the plastic pollution as Bangladesh which is a major contributor of (Fisner et al., 2017; Vince and Hardesty, 2017; Yu et al., 2018) plastic wastes to the Bay of Bengal.

1.1.3 Challenges to Healthy Ocean for Blue Economy – Global and Local

Oceans are the only repository of global natural resource pool which is yet to be discerned and explored to its fullest. The lack of technology to explore oceans and seas are the main barriers which has shielded the oceans from destructive and unsustainable human explorations to some extent. However, the situation is changing quite rapidly due to the rapid progress in the technological frontier which are evident from (Candeloro et al., 2015; Greenemeier, 2014; Moore, 2007; Pai, 2015). In contrary to worries, there is a glimmer of hope since the exploration of oceans and seas commence at a time when there is a global consensus on exploring resources sustainably and we, as humans, are becoming more capable of ensuring sustainable resource exploration and utilization. Nations are becoming more interested in the concept of circular economy, sustainable development, low carbon growth, environmental conservation.

The challenges associated with keeping the oceans healthy are both global and local since the oceans are all connected and any problem caused locally has global implications. Gulfs, Bays and Seas have economic zone marked for adjoining countries and are sources of disputes as exemplified by the recent resolution of dispute between Bangladesh, India and Myanmar (Alam, 2018; Qiu and Gullett, 2017) which has culminated in a verdict in favor of Bangladesh. The major challenges in maintaining healthy oceans include checking the flow of pollutants and contaminants through river discharges, atmospheric transportation and This is one example of internationalization of local dispute over seas. This has created an immense opportunity for Bangladesh to take steps in making its portion of the Bay of Bengal healthier and conserve the ecology and biodiversity therein to attain the SDGs of the country (Shamsuzzaman and Islam, 2018).

1.1.4 Blue Economy vs. Healthy ocean – Bangladesh Context

Blue Economy, a term first used by Belgian economist Gunter Pauli, denotes effective and planned utilization of resources from blue ocean water strategically for sustainable economic development through generation of new jobs and social capital while conserving the existing (Rahman, 2017). It can be envisaged as a framework for sustainable ocean governance for development based on marine and coastal resources (Gamage, 2016) without aggravating environmental degradation. The origin of this concept stems from technological advancements which has enhanced the interest in sustainable exploration of ocean resources. Also, Blue Economy can be considered as an integration of activities related to coastal ecosystem marine ecosystem, marine and coastal resource extraction and livelihood, maritime trade under one umbrella due to our increased understanding of the intricate relationships among these activities (Smith-Godfrey, 2016). The Blue Economy aims to achieve a sustainable ocean economy through the balanced use of ocean and coastal resources without jeopardizing their health and resiliency (Patil et al., 2016).

Bangladesh has taken the opportunity offered by the concept of blue economy very seriously especially after it has won the maritime boundary dispute with India and Myanmar and established legal right over a large tract of the Bay of Bengal as he its exclusive economic zone. Bangladesh has established a blue economy cell under the ministry of power energy and mineral resources in the beginning of 2017 in order to coordinate the related activities. A number of projects have already been launched under the banner of Blue Economy in Bangladesh which includes projects on coastal aquaculture on the exploration of economically important Maritime flora, decide organizing a number of seminar, conferences and dialogues. Different Ministries associated with the management of marine and coastal resources have taken steps to develop projects on the theme of Blue Economy. however, he is this project are not coordinated and implemented concertedly; these projects will result in bad outcome. Therefore, the urgent need for Bangladesh to take a lead in the development of Blue Economy in the Bay of Bengal, used to establish an umbrella organization in order to streamline the formulation of policy and programs and their implementation by line Ministries efficiently with desired outcomes.

Due to the action of a large number of Mega development projects near the coastal zone of Bangladesh including the establishment of exclusive economic zones in Mangla, Bhola, Mirsarai, Sitakunda, Anwara, MaheshkhalI, Teknaf areas may go against the blue economy development, if proper infrastructure development along with waste and effluent management

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systems are not put in place to save the coastal and Marine environment from the pollution which will be created from these economic zones.

2 ECOSYSTEM GOODS AND SERVICES FROM OCEAN – THE CASE OF BAY OF BENGAL

Bangladesh depends on the Bay of Bengal because comprises the largest river delta in the world formed as it was by the deposition of sediments carried by the Ganges-Brahmaputra river system at the foothills of the Himalayan mountain range. Major aspects of life in Bangladesh are shaped by the Bay of Bengal due to the wide range of ecosystem goods and services which the country receives from it. An exhaustive list of ecosystem goods and services from the Bay of Bengal is still to be enumerated. A map of ecosystem services is shown in Figure 24.

2.1 Provisioning Services

The countries' 710 km coastline has created a large community of people dependent on coastal and Marine resources for their food and livelihood. People of Bangladesh are very much dependent on fish catches from the Bay of Bengal to meet their dietary protein needs. The coastal and Marine fishery and its related industries are a very big employment sector of the country providing livelihood for millions of people. A large population in coastal districts are dependent on shrimp farming and salt production - two industries which are completely dependent on the Bay of Bengal. The coastal sand and the sediment at the Bay of Bengal has high concentration of rare Earth elements for which the Limited efforts has this far been employed. Marine and coastal roads of the country are very busy transportation routes which acts as a blood stream by regulating the supply chain of the country. The mangroves and coastal plantations are also substantial sources of ecosystem goods wheat economic values. In addition, Bangladesh has started to get gas and petroleum from beneath the seafloor at the Bay of Bengal.

Unfortunately, Bangladesh has so far failed to explore the full potential of provisioning services that the Bay of Bengal can render to its economy. Due to the concentration of entire fishery industry to shallow water fisheries in the coastal region, and due to the lack of survey data font the availability and stock of deep sea fishes - the provisioning services in terms of fishery is yet to be realized. The Hilsa fishery alone contributes about 1% of the GDP of Bangladesh which is adequate to exhibit the role that blue economy can play in pushing the GDP growth of Bangladesh they are on the magical 10% figure.

There is no visible Seaweed industry in the country, mariculture, cage culture of fishes, pearl farming, utilization of the energy potential in the tide and wave of the Bay of Bengal as well as the wind energy potential in the coastal region has not been seriously investigated. on the other hand, the huge discharge of Methane containing sediment into the Bay of Bengal has made the Bay a potential stockpile of Methane hydrate which is considered as source of abundant energy for the future growth of this planet.

Due to the population growth in the urban centers coupled with serious pollution in the freshwater carrying rivers, the country is approaching towards a situation when it will face shortage in fresh water supply for its population. The country has to rely on desalination of water from the Bay of Bengal to meet freshwater demand and planning to that and needs to be started now.

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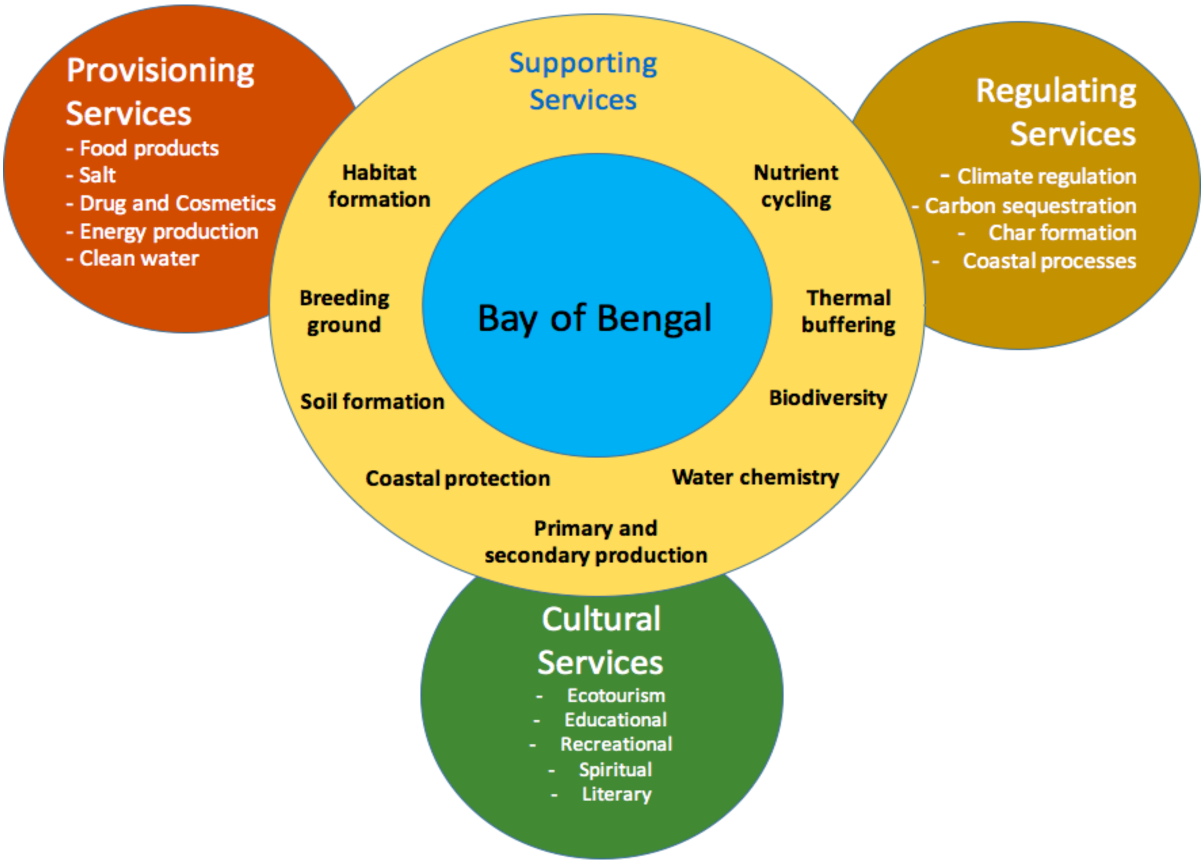

Figure 1: Map of ecosystem services at the Bay of Bengal

2.2 Regulating Services

The Bay of Bengal regulates the pattern of climate and weather of Bangladesh. The temperature, humidity, rainfall and all the related phenomena are totally dependent on the behavior of the Bay of Bengal. Bangladesh is a country of Six Seasons and the division of seasons are dictated by regulation of thermal and hydrological cycles in the region by the Bay. Bangladesh is also known as a country of flood caused by torrential rainfall during the rainy season from clouds originated in the Bay of Bengal and moved to the north by the monsoon wind. Though the floods a devastating, it’s regulate the formation of land by changing the river and Canal courses, by recharging the in law what is including groundwater table, buy distribution of fertile sediments on the arable land throughout the country. In a sense, most of the major infrastructure projects of Bangladesh are associated with the management of hydrological resources and floods as well as with the construction of dams and bridges to cross barrier among different parts of the country created by the extensive River system. Therefore, the future adoption of different development projects in the country should and buy shares its relationship with the Bay of Bengal and its bearing on the development of blue economy be it in the coastal region of the country or in the deep Northern region - far away from the coast in order to enhance the regulatory services provided by the Bay of Bengal and to reduce the impacts of negative regulatory ecosystem services.

2.3 Supporting Services

The Bay of Bengal is rich in biodiversity is rich in biodiversity of of fishes, crabs, shrimps, birds, marine turtles and other aquatic flora and fauna. The Bay of Bengal large Marine ecosystem provides the habitats, supplies nutrients and acts as the breeding ground for all these species. the Bay acts as a reservoir a huge volume of sediments and by using the sediments the currents in the Bay create new offshore Islands and controls the dynamics of coastal land accretion and erosion. The newly formed coastal lands known as Chars and the of your Islands, forms vibrant ecosystem to support a rich assemblage of terrestrial flora and fauna through the process of succession. A great example is Nijhum Dwip - a recently formed offshore Island that now supports a vibrant Island mangrove ecosystem. Most of the industrial and municipal wastes generated by 150 million people of Bangladesh ultimately find their way into the Bay of Bengal. Hence, the day can be considered as the final sink and ultimate treatment facility of wastes.

On the majority of the inhabitants of Bangladesh are dependent on agriculture and their farming is in turn completely reliant on the rainwater from the Bay of Bengal through the unique weather phenomena related to the Bay of Bengal known as the monsoon.

2.4 Cultural Services

The Bay of Bengal controls all the major aspects of life and livelihood in Bangladesh. it is therefore inevitable that all forms of cultural activities in the country has a strong correlation with the Bay and its changes throughout the year. There are unique forms of songs, crafts, craftsmanship related to boat building and net making related to lifestyles in the coastal region based on its dependency on the Bay of Bengal. All these has created a unique heritage for the country and a rich source of interest among people for the development of tourism. In Bangladesh, the cost of Cox's Bazar is the most popular tourist destination followed by the Saint Martin Island, the Kwakata sea beach and the Sundarban mangrove forest which is the only Coral island of the country located at the fringe of the Bay of Bengal. However due to the lack of facilities for tourists in terms of transportation, accommodation and amusement has hindered the growth of coastal and Marine tourism in Bangladesh. If proper attention is given, infrastructural and industrial development are taken cautiously, security in transportation at movement are assured and promotions to attract International tourists taken care of - the traditional tourism and eco-tourism in the coastal and marine regions at joining the Bay of Bengal will be able to add substantially to the GDP growth of the country.

2.5 Keeping Bay of Bengal Healthy: Challenges, Current Efforts and Future Needs

2.5.1 Challenges

2.5.1.1 Climate Change

There are 66 Large Marine Ecosystems (LMEs) in the world which produces more than 80% of the total fish catches in the world and contributes about $12 trillion per annum in ecosystem services goods and services (Sherman, 2001; Sherman and Hamukuaya, 2016). Bay of Bengal

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Large Marine Ecosystems (BOBLME) is the largest among the LMEs supporting about half billion people by food, livelihood and security through its coastal and marine resources. Climate change is threatening to bring forth sweeping changes to the BOBLME in terms of water pH, salinity, dissolve oxygen, temperature and so on (Vivekanandan et al., 2016) which will increase water column stratification and inhibit primary production. The ultimate outcome will be declining fish stock and diminishing sustainable levels of fisheries yields. The ultimate outcome will stress on food security of billions of people and livelihood of hundreds of millions of BOBLME depended coastal communities (Sherman and Hamukuaya, 2016). On the other hand, the pattern of cyclones and climate change induced sea-level rise at the Bay will be inevitable. The ultimate outcome of changes in ecosystem will result in the Impaired ecosystem productivity due to the modification of living environment and associated biological and nutrition cycles leading to modified distribution and phenological traits of marine and coastal flora and fauna. These will impact the fish catch in quantity and composition especially for the traditional fishermen. [(Carson et al., 2015). On the other hand, sea level rise due to climate change in the Bay of Bengal region may displace as many as 100 million people living in the coastal districts of Bangladesh by resulting in the loss of home, agricultural land, industries, the entire belt of shrimp farming and salt producing area in the coastal zone (Ahmed and Diana, 2015). The climate change will also affect Sundarban mangrove forest and the coastal vegetation which is very crucial to the food chain of the Bay of Bengal. Sea level rise will also hamper the sediment movement dynamics in the way of Bangalore and the pattern of accretion and erosion of land in the coastal Islands and the entire post of Bangladesh (De, 2013). On the other hand, climate change induced climatic events and sea level rise will also impact the budding tourism industry of the country (Hassan and Rahimi, 2018). Therefore, a large scale mitigation and adaptation activities are needed in order to come back and the ecological and economic disaster created to the coastal communities and to the coastal ecosystem.

2.5.2 Environmental Pollution

2.5.2.1 Pollution from Ship Breaking

Ship breaking and recycling industry (SBRI), due to its open-beach dismantling of scrap ships in Sitakunda-Bhatiary region on the coast of Bay of Bengal, takes a great deal of blame for the pollution to water and sediments by heavy metals, asbestos, paints, oil spills, and different persistent organic pollutants including dioxin. Some reports attributed the occurrence of higher than natural level of trace metals in fishes from the nearby coastal areas.

2.5.2.2 Pollution from Municipal, Industrial and Agricultural Runoff

Bangladesh is the largest delta which has formed due to the deposition of sediments carried by every active river system consisting of the Padma, the Yamuna, The Brahmaputra besides the Karnaphully, Sangu and Matamuhuri river system. In the past most of these rivers wear flowing through Christian landscapes hands the sedimentary carried away free from anthropogenic contaminants of pollutants. However due to the rapid population growth in Indian sub-continent most of this rivers now flow through multiple municipal, agricultural and industrial areas cause rivers to carry a very high load of pollutants including heavy metals, hazardous industrial wastes, pesticides and other active chemicals, I level of organic and nutrient loads. Hence, the sediments which is carried to the Bay of Bengal by this way active river system laden with pollutants of all descriptions which ultimately contaminates the nearest area of Bay of Bengal which is the main fishing region of the Bay of Bengal. This is difficult to separate the pollution from ship breaking industry and the pollution from pollution carrying sediments. However, the high level of heavy metals, persistent organic pollutants, microplastics etc., in different fishes the occurrence of trace elements are clearly indicating a gloomy future in getting pollutant free catches of fish and other biomass from the Bay of Bengal. It becomes urgent for the policy makers and all other stakeholders to take immediate and pragmatic actions to stop the flow of pollutants into the rivers from Industries, Municipal sources, and hazardous coastal activities including ship breaking.

2.5.3 Atmospheric Deposition

During the dry season, air containing different kinds of contaminants including reticulate matters of wearing nature from households, industrial sources, power generation units close to the Bay of Bengal beside marine transportation by engine boats and other marine vessels. The airborne pollutants are ultimately deposited into the Bay of Bengal and contaminates the water. Do the severity of pollution from this source vary seasonally and spatially, due to the establishment of a large number of big coal based power plants in in the coastal belt of Bangladesh and its neighbouring countries, the possibility of enhanced load of atmospheric deposition is becoming worry. It becomes very important to show the policy makers and planners to take the sources of pollution of Bay of Bengal very seriously and then the development intervention in a way to minimise atmospheric deposition to the Bay of Bengal instead of enhancing the possibility of more pollution from this source since unlike water pollution atmospheric deposition is very difficult to control.

2.5.4 Transboundary Pollution

The Bay of Bengal Large Marine Ecosystem (BOBLME) Project includes 8 countries joining the Bay of Bengal which is indicative of the very international nature of the Bay of Bengal. Rivers are quite dynamic and hence the pollutants released into the Bay of Bengal it become dispersed and effect the whole of the Bay and its ecosystem including the economic resources. Therefore, formation of a stronger cooperation in order to ensure the closure of flow of pollutants from any of these countries is very crucial to the health of the Bay of Bengal. Formation of a joint pollution control and monitoring initiative should be immediately organized among the nine countries of BOBLME in order to ensure good health of the Bay of Bengal in the future and to ensure the sustainable flow of ecosystem services and economic benefits to ensure proper utilization of blue economy opportunities offered by the Bay of Bengal. All trans-boundary rivers should be kept clean of pollutants in the respective parts of these rivers introspective the countries and the joint monitoring system should monitor the adherence of respective countries to the scheme. In addition, transponder movement of pollutants through atmospheric circulation needs to be monitored in order to check atmospheric deposition of pollutants into the Bay beyond its natural assimilative potential.

2.5.5 Microplastics

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The BOBLME encompasses eight countries including Bangladesh, India, Indonesia, Malaysia, Maldives, Myanmar, Sri Lanka, and Thailand. Among these countries Indonesia, Sri Lanka, Thailand, Malaysia and Bangladesh among the top 20 Countries which are adding substantial amount of unmanaged plastic wastes into global water. The respective contribution of these countries 3.2 million, 1.6 million come 0.9 million 0.8 million metric tons of unmanaged plastic wastes (Figure 25). Therefore, the total amount of plastic wastes sent to the BOBLME region by 20 countries is 7.5 million MT. Since it is expected that the plastic pollutants in the ocean will become one third of the total Ocean biomass in near future, the situation will be greater in the case of Bay of Bengal since the countries in this region are amongst the largest release year of plastic pollutants into BOBLME ecosystem. Therefore, it becomes inevitable to check the flow of unmanaged plastics into the Bay of Bengal to ensure the future health of the Bay of Bengal. On the other hand, if the plastic pollution is controlled from the rivers carrying lots of plastics from urban centers in the densely populated Indian sub-continent and its neighboring countries, this single source of pollution is adequate to jeopardize the total health of the ecosystem of the Bay of Bengal and bring down the biomass production at the bay to a halt.

2.5.6 Oil Spills and Waste Disposal from Marine Vessels

Bay of Bengal is amongst the busiest marine transportation routes since most of the countries along the coast of the bay amongst the rapidly developing countries in the world. In the future, with this establishment of new posts, expansion of the exploration of ocean resources due to the enhanced emphasis on blue economy, the number of ocean going classes are going to increase at a faster rate. Ocean going vessels and with the growing number of main industries in the bay region account for an increasing share of pollution. The solution from this source is going to aggregate. On the other hand, this country is in the coastal region of the Bay of Bengal are becoming increasingly reliant on imported petroleum through the ocean route which is increasing the chance of largest oil spills from accidents associated with crude carriers. This type of accidents has happened in different parts of the world in the past. However, as the countries in the coast of the Bay of Bengal doesn't have the technological and economic preparation to combat if largest oil spill or similar marine pollution occurs in the Bay of Bengal. It becomes a big responsibility these countries to initiate process of transporting petroleum through pipelines in order to reduce the risk of jeopardizing the help of the ecosystem and the biosphere at the Bay of Bengal severely.

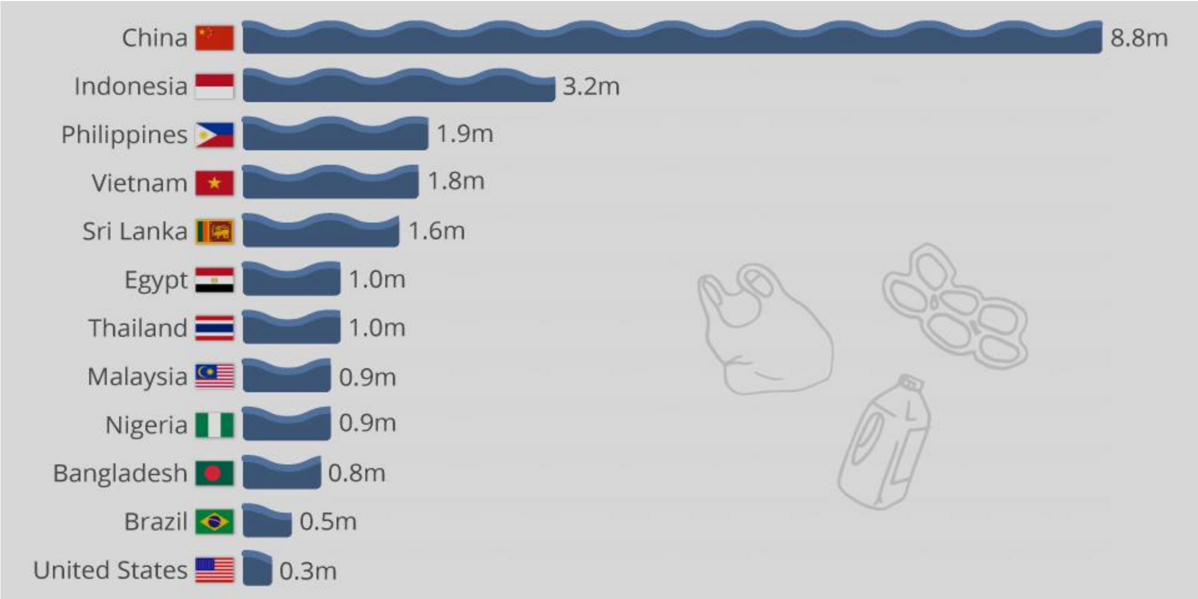

Figure 2: The countries polluting the oceans the most in terms of annual metric tons of mismanaged plastic wastes in global waters. Source: The Wall Street Journal, 2010.

2.5.7 Tourism Related Contaminations

Most of the countries on the coast of the Bay of Bengal are the most densely populated countries in the world. As these countries are in a trajectory of development, the people are becoming more solvent and interested in in-country and regional tourism. In Bangladesh, the enhancement in the flow of tourists to the coastal region is exemplified by the following figure which shows the increase in the number of tourists visiting the Cox's Bazar sea beach and the Saint Martin Island over the past 5 years. The number of tourists visiting this places are already beyond the carrying capacity of these places. Seems that residents of these countries are most educated and unaware, the regulatory and infrastructural facilities at the tourist spots are inadequate, the vigilance by the regulatory authorities are inadequate and poor, each tourist is creating more or less contamination to the places they are visiting in the coastal region. Accordingly, the pollutants they are releasing are getting into the water of the Bay of Bengal. If this continues to grow undeterred, the tourism industry will become one of the biggest contributor of pollutants to the Bay of Bengal and hence want to the biggest threat to the future health. It is therefore crucial to take immediate measures to calculate the carrying capacity of coastal tourism spots along the coast of the Bay of Bengal to put regulatory and infrastructural projects in place and to make the tourists every year to behave environmentally friendly way to sustain the growth of tourism without affecting the health of the Bay of Bengal.

2.5.8 Biodiversity Conservation

The conservation of biodiversity at the Bay of Bengal is crucial to sustaining the flow of ecosystem services and goods. There are a number of initiatives in different forms which has been adopted over the decades for the conservation of different Marine and coastal species. For example, there are ongoing projects for the conservation of marine Turtle in the Saint Martin Island, at Cox's Bazar sea beach and at Sonadia Island. A prominent example large scale effort of biodiversity conservation is the ban on harvesting all kind of fishes and crustaceans in the Exclusive Economic Zone of the Bay of Bengal for 65 days starting from May 20 till July 23 every year to support the breeding of fishes and crustaceans in order to maintain their stock at sustainable level. Bangladesh has already enjoying the benefit of measures taken for the conservation of Hilsa fish from October 1 to October 22 every year in order to stop unnecessary killing of Hilsha fries. Due to this conservation scheme, in 2017, Hilsa contributed more than 1% of the country's GDP. the department of environment has declared the Cox's Bazar sea beach as the ecological critical area and has taken a number of steps, with poor implementation, to safeguard different Marine species including Turtles which are dependent on coastal ecosystem at some point of their life cycle. This kind of initiative has to be replicated in the other coastal areas which are important for breeding of marine species. The fishing ban alike that of Hilsa fish can also be replicated for other economically important and popular fish species with proper scientific investigation to increase the size of the stock and subsequently the volume of catch. Many people in the coastal region are dependent on catching shrimp fries and crabs for their livelihood by using zero mesh fishing nets. This dangerous practice catches all other small marine organisms besides shrimp fries which are usually discarded at the sea beach to die. The campaign to raise awareness among people associated with this destructive activity next to be strengthened hundred folds to stop indiscriminate killing of marine organisms and fries of non-commercial fish species in masses.

2.5.9 Coastal Vegetation

Bangladesh has a 710 km long coastline boarding the Bay of Bengal besides the coastline for offshore islands numbering. In addition, to continue changes to the shoreline due to the accretion and erosion of land, there are continuous formation and erosion of offshore charland. Since all of these landforms are lucrative sites for natural succession for mangrove species in forming a coastal mangrove ecosystem and a very promising site for coastal plantation. Bangladesh has a great success story in creating a dense coastal vegetation belt specifically after the devastating cyclone in 1991 that killed hundreds of thousands of people and destroyed properties worth billions. On the other hand, natural succession has created mangrove vegetation and in some places enhanced the manmade vegetation cover along the coast and in islands and chars. Bangladesh is fortunate to have Sundarban Natural Mangrove Forest (area) on the southwestern part and unfortunate to destroy the Chakaria Natural Mangrove Forest on the North eastern corner between 1980 - 1995. Ownership of these coastal chars is with he Forest Department and after the land is stabilized, the ownership goes to the Land Ministry and managed by public administration of the local government. There are numerous examples of destruction of coastal natural and planted coastal vegetation in the name of development by the government in one hand, local power brokers and private sector on the other hand. For example, the state sponsored destruction of coastal vegetation in Maheskhali for recent developments in the area, the complete destruction of the Chakaria Sundarban for shrimp farming, the large scale destruction of coastal Forest by Mirsarai Economic Zone Project under implementation.

The coastal mangroves provide a long list of ecosystem services for which Sundarban has gained the status of world heritage site from UNESCO. They provide food and livelihood, provides habitats for many keystone species that cannot occur elsewhere and play a key role in the flow of nutrient for the coastal and marine fisheries. There are different stressors which are affecting the coastal vegetation and the natural mangroves mainly related to man made changes in the upper watershed, climate change and the reckless development intervention due to the lack of understanding on the critical roles this vegetation plays in mitigating climate change, enhancing climate change adaptation, safeguarding from climate change induced devastating cyclones and tidal surges. The future of blue economy development of the Bay of Bengal depends on action oriented scientific understanding of these stressors as they regulate the food chain and nutritional level along with water quality while directly supporting numerous terrestrial, coastal and Marine species of economic importance by functioning as a habitat.

Therefore, safeguarding the future health of the Bay of Bengal instead of making the health of the bay to wane, a critical evaluation of the existing mangrove cover and coastal plantation should be done to find means not only to check their further deterioration but also to take all out measures for the enhancement of activities and programs to create and conserve coastal vegetation in yet-to-be planted areas and newly accreted char land. In order to ensure the sustainability, the programs are need to be adopted for diversification of value-added economic use of products and services from the coastal vegetation and mangroves. There had been some assessment on the possibility of revival and restoration of Chakaria Sundarban which needs to the put together to come up with projects for actually doing it following the shrimp farming model in Thailand and Vietnam where shrimp farms' productivity has-been enhanced by mangroves.

2.5.10 Sediment Movement and Deposition

The Bay of Bengal receives water discharges from a number of river systems as listed in Table 10 below as adapted from (Kumar et al, 2005) and as shown in Figure 26. The Bay of Bengal receives water discharges from Ganzes river system, Irrawati river system and Godawari rivers system (Yaremchuk et al., 2005). 3-D Princeton Ocean Model (POM) based calculation showed the seasonal circulation and mixed layer depths in Bay of Bengal which indicated increased fresh-water flow affecting only the western parts of the Bay of Bengal. Due to the opposing northward ocean currents created by monsoon winds and southward current due to fresh-water discharge that results in strong vertical salinity stratification, the monsoon induced turbulence is subdued (Chamarthi et al., 2008). Decreasing sediment flow (Rahman et al., 2011) has been reported and linked to the decreased productivity of the marine ecosystem. Marine sediments along the Chennai coast of the Bay of Bengal contained 1.88 to 39.76 ppm petroleum hydrocarbons (PHC) with higher concentrations in in the northern part receiving wastes from shipping activities and polluted sediments through the rivers like Kuvam (5.5–39.72 ppm) and Adayar (7.26–16.83 ppm) and the vertical distribution of PHCs in the sea bed clearly indicated anthropogenic origin of PHCs (Veerasingam et al., 2011; Venkatachalapathy et al., 2010)

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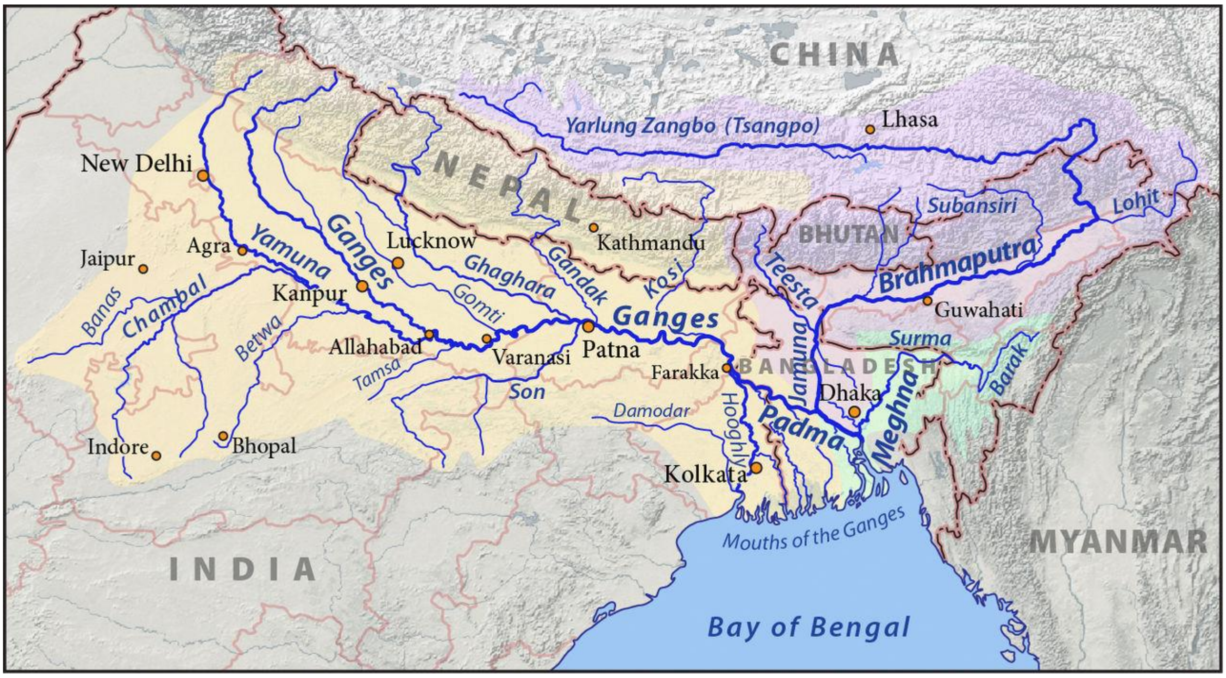

Figure 3: The river system contributing water and sediment discharges to the Bay of Bengal. Source: Pfly - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=15068725

Rivers are a big sources of methane (CH4) Methane to oceans. Atmospheric depositions and coastal swamps are other sources. The huge volume of discharge from active river systems containing increasing methane loads will enhance methane concentration at the Bay of Bengal. Southwest coast region of the Bay of Bengal showed higher methane concentration (4.4 ± 0.9 nM) with super-saturation (208 ± 37%) compared to Northwest region (2.5 ± 0.1 nM and 116 ± 2.6% respectively). Evidently, Indo-Bangla coasts send a total of 21.9×109 g CH4 yr−1 (Rao and Sarma, 2017).

Table 1 : The river system contributing water and sediment discharges to the Bay of Bengal. Source: Kumar et al, 2005

Region	River	Length (km)	Drainage area (km²)	Average discharge (m³/s)
Indo-Bangladesh	Ganges - Brahmaputra - Meghna	2948	1,635,000	38,129 (Trans-boundary, 3rd largest discharge in the world)
Indian-Deccan	Godavari	1465	312,812	3505
Indian-Deccan	Krishna	1400	258,948	2213
Indian East Coast	Mahanadi	858	141,600	2119
Indian East Coast	Brahmi-Baitarani	480	39033	903
South India	Cauvery	765	81,155	677

Region	River	Length (km)	Drainage area (km^2)	Average discharge (m^3/s)
Indian East Coast	East flowing rivers between Mahanadi and Godavari	-	-	561
Indian East Coast	Subarnarekha	470	19300	392
Central India	Mahi	580	34842	383
South India	Penner	597	55213	200.4
India-Myanmar	Kaladan	450	-	3468
Myanmar	Irrawaddy	2170	411000	13000

The water and sediment in the Bay of Bengal is getting contaminated with heavy metals such as Fe, Cd, Mn, Ni, Pb, U, Zn, Co, Cr, As, Cu, Rb, Sr, and Zr etc. from riverine inflows carrying industrial and urban wastes besides pollution from ship breaking yard and other coastal activities including shipping (Khan et al., 2017; Siddiquee et al., 2012). There are many instances of the occurrence of heavy metals in fishes and other food from the Bay of Bengal indicating bioaccumulation and bio-magnification of these contaminants into the food chain. and if not properly regulated through constant monitoring of water and sediment qualities, the health of the Bay and the people dependent on its fisheries and other food resources will be affected.

2.5.11 Marine Spatial Planning

For Bangladesh, the conservation of the future health of the Bay of Bengal in order to avail the opportunities offered by the prospects of blue economy, marine spatial planning is utmost important. MSP will provide a framework for the monitoring of the health of the Bay based on the spatial challenges to its health. The formulation of the MSP should take into consideration the spatio-temporal pattern of water and sediment qualities, the geographic distribution and characteristics of the habitats of different species in the bay of bengal, the life cycle of different species in context of their spatial, water and sediment quality needs. The flow of water and sediments and maintaining their qualities should also be a part of MSP. Based on the background data, MSP should create and outline the management of proper zoning of activities, resource conservation, resource extraction and utilization should propose TO-DOs and NOT-TO-DOs for respective zones by promulgating the means of implementing them through the liaison among the public and private sector stakeholders. The MSP should contain a strong monitoring and evaluation plan in order to check the efficacy of its directives and make improvements where the proposed intervention falls short in ensuring the health of the Bay. An organizational framework to ensure the guardianship of the plan and its follow through also need to be sought by outlining its structure, roles, coordination needs both locally, regionally and internationally to safeguard the marine ecosystem and its productivity for the future generations.

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2.5.12 Marine Protected Areas

Among different tools that MSP can adopt are the creation of marine protected areas in the forms of marine reserve, species sanctuary, banning catches of single or multiple species for specific period time under strong scientific basis with consideration of the livelihood of people dependent on those sources (already in place), formation of captive breeding centres to ensure the conservation and reintroduction of endangered and threatened species. The coastal and marine areas are to be brought under the scheme of ECAs in order to arrest further degradation and take measures to restore the degraded aspects of such areas Chakaria Sundarban. This scheme should be designed in such a manner that not only the designated areas are under the protection but also the threats from outside sources including pollution flow are properly regulated for the success of such schemes. Declaration of such designated areas are quite inadequate in the absence of proper

2.5.13 Regional Collaboration and Cooperation

Eight countries are associated with the Bay of Bengal large Marine ecosystem. Many rivers and river systems flowing through these countries are contributing water sediment and pollutants to the ecosystem at the Bay of Bengal which has further been complicated by the fact that some of the rivers flowing through these countries trans-boundary in nature. on the other hand, there are instances of past disputes over the boundary of marine territory which is taken some of these countries to International court, for example Bangladesh solved Maritime boundary disputes with India and Myanmar through International Court. Moreover, no single country among the eight is technologically, economically and logistically capable enough to handle the management of the Bay of Bengal large Marine ecosystem by itself while any harm caused by any of these countries will affect all other countries by affecting the health of the Bay of Bengal ecosystem. Therefore regional collaboration and cooperation are essential and Bangladesh should put motion in place to take the lead in the formation of regional framework for the joint management of the Bay of Bengal large Marine ecosystem by using shared pool of resources, sharing pertinent research and monitoring data and taking all policy plans and programs in consultation with the others to conserve the ecosystem and its resources to ensure sustainable health of the Bay of Bengal large Marine ecosystem in the future.

2.5.14 Monitoring Health of Bay of Bengal

2.5.14.1 Importance

Action with science is many-a-time more harmful than no action. It is essential to gather science about different aspects of health of the Bay of Bengal in order to launch and maintain a successful program to harness the potential of blue economy be keeping the ecosystem healthy and productive. Only then focused planning and strategy can be formulated to ensure adoption of effective projects and programs for exploitation of resources without jeopardizing the base of productivity - the valuable LME of the Bay of Bengal. The continuous flow of the full range of ecosystem services that the bay is capable to deliver can only be obtained by keeping it healthy through continuous vigilance on its health and rapid action based on monitoring data to correct any wrongdoing. There are sources of problems causing harm to the health of Bay of Bengal and identification of the source and measuring the extent of such harm is needed in advance to ensure justice against the agents of damage.

2.5.14.2 Indicators and Tools

A proper set of indicators should be identified or designed specific to the Bay of Bengal needs to be readied and refined which will be able to reflect the health and dynamic changes in the ecosystem. The tools to measure those indicators are to be designed and put in place. There are already some research done in the area (Borja et al., 2008; Knap et al., 2002; Wells, 2003) but none is available in context of the Bay of Bengal. It is urgent to adopt large scale research activities by including all pertinent academic and research organizations in the country to meet this shortfall.

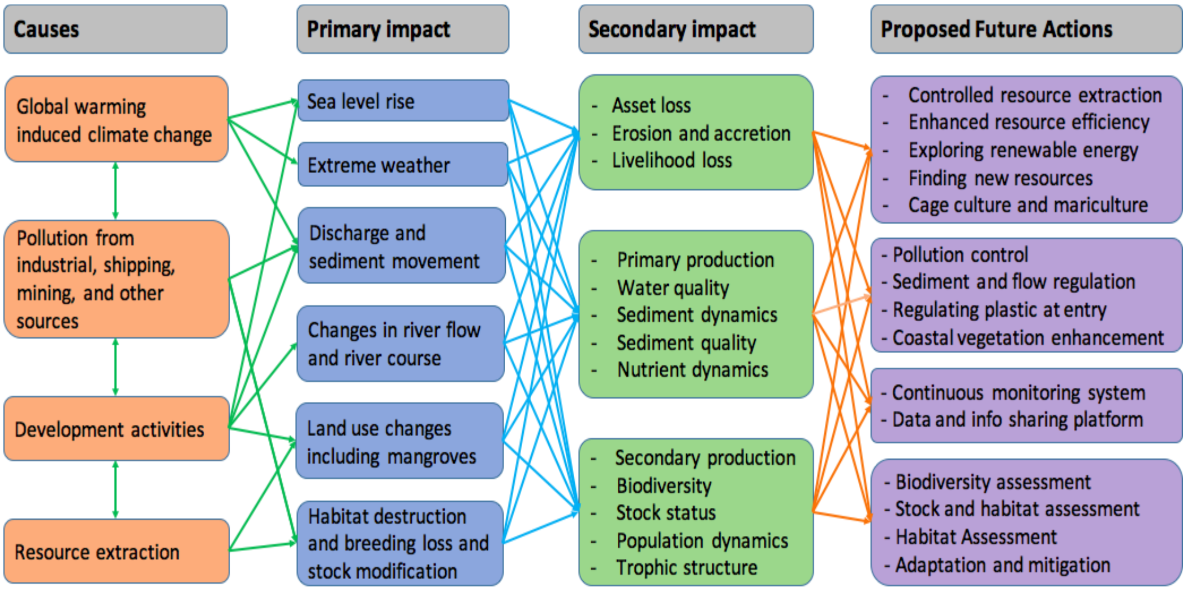

Figure 4: The decision matrix for future health of the Bay of Bengal

2.5.14.3 Means

Physicochemical monitoring: There are existing sensor systems to measure different physico-chemical parameters related to marine environment as part of the global monitoring initiatives related to ocean. However, accessing the state how are not a straight forward for the scientists and practitioner. However, accessing this data are not straightforward for the scientists and practitioner for Bangladesh from Bangladesh which delays important decision making related to the management of the health outerwear Bangalore. Therefore, Bangladeshi take immediate step on its own and kickstart collaboration with the beneficiary countries of the day of Bengal large Marine ecosystem in order to put a network of sensors in place at the Bay of Bengal for real time gathering of data on the physico-chemical properties of water and sediment. The recently launched to Bangabandhu satellite can have a very good use in this pursuit which needs to be explored.

Biological monitoring: Bio-monitoring of marine environment is an emerging field of science which depends on the behaviour of ocean dwelling flora and fauna to assess the changes in the marine environment (Wells, 1999), (Chaumot et al., 2014). There are many species in the ocean which are indicative of the different aspects of ocean water (Cunha et al., 2008) and sediment quality, pollutants such as trace heavy metals (Lafabrie et al., 2007; Rainbow, 1995), PAH (Baumard et al., 1998), organic pollutants, benthic environment (Chakraborty et al., 2014) etc. In Bangladesh, the science of bio-monitoring of ecosystem health of the Bay of Bengal is still at its infancy and this gap needs to be addressed quickly by adopting research programs on the use of locally available indicator species for the monitoring of the health of BOB.

Remote monitoring: GIS and remote sensing has been extensively used in different parts of the world to monitor different aspects of the ocean health including primary productivity. Already there are some global monitoring system in place under international collaboration (Harnayak, 2016). However, the availability of data is always an issue for which there should be alternative local remote sensor based monitoring system should be established.

Artisanal monitoring: The local fishermen and the other people whose livelihood are dependent on the availability of resources for extraction usually develop insights from their day to day exposure to the ocean and marine environment regarding the health of it. There are examples of the use of traditional and indigenous knowledge in the monitoring and management of ecosystem health in marine and coastal environment. The accumulated experience of this artisans can be accumulated through a project for gathering indigenous knowledge and technology (ITK) for ocean health monitoring. This can then be used in Combination with other indicators and tools to get a better picture of the changes in water and sediment qualities as well as the ecosystem health in terms of the changes in the availability of fishes and other catches which the extract from the coastal and marine ecosystem.

Resource output based monitoring: Health index: Based on the multitude of data different, different ocean health indices for quantitative assessment of the health of the Bay of Bengal should be constructed through research initiatives. There are already some models of ocean health indices (Anon, 2018). Based on which new indices for different aspects of health and indices based on different indicators of health can be constructed. Quantitative indices are helpful not only in getting a clear understanding on the health of the marine or coastal ecosystem, it also helps to analyze the factors and different management options. Immediate research initiatives are necessary to meet this gap.

Monitoring Framework: Monitoring the ecosystem health the outer way of Bangalore in near future and in long term is basically a continuous process that requires Collection of data by different means from different sources and analyzing the data to come up with qualitative and quantitative indicator values depicting the health of marine and coastal environment and the resources therein. Consequently, a well-designed framework is needed for a successful monitoring program which will include different stakeholders as providers and consumers of data, a mechanism of exchanging data and outcomes combined with a system of conveying the results relevant authority is for quick response. Planning for designing a monitoring Framework through local and regional collaboration should be set forward immediately if we want to measure the impact of different interventions at the Bay of Bengal for all forms of conservation, assessment and utilization to meet the ends of blue economy.

Data hub and sharing: Data is the cornerstone of informed decision making in any kind of management and making sense of data through different kind of analysis is very crucial for making policy decisions and subsequent program designs. Information and Communication Technology has created immense opportunity of generating, storing, sharing and making sense of huge volume of data known as big data through analysis at convenient time points or in real time. Since Bay of Bengal is the largest among the large Marine ecosystems of the world that provides services to billions and if its health is affected, millions of people in 8 countries dependent on this ecosystem will be affected, there should be a robust, open, versatile and strong data hub and data sharing system in place so that all the stakeholders can share their data and insights with the others to make sure collaborative conservation of the Bay of Bengal large Marine ecosystem. Bangladesh should take immediate steps in creating this platform in order to assert leadership and the benefits of being a host of such hub with international collaboration. Figure 27 shows a decision support system based on the discussions and ideas added into this chapter.

3 POTENTIAL NEW USES FROM THE BLUE ECONOMY PERSPECTIVE

3.1 Wave Energy

(Basu, 2018) Proposed the use of already available sensor network in the Bay of Bengal as wave power generators beside their use in the disaster warning system.

Table 2: Stations Summary

Serial No	Station Name	Latitude	Longitude	Tidal Range, H (m)	Basin Area, A (km^2)	Annual Average Power Generation (MW)
L1	Saint Martin	20.59583	92.331388	2.22	38.13	18.1
L2	Cox's Bazar	21.439464	92.007732	2.54	90.26	55.04
L3	Jahaizzer Char West	22.37436	91.449405	2.94	103.66	80.73
L4	Jahaizzer Char East	22.37436	91.449405	2.94	60.5	47.06
L5	Charchanga	22.03662	90.92496	2.41	159.2	84.65
L6	Khepupara	21.81791	90.279263	2.05	68.3	28.2
L7	Hiron Point	21.72046	82.432934	2.04	35.8	13.78

3.1.1 Rare Earth Metals

The beach sand of Cox's Bazar in Bangladesh is known to contain very high concentration of rare Earth metals including zirconium. This indicates a great potential for Bangladesh since the demand for rare earth metals increasing Global it due to their demand in making high value electronic equipment. Bangladesh is established a reset installation at Cox's Bazar in support with the Australian government to study the concentration of rare Earth metals in the beach sand and to find out optimum path for separating it from sand matrix. keeping the quality of ocean water in Pristine condition will also dictate the cost of separating these minerals from their matrices.

3.1.2 Pure Water

The technology for converting seawater into potable water are becoming economically viable and technologically stronger (Bharadwaj et al., 2008; Hocking, 2013; Hsu et al., 2002; Kamal, 2005). As the population of Bangladesh is rising and the sources for collecting treatable water to meet the demand of rapidly growing population in urban centers, the country will need to evaluate the possibility of purifying water from the Bay of Bengal to meet the demand of water in the coastal regions. Besides drinking water, low cost conversion of saline water can also provide for irrigation (Martínez-Alvarez et al., 2016) and industrial water use (Pais and Ferreira, 2007). Under the climate change scenario, as Bangladesh is worried about the submersion of the low lying coastal land under water, it is inevitable for the country to initiate programs on seawater desalination through promotion of technology to do so. It can be coupled with the salt production (Tanaka et al., 2003; Turek, 2003) to make the process more sustainable. However, the success of any such scheme will largely depend on keeping the water in the oceans free from pollutants which are very difficult to remove during water desalination (https://www.climate-policy-watcher.org/reverse-osmosis/global-desalination-situation.html).

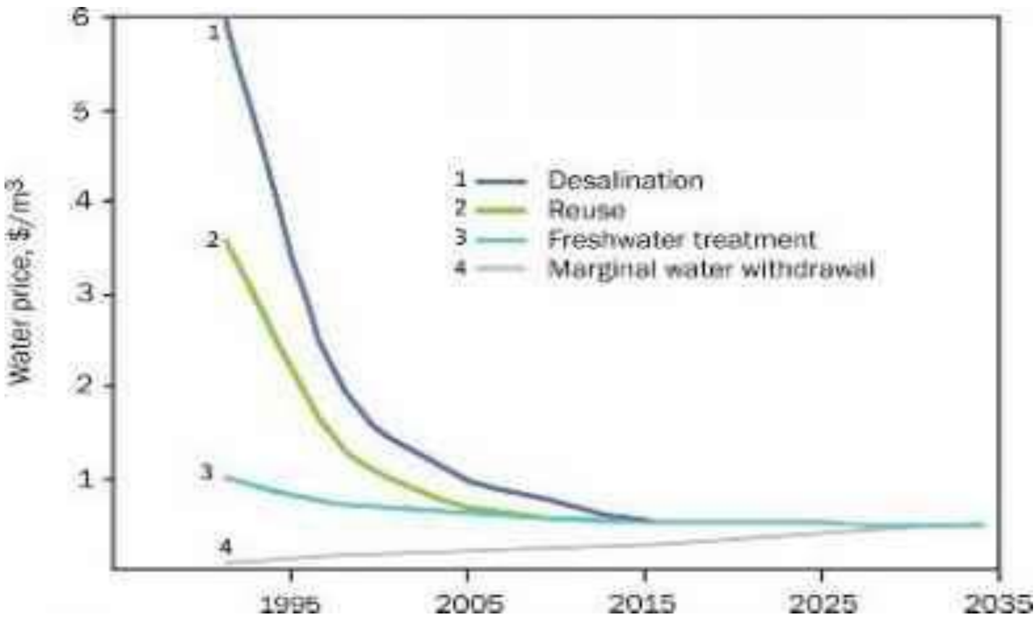

Figure 5: Evolution of water price depending on sources

4 CONCLUSIONS

Blue economy development is crucial for this world in order to sustainably explore and utilize the largest part of the earth's surface covered by blue oceans. It is more so for the countries like Bangladesh which are heavily dependent on coastal and marine environment for food, livelihood, supporting and regulatory ecosystem services provided by the coastal and marine ecosystems. In this context, meaningful schemes of conservation of marine ecosystem and its resources has to be adopted by Bangladesh on a priority basis to maintain the future health of the Bay of Bengal if it wants to sustain and add to the GDP growth other country. This chapter outlines the challenges associated with the future health of the large Marine ecosystem at the Bay of Bengal and has proposed a number of interventions necessary to overcome those challenges. Specifically, the issues related to climate change and its impacts, development induced pollution management, aspects of water and sediment discharge, status of biodiversity and extraction of marine and coastal resources were highlighted.

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