Journal of Ocean and Coastal Economics

Volume 6
Issue 2 *Special Issue on the Blue Economy of Bangladesh*

Article 5

October 2019

Coming Stakes in the Ocean: Food Production, Shipping and Trade, Tourism, Ecosystem-biodiversity, New Technologies and Climate Change Challenges in Bangladesh

Muhammad Abdur Rouf
Fisheries & Marine Resource Technology Discipline, Khulna University, Bangladesh

Md. Moshiur Rahman
Fisheries & Marine Resource Technology Discipline, Khulna University, Bangladesh

Sk Mustafizur Rahman
Fisheries & Marine Resource Technology Discipline, Khulna University, Bangladesh

Md Nazmul Ahsan
Fisheries & Marine Resource Technology Discipline, Khulna University, Bangladesh

Recommended Citation

Rouf, Muhammad Abdur; Rahman, Md. Moshiur; Rahman, Sk Mustafizur; and Ahsan, Md Nazmul (2019) "Coming Stakes in the Ocean: Food Production, Shipping and Trade, Tourism, Ecosystem-biodiversity, New Technologies and Climate Change Challenges in Bangladesh," *Journal of Ocean and Coastal Economics*: Vol. 6: Iss. 2, Article 5.
DOI: https://doi.org/10.15351/2373-8456.1102

1.1 INTRODUCTION

The blue economy approach is based on a vision of "improved wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP 2013). Blue economy is an emerging concept and a frequently discussed issue for strategic planning in all over the world in recent years. It is a revolutionary concept that has opened enumerates number of windows to uplift a national economic functional ecosystem and can act as a milepost from developing to a developed country. Emphasis on this concept and its potentialities, possibilities, and exploiting untapped marine environment would make the economic backbone more strong as well as improving human welfare, creating opportunities for employment, alleviating poverty, ensuring national food security, protecting environmental balance, a solution for adverse impacts of climate change. Bangladesh, as a part of Indian Ocean Rim countries, is also at the nascent stage of development and assessment of blue economy. The concept of 'blue economy' has new impetus in Bangladesh following the resolution of maritime boundary disputes over Myanmar and India giving her sovereign rights on over 118,000 square kilometers of maritime territory, 200 nautical miles of Exclusive Economic Zone (EEZ), and 354 nm continental shelves. An international workshop on blue economy was held in 2014 which highlighted that Bangladesh should move ahead with a 'Bay of Bengal partnership for Blue Economy' to secure sustainable development among the coastal or littoral states ensuring an inclusive and people-centric blue economy. The workshop raised hopes of extracting "plenty of resources" from the Bay of Bengal. The concept of blue economy is subject to multiple activities that are interlinked. These activities include twenty-six maritime economic functions (Alam, 2014) following six broad categories mentioned below which can be identified as integral part of blue economy of Bangladesh. The functions include:

- Food and livelihood – fishery (capture and culture), marine aquatic products, marine biotechnology;
- Energy – oil and gas, sea salt production, ocean renewable energy, blue energy (osmosis) and biomass, aggregates mining, marine minerals mining;
- Tourism – coastal tourism, recreational water sports/yachting and marinas, cruise tourism;
- Maritime trade and shipping – shipping, coastal shipping/feeder services, sea ports, passenger ferry services, inland waterway transport, ship building, ship recycling industries;
- Coastal protection/artificial islands/greening coastal belts;
- Human resource/maritime surveillance and spatial planning.

Explaining all these functions are beyond the capacity of this paper The major stakes such as food production, shipping and trade, tourism, ecosystem-biodiversity, new technologies and climate change challenges are discussed below to project the present and future potential,

constrains, ways to overcome in the context of the blue economy of Bangladesh following published journal articles, reports and different official web documents.

1.2 MARINE FOOD PRODUCTION

1.2.1 Past and Current Situations

Bangladesh has a total of 284,813 $km^2$of marine water area, a coastal belt of 710 kilometers long and a 118,813 km^2 Exclusive Economic Zone (EEZ) which extends from the baseline to 200 nautical miles seaward(Department of Fisheries, 2017; Hossain *et al.*, 2017; Islam *et al.*, 2017). This vast water body produced about 626,528 MT fish in 2016 (16.15% of total production) of which 105,348 MT was caught by trawling, while 521,180 MT was harvested by artisanal fishing (Department of Fisheries, 2017; FRSS, 2017). Bangladesh has also 8,538.63 km^2 rivers and estuaries, and 1,777.00 km^2 the Sundarbans water area which produced approximately 178,458 MT (4.6% of total production) and 16,870 MT (0.43% of total production) fish respectively during 2015-16. In addition, shrimp and crab culture areas are around 2,755.09 km^2 which produced approximately 239,798 MT shrimp (6.18% of total production) and 13,160 MT crab (0.34% of total production) respectively (Department of Fisheries, 2017; FRSS, 2017).

A total of four surveys (1973, 1981, 1983 and 2016) were carried out to assess the stock of marine fisheries resources in Bangladesh (see Table 1). These surveys also identified 149 fish species, 13 shrimp species and 14 different species of other crustaceans and mollusks in marine water areas of Bangladesh (Department of Fisheries, 2017).

Table 1 : Stock of marine fisheries resources (tonnes) in Bangladesh assessed by four surveys

Demersal fish	Pelagic fish	Shrimp	References
264,000-373,000	-	9,000	West (1973)
160,000	90,000-160,000	-	Saetre (1981)
200,000-250,000	160,000-200,000	4,000-6,000	Penn (1983)
Ongoing	Ongoing	Ongoing	Department of Fisheries-FAO (2016-17)

Source: Hossain *et al.*, 2017

Bangladesh earns a great deal of foreign currency (US $505.80 million) by exporting a large proportion of these marine fisheries resources which contribute to 3.65% of its GDP (Department of Fisheries, 2017). It mainly exports ten categories of fishery products (Frozen freshwater fish, frozen marine water fish, frozen shrimp, chilled fish, live fish, dry fish, salted dehydrate, live kusia, live crab, and fish scale/shrimp scull) to more than 55 countries (Ghose, 2014). In 2016, the total exported fishery products (in terms of quantity) from Bangladesh consisted of approximately 53.77% frozen shrimp followed by 16.97% live fish, 14.70% frozen fish and the rest were other fishery products (Department of Fisheries, 2017). The fisheries export data also revealed that out of 4282.82 crore take (in 2016), 84.03% came from only

frozen shrimp export, while 6.39% from frozen fish, 4.30% from live fish and the rest were from other fishery products.

About 5.16 lakhs fishers are working in marine and coastal areas of Bangladesh and 8.33 lakhs farmers are involved in shrimp farming(Department of Fisheries, 2017). Studies showed that around 67,669 unlicensed fishing boats are engaged in fishing in these areas, of which about 51% are non-motorized boats (Shamsuzzaman *et al.*, 2017), and only 242 trawlers are allowed for fishing by the government (MoFA, 2014). There are about 100 fish processing plants (EU approved) where over 1 million people are working as full time or part-time employees (Department of Fisheries, 2017).

1.2.2 Future Potentialities

Future food security and export earnings of Bangladesh may significantly depend on our coastal and marine resources. Since our natural water systems have limitations, it is unlikely that our future requirements will be met without major change. Therefore, the following issues can be considered to increase the existing marine food production sustainably:

(i) Distance fishing: The majority of fishing boats and vessels in Bangladesh operate in coastal areas within 40 m depth (Hossain *et al.*, 2017) which clearly limits the scope for distance fishing in deep waters and high sea fishing zones.

(ii) Modern fishing technology: In Bangladesh, currently fishing practices are carried out with smaller tonnage vessels and using some gear which is unable to harvest deep sea and distant fishery resources (Hossain *et al.*, 2017). So, we can adopt appropriate deep sea fishing technologies, i.e. long line and hook fishing and the utilization of modern gear and vessels to harvest high-valued species, i.e. tuna and other pelagic large fish.

(iii) Mariculture: There are huge opportunities to initiate and introduce both brackish and marine aquaculture in Bangladesh. Breeding and farming of sea bass, mullets, sea bream, etc. could be initiated as important high-valued aquaculture species. Mud crab fattening in ponds and cages, breeding and farming would be the most potential intervention in this sector. In addition, opportunities for breeding, larval rearing and farming of hilsa shad, grouper, oyster, mussel, lobster, etc. also exist as they are species of high interests and demands. Mass culture of different sea weeds could be another valuable option of marine food production Hossain *et al.*, 2017; Hussain *et al.*, 2017). The future growth of mariculture will largely depend on domestication of target species which may ensure better growth, reproduction and minimize the cost of production (Hossain *et al.*, 2017).The existing aquaculture systems in Bangladesh (e.g. shrimp farming) are mostly traditional or extensive methods which follow low stocking density and minimum inputs that produce low yields. Therefore, modern farming techniques (e.g. semi-intensive) should be carried out to boost up the existing production.

(iv) Innovative farming: Coastal and marine (off-shore) ‘cage culture’ can be introduced in Bangladesh using simple technique with minimum cost to produce some valuable species (e.g. sea bass, mullet, hilsa, sea bream, etc.). ‘Aqua silviculture’ or ‘integrated mangrove-aquaculture’ (e.g. mangrove-shrimp/crab) culture can be practiced in

suitable locations which may strengthen the livelihoods of associated stakeholders without environmental damage. 'Integrated multi-tropic aquaculture' could be another system where wastes from the target species (i.e. fish) can be utilized by other species as food (e.g. organic matters for oysters/mussels and inorganic nutrients for seaweeds). Thus, these innovative farming systems can be introduced to produce more marine foods providing environmental sustainability, economic diversification and social acceptability in some selected suitable areas of Bangladesh (Hossain *et al.*, 2017).

(v) Product diversification and value addition: The Bangladeshis mainly consume different types of marine fish and only some selected varieties of crustaceans (shrimp, crab and lobsters), whereas by-catch and many unconventional species (e.g. sole, ray, mollusks, some crustaceans, aquatic reptiles and mammals, seaweeds, echinoderms, etc.) remain unused for consumption and exportation. Thus, there is an excellent opportunity to harvest these unexploited and locally unconsumed fisheries resources to utilize for various purposes (e.g. making fish cutlets/fingers/cakes/balls/sticks, producing fish oils/sauces, shrimp skewer, squid rings, etc.). On the other hand, the fish processing wastes can be used to produce fish meal, silage and compost, and some value added products such as protein, oil, amino acids, minerals, enzymes, bioactive peptides, collagen and gelatin (Hossain *et al.*, 2017). Thus, producing more diversified and value-added products will create great opportunities to find more international markets for higher export earnings.

(vi) Fish stock assessment: The regularly surveyed stock assessment data (e.g. Table 5) can be utilized to i) estimate the optimal harvesting strategy, ii) monitor the abundance and productivity of exploited fish populations, and iii) support sustainable fisheries conservation and management of the existing fish stocks (Hossain *et al.*, 2017).

(vii) Ecosystem-based fisheries management: This is a systematic approach to fisheries management in a geographically specified area that contributes to the resilience and sustainability of the ecosystem and recognizes the physical, biological, economic and social interactions. Thus, this management system can (i) balance the needs of fishing communities with species sustainability and (ii) minimize the anthropogenic activities (e.g. pollution) in the selected ecosystem (Hossain *et al.*, 2017).

(viii) Live feed culture and production: *Artemia spp*. are popularly used to feed different marine fish and crustaceans larvae/juveniles, but the cultivation of live feeds remains to be a bottleneck in Bangladesh. Therefore, it is necessary to produce live feeds following the appropriate technology for sustaining the mariculture industry.

(ix) Disease and health management: Some of the interventions may include developing disease resistant stocks, improvement of husbandry, application of bio-security and eco-friendly health management techniques (e.g. probiotics, immunostimulants), avoid and prevent the irrational use of antibiotics, and embracing organic farming and traceability requirements (Hossain *et al.*, 2017).

(x) Marine biotechnology: This technology can be applied to improve product quality (e.g. lower fat-content, color, texture of flesh) and growth rates, enhance reproduction and

early development success, achieve appropriate stock maturity regimes, control diseases (vaccines, probiotics, SPF and SPR stocks), etc. Since Bangladesh is still lagging far behind in the application of this modern technology, it is necessary to ensure the support facilities in order to enhance the existing marine food production(Hossain *et al.*, 2017; Hussain *et al.*, 2017).

1.2.3 Constraints

The following constraints can be addressed that are needed to solve or improve in order to increase the existing marine food production in a sustainable manner:

(i) Overexploitation: except some mollusk species, major commercial species in coastal and marine waters are overexploited (Islam *et al.*, 2017).

(ii) Lack of rules on by-catch: no regulation and enforcement measures have yet been undertaken on by-catch or trash fish issues. So, the biodiversity is declining which is dangerous for future sustainable management of marine stocks (Hussain *et al.*, 2017).

(iii) Lack of mariculture: very limited numbers of commercially important species are cultured due to various reasons (e.g. domesticated brood and larval availability, hatchery and farming facilities, technological supports, etc.) (Hossain *et al.*, 2017; Hussain *et al.*, 2017).

(iv) Inappropriate knowledge on fish stock: since 1984, there have been no comprehensive fishery surveys in the Bay of Bengal. Hence, the standing stock and maximum sustainable yield values are unknown to policymakers(Islam *et al.*, 2017).

(v) Lack of modern craft and gear: due to the lack of modern craft and gear, it is impossible to harvest and catch the larger fish stocks in deeper areas of the Bay of Bengal (Hussain *et al.*, 2017).

(vi) No specific marine protected area (MPA): in Bangladesh, no straight forward planning has yet been made to declare and establish specific MPAs (Hussain et al., 2017).

(vii) No ecosystems approach to fisheries management (EAFM): lack of planning in the country to implement an EAFM according to FAO Code of Conduct, 1995 (Hossain *et al*., 2014).

(viii) Lack of application of marine biotechnology: lack of planning to initiate application of marine biotechnology for successful marine food production (Hussain *et al.*, 2017).

(ix) Lack of coordination: a clear lack of coordination between public administrations and research institutions; between administrations and private entrepreneurs/businessmen; between/among public and private sector agencies (Hussain *et al.*, 2017).

(x) Marine pollution: Coastal aquaculture, pollutants from seaports and pollution from ship-breaking activities negatively affect coastal fisheries (Ghose, 2014; Islam *et al.*, 2017).

(xi) Middleman in fish chain: Due to limited access to formal credit, most fishers are entrapped into long-term debt bondage with a middleman, who often forces fishers to resort to destructive fishing for more profit(Islam, 2012).

(xii) Extreme weather conditions: Rough seas, as well as frequent cyclones, often force coastal fishers to stay home or to abandon their incomplete fishing trips (Islam, 2012).

(xiii) Widespread poverty: The majority of the small-scale fishers are poor, socially excluded and politically disempowered (Islam, 2012).

1.2.4 Institutional Perspectives

Although some institutions do exist (please find the list in Hossain *et al.*, 2017)to channel stakeholder participation, the enforcement of laws and regulations is sometimes lacking. Therefore, the institutions underlying fisheries and coastal resources management in Bangladesh are important for the following reasons:

(i) Institutions could play a significant role in the management of fisheries and coastal resources in the region to ensure the transfer (or conservation) of the present resource endowments for future generations(Torell and Salamanca, 2001)

(ii) Appropriately crafted formal institutions together with strong political support can enhance the management of common pool resources such as fisheries (Ostrom, 1990).

(iii) Interest in cooperation and interaction between governments, agencies and resource users as well as community involvement in resource management is increasing due to the benefits that accrue from sharing responsibilities and ownership(Pomeroy, 1993).

(iv) Formal institutions provide a structure for cooperation between resource users and government and for participation of local communities and various fisheries organizations as well as other private sector stakeholders in managing natural resources(Torell and Salamanca, 2001).

In Bangladesh, the institutional changes are needed to realize its plans for fisheries recovery and marine ecosystem and therefore, we suggest the following specific measures:

(i) The introduction of regional institutional management councils, whereby all important stakeholder groups are well represented, and the best available science is used in the decision-making process for marine fisheries management. Within such a system, fishing limits would not exceed scientifically determined sustainable levels, and fishermen would need to comply with these limits. Key stakeholder groups would include government, industry, independent scientists, and civil society.

(ii) The introduction of incentives that improve fishing incomes without increasing fishing effort and aggregate fish catch, for example, through the allocation of individual fishing limits or quotas. Funding programs to remove excessive fishing capacity and to promote alternative employment opportunities and workforce training would enhance the success of this initiative, as would the removal of most existing subsidies to the fishing industry.

(iii) The expansion, effective implementation, enforcement, and sustained financing of MPAs throughout EEZ to enhance the recovery of fisheries stocks and the resilience of marine ecosystems.

(iv) The implementation of uniform management and enforcement mechanisms across all water bodies in Bangladesh to ensure that communities and the fishing industry throughout the country are subject to equivalent and effective fisheries regulations.

(v) The promotion of educational opportunities for scientists and fisheries managers to learn from the successes and failures of other nations in marine resource management.

(vi) The establishment of a public process for data sharing and transparency on fisheries practices, catch, stock status, and ecological impacts.

If we are able to carry out these institutional reforms, it will likely experience a true paradigm shift in fisheries management. To be successful, however, the government will need to commit financial resources to cover the transition costs of institutional change. Without adequate funding, efforts to transform fisheries management in Bangladesh will likely be futile.

1.3 SHIPPING AND TRADE

1.3.1 Importance and Present Status

Shipping as a carrier of trade and is more sustainable than any other mode as it is the safest, most secure, most efficient and most environmentally sound means of bulk transportation – with declining rates of accidents, zero terrorist incidents, improving turnaround of ships and significant reductions in discharges to sea or emissions to air. Bangladesh, having long coastline and age old tradition of sea navigation, has a relatively strong development of maritime services that support the sea trade and sea transport functions ranging from shipping agents, freight forwarders, and insurance to classification and inspection, and maritime education in the Marine Academies/Dockyards/Shipyards/ Nautical Institutes etc. According to BSC (2017), net benefit from the sector was 8.66 crore in 2016-17 fiscal year which is 4.31 times higher than the net benefit in 2012-13 and indicates a growing industry in Bangladesh. More than 90% of its external freight trade is seaborne. There are 74 registered merchant ships and 124 registered shipyards in the country. Among the shipyards, most of them can design and fabricate ship up to 3500 DWT and eleven local shipyards of international standard are capable of making ships up to 10000 DWT. Bangladesh has started exporting her ocean going ships to a high-end market like Denmark competing with giant competitor like China, India and Vietnam since 2008. Shipbuilding has shifted from developed country like Europe, Japan to China, India and now in Bangladesh due to the lower labor cost and overhead. Nearly fifty thousand skilled workers and one lac semi-skilled workers are now working in these industries.

1.3.2 Constraints

Huge investment is the prime requirement for the industry. There is dearth of capital and investment due to high risk for both the entrepreneurs and bankers. In addition, interest rate for

the industry (12-16%) is higher than the garments industry (7%). Moreover, the industry required local and foreign banks as guarantee. Bank guarantee for export of ships from Bangladesh is about 16% whereas for other sectors it is around 1 - 2%. On the other hand, it is 0% in other competing countries like Korea, China, Japan, India etc. Commission for opening import L/C at the rate of 0.20% is charged by banks of other competing countries whereas 8% is charged by the Bangladeshi commercial banks. Therefore, additional financial cost of ships built in Bangladesh is about 15 to 25% which is higher than the other competing nations like China, Korea, Japan, India, Vietnam, and Brazil.

Safety health and environment aspects including management cultures are very poor which hinders the employee right and creates or increases pollution. Ancillary industries, research and development (R&D), skilled manpower, model testing facilities, other facilities like electricity, gas are insufficient in the country to support the industry for price competitiveness in international ship markets.

1.3.3 Policy Recommendations

To acquire the benefit of blue economy to its greatest potential a sustainable and equitable basis, modernization of the port, modern merchant ships, settlement between national and international industry are necessary. The present ocean going vessels in Bangladesh are more than thirty years in age. As a result, they have higher maintenance costs and suffer greater down time when compared with newer ships. To compete with other Asian shipbuilding giants, the ship building industry should be facilitated with a subsidy of at least 20%, sufficient raw materials with ancillary industries need to venture. It is also essential to establish a corporate management culture in this industry with ensuring employee rights, safety and health, and sustaining environment following IMO regulations. At present most of the shipyards located in Narayangonj, Dhaka but international market oriented shipbuilding farms should be shifted in coastal areas (Patuakhali, Bhola, Chittagong).

The World Maritime Day (WMD) – 2017 with the theme of ‘Connecting Ships, Ports and People’ in Bangladesh recognizes the importance of shipping safety, maritime security and marine environment and acknowledge maritime industry. Bangladesh government has been declared the industry as a “Thrust Sector” and initiating various action plans to overcome the aforementioned weaknesses. Government as well as local and private shipping companies need to go some forward and have to have clear concept and knowledge about the benefits of ocean could give us.

1.4 TOURISM

1.4.1 Importance and Present Status

Tourism is an emerging global economic force in the 21st century which creates jobs, drives exports, and generates prosperity across the world. According to the world travel and tourism council, travel and tourism continues to be one of the world’s largest industries in the world and is shown to account for 10.4% of global GDP and 313 million jobs, or 9.9% of total employment, in 2017 (WTTC, 2018a). In Bangladesh, the direct contribution of the sector to

GDP was US$5,310.4mn (2.2% of total GDP) and the total contribution was US$10,567.4mn (4.3% of GDP) in 2017. Regarding employment in 2017, the sector directly supported 1,178,500 jobs (1.8% of total employment) and total 2,432,000 jobs (3.8% of total employment) including indirectly supported jobs in Bangladesh (WTTC, 2018b). Tourism destinations in Bangladesh are mostly nature based and some them are included in the UNESCO Heritage List. The popular tourist destinations and attractions are historical mosques and sites and monuments, archaeological sites, world's longest sea beach, hilly areas and forests of Sundarban and wildlife in the Chittagong hilly area, tribes, miles of rolling tea gardens of world famous brands and islands. The sector is in developing stage and the market has both national and international tourist actors competing for the existing market (BPC 2015). At present, Bangladesh Parjatan Corporation (BPC) looks after the tourism sector in Bangladesh under the ministry of Civil Aviation and Tourism. Bangladesh government has reformed the national tourism policy in 2010. The aims and goals of this policy are to increase employment, ensure economic development, environmental purity and sustainability (Siraj et al., 2009). The major objective of the policy is to develop Eco-tourism through conservation of natural resources and promote well-being of the community, preservation of cultural values of the local community and their participation and sharing benefits.

Bangladesh Tourism Board established in 2010 to meet the strong demand for private sector and the tourism professionals. It is affiliated with United Nations World Tourism Organizations (UNWTO).

1.4.2 Constraints

Tourism growth in Bangladesh is slower than the pace of growth at world level as well as SAARC countries (WTTC, 2012). The rate of contribution to national GDP is also decreasing.

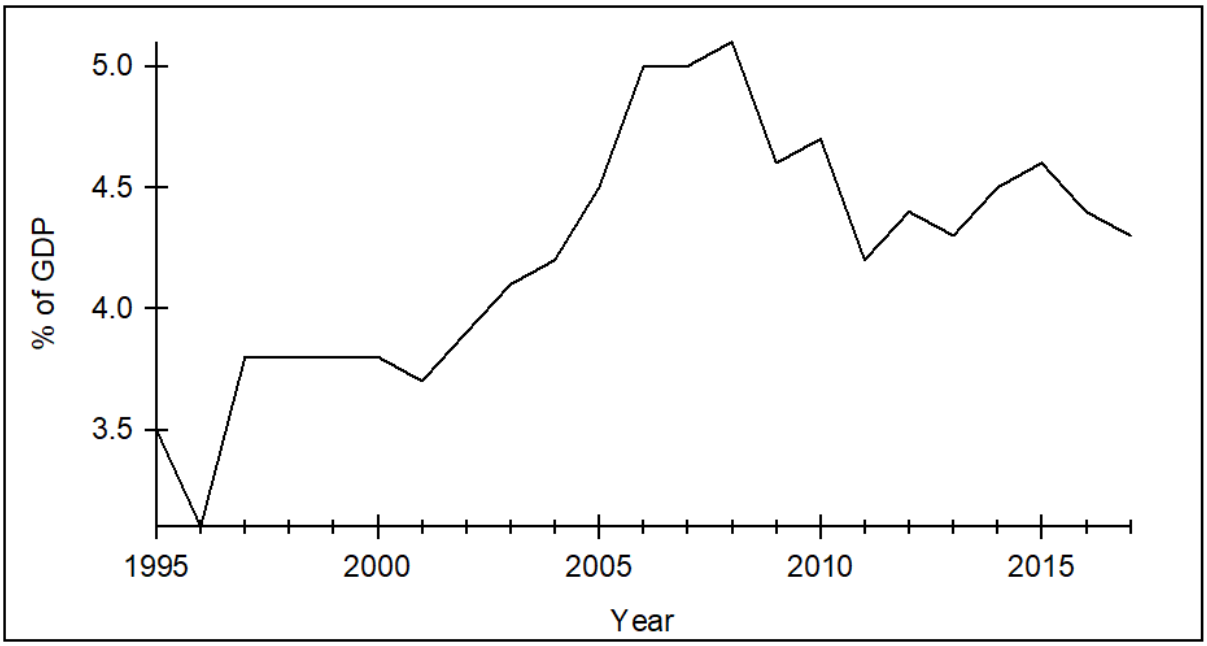

Figure 1 : Trend of the tourism sectors contribution to national GDP in Bangladesh. Source : https://knoema.com/atlas/Bangladesh/topics/Tourism/Travel-and-Tourism-Total-Contribution-to-GDP/Contribution-of-travel-and-tourism-to-GDP-percent-of-GDP

Major constrains in this sector include unplanned development of the industry, lack of adequate knowledge and professionalism, lower level of co-operation and innovation in the sector. The lack of government support has resulted in poor infrastructure such as the poor condition of transport and power. The airline sector of Bangladesh has also negatively affected tourism industry due to limited flights in domestically and internationally, flight delays, inefficiency and mismanagement at the airports. Local travel is hampered by lack of amenities on the highways, poor road conditions as well as frequently road accidents. Political unrest, adverse security situation within Bangladesh deterred both domestic as well as foreign tourists from exploring the country. Natural calamities like devastating floods and cyclone causes extensive damage to the country and negatively effect on tourism. In addition, availability and access to the right information is not easy and the insufficient safety measures make the tourists worried.

1.4.3 Policy Recommendations

A dynamic and supporting ministry of tourism is needed which could focus on ground at gross root level and able to move out to top level. This ministry or responsible government organization needs to determine the issues and strategies for short term and long term to run and develop the product and services, market, infrastructure, human resources and environment associated with the industry. Management, administration and control of the sector without having any bureaucratic process are also a serious concern.

Government needs to create corporate culture in the tourism industry and forthcoming to involve private sector to develop and diversify the marketing aspect. Focus on using social media and information technology, allocating promotional fund and event based promotional activities are also needed for tourism marketing.

It is also essential to take initiatives to develop infrastructural facilities, facilitate easy access to different destination with standard accommodation, liberalize air transportation and visa

facilitation, build better image of Bangladesh, ensuring safety and security of tourists, and create social awareness and responsiveness. Thereby the industry will increase the national GDP with employment opportunities as well as disseminate and uphold the culture and customs of the country.

1.5 NEW TECHNOLOGY

1.5.1 Importance and Present Status

Marine biotechnology is the creation of products and processes from marine organisms through the application of biotechnology, molecular and cell biology, and bioinformatics. There are promising and exciting achievements in biochemistry, genetics, genomics, aquaculture, bioenergy, and other related fields, beginning with genetic recombinant technology as applied to marine algae. Marine biotechnology clearly incorporates enormous social and economic benefits, thus providing a foundation for problems related to food as exemplified by ocean farming.

Marine biotechnology is one of the youngest biotechnology approaches. Modern marine biotechnology has been developing rapidly since the 1980s. The opportunity for application of marine biotechnology in Bangladesh is highly promising but very little is done in this area. The main marine biotechnology industry at present is aquaculture, which concentrates on few marine fish/shrimp farming and breeding. The country up to now has not harnessed the marine resources. Therefore, it is extremely important that efforts are made on research and development in the areas of marine biotechnology.

1.5.2 Constraints

There is the risk of unintended extraction of marine species associated with blue biotechnologies. This field is yet ill defined and poorly regulated. The precautionary principle should be applied to bio-nanotechnology, biomaterials and the introduction of genetically modified fish, shellfish and microorganisms. In Bangladesh due to lack of implementation and enforcement of management measures, many opportunities in marine resources development remain untapped. Obstacles in development potential of marine biotechnology including, lack of funding, lack of infrastructure, lack of available workforce (quantity/quality), deficiency of information, policy landscape, political vision, indigenous skilled capacity, scientific research capacity, scientific research strategy, and so on.

1.5.3 Policy Recommendations

The development of blue biotechnology for food, health products and pharmaceuticals presents novel possibilities, and strategies for developing these possibilities are suggested. Where there are opportunities for rationalization of activities under different policy initiatives and between sectors to achieve the overarching objectives of the blue economy, this is strongly supported. To be sustainable, the sectors that are developed need critical mass. This can result in local synergies, sharing of resources and enhanced capacity to add value. Moreover, international interaction will invariably be easier and more equitable. A standard approach, used internationally to facilitate the creation of such a critical mass, is the development of

technology incubators, science parks, etc. Listed below are additional recommendations that address the full range of factors that need to be in place to implement a robust, successful blue economy.

- Locally generated or internationally awarded funds could be allocated to specific projects through specific fund for blue economy activities.
- A coordinated research and development strategy is needed to address specific sector requirements and the broader implementation of the blue economy.
- Capacity-building, effective international networking and collaboration, and skills transfer from foreign academic organizations and technology providers, in addition to regional cooperation, are crucial because of limited in-country resources.
- Need a linkage among the policy makers, researchers, GOs and NGOs towards the exploitation or development of blue resources.

1.5.4 Future Potential

Marine biotechnology may include techniques such as bioprocessing, bioharvesting, bioprospecting, bioremediation, using bioreactors etc (so called process biotechnology techniques); aquaculture/fisheries; gene, protein, or other molecule based techniques; while applications may include: health, food, cosmetics, aquaculture and agriculture, fisheries, manufacturing, environmental remediation, biofilms and corrosion, biomaterials, research tools etc. Therefore, marine biotechnology has a horizontal scope encompassing very different applications, for all of which the marine environment is providing the resources. The term “marine biotechnology” denotes a potentially wide variety of activities, which may be divided into the following categories.

1.5.4.1 Aquaculture Industry

The use of modern biotechnological tools for rearing and enhancing the production of aquatic species can not only help meet the global demands of seafood, but also enhance aquaculture farming per se. These techniques also improve the health, reproduction, development and growth of aquatic organisms, and thus promote the inter-disciplinary development of environmentally sensitive and sustainable systems. This in turn will lead to substantial commercialization of aquaculture. Biotechnology has the potential to offer solutions to several problems in the areas of aquaculture.

Reproduction: Several fishes do not spawn spontaneously when placed under captive conditions. In the past, fish gonadotropin, a group of hormones that stimulate reproduction, were produced in small amounts by extraction and purification from crude preparations of thousands of pituitary glands. At present, large quantities of highly purified gonadotropin can be produced in the laboratory through recombinant DNA technology. Hermaphrodism is a common phenomenon in many coral reef fishes. Some species are male in the early stages of their life cycle, and turn female on the later stages or vice versa. Through genetic engineering, sex of the species can be regulated as it reaches maturity.

Transgenic fish: Conventional fish breeding is based on selecting the fish brood so as to enhance the desirable traits in the fish. However, this process is slow and unpredictable. New molecular tools are much more efficient in identifying, isolating and constructing the genes responsible for desirable traits, and subsequently transferring them to the brood. The production of transgenic fish is in-fact much easier than producing other transgenic mammals. This is because fish produce a large number of eggs (from several dozens to several thousand), which can generate large quantities of genetically uniform material for experimentation. Genetic engineering is also considered to have significant potential to enhance aquaculture through the use of recombinant DNA techniques that would yield faster-growing and/or disease-resistant varieties of fish or mollusks.

Growth promotion: Majority of transgenic research on commercially important fish species are focused on improving growth rates by transfer of growth hormones. This is economically sound because transgenic fish with altered growth traits reach maturity in a shorter span of time than non-transgenic fish and exhibit better feed conversion efficiency. These advantages further translate to shorter production cycle, lower production costs, and reduced pollution in aquaculture facility.

Nutrition: Trash fish or wild fish species for fish meal as protein source for aqua feeds are very limited. Thus, plant-based protein sources are a sustainable option with additional advantage of being cheaper. However, most plants have anti-nutritional characteristics that are not favorable for feed utilization. For instance, carnivorous fishes have limited ability to use up carbohydrates due to the digestibility of polysaccharides. To address this concern, carbohydrate metabolism of salmonid fish was enhanced through genetic engineering. Fish oil is economically important in fish feed production, as well as to human health. The demand for fish oil continued to grow alongside the expansion of aquaculture industry because it is a major lipid source in aqua feeds.

Health management: Traditional disease diagnosis involves analysis of cells and tissues of organisms, which takes a long time to be done. Molecular biology (PCR) provides valuable information about life cycles and mechanisms of pathogenesis, antibiotic resistance and disease transmission. This information can enhance our understanding of host immunity, resistance, susceptibility of diseases and associated pathogens.

Freeze resistant fish: Recombinant techniques can be used to transfer an antifreeze protein (AFP) gene to confer freeze resistance on various species. AFPs are produced by several cold-water marine teleosts (like winter flounder, ocean pout, sea raven, shorthorn sculpin). These proteins prevent ice crystal formation in the blood, and hence protect the fish from freezing.

Conservation: Molecular tools can be used to identify and characterize important aquatic germ-plasm including many endangered species. These tools have made it possible to analyze the genomes of many aquatic species. They have also helped us understand the molecular basis of gene regulation, expression and sex determination. This can improve the methodologies for defining species, stocks and populations.

1.5.4.2 Seaweeds Industry

Seaweeds are marine algae (macro algae) that exist in the marine environment. These are sea-dwelling plants that lack true stems, roots and leaves. Just like land plants, seaweeds too have photosynthetic machinery and use sunlight to produce food and oxygen from carbon dioxide and water. Seaweeds are a rich source of food, fodder and a host of industrially important chemical compounds. In fact, seaweed is a billion-dollar industry. The most valued seaweed is the red algae Porphyra or nori, which is a major source of human food throughout the world. The other edible seaweeds include *Gracilaria, Undaria, Laminaria,* and *Caulerpa*.

1.5.4.3 Pharmaceutical Industry

Biotechnology researchers have isolated many bioactive substances from the marine environment, which hold great potential for treating various human diseases (anti-bacterial/viral & anti-tumor agents). Particular attention has been paid to a variety of toxins formed by marine organisms. Nutraceuticals constitute a variety of substances used in the food supplement and "natural health" markets.

1.5.4.4 Chemical Industry

Marine organisms are the source of a variety of chemicals used in industrial processes. The best-known example is carrageenan, extracted from seaweed and used as a thickener in ice cream and other foods and as a laboratory culture medium. A variety of other chemicals (Agar-agar, alginates, enzymes etc.) used both in food processing and other manufacturing processes have also been developed from marine resources. Oyster shells are providing a new source of synthetic biodegradable polymers with a wide range of useful industrial properties. These polymers are used for water treatment and agricultural applications.

1.5.4.5 Pollution Control

Degradation of environmental pollutants is an important concern globally. Studies have shown that marine microorganisms exhibit unique biodegradation pathways for breaking down several organic pollutants. Immobilized cells of bacterium *Pseudomonas chlororaphis* produce pyoverdin, which hastens the breakdown of toxic organotin compounds in seawater. Other studies have also shown that some marine organisms produce eco-friendly chemicals like biopolymers and biosurfactants which can be used in environmental waste management and treatment. Anti-fouling products that can be extracted *e.g.* from marine organisms, including bacteria as well as the mucus of fish and starfish prevent sessile marine organisms such as barnacles from attaching to boats, piers and other submerged manmade structures are examples.

1.5.4.6 Biofuel Industry

Biofuels from microalgae is one of the economically viable ways to reduce fossil fuel consumption. Microalgae are considered better sources of biofuels than higher plants because of their high oil content; ease of propagation (can be cultivated in seawater or brackish water,

thus do not compete with the resources of conventional agriculture); residual biomass after oil extraction can be used as feed or fertilizer or fermented to produce ethanol or methane; and the biochemical composition can be controlled by modifying growth conditions. Microalgae with superior biomass productivity and lipid content include *Chlorella, Tetraselmis, Chaetoceros, Isochrysis, Skeletonema,* and *Nannochloropsis.*

1.5.4.7 Job Market

The enormous biodiversity and growing genetic life in sea are the key driving factors for the growth of marine biotechnology market. Rising cosmetic industry, increasing need for environmental safe feed stocks for sustainable production in display technologies and growing healthcare industry are driving the global marine biotechnology market. Rising support of key players towards providing sustainable products helps in boosting the global marine biotechnology market.

1.6 BIODIVERSITY

1.6.1 Importance and Present Status

Marine biodiversity includes coastal and marine plant and animal species, their genetic variety, the habitats and ecosystems they form part of, and the ecological processes that support all of these. Marine biodiversity plays a key role through ecosystem services (provisioning and regulation, amongst others). They provide economic wealth and resources that range from active ingredients for pharmaceuticals and medicine to products from fisheries and aquaculture, as well as contributing to cultural well-being and supplying relevant "biological models" for both basic and applied research. Based on the International Union for Conservation of Nature and National Resources, 2514 species of teleosts are already extinct in the wild or threatened to some degree. Many subspecies, varieties, geographically isolated subpopulations or stocks, which are often of particular interest as fishing resources, are also in danger of extinction.

Bangladesh is ranked 3rd largest in aquatic biodiversity in Asia behind China and India, with approximately 300 species of fresh and brackish water fish species (Hussain and Mazid, 2001). This species diversity has been attributed to one of the world's largest wetland (Bengal Delta) and three large river systems that flow from the Himalayan Mountains into the Bay of Bengal. The Bay of Bengal is blessed with 442 fish species, 36 marine shrimps. About 336 species of mollusks, covering 151 genera have been identified. In addition, 3 lobsters and 7 species of turtles and tortoises, 168species of seaweeds, 3 sponges, 16 crabs, 3 lobsters, 10 frogs, 3crocodiles, 24 snakes, 3 otters, 1 porcupine, 9 dolphins and 3species of whale found in Bangladesh territorial water. Among the marine and migratory species of animals, 4 fishes, 5 reptiles, 6 birds, and 3 mammals are threatened.

1.6.2 Constraints

The loss of marine biodiversity is weakening the ocean ecosystem and its ability to withstand disturbances, to adapt to climate change and to play its role as a global ecological and climate regulator. The ocean is home to millions of species. The health of the oceans is strongly

dependent upon this marine biodiversity. Life in the ocean is an essential component of climate regulation.

Fish is a primary source of animal protein for at least one billion people in the world. Apart from overfishing or pollution, climate change alone heavily affects the food resources for human populations, in developing/least developing countries like Bangladesh. Losses in biodiversity also imply a loss of genes and molecules that are potentially valuable for medical research and industry. Though Bangladesh is a small and densely populated country it is rich in biodiversity. Rapid extraction of seed as well as brood fish from natural waters combined with destructive unregulated fishing practices has led to the endangerment and possibility extinction of a number of rather valuable native species. Loss of aquatic habitat due to climate change, temperature raring, acidification, siltation, dam construction, and other anthropogenic activities has been one of the primary causes of species loss. The major constrains for the degradation marine biodiversity in Bangladesh includes high population density; poor integration among the respective departments; policy and information gaps; lack of enforcement or accountability; over exploitation; illegal fishing practices; PL collection, by catch; inadequate and poorly managed system of protected areas; no political vision; lack of awareness; climate change (ice melting due to temperature raise, ocean acidification); lack of alternate livelihoods in sensitive habitats; pollution (effluent, sedimentation, siltation, shipbreaking industry / ship recycling); invasive species; and Corruption.

1.6.3 Policy Recommendations

The biodiversity losses in the nature could be overcome with the following activities:

- Establish baselines to study climate change impacts on biodiversity and establish a monitoring program to track changes
- Ensure alternative income for the communities those engaged in shrimp fry collection (to avoid by catch) or fishing (to protect brood fish during breeding season)
- Support rehabilitation of the rare, threatened and endangered native, wild and domesticated species. Develop breeding (in-situ) or preservation techniques (ex-situ) for important aquaculture species or endangered species for future restoration process
- Develop course curricula in University level and provide training of the trainers on biodiversity
- Promote understanding and awareness of the stakeholders of the importance and methods of conservation through developing appropriate communication tools, including materials
- Develop the capacity of different sectors, including the Government, of implementing the necessary tasks in respect of biodiversity conservation, as appropriate
- Conduct village-based inventory of flora and fauna, including their traditional uses.
- Identify the impacts of climate change, desertification, floods and other processes on the integrity of ecosystems and species and develop suitable management plans.

- Develop action plans for reducing levels of pollution
- Encourage co-management activities that include sound representation from local communities, not only the rich and politically connected for the protection of biodiversity
- Strengthen mechanism where international donors and project implementing agencies in the environment field gather regularly to share ongoing project results, data, lessons learned and information on planned projects

1.6.4 Future Potential

Biodiversity is important to science because it helps us understand how life evolved and continues to evolve. It also provides an understanding on how ecosystems work and how we can help maintain them for our own benefit. Being a natural resources dependent economy, biodiversity plays very important role to the life and livelihoods of the people here in Bangladesh. The globally important ecosystems, such as the forests, freshwater wetlands, and marine fishing area indeed make up a significant portion of ecosystem services and national economy. Well-functioning ecosystems and human well-being are directly related, where biodiversity contributes significant value to services given by any ecosystem. The economic potentials of marine biodiversity are summarized with the following areas.

- Food resources: agriculture, livestock, fish and seafood, seaweed
- Biomedical research: coral reefs are home to thousands of species that may be developed into pharmaceuticals to maintain human health and to treat and cure disease
- Tourism and recreation: Beaches, forests, parks, ecotourism
- Industry: Textiles, building materials, cosmetics, trash fist for feed industry etc., and
- Conservation: Economical important species

1.7 CLIMATE CHANGE CHALLENGES

1.7.1 Climate Change and Marine Resources in Bangladesh

Bangladesh has been identified as one of the most climate change affected countries in the world (Kreft *et al.*, 2017). Several evidences have already shown the long-term changes in sea water temperature (Singh, 2012), acidification(Da Silva *et al.*, 2017), deoxygenation (Diaz and Rosenberg, 2008), salinity distribution (Hussain *et al.*, 2012), sea level (Brammer, 2014) and cyclones (Balaguru *et al.*, 2014) in the Bay of Bengal. These multiple stressors are likely to have serious effects, in particular on the Bay of Bengal ecosystem which is high in productivity and support significant fisheries resources. Thus the productivity, habitats and biological process of this large ecosystem have been affected due to unexpected fluctuations of climate change variables(Jagtap and Nagle, 2007; Vivekanandan *et al.*, 2009a; Hoegh-Guldberg and Bruno, 2010; Vivekanandan *et al.*, 2016; Da Silva *et al.*, 2017).

Distribution (Poloczanska *et al.*, 2013), composition of communities (Perry *et al.*, 2005), physiology (Somero, 2010) of different fish species, increase in frequency and intensity of coral bleaching (Vivekanandan *et al.*, 2016), prevalence, transmission and pathogenicity of parasites and diseases (Britton *et al.*, 2011; Macnab and Barber, 2012), etc. have become evident due to alterations of physicochemical conditions of any ecosystem like the Bay of Bengal. Some investigations have revealed the impact of climate change variables on different marine fish species of the Bay of Bengal, for examples: (i) extension of distributional boundary of the oil sardine (*Sardinell alongiceps*) and the Indian mackerel (*Rastrelli gerkanagurta*) (Vivekanandan *et al.*, 2009b); (ii) evidence for a shift in latitudinal distribution and abundance of some catfish species (Vivekanandan *et al.*, 2016); (iii) shift/extension of depth of occurrence of the Indian mackerel (*R. kanagurta*) (CMFRI, 2008); and (iv) phenological changes, such as the occurrence of spawners of the two species of threadfin breams (*Nemipterus japonicus* and *Nemipterus mesoprion*) linearly decreased with increasing temperature during April–September, but increased with rising temperatures during October–March (Vivekanandan and Rajagopalan, 2009).

It has been predicted that fisheries resources of Bangladesh, particularly traditional fisheries, will be the most vulnerable to climate change (Minar *et al.*, 2013; Vivekanandan *et al.*, 2016). Climate warming will also affect the inland and coastal aquaculture sectors of this country(Ahmed and Diana, 2015; Kais and Islam, 2017). Impacts will include changes in hydrology and therefore availability of water, physical threats to aquaculture facilities, and prevalence or spread of known and new diseases of aquatic organisms (Vivekanandan *et al.*, 2016). Prediction also shows that the sundarbans ecosystem will be affected which is one of the major source of marine fisheries resources in Bangladesh (Chowdhury *et al.*, 2010; Minar *et al.*, 2013). Thus the impacts of long-term climate change will decrease the Bay of Bengal's productivity, alter food web dynamics, reduce abundance of habitat-forming species, shift species distributions, and a greater incidence of diseases (Chowdhury *et al.*, 2010; Hoegh-Guldberg and Bruno, 2010; Fernandes *et al.*, 2013).In addition, when the climate-induced environmental changes will interact with other anthropogenic alterations (pollution, nonnative species, habitat degradation: Staudt *et al.*, 2013), they may have direct or indirect influence on different life-history traits of living organisms (Pörtner *et al.*, 2001; Rijnsdorp *et al.*, 2009; Vivekanandan and Rajagopalan, 2009; Pörtner and Peck, 2010; Anttila *et al.*, 2013). Thus, predicted climate change will seriously affect the coastal and marine ecosystem of Bangladesh and thereby influence the overall future marine fisheries production of this country.

1.7.2 Adaptation Strategies

Bangladesh Climate Change Strategy and Action Plan (BCCSAP, 2009) which is built on the following six main pillars has provided the best strategies and plans to tackle the climate change effects in this country (Bhuiyan, 2015):

(i) Food security, social protection and health: To ensure that the poorest and most vulnerable in society, including women and children, are protected from climate change

and that all programs focus on the needs of this group for food security, safe housing, employment and access to basic services, including health.

(ii) Comprehensive disaster management: To further strengthen the country's already proven disaster management systems to deal with increasingly frequent and severe natural calamities.

(iii) Infrastructure: To ensure that existing assets like coastal and river embankments are well maintained and fit-for-purpose and that urgently needed infrastructure, such as cyclone shelters and urban drainage, is put in place.

(iv) Research and knowledge management, which facilitate prediction of likely impacts of climate change on different sectors of the economy and socio-economic groups, to ascertain future investment strategies and to ensure that Bangladesh is networked into the latest global thinking on science and best practice regarding climate change.

(v) Mitigation and low carbon development, used to evolve and implement low carbon development options, as Bangladesh's economy is expected to grow over the coming decades and the demand for energy increases.

(vi) Capacity building and institutional strengthening: To enhance the capacity of government ministries and agencies, civil society and the private sector to meet the challenges of climate change and mainstream them as part of development actions.

In case of marine fisheries, the most important and critical adaptation measures will be to develop human resources capacity to increase understanding of the coastal and marine resources, and implement measures to sustainably manage fisheries. Two main directions can be taken for climate change response (i) contribution to the understanding of large-scale processes and climate change effects, and (ii) contributions to adaptation by addressing habitat degradation, pollution (Srinivas *et al.*, 2015; Ramana and Devi, 2016) and fisheries management, as well as developing capacity and resilience of coastal populations. Recognizing that current problems in weak fisheries management make the sector vulnerable to climate change, different organizations (i.e. government, non-government, national or international) should provide supports for adaptation and increase resilience by strengthening fisheries management and providing assistance to improve fisheries assessments. By strengthening governance, it will be another good strategy for the integration of climate change adaptation into decision-making and response initiatives, e.g. disaster risk management plans (Vivekanandan *et al.*, 2016).

If the above-mentioned strategies and plans are implemented properly, the overall coastal and marine fisheries sector of Bangladesh may able to cope with the climate change impacts and adapt well to keep sustainable production from this sector.

1.7.3 Problems in Implementing Policies

A number of barriers to climate change adaptation in coastal and marine fisheries sector of Bangladesh include-technologically poor boats, inaccurate weather forecast, poor radio/other signal, lack of access to credit, low incomes, underestimation of cyclone occurrence, coercion

of fishermen by the boat owners and captains, lack of education, skills and livelihood alternatives, unfavorable credit schemes, lack of enforcement of fishing regulations and maritime laws, and lack of access to fish markets. These local and wider scale factors interact in complex ways and constrain completion of fishing trips, coping with cyclones at sea, safe return of boats from sea, timely responses to cyclones and livelihood diversification (Islam *et al.*, 2014; Islam and Nursey-Bray, 2017).

1.7.4 Role of Different Organizations:

Formal institutions can play a major role in implementing and resourcing various forms of adaptation and/or interventions, which can take the form of knowledge (training/skill development), information, and support (technological, inputs, financial) (Islam and Nursey-Bray, 2017). In turn these initiatives could change local perception of risk thus improving the adaptation capabilities of local people through formal and informal institutions (Agrawal *et al.*, 2008).

The Ministry of Fisheries and Livestock and the Ministry of Food and Disaster Management deliver climate change adaptation programs and have vital roles in shaping climate change adaptation in fisheries in Bangladesh. In addition, coastal afforestation programs, have been implemented by Ministry of Environment and Forests of Bangladesh to reduce the vulnerability of coastal communities to climate change (Sovacool *et al.*, 2012). Climate adaptive fisheries can be implemented by the development of climate change resilient production technologies, species varieties (adaptive aquaculture species), sustainable fishing, fish breeding technologies, community awareness building and ensuring a flow of climate related information in policy and planning. Thus, different organizations can play very important roles to adapt the climate change challenges in coastal and marine fisheries sector of Bangladesh.

1.8 CONCLUSION

The peaceful resolution of maritime discords has opened a golden opportunity to explore and exploit the vast valuable resources in the coastal and marine waters of Bangladesh. Sustainable management of these resources can give us the optimal benefits to uplift our existing economic condition. In this chapter, we show how these resources can be properly utilized for food production, shipping and trade, tourism, ecosystem-biodiversity conservation, new technologies and climate change challenges. Considering huge potentialities of these resources and major obstacles to achieve blue economy goals, we also suggest some strategies or policies to exploit these non-renewable resources in sustainable manner. Bangladesh has a very appropriate position to take the advantage of the blue economy, but there should be a sustainable blue economic approach in order to achieve the SDG Goals. Since the economy of Bangladesh is innately affected by natural, cultural, and other societal factors, there is the possibility of transitioning from unsustainable growth approaches to sustainable approaches through blue economy. In order to achieve such a transition, we strongly suggest adopting effective strategies for the sustainable blue economy. Therefore, more collaborative and inclusive patterns of work should be taken for the full potential of these resources. If the sustainable blue economic approach is followed properly, Bangladesh can be a successful

benchmark of blue economy for the developing world. Thus, we consider blue economy not only the means of using ocean and marine resources, but also a path of providing secured life for the most vulnerable coastal people of Bangladesh.

1.9 REFERENCES

Agrawal, A., McSweeney, C. & Perrin, N. (2008). Local Institutions and Climate Change Adaptation. The World Bank. https://openknowledge.worldbank.com/handle/10986/11145 (Accessed 09 June 2015).

Ahmed, N. & Diana, J. S. (2015). Threatening "white gold": Impacts of climate change on shrimp farming in coastal Bangladesh. *Ocean & Coastal Management* 114: 42-52.

Anttila, K., Dhillon, R. S., Boulding, E. G., Farrell, A. P., Glebe, B. D., Elliott, J. A., Wolters, W. R. & Schulte, P. M. (2013). Variation in temperature tolerance among families of Atlantic salmon (Salmo salar) is associated with hypoxia tolerance, ventricle size and myoglobin level. *Journal of Experimental Biology* 216(Pt 7): 1183-1190.

Balaguru, K., Taraphdar, S., Leung, L. & Foltz, G. (2014). Increase in the intensity of postmonsoon Bay of Bengal tropical cyclones. *Geophysical Research Letters* 41(10): 3594-3601.

BCCSAP (2009). Bangladesh Climate Change Strategy and Action Plan 2009. Government of Bangladesh, Dhaka.

Bhuiyan, S. (2015). Adapting to Climate Change in Bangladesh. *South Asia Research* 35(3): 349-367.

Brammer, H. (2014). Bangladesh's dynamic coastal regions and sea-level rise. *Climate Risk Management* 1: 51-62.

Britton, J. R., Pegg, J. & Williams, C. F. (2011). Pathological and Ecological Host Consequences of Infection by an Introduced Fish Parasite. *PLoS ONE* 6(10): e26365.

Chowdhury, M. T. H., Sukhan, Z. P. & Hannan, M. A. (2010). Climate change and its impact on fisheries resource in Bangladesh. Proceedings of International Conference on Environmental Aspects of Bangladesh (ICEAB10), Japan, Sept. 2010. 95-98pp.

CMFRI (2008). Research Highlights 2007–2008. Central Marine Fisheries Research Institute, Cochin, India36.

Da Silva, R., Mazumdar, A., Mapder, T., Peketi, A., Joshi, R. K., Shaji, A., Mahalakshmi, P., Sawant, B., Naik, B. G., Carvalho, M. A. & Molletti, S. K. (2017). Salinity stratification controlled productivity variation over 300 ky in the Bay of Bengal. *Scientific reports* 7(1): 14439.

Diaz, R. J. & Rosenberg, R. (2008). Spreading Dead Zones and Consequences for Marine Ecosystems. *Science* 321(5891): 926-929.

Department of Fisheries (2017). National fish week, compendium (In Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Government of Bangladesh, Dhaka.

Fernandes, J., A., Cheung, W., W. L., Jennings, S., Butenschön, M., Mora, L., Fröliche, r. T., L., Barange, M. & Grant, A. (2013). Modelling the effects of climate change on the distribution and production of marine fishes: accounting for trophic interactions in a dynamic bioclimate envelope model. *Global Change Biology* 19(8): 2596-2607.

FRSS (2017). Yearbook of Fisheries Statistics of Bangladesh. Fisheries Resources Survey System (FRSS), Department of Fisheries, Bangladesh. Vol. 33, pp 1-56.

Ghose, B. (2014). Fisheries and aquaculture in Bangladesh: challenges and opportunities. *Annals of Aquaculture and Research* 1(1): 1001.

Hoegh-Guldberg, O. & Bruno, J. F. (2010). The Impact of Climate Change on the World's Marine Ecosystems. *Science* 328(5985): 1523-1528.

Hossain, M. S., Chowdhury, S., R & Sharifuzzaman, S. M. (2017). Blue economic development in Bangladesh: A policy guide for marine fisheries and aquaculture. Institute of Marine Sciences and Fisheries. University of Chittagong, 32pp.

Hossain, M. S., Chowdhury, S. R., Navera, U. K., Hossain, M. A. R., Imam, B. & Sharifuzzaman, S. M. (2014). Opportunities and strategies for ocean and river resources management (Background paper for preparation of the 7th Five Year Plan). Food and Agricultural Organizations, Dhaka. 61pp.

Hussain, M. A., Islam, A. K. M. S., Hossain, M. A. & Hoque, M. T. (2012). Assessment of Salinity Distributions and Residual Currents at the Northern Bay of Bengal considering Climate Change Impacts. *The International Journal of Ocean and Climate Systems* 3(3): 173-186.

Hussain, M. G., Failler, P., Karim, A. A. & Alam, M. K. (2017). Major opportunities of blue economy development in Bangladesh. *Journal of the Indian Ocean Region* 14(1): 88-99.

Islam, M., M., Sallu, S., Hubacek, K. & Paavola, J. (2014). Limits and barriers to adaptation to climate variability and change in Bangladeshi coastal fishing communities. *Marine Policy* 43: 208-216.

Islam, M. M. (2012). Poverty in small-scale fishing communities in Bangladesh: Context and responses (Ph.D. thesis), University of Bremen, Germany, 2012, pp. 150.

Islam, M. M., Shamsuzzaman, M. M., Hoque Mozumder, M. M., Xiangmin, X., Ming, Y. & Abu Sayed Jewel, M. (2017). Exploitation and conservation of coastal and marine fisheries in Bangladesh: Do the fishery laws matter? *Marine Policy* 76: 143-151.

Islam, M. T. & Nursey-Bray, M. (2017). Adaptation to climate change in agriculture in Bangladesh: The role of formal institutions. *Journal of Environmental Management* 200: 347-358.

Jagtap, T., G. & Nagle, V., L. (2007). Response and adaptability of mangrove habitats from the Indian subcontinent to changing climate. *AMBIO: A Journal of the Human Environment* 36(4): 328-334.

Kais, S. M. & Islam, M. S. (2017). Impacts of and resilience to climate change at the bottom of the shrimp commodity chain in Bangladesh: A preliminary investigation. *Aquaculture*.

Kreft, S., D. Eckstein & Melchior, I. (2017). Global climate risk index 2017. Who suffers most from extreme weather events? Weather-related loss events in 2015 and 1996 to 2015. Germanwatch e.V. URL: www.germanwatch.org/en/cri.

Macnab, V. & Barber, I. (2012). Some (worms) like it hot: fish parasites grow faster in warmer water, and alter host thermal preferences. *Global Change Biology* 18(5): 1540-1548.

Minar, M. H., Hossain, M. B. & Samsuddin, M. (2013). Climate Change and Coastal Zone of Bangladesh: Vulnerability, Resilience and Adaptability.

MoFA (2014). Ministry of foreign affairs, press Release: Press statement of the Hon'ble foreign minister on the verdict of the arbitral tribunal/PCA. Dhaka, 08 July 2014. URL: http://www.mofa.gov.bd/PressRelease/PRDetails.php?TxtUserId¼&PRid¼854/.

Ostrom, E. (1990). Governing the commons: the evolution of institutions for collective action. Cambridge University Press, Cambridge.

Perry, A. L., Low, P. J., Ellis, J. R. & Reynolds, J. D. (2005). Climate Change and Distribution Shifts in Marine Fishes. *Science* 308(5730): 1912-1915.

Poloczanska, E. S., Brown, C. J., Sydeman, W. J., Kiessling, W., Schoeman, D. S., Moore, P. J., Brander, K., Bruno, J. F., Buckley, L. B., Burrows, M. T., Duarte, C. M., Halpern, B. S., Holding, J., Kappel, C. V., O'Connor, M. I., Pandolfi, J. M., Parmesan, C., Schwing, F., Thompson, S. A. & Richardson, A. J. (2013). Global imprint of climate change on marine life. *Nature Climate Change* 3: 919.

Pomeroy, R. S. (1993). A research framework for coastal fisheries co-management institutions. NAGA, The ICLARM Quarterly 1.

Pörtner, H. O., Berdal, B., Blust, R., Brix, O., Colosimo, A., De Wachter, B., Giuliani, A., Johansen, T., Fischer, T., Knust, R., Lannig, G., Naevdal, G., Nedenes, A., Nyhammer, G., Sartoris, F. J., Serendero, I., Sirabella, P., Thorkildsen, S. & Zakhartsev, M. (2001). Climate induced temperature effects on growth performance, fecundity and recruitment in marine fish: developing a hypothesis for cause and effect relationships in Atlantic cod (Gadus morhua) and common eelpout (Zoarces viviparus). *Continental Shelf Research* 21(18): 1975-1997.

Pörtner, H. O. & Peck, M. A. (2010). Climate change effects on fishes and fisheries: towards a cause-and-effect understanding. *Journal of Fish Biology* 77(8): 1745-1779.

Rahman, M. A. (2018). Governance matters: climate change, corruption, and livelihoods in Bangladesh. *Climatic Change* 147(1): 313-326.

Ramana, M. V. & Devi, A. (2016). CCN concentrations and BC warming influenced by maritime ship emitted aerosol plumes over southern Bay of Bengal. *Scientific reports* 6: 30416.

Rijnsdorp, A. D., Peck, M. A., Engelhard, G. H., Möllmann, C. & Pinnegar, J. K. (2009). Resolving the effect of climate change on fish populations. *ICES Journal of Marine Science* 66(7): 1570-1583.

Shamsuzzaman, M. M., Xiangmin, X., Ming, Y. & Tania, N. J. (2017). Towards sustainable development of coastal fisheries resources in Bangladesh: An analysis of the legal and institutional framework. *Turkish Journal of Fisheries and Aquatic Sciences* 17(4): 833-841.

Singh, O. P. (2012). Satellite derived sea surface temperature variability in the Bay of Bengal.

Somero, G. N. (2010). The physiology of climate change: how potentials for acclimatization and genetic adaptation will determine 'winners' and 'losers'. *Journal of Experimental Biology* 213(6): 912-920.

Sovacool, B. K., D'Agostino, A. L., Meenawat, H. & Rawlani, A. (2012). Expert views of climate change adaptation in least developed Asia. *Journal of Environmental Management* 97: 78-88.

Srinivas, B., Sarin, M. M. & Sarma, V. V. S. S. (2015). Atmospheric outflow of nutrients to the Bay of Bengal: Impact of anthropogenic sources. *Journal of Marine Systems* 141: 34-44.

Staudt, A., Leidner, A. K., Howard, J., Brauman, K. A., Dukes, J. S., Hansen, L. J., Paukert, C., Sabo, J. & Solórzano, L. A. (2013). The added complications of climate change: understanding and managing biodiversity and ecosystems. *Frontiers in Ecology and the Environment* 11(9): 494-501.

Torell, M. & Salamanca, A. M. (2001). Institutional issues and perspectives in the management of fisheries and coastal resources in Southeast Asia. Technical Report 60, pp. 212.

Vivekanandan, E., Hermes, R. & O'Brien, C. (2016). Climate change effects in the Bay of Bengal Large Marine Ecosystem. *Environmental Development* 17: 46-56.

Vivekanandan, E., Hussain, A. M. & Rajagopalan, M. (2009a). Vulnerability of corals to seawater warming. In: Impact, Adaptation and Vulnerability o fIndian agriculture to climatechange (ed. P.K. Aggarwal), Indian Council of Agricultural Research, New Delhi, pp. 97–100.

Vivekanandan, E. & Rajagopalan, M. (2009). Impact of rise in seawater temperature on the spawning of threadfin breams. In: Impact, Adaptation and Vulnerability of Indian agriculture to climate change (ed. P. K. Aggarwal), Indian Council of Agricultural Research, New Delhi, pp. 93–96.

Vivekanandan, E., Rajagopalan, M. & Pillai, N. G. K. (2009b). Recent trends in sea surface temperature and its impac ton oil sardine. In: Impact, Adaptation and Vulnerability o fIndian agriculture to climate change (ed. P. K. Aggarwal), Indian Council of Agricultural Research, New Delhi, pp. 89–92.

WTTC, 2018a. World Travel & Tourism Council: Travel & Tourism: Global Economic Impact & Issues.

WTTC, 2018b. World Travel & Tourism Council: Travel & Tourism Economic Impact 2018 - Bangladesh.

WTTC, 2012. World Travel and Tourism Council: UNWTO Tourism Highlight 2012 edition, .p.8