

Potentials for the Development of Blue Economy: Prospects and Challenges of Mariculture in Bangladesh

M. Gulam Hussain^{a*}, Sheikh Aftab Uddin^b, and Pierre Failler^c

^aFeed the Future Innovation Lab for Fish, Mississippi State University, USA

^bInstitute of Marine Sciences (IMS), University of Chittagong, Chittagong-4331 Bangladesh

^cEconomics and Finance Group, Portsmouth Business School, University of Portsmouth, Portsmouth, UK

Abstract

This paper sets out to address the prospects and potentials for the development of blue economy in Bangladesh through the sustainable use of its vast marine resources. It lays out the current state of comprehensive knowledge regarding opportunities and challenges for developing the sector as well as the emerging potentials in developing the blue economy for improving social and economic conditions of the country. The paper also highlights a total of 26 productive blue economy development and economic sectors, which have been identified for full utilization of ocean-based resources within the present maritime boundary of Bangladesh, among which 12 sectors have been prioritized as major sectors including Marine Fisheries and Aquaculture. Emphasis has been given to this sector as the most potential one for overall economic benefit and livelihood development of hundreds and thousands of coastal rural peoples of the country. Specifically, prospects for developing mariculture opportunities of both brackish and marine fish species as well as mariculture of non-traditional marine species in the coast, near shore and offshore areas have been addressed. In fine, the paper describes the current framework of marine resource management in the Bay of Bengal, delves into the challenges of mariculture development under the concept of blue economy in the seventh 5 Year Plan of the Govt. of Bangladesh and also recommends ways to advance blue economy governance in order to address pressures and ensure sustainable development of mariculture in the country. However, further researches/investigations are required to make a detailed account about the prospects, contributions, challenges and managements of mariculture-based blue economy in the development of Bangladesh's economy in commensurate with the national and international perspectives.

Keywords

Potentials; Blue Economy Development; Bangladesh; Mariculture; Prospects; Challenges

*Corresponding author Email: hussain.mgulam@gmail.com

1. Introduction

In Bangladesh, discussions on blue economy started after the settlement of maritime boundary delimitation dispute with Myanmar in 2012 and India in 2014, respectively. The productive economic sectors of blue economy are emphasised and considered in harnessing the full utilization of ocean-based resources within the present maritime boundary of Bangladesh. If these ocean-based resources are managed by proper planning and inter-sectoral coordination of public-private partnership and investment, it will certainly generate strong foundation for earnings and economic benefits under the approach of blue economy. On the other hand, the blue economy can create some opportunities to resolve the issues of climate changes at the coastal areas provided these marine based economic resources with potential sectors be managed and governed by principles of biodiversity protection, conservation and efforts for care with a vision of scientific understanding. It might also generate jobs and bring about tangible changes in the lives and livelihood of the millions of people inhabiting along

the coastline and islands in Bangladesh. A coordinated approach with concerned stakeholder groups is required to determine the extent to which the constraints can be turned into opportunities, and to ensure that development of the blue economy does not result in unsustainable and damaging practices towards the benefit of short-term economic gains over long-term sustainable economic and social benefits. In particular, for Bangladesh, this involves developing a maritime/marine spatial planning directive to detail coordination between blue economy sectors and stakeholders to ensure sustainable development.

A total of 26 productive blue economy development and economic sectors have been identified for full utilization of ocean-based resources within the present maritime boundary in Bangladesh, among which 12 sectors have been prioritized as major sectors including Marine Fisheries and Aquaculture. This sector is most potential for overall economic benefit and livelihood development of hundreds and thousands of coastal rural peoples of Bangladesh. Aquaculture and Fisheries in Bangladesh has three main subsectors: aquaculture (contributing 56.44 % of total production), inland capture fisheries (28.14 %), and marine and coastal capture fisheries (15.42 %), with the estimated total production of 4,134,434 MT in 2016-17 (DoF, 2017). As in much of Asia, capture fisheries production of Bangladesh has been declining with a dramatic increase in aquaculture production. About 94 percent of aquaculture production in Bangladesh is destined for domestic consumption, especially farmed carp and tilapia, which helps in domestic food security and related livelihoods. Both homestead farms and intensive farming techniques have contributed to the aquaculture industry. So, presently aquaculture (mostly inland freshwater and partly coastal aquaculture) is making a major impact on production, protein supply, economic development and livelihood aspects for the millions of people of the country. On the other hand, the country owns vast coastal and marine water resources, and therefore, the recent blue economy concept of the government has extensively widen up the potentials for developing mariculture opportunities in the coast, near shore and offshore areas of the Bay of Bengal.

This paper addresses the emerging blue economy in Bangladesh, and the potentials and opportunities regarding its development. The paper is laid out as follows: the next section considers the blue economy concept and its relevance to Bangladesh along with other sections where mariculture of both brackish and marine fish species as well as mariculture of non-traditional marine species have been briefly described. The overall future perspectives and challenges of mariculture development were emphasized under the concept of blue economy development and seventh 5 Year Plan of the Govt. of Bangladesh.

2. The Concept of Blue Economy

Oceans cover over 70% of the surface of the planet. Life originated in the oceans and they continue to support all lives today by generating oxygen, absorbing carbon dioxide, recycling nutrients and regulating global climate and temperature. Further, they are the means for providing a significant amount of the world's demand for food and livelihood generation, accounting for a mean of transport for over 80% of international trade (UNCTAD, 2012). However, development of the oceans, as a source of food and economic activity, has affected the resilience of oceans, reducing biodiversity and ecological function as well as causing the decline of environmental services. For example, the [FAO \(2014\)](#) estimated that over 75% of commercial fish stocks are fully or over-exploited. Both developed and developing countries have recognized the potential of the blue economy to deliver on development purposes. For example, the UK is one of the world's leaders in offshore renewable energy platforms and many developing countries have developed coastal aquaculture and tourism.

The development of the blue economy in a country like Bangladesh, leading to a sustainable marine economy that can generate jobs and bring significant tangible benefits to change the lives and livelihoods of millions of people inhabiting coastal areas, can develop a strong economy to benefit the country's population. This is, of course will be possible, if resource management is governed by the principles of the protection of the oceans, including biodiversity conservation, ecological function and sustainable environmental services. A country like Bangladesh, who currently have an underdeveloped blue economy, is well positioned to develop sectors related to the blue economy. For example, coastal aquaculture offers huge potential for the provision of food and livelihoods by creating sustainable employment and producing high value species for international export markets. However, a strategic approach, supported with a governance structure, is imperative to develop the blue economy – otherwise the example of coastal aquaculture development given here could easily lead to resource exploitation (e.g., biodiversity loss and ultimately the destruction of ecological function).

3. Maritime Boundary Settlement and Current Situation of Marine Economic Sectors in Bangladesh

Bangladesh has received entitlement to 118,813 km² in the Bay of Bengal (BoB) after the end of the final settlement of maritime boundary disputes with neighboring countries Myanmar and India in 2012 and 2014 respectively. This award allowed Bangladesh to establish sovereign rights over the living and non-living resources of BoB territorial waters up to 12 nm, Exclusive Economic Zone (EEZ) within 200 nm and Continental Shelf extending up to 354 nm from the Chittagong coast (MoFA, 2014). Side by side, all major river inlets and estuaries comprising together as a part of the marine ecosystems, and finally the total marine waters of the country stand at 121,110 km² of which coastal waters and the shallow shelf sea constitute about 20% and 35%, respectively, and the remaining 45% is lying in deeper waters (Hossain et al. 2017a). So, the Government has recently started dialogues with the stakeholders to adopt the concept of blue economy across relevant policies and plans (Hussain et al. 2017a; Hussain et al. 2017b). Figure 1 shows the present maritime boundary/area of Bangladesh (Chowdhury, 2014).

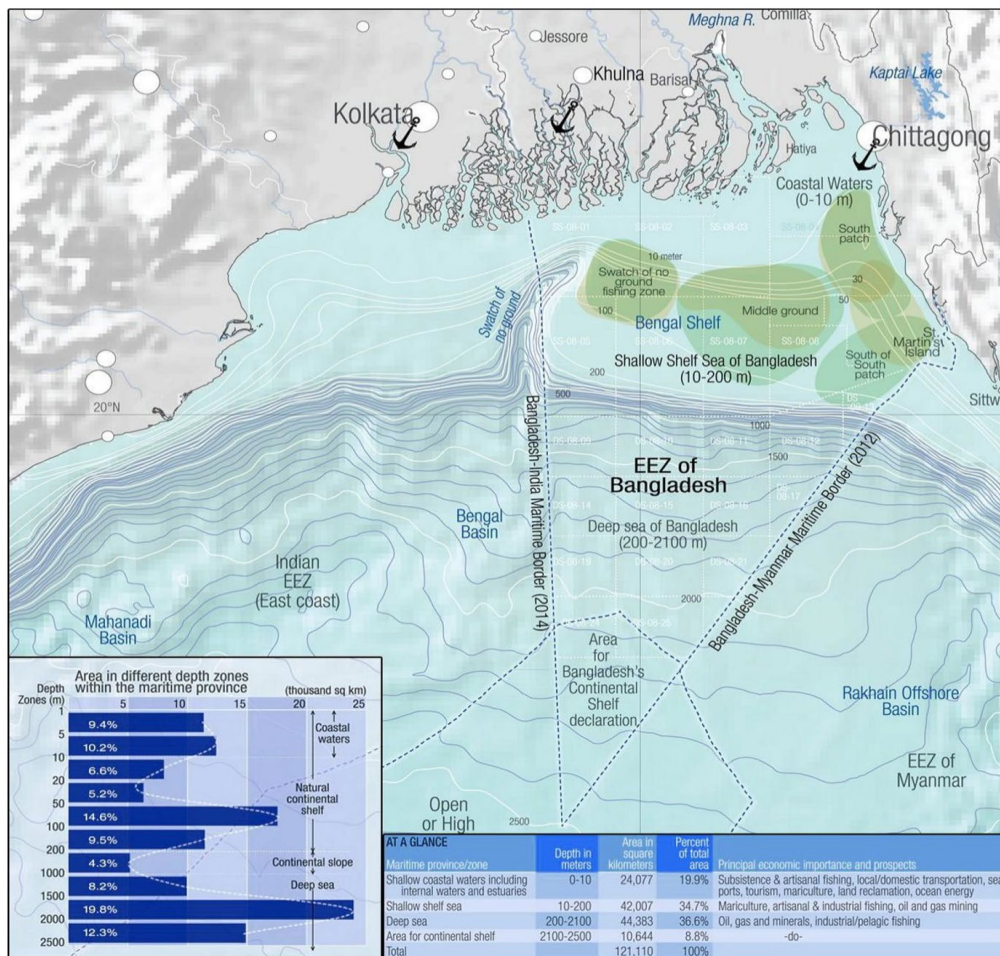


Fig. 1. Maritime area of Bangladesh (Chowdhury, 2014).

In fact, Bangladesh having the widest shallow shelf area within the BoB, extending more than 100 nm (185 km), is 3-4 times wider than those of Myanmar, even wider than eastern coast of India and global average (65 km), ultimately having a greater shallow bottom fishing area per unit length of coastline than its close neighbours (Hossain et al., 2014). The coast of Bangladesh is in a continuous process of reshaping itself, which will continue towards millennia in the future due to being located in the largest delta of the world. For the national economy and overall social benefits, marine resources are extremely important because one fifth of the population (i.e., about 30 million peoples) are dependent on these resources for activities like fisheries, aquaculture, tourism, shipping, shipbuilding and ship decommissioning, salt production, and offshore oil and gas production (Hossain et al., 2014). Table 1 presents the monetary valuation of production of major economic sectors for the last five years (2010 – 2015) related to blue economy in Bangladesh.

Table 1. Monetary valuation of production (2010 – 2015) of major economic sectors related to blue economy in Bangladesh (Million US\$)

Economic sector	2010	2011	2012	2013	2014	2015
*Inland Fisheries	3,632.34	4,113.20	4,844.21	5,596.15	6,308.16	7,089.66
*Marine Fisheries	843.75	949.48	1,107.42	1,231.06	1,384.77	1,475.66
*Oil	21.90	23.84	26.82	28.77	29.35	34.05
*Gas	948.35	956.30	1,041.35	1,127.73	1,158.13	1,305.42

*Sea salt	119.25	123.48	160.90	206.00	212.35	214.84
*Coals, sands and minerals	735.18	944.39	1,183.79	1,452.46	1,644.08	1893.14
*Water transport	1,215.14	1,330.36	1,450.21	1,606.10	1,682.31	1,816.67
*Trade & other transport	31,390.15	36,178.04	41,728.94	47,156.44	52,078.80	58,466.90
**Shipping (Freight in/out bound shipping)	-	15.77	16.28	19.07	22.48	25.83

Source: *Data from Bangladesh Bureau of Statistics (BBS) ** Data from Ministry of Shipping, Bangladesh Shipping Corporation

Patil et al. (2018; 2019) showed in their recently published report of World Bank Group regarding the annual gross value-added Ocean Economy from different activities of Bangladesh. In that report, they mostly used disaggregated data provided by Bangladesh Bureau of Statistics (BBS) and supplemented by reports from industry and other agencies where available. Figure 2 summarizes an initial estimate of the gross value added (GVA) to the Bangladesh economy from ocean activities in recent years. These estimates are coarse and should be seen as indicative of only the order of magnitude of the annual output from Bangladesh’s ocean economy. However, such estimates reveal a baseline measure of the ocean economy, which can be a useful as the starting point towards setting targets for Bangladesh’s blue economy aspirations (Patil et al. 2018).

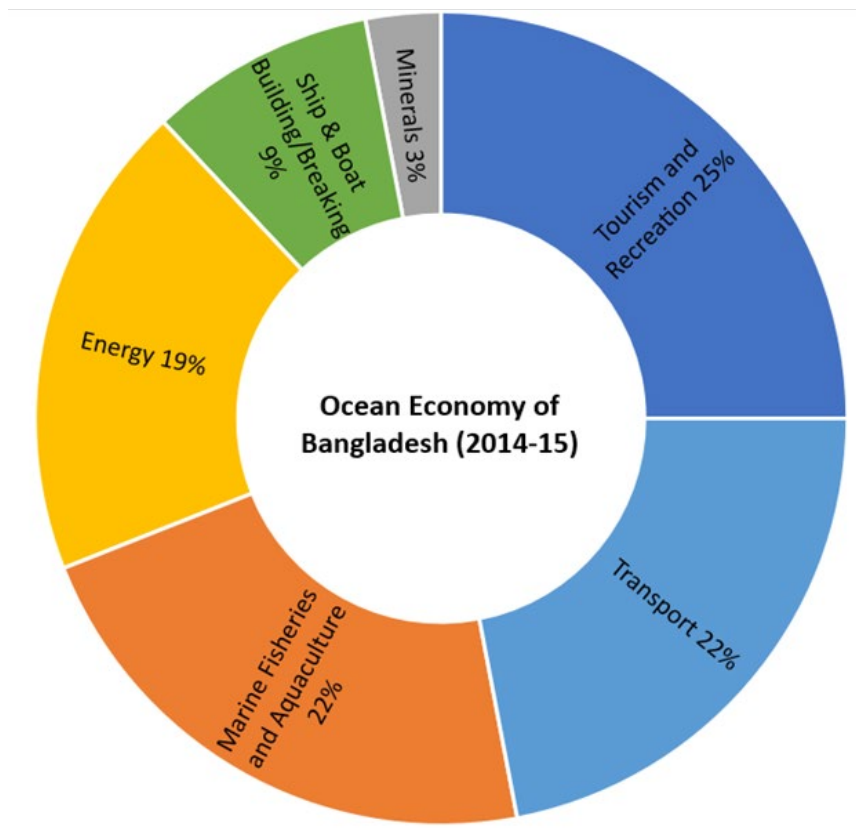


Fig. 2. Composition of the percent contribution of Gross Value Added Ocean Economy from different activities (2014-15) in Bangladesh (Patil et al, 2018)

4. Blue Economy Opportunities: Potentials of Marine Fisheries and Aquaculture

Meanwhile, in Bangladesh within its present maritime boundary, a total of 26 productive blue economy development and economic sectors have been identified for full utilization of ocean-based resources. Among these, the major economic sectors are: i) Marine Fisheries and Aquaculture; ii) Marine Non-Traditional Species Culture; iii) Marine Biotechnology; iv) Carbon Sequestration; v) Oil, Gas and Minerals Mining; vi) Ocean Renewable Energy; vii) Sea Salt Production; viii) Marine Trade, Shipping and Transport; ix) Marine Tourism; x) Marine Education and Research; xi) Maritime Surveillance; xii) Marine Spatial Planning etc (Fig. 2). Under the blue economy approach within a comprehensive framework of ecosystem based management, if ocean spaces are properly planned and managed to carryout inter-sectoral coordination with public-private partnership and investment, it will certainly generate strong foundation of huge earnings and economic benefits for the country.

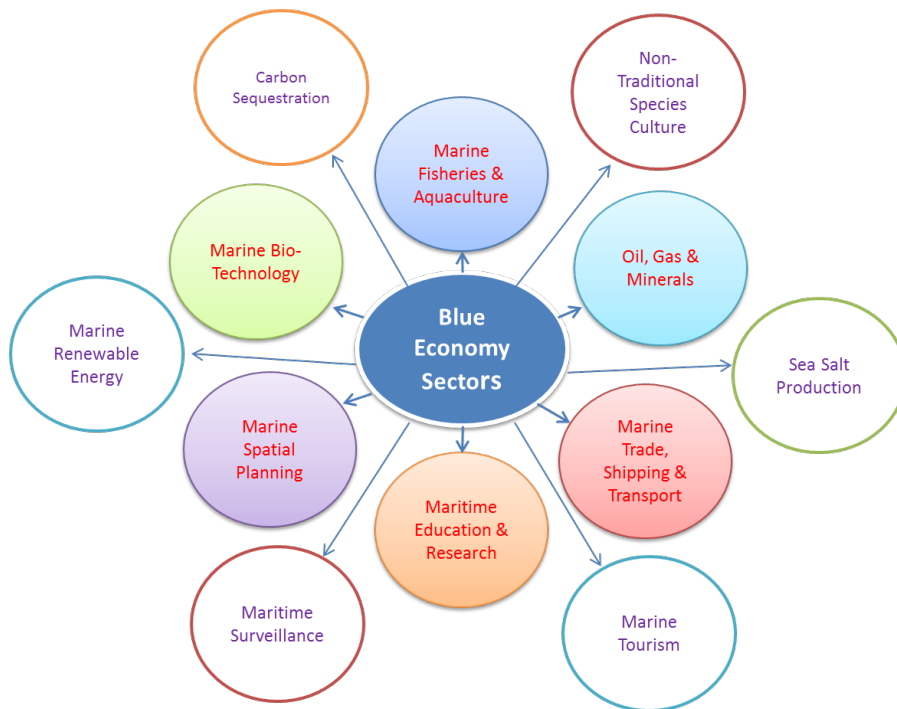


Fig. 3. Major economic sectors related to blue economy in Bangladesh (Hussain et al. 2017a; Hussain et al. 2017b)

Among these sectors, Marine Fisheries and Aquaculture sector is most potential for overall economic benefit and livelihood development of hundreds and thousands of coastal rural peoples of Bangladesh. Compared to inland capture and culture fisheries, production of marine capture fisheries is meagre because almost all of Bangladesh's marine fishing is carried out in shallow and shelf waters, beyond which no fishing is being currently practiced due to lack of vessel capacity and appropriate fishing technologies. But under the concept of the blue economy, marine fisheries and aquaculture are extremely promising. In view of expanding capture fisheries production, the country should adopt appropriate deep sea fishing technologies such as long line and hook fishing and the utilization of supporting gears and vessels for harvesting large pelagic fish (i.e., tuna and other pelagic species). Being a new member state of IOTC (Indian Ocean Tuna Commission), Bangladesh is yet to achieve the access for tuna fishing in the BoB of Indian Ocean. It is expected that the country would be able to earn huge foreign exchange by exporting tuna fillets and other value-added items to the international markets. Rehabilitation of hilsa fishery is another important task that requires intervention at the trans-boundary level. At present 50-60% of global hilsa catch takes place in the coastal and marine waters of Bangladesh, followed by 20-25% in Myanmar, 15-20% in India and the remaining 5-10% in other countries (Hossain, et al., 2014). Bangladesh is one of the leaders and stands 5th in the ranking among

the top 10 countries of the world for freshwater aquaculture. There are opportunities to initiate and introduce both brackish and marine aquaculture as well.

4.1 Prospects and Challenges of Mariculture Development

Marine aquaculture is demarcated as the establishment of land-based ponds, enclosures/cages in the onshore and offshore areas to raise marine aquatic species/groups such as finfish, shellfish & seaweeds for commercial farming to get economic benefit as well for the human consumption purposes. There have been limited attempts to promote mariculture in Bangladesh over the last 40 years except the tiger shrimp (*Penaeus monodon*) farming, using traditional and improved extensive practices in the coastal areas. In the Asia Pacific region, the countries such as China, Indonesia, Malaysia, Taiwan Province of China, Thailand, Singapore and Vietnam are making headway in finfish mariculture using hatchery produced seeds and formulated feeds. Lessons can be learned from these countries and the concept of blue economy development of the government. Bangladesh might initiate marine aquaculture farming urgently with the available and identified finfish, shellfish and non-traditional species. As it is mentioned in earlier section that after the end of the final settlement of maritime boundary disputes recently with neighboring countries viz., Myanmar and India, Bangladesh is allowed to establish sovereign rights over the living and non-living resources of the huge maritime areas. The shallow coastal waters (including internal waters and estuaries) and shallow sea shelf constitute about 20% and 35% of total marine waters, respectively (Hossain et al. 2017a). These facilities have extensively widen up the potentials and opportunities for developing mariculture in the coast, near shore and offshore areas. So, there are enormous scopes for flourishing mariculture of both brackish and marine fish species as well as opportunities exists also for mariculture of non-traditional marine species like seaweed, macro algae, shellfish (i.e., mussel, oyster etc., sea urchin, sea cucumber etc.) (Hussain et al. 2017a, Hussain et al. 2017b). If these opportunities could successfully be implemented under the concept of blue economy development and seventh 5 Year Plan of the Govt. of Bangladesh in the coast, near shore and offshore areas, the country would be able to achieve expected solutions for the requirements of mass protein in the diet of the people as well as get sustainable benefits in economic sectors. The vision in this respect is to develop a viable and sustainable mariculture industry for producing suitable and selected marine fin fish, shellfish and marine plants for the long term benefits of Bangladesh's economy, environment and coastal communities.

4.1.1 Potential species for mariculture

A wide range of biodiversity such as bony and cartilaginous fishes, shrimps, crabs, seaweeds, mollusks and mammals exists in the coastal and marine ecosystems of the Bay of Bengal (Hossain, 2001; Islam, 2003; Ahmed et al., 2008). Murshed-E-Jahan et al. (2014) listed around 511 marine species together with shrimps, that exist within Bangladesh marine waters. Among these marine species, categorically species/groups are: i) Marine fish such as Sea bass (*Lates calcarifer*), Grey mullet (*Mugil cephalus*), Green back mullet (*Chelon subviridis*), Pomfret (*Pampus argenteus*), Hilsa (*Tenualosa ilisha*), saline tolerant tilapia and other species; ii) Marine shrimps such as *Penaeus monodon*, *P. indicus*, *P. Merguensis*; iii) Marine crab such as Mud crab, *Scylla serrate* etc. are potentially important for mariculture. Among marine non-traditional species, seaweeds (both macro and micro algae); mussels such as green mussel (*Perna viridis*), Clam (*Meretrix meretrix*) and oyster (*Crassostrea madrasensis*); corals, sea cucumber, sea urchin etc. are also important for marine aquaculture in Bangladesh.

The marine aquaculture potentials and opportunities were thoroughly discussed in recent regional workshop on "Blue Economy in South East of Bangladesh: Major Opportunities and Constraints", held in Chittagong, Bangladesh and jointly organized by Chittagong University, European Union Delegation (EUD), Dhaka and Maritime Affairs Unit, Ministry of Foreign Affairs, Govt. of Bangladesh (Hussain et al. 2017b). Several potential areas of marine aquaculture have been identified for implementation under the concept of blue economy in Bangladesh) Table 2(.

Table 2. Species/group wise opportunities of aquaculture in coastal and marine waters of Bangladesh

Species/Group	Main locations/areas for mariculture
Marine fin fish breeding and farming	
Sea bass) <i>Lates calcarifer</i> (, Grey mullet) <i>Mugil cephalus</i> (, Green back mullet) <i>Chelon subviridis</i> (, Pomfret) <i>Pampus argenteus</i> (, Hilsa) <i>Tenualosa ilisha</i> (, saline tolerant tilapia and other species	Land-based brackishwater pond culture, cage culture and pen culture in inshore and offshore areas i.e., Moheshkhali-kutubdia channel, Sonadia island and Dubla island
Marine shrimp broodstock domestication, and SPF seed production and farming	
Broodstock domestication, and breeding and farming of <i>Penaeus monodon</i> , <i>P. indicus</i> , <i>P. merguensis</i>	Cox's Bazar, Satkhira, Khulna
Crab breeding and farming	
Mud crab, <i>Scylla serrata</i>	Shamnagar, Shatkhira; Moheshkhali; Cox's Bazar
Mussel breeding and culture	
Clams) <i>Anadara</i> (Chittagong, Moheshkhali, Kutubdia coast
Mussel)green mussel, <i>Perna viridis</i> (St. Martin's Island, Moheshkhali, Kutubdia
Clam) <i>Meretrix meretrix</i> (and oyster) <i>Crassostrea madrasensis</i> (Cox's Bazar, Sundarban mangrove
Pearly oyster)blacklip, nei(Cox's Bazar, Patuakhali
Culture of marine aquatic Plants	
a. Seaweeds <i>Sargassum</i> sp., <i>Hypnea</i> sp., <i>Caulerpa</i> sp. <i>Ulva</i> sp. and others.	St. Martin's, Cox's Bazar and Khulna
b. Marine micro algae Marine micro algae viz. <i>Skeletonema costatum</i> , <i>Thalassiosira</i> sp., <i>Chaetoceros gracilis</i> , <i>Tetraselmis</i> sp., <i>Nanochloropsis oculata</i> , <i>Chlorella</i> sp. etc.	Chittagong, Cox's Bazar, Dhaka, Khulna)can be used as live feed and biodiesel production by marine biotechnology(
Culture of marine coral and other non-traditional species	
Corals, sea cucumber, sea urchin etc.	St. Martin's Island

4.1.2 Prospective future and challenges of marine aquaculture

There is no marine aquaculture currently being practiced in Bangladesh and no marine/coastal fin finfishes are farmed (Hossain, 2014). Mariculture is completely a new arena of farming marine animals (i.e., marine fish and shellfish and other non-traditional species) and aquatic plants (i.e., sea weeds and other macro algae). So lessons can be learned from our inland aquaculture as well as recent development in other countries to develop the mariculture industry to its full potential. The essential requirement of the elements for successful implementation of mariculture is described in the following paragraphs:

4.1.2.1 Suitable site selection for mariculture farming infrastructures

In view to the establishment of all necessary mariculture facilities, suitable site selection in the coast, inshore and offshore areas is extremely important. The geographical position and climatic condition of Bangladesh have made her coastal and related areas suitable for varied species and forms of marine aquaculture. So, site selection should be species specific. Before selecting the sites for specific mariculture, a thorough feasibility studies considering a required environmental and ecosystem related parameters should be given extreme priority. All ideal sites either seed producing hatcheries, nurseries or commercial farms should have well road connections, essential value chain infrastructures, ice factories and market access.

4.1.2.2 Establishment of hatcheries for seed production of marine species

Hatcheries are the most vital and integral part of infrastructures for the production of abundant seeds to support successful mariculture development. It is obvious that the mariculture industry will not thrive without adequate quality, quantity and consistency of seeds or juveniles of marine species (Anon, 2018). Unfortunately, there is no seed producing hatcheries/centers available for marine fin fish, crabs, mussels and sea weeds in the country. However, there are quite a good number of shrimp

hatcheries in the Cox's Bazar region, from where tiger shrimp seeds are air lifted to Khulna and Shatkhira regions to support existing shrimp farming. But the indoor facilities of most of these shrimp hatcheries are primitive except very few of those infrastructures. There is only a Specific Pathogen Free (SPF) seed production hatchery of tiger shrimp named M.K.A. Shrimp Hatchery, which is located at Sonapara, Ukhia, Cox's Bazar. Inadequate SPF seeds are produced using base population of tiger shrimp taken from Hawaii, USA. More SPF hatcheries are needed to be established at South East and South West coasts of Bangladesh. A number of marine fin fish and crab hatcheries need to be urgently designed and established in the suitable sites of Khulna, Shyamnagar, Shatkhira, Moheshkahi, Kutubdia and Cox's Bazar regions. These hatcheries should have all modern indoor and outdoor seed growing facilities like egg incubators and jars, larvae rearing troughs and tanks, fry nursing tanks and ponds etc. including adequate saline water supply systems. Side by side, special hatchery technologies could be taken from South Korea, Japan and Australia to design and establish mussel and seaweed seed production hatcheries and seed growing facilities/centers at the coast of Saint Martin's Island and other similar places.

4.1.2.3 Designing and implementation of marine aquaculture farming infrastructures and other related facilities

While adequate seeds/juvenile production and availability will be ensured, then next task is to build commercial marine aquaculture farming infrastructures for growing marine fish/shellfish and other suitable species. In view of that following systems need to be constructed as priority basis:

a. Development of coastal earthen ponds

For traditional shrimp farming in Bangladesh, generally vast areas of low lying coastal lands are used mostly in South West region, Khulna and Shatkhira areas, where yield of shrimp per unit area become extremely low, which is around 250-300 kg/ha. Better farming infrastructures can be constructed in those areas, particularly in greater Khulna region as well as in Chakuria, Kutubdia and Moheshkhali of Cox's Bazar region to initiate semi-intensive shrimp and crab farming, and fin fish species like Sea bass (*L. calcarifer*), Grey mullet (*M. cephalus*), Green back mullet (*C. subviridis*), Pomfret (*P. argenteus*) etc. In this system artificial feeding with high quality floating or sinking pelleted feeds will be a prerequisite for better yield and production. A well-designed earthen farms should be >5– 25 hectares with adequate saline water supply and recommended water depths.

b. Development of inshore raceways

There are many suitable coastal areas to construct inshore raceways, where net enclosures can be building up at different lengths and desired depths in the coastal lagoons and canals. Polyethylene/nylon net materials having mesh sizes >2–5 cm can be fixed with bamboo, PVC or steel made poles. Marine finfish juveniles like hilsa, seabass, grey mullet etc. can be stocked intensively and cultured to grow them marketable size with supplementary feeding.

c. Floating net cages at offshore areas

Offshore net cage farming of marine finfish species will be a new initiative in Bangladesh. It is a common practice in Indonesia, China, Norway, Japan, Brazil, Mexico and some countries of Indo-Pacific Region. Net cage farming can be introduced in the country at artisanal level with simple design and small size of 3 x 3 m to 5 x 5 m and depth of 4-5 m (Hussain et al. 2017a). They suggested that local fishers/farmers themselves can make cages using locally available materials including bamboo, wooden boards, steel/PVC pipes and nylon nets. In future, much better construction of net cages can be initiated at offshore areas of Moheshkhali-Kutubdia channel, Sonadia island, Andermanik rivers and other suitable places. To grow in net cages, marine finfish juveniles like hilsa, seabass, grey mullet, sea bream etc. can be stocked intensively and cultured with regular high quality artificial feeding.

d. Mussel culture hanging racks and floating rafts

The non-traditional marine species like mussels are very much common in the littoral zone of our marine waters. These animals being the filter feeder of phytoplankton and various detritus materials available in the sea water, are attached in clusters on various substrates. Mussels are the most efficient converter of organic matters produced by marine organisms into palatable and nutritious animal protein (Aypa, 1980). Both hanging racks in the shallow region and floating rafts are generally used to grow the collected mussel spats into marketable size. This will certainly be a new practice in this country. There are good opportunities for green mussel (*P. viridis*), clam (*M. meretrix*) and oyster (*C. madrasensis*) production, especially in Moheshkhali, Kutubdia and Sonadia islands of Cox's Bazar and Teknaf regions (Shahabuddin et al., 2010). Lessons regarding the most useful techniques for breeding and culture of various types of mussels can be learned from the countries like Australia, Japan, South Korea, Philippines, Spain etc.

e. Seaweed culture at reef flats, mangrove stakes/nets and long lines

Seaweeds are being used as delicious food items, particularly in China, Japan, Korea and Thailand. As these marine aquatic plants have a tremendous advantage and being utilized in those countries in producing phycocolloid or hydrocolloid, cosmetics, biofuel, pharmaceuticals, waste water treatment and bioplastic industries. Therefore, seaweed culture could be widely initiated in this country for using as food items as well as for foreign exchange earnings. In Bangladesh, naturally growing seaweeds are seen in the littoral and sub-littoral zones of St. Martin's Island to Sundarbans Mangrove forest, and are available from October to April throughout the whole Southern coast (Islam and Aziz 1987; Islam, 1998). Suitable water quality parameters and rocky substratum make the St. Martin's Island an excellent place for naturally occurring seaweeds (Khan, 1990; Tomascik, 1997; Zafar, 2005). In total, 193 seaweed species including 19 commercially important species are found in Bangladesh and about 5,000 metric tonnes of seaweed biomass are available (Sarkar et al., 2016). For the commercial culture of seaweeds, both reef flats and long line methods (as the most common practice) could be introduced in this country. Seedlings are usually tied to monofilament lines and strung between mangrove stakes pounded into the substrate. This off-bottom method is still considered as one of the major methods used to set up in one meter depth. There are new long-line cultivation methods that can be used in deeper water approximately 7 metres in depth. It is widely said that seaweed farming can also be an actor in biological carbon sequestration.

4.1.2.4 Domestication of potential mariculture species

Domestication of wild fish species for using them in artificial seed production is a common practice both for inland aquaculture and mariculture systems all over the world. Similar mariculture practices both for marine fish breeding and farming will be more or less similar for selected marine fin fish and shellfish species in Bangladesh. So prior to initiate seed production in the marine hatcheries, wild collected juveniles or brood stocks need to be accustomed and domesticated in the captive conditions at the breeding tanks or ponds under optimum salinity for few months by adequate care and feeding to enhance their sexual maturity. Next step is to select best-sized and well-ripped fish/shellfish for breeding in the hatcheries. Similar situation might need to be followed for growing mollusks and other non-traditional species. To avoid genetic deterioration conventional selective breeding or marker assisted selective breeding technique(s) could be followed for some selected breeding stocks for marine aquaculture.

4.1.2.5 Production of high quality feeds

Intensive feeding with high quality feeds is required for some species, such as tiger shrimp and carnivorous finfish such as seabass and may be desirable in the case of other marine species to increase yield, reduce grow out times, pay off investment in ponds or cages more rapidly. The trend in Bangladesh has been towards the application of dry pelleted formulated feeds, as the country have some reputed feed mills (e.g., Saudi Bangla fish feed, Quality feed, Paragon feed mills etc.). Modern fish feeds are scientifically and economically optimal in producing high and consistent performances.

They are easy to store and handle and thus greatly reduce labour costs. Unfortunately, feed conversion ratios and feed management practices for marine fish/shrimps are not well-established in Bangladesh, and therefore need to be initiated at the same time of expanding marine aquaculture. Side by side, import of high quality fish meal or other essential ingredients from abroad for ensuring optimum standard of such feeds need to be considered to maximize the feed costs vs quality perfectly.

4.1.2.6 Necessary investment in mariculture

As mariculture is presently a new venture and risky task, securing adequate capital to support mariculture operations remains a challenge for many interested parties in Bangladesh. Development of new infrastructures for marine hatcheries, commercial land based farms, inshore raceways, offshore cages etc. need huge investment. No party will be interested unless or until any foreign donor or internal state owned bank will come forward to support such initial costs for infrastructural development and mariculture operations. Obviously, it will be wiser to develop Public-Private Partnership for running long term mariculture industry. In this respect, concerned Govt. Department(s) and Ministries should take proper initiative for the benefit of industry.

4.1.2.7 Mariculture related public understanding and support

Unlike other fisheries and agricultural sectors/sub-sectors, one of crucial elements of developing mariculture in Bangladesh is building public understanding and support for one of the newly emerging sectors of blue economy like mariculture. Without the strong support to the affected peoples related to mariculture as well as the subsequent political approval, no amount of public and private investment can result in implementation and success (Anon, 2018). It is obvious that sustainable impact of mariculture will affect positively on coastal-resource poor community and will ultimately enhance the environmental and economic benefit of the country.

4.1.2.8 Mariculture markets and products development

It is a reality that some of the mariculture items and processed products like shrimps, crabs, mussels and seaweeds might not have enough consumers in the country at this moment. So it will be an anxiety of the producers as well relevant Government Departments/Ministries on how to export those mariculture products to domestic and international markets. In this respect, mutual collaboration among domestic and international marketing agencies will be required to find out an effective solution.

4.1.2.9 Establishment of mariculture research and technical education institutions

In regards to apply mariculture research and education, no sole technical institutions are available in Bangladesh except the Marine and Technology Station of Bangladesh Fisheries Research Institute (BFRI). Research facilities at BFRI's Marine Research Station in Cox's Bazar are not adequate yet to carryout need-based marine fisheries/aquaculture and oceanographic research (Hussain et al. 2017b). In this context, there is scope and opportunity for an equitable and mutually beneficial collaboration between Bangladesh's research institutions/universities and some European and other international universities to develop high tech mariculture related education systems. On the other hand, a new initiative can be undertaken soon to establish a full-fledged new mariculture research institution having all labs and facilities including breeding/propagation, biotechnology, culture and product development of marine fish/shellfish and non-traditional species in the coastal belt of Cox's Bazar.

5. Conclusions

The Blue economy conceptualizes oceans and seas as “Development Spaces” where spatial planning integrates conservation, sustainable use of living resources, oil and mineral extraction, bio-prospecting, energy production and marine transportation (Alam 2014). The Blue Economy approach is founded upon the assessment and incorporation of the real value of the natural (blue) capital into all aspects of economic activities (viz., conceptualization, planning, infrastructure development, trade,

travel, renewable resource exploitation and energy production/consumption). Thus Blue Economy requires a balanced approach between conservation, development and utilization of marine and coastal ecosystems, all oceanic resources and services with a view to enhancing their value and generates decent employment, secure productive marine economy and healthy marine ecosystems (Patil et al, 2018). In respect of sectoral issues, Fisheries and Aquaculture is one of the priority sectors. Presently, Bangladesh is one of the leading countries for aquaculture production in Asia Pacific region as well in the world. Over the last 15 years, major advancement has been occurred in freshwater aquaculture sub-sector rather than in marine aquaculture. Although marine fish farming is a promising area of aquaculture here but it was not properly flourished except partly in shrimp, due to less availability of hatchery produced seeds, low levels of farming technology development and transfer to the farmers, lack of affordable formulated feeds, and lack of serious initiatives by the public and private sector organizations and entrepreneurs. In Asia Pacific region, the countries like China, Indonesia, Malaysia, Taiwan Province of China, Thailand, Singapore and Vietnam are making headway in finfish mariculture using hatchery produced seeds and formulated feeds. Lessons can be learned from these countries and under the context of blue economy development of the government, Bangladesh might urgently initiate marine aquaculture farming with the available and identified finfish, shellfish and non-traditional species (mentioned above). Respective Ministries, Departments and Research Institutions along with interested Private Entrepreneurs might sit together for proper formulation of strategies, planning and coordination for effective development and implementation of marine aquaculture farming in the coast, near shore and offshore areas of the country.

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