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Fisheries resources of Bangladesh: A review

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Abstract
Fisheries sector plays a significant role in national food security, empowerment and foreign exchange earnings in the national economy of Bangladesh. At the same time, Bangladesh is blessed with enormous water resources of inland culture (8,21,923 ha), inland capture (38,90,282 ha) and marine (1,18,81,300 ha), having great potentials of fisheries production. Inland culture, inland capture and marine fisheries provides 56.76%, 28.19% and 15.05% fisheries production, respectively. The aim of this review paper is to provide a comprehensive overview on fisheries resources of Bangladesh, those are underutilized and/or need emphasis to enhance more fish production. Recently, inland culture fisheries production has increased rapidly due to adoption of improved farming practices by the farmers. However, inland capture and marine fisheries production has not yet been attained to its optimum level due to over exploitation, fish habitat degradation, siltation of water bodies and water pollution. Therefore, to increase inland capture fisheries production and conserve biodiversity, various approaches such as community-based fisheries management, beel nurseries, stocking fingerlings of endangered species, establishment of fish sanctuaries, cage and pen culture systems can be adopted. Additionally, existing banning rules and regulations of catching fish during breeding season from inland capture water bodies like rivers, haors, baors, beels etc. should be implemented properly for conserving biodiversity and increasing fish production, as banning of 22-days in rivers and 65-days in marine water have significantly increased hilsha fish production. In addition, blue economy has recently gained impressive attention in Bangladesh due to getting huge marine water resources from Myanmer in 2012 and India in 2014. Therefore, marine aquaculture systems for example farming of seaweed, sea bass, mullets, promfrets, mud crab etc. should be adopted for achieving the United Nations agenda on sustainable development goal 14 on conservation, sustainability and use of oceans, seas and marine resources for increasing economic benefits.

Keywords: aquaculture, marine, production, blue economy

Introduction
Fisheries resources plays a significant role in food security, employment and foreign exchange earnings in the national economy of Bangladesh and represents as dynamic and most productive resources [1]. Totally, 12% of the total population of Bangladesh is involved in fisheries sector on full time and part time basis for his or her livings [2]. About 60% of animal protein consumption comes from fish [3]. Fisheries sector contributing 3.50% to the country's Gross Domestic Product (GDP) and contributing to the agricultural GDP, almost one-fourth (25.72%) [3]. Fisheries sector in Bangladesh is broadly divided into three subsectors: inland culture (8,21,923 ha), inland capture (38,90,282 ha) and marine water (1,18,81,300 ha) [3]. Among them, inland capture, inland culture and marine fisheries subsectors contributed to 28.19%, 56.76% and 15.05% of the country's total fisheries production, respectively [3].
Inland culture subsectors contributed to maximum fish production due to adoption of improved farming practices by the farmers and need-based extension services at farmer's level [3]. In contrast, inland-capture fisheries production has been declined due to over exploitation, fish habitat degradation, siltation of water bodies and water pollution [4] in spite of having the maximum fisheries resources of the capture fisheries. Therefore, to increase the inland capture fisheries production, several socio-eco-friendly programs are being implemented such as stocking of fingerlings of endangered species, establishment of beel nursery management, community-based fisheries management program, establishment and maintenance of fish sanctuaries, cage and pen farming system in the water bodies [5]. On the other hand, marine fisheries production has also declined due to over exploitation and complications in

implementing management strategies [6]. To increase marine fisheries production, government and non-government organization are strictly followed the banning of 22-days for coastal estuaries and 65-days for marine water, consequently increased hilsha fish production significantly [3].

Recently, blue economy has gained impressive attention in Bangladesh due to getting huge marine water resources (1,11,631 sq. km) from Myanmer in 2012 and (19,467 sq. km) from India in 2014 [7]. Despite having the long coastline and large marine water area, marine fisheries sector is still in its early stage of development. However, proper utilization and preservation of marine resources can support food security, improve livelihoods [8], without hampering the ocean ecosystem for achieving the United Nations agenda on sustainable development goal 14 [9]. In this context, the objectives of the present study are (i) to review the fisheries resources available in Bangladesh and (ii) to identify the prospects, challenges and possible solutions for fisheries resources in Bangladesh.

Inland culture (closed water) fisheries

Farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants along with intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. and individual or corporate ownership is called aquaculture[5]. Inland closed water fisheries provides around half of the direct human fish consumption in Bangladesh. The culture fish production of pond, seasonal waterbody, baor, shrimp farm, pen culture and cage culture were 19.74, 2.17, 0.10, 2.58, 0.12 and 0.04 lakh MT in 2018-19, respectively. Subsequently, the corresponding contributions of culture fisheries to total fisheries production were 45.04, 4.96, 0.24, 5.89, 0.28 and 0.09%, respectively. The culture fish production became quite double (9.19 lakh MT in 2005-06 to 24.88 lakh MT in 2018-19) during the last ten years due to adoption of improved farming practices by the farmers. The general growth performance of inland culture shows a moderate, reasonable and admirable increasing trend. The total inland culture fish production of the country was 9,45,812 MT in 2006-07 and has become 24,88,601 MT by 2018-19 (Fig. 1). That means that the inland culture fish production of Bangladesh has increased more than double by the last decades, but inland capture fish production has not increased in the same trend. Mainly two types aquaculture are practices in Bangladesh: freshwater and coastal aquaculture. Till now, marine aquaculture is not practiced in Bangladesh. Carps (indigenous and exotic), tilapia and pangus are the major freshwater aquaculture species and shrimp (*Penaeus monodon*) and prawn (*Macrobrachium rosenbergii*) farming in ghers are the major coastal aquaculture species. In Bangladesh, about 20 fish species have been domesticated and their breeding and rearing protocols have been developed [10]. Although, domestication of wild fishes gives benefits both the fish farmer and the environment [11]. But, domestication of exotic species has been recognized as an agent of the loss of indigenous biodiversity and ecosystem [12].

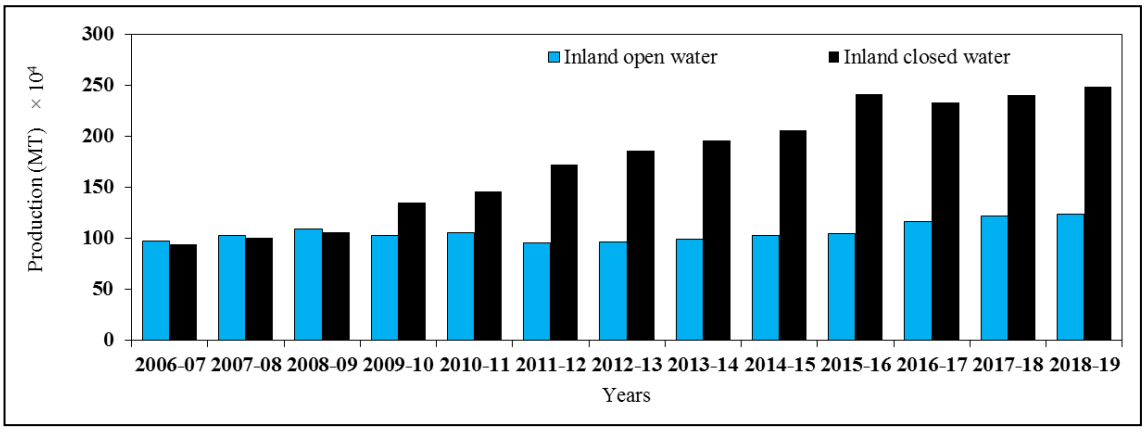

Fig 1: Trend in inland (open and closed) fish production in Bangladesh (Reference 3).

Inland capture (open water) fisheries

Bangladesh has huge capture fisheries resources with a wide range of aquatic diversity. Biodiversity is also enriched; 260 freshwater fish species is available in the inland waterbodies. The inland capture fish production such as river, beel, floodplain and Kaptai lake were 3.25, 0.99, 7.81 and 0.11 lakh MT in 2018-19, respectively. Subsequently, the corresponding contributions to total fisheries production were 7.42%, 2.28%, 17.82% and 0.24%, respectively. Inland capture fish production has been increased compare to previous year (4.71 lakh MT in 1983-84 to 12.35 lakh MT in 2018-19) but their share has been declined, from 38.68% in 2000-2001 to only 28.19% in 2018-2019 and has not yet been attained to its optimum level due to over exploitation, fish habitat degradation, siltation of water bodies and water pollution [4] in spite of having the maximum fisheries resources of the capture fisheries. However, major carps, exotic carp, pangus, tilapia, other inland fish and hilsha are the dominant species from inland water area [3] (Fig. 2). But, hilsha production increases day by day due to the management activities of the government including ban on catching brood fish and fries, implementation of jatka conservation program, management of fish sanctuary and implementation of hilsha spawning protection activities (Fig. 3). According to the Fisheries Statistical Report of Bangladesh 2018-19, the country's total hilsha production were 5,32,795 MT of which 2,42,479 MT from inland source and 2,90,316 MT from marine catches [3]. Hilsha alone contributes 12.15% of the country's total fish production. Around 1% of country's GDP comes from hilsha.

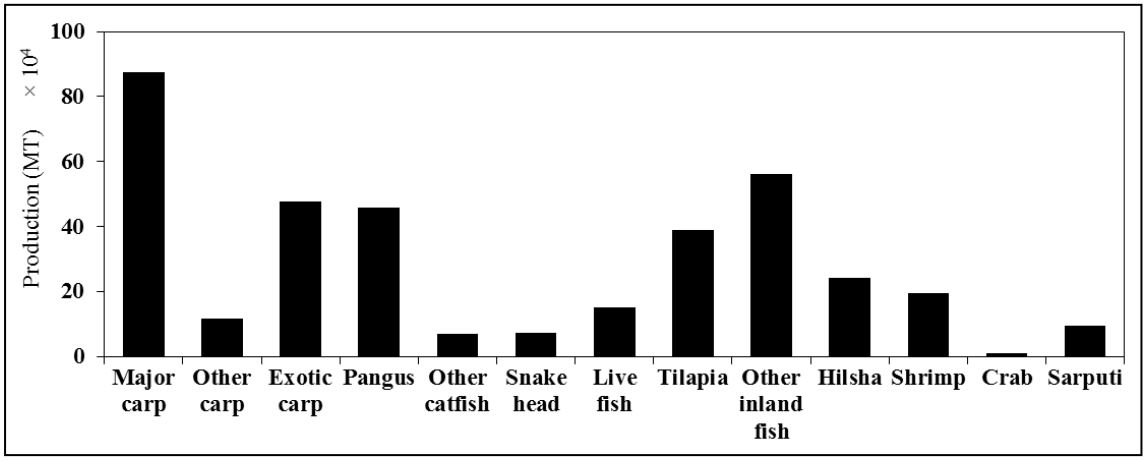

Fig 2: Species-wise annual fish production in inland fisheries in 2018-19. Major Carp; Rui, Catla, Mrigal, Other Carp; Kalibaus, Bata, Ghania, Exotic Carp; Silver Carp, Grass Carp, Common Carp, Mirror Carp, Big Head Carp, Black Carp, Other Cat Fish; Boal, Air, Silon, Rita, Snake Head; Shol, Gazar, Taki, Live Fish; Koi, Singhi, Magur (Source: Reference 3).

Marine fisheries

Fish and other aquatic organisms living in the ocean is called marine fisheries resources. The marine environment of Bangladesh is enriched with nutrients from the land and creating high productivity due to warm tropical climate and high rainfall [14,15]. Bangladesh got 1,18,81,300 ha huge marine water resources from Myanmer in 2012 and India in 2014 according to the judgment of International Tribunal for Law of the Sea [16] (ITLOS) (Fig. 4). Thus, the country has huge potential for marine fisheries in artisanal, industrial and coastal sub-sectors. 475 species of fish under 13 families has been identified from the coastal and marine waters. Hilsha (Ilish), shrimp and prawn, bombay duck, jew fish are the dominant species among others captured fish in the Bay of Bengal [3]. There are four fishing grounds in the Bay of Bengal such as south patches, south of south patches, middle ground and swatch of no ground [17] (Fig. 5). Major commercial species such as Indian salmon, hilsha, pomfret, ribbonfish, bombay duck, carangids, eel, jew fish, catfish, sharks and rays are found in the south patches, pomfret, red snappers, ribbonfish, silver jew, carangids, shrimp are found in the south of south patches, Indian mackerel, snappers, groupers, jew fish are found in the middle ground and shrimps, hilsha, pomfret, ribbonfish, bombay duck, jew fish are found in the swatch of no ground [2]. According to Ahmed (1990), total 56 species of shrimp and prawn are available in Bangladesh. Only four species are exported to the world countries and 10 species are commercially exploited [18] (Table 1). Shrimps and prawns are mainly produced in coastal districts such as Khulna, Satkhira, Barisal, Patuakhali, Bagerhat, Vola, Chittagong, and Cox's Bazar. As a result of increasing demand and price, shrimp culture started to expand in 1970s aiming mainly the export markets [19]. Shrimp production increased form 8,219 MT in 1983-84 to 2,58,039 MT in 2018-19 [3]. The average production in the shrimp farms is about 998 kg/ha [3]. Total 16 species of crabs are available in Bangladesh and 3 species are exported to different world countries [20, 21] (Table 2). Seeds of this species are also available throughout the coastal belt [22]. According to fisheries statistical yearbook of Bangladesh, in 2015-16 fiscal year, the total production of mud crab was 13,160 MT, which has reached at 12,084 MT in 2018-19 [3]. Total 6 freshwaters and 142 marine bivalves have been recorded from Bangladesh [23]. Although, eight species of genus *Pinctada* and one species under *Placuna* belongs to pearl oyster. But, *Pinctada fucata* is the best pearl production species through induced technique among them. Four mussel's species are economically important such as *Lamellidens marginalis*, *Lamellidens jenkinsianus*, *Perna viridis* and *Perna indicus.* Bangladesh export blood clams to the world countries [24]. Additionally, the marine environment of Bangladesh is suitable for seaweed culture. The natural abundance of commercially important seaweeds in Bangladesh is reported to be very low [22]. Only, about 30 km of the coastline, St. Martin Island have got rocky substratum and are suitable for seaweeds. Although, 133 species of seaweed found in the Bay of Bengal, but only 8 species of seaweed are commercially important and *Hypnea* sp. was the most abundant species [25,26] (Table 3). In St. Martin Island, the fishermen, women and their children are engaged in collecting seaweeds. The collected seaweeds are sundried on the open beach due to there is no industrial set up for seaweed processing and utilization in Bangladesh.

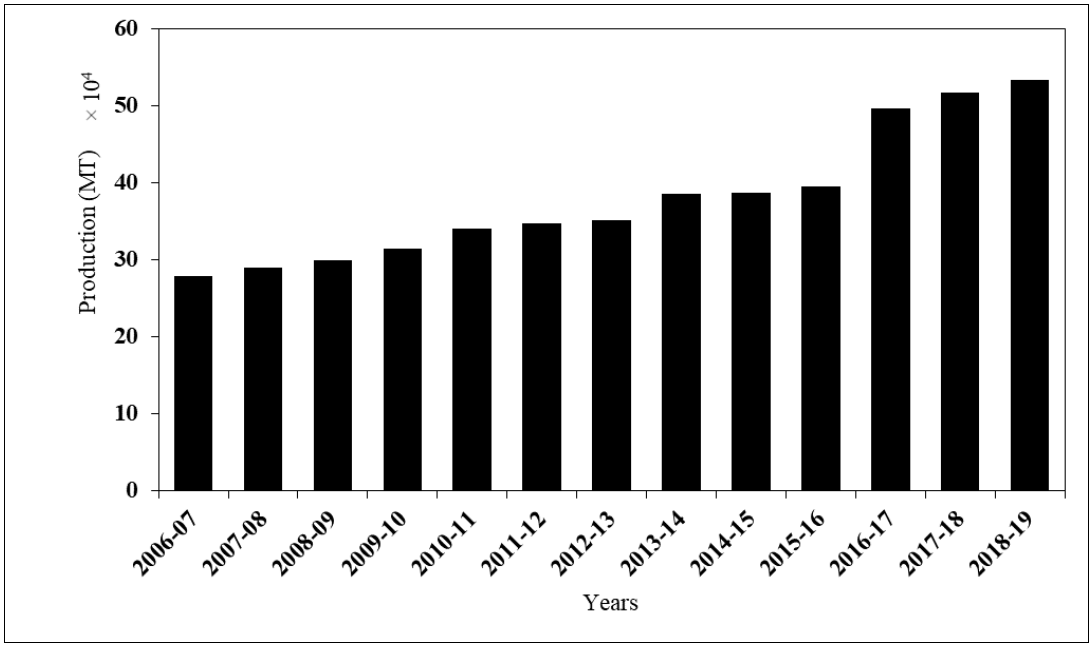

Fig 3: Hilsha production in Bangladesh (Source: Reference 3).

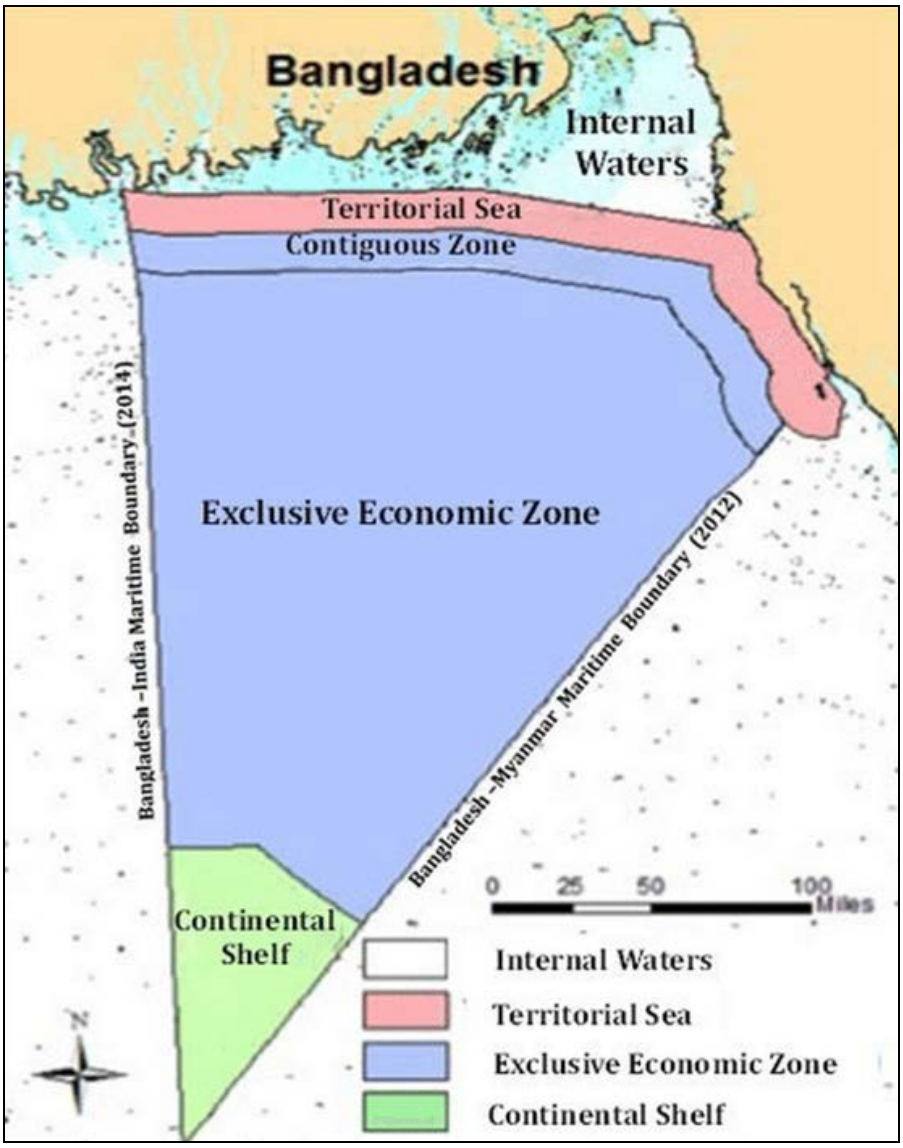

Fig 4: Maritime area of Bangladesh (Source: Reference 16).

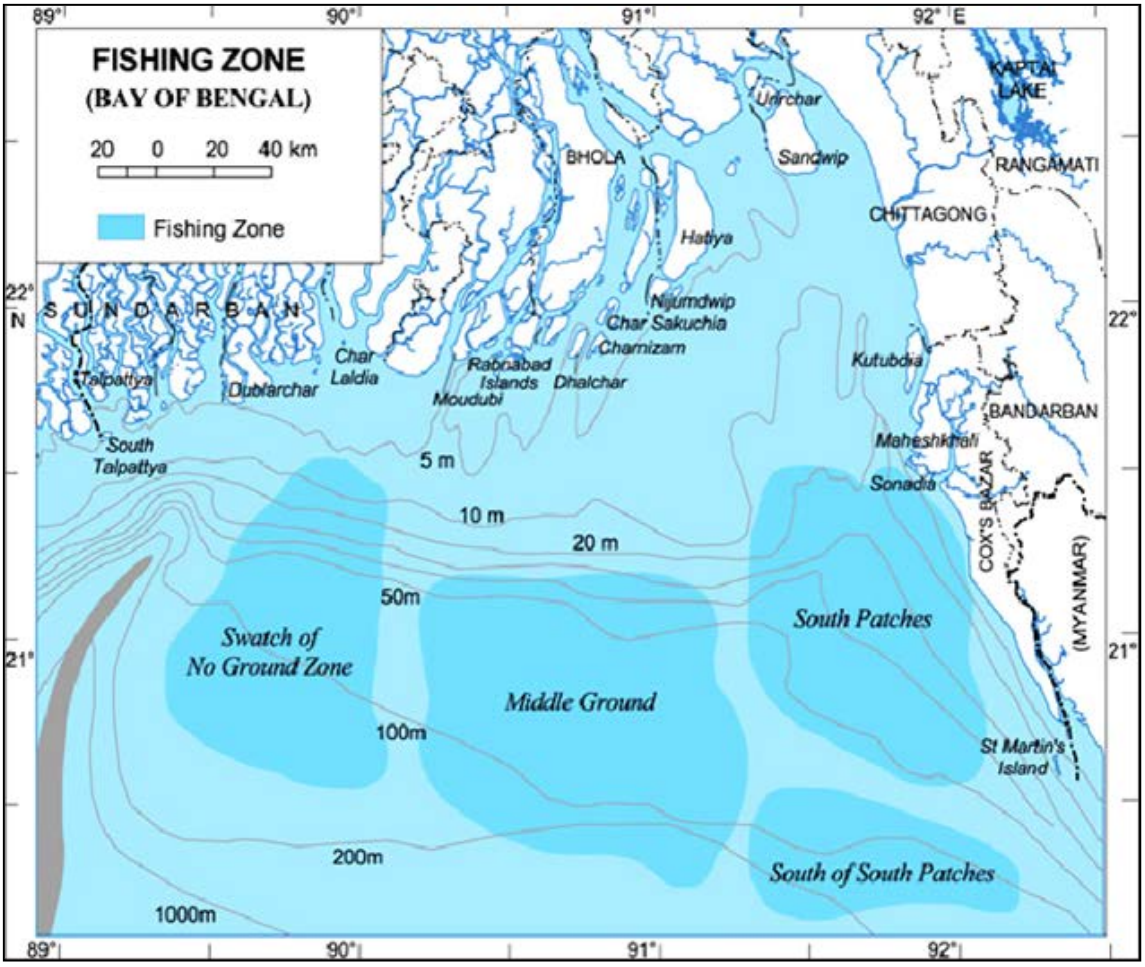

Fig 5: Fishing grounds in the Bay of Bengal (Source: Reference 17).

Table 1: List of commonly harvested shrimp and prawn in Bangladesh

Group	Bengali name	English name	Scientific name
Prawn	Golda chingri	Giant Freshwater Prawn	*Macrobrachium rosenbergii**
Shrimp	Bagda chingri	Giant tiger Shrimp	*Penaeus monodon**
	Baghtara chingri	Green tiger Shrimp	*Penaeus semisulcatus*
	Baghtara chingri	Kuruma Shrimp	*Penaeus japonicus*
	Chaga chingri	White Shrimp	*Penaeus indicus**
	Bagha chama	Blue-tail Shrimp	*Penaeus merguiensis*
	Horney chingri	Speckled Shrimp	*Metapenaeus monoceros**
	Nona chingri	Yellow Shrimp	*Metapenaeus brevicornis*
	Ghora chingri	Kadal Shrimp	*Metapenaeus dobsoni*
	Gura chingri	Roshma Shrimp	*Palaemon styliferus*
	Ruda chingri	Rainbow Shrimp	*Parapenaeopsis sculptilis*

* indicates commercially exportable species (Source: Reference 18)

Table 2: List of economically important crab species in Bangladesh

Bengali name	English name	Scientific name
Shila Kankra	Giant Mud Crab	*Scylla serrata**
Sataru Kankra	Swimming Crab	*Portunus pelagicus**
Tin Fota Kankra	Three-spot Swimming Crab	*Portunus sanguinolentus**
Gasho Kankra	Paddler Crab	*Metopograpsus thukuhar*
Gasho Kankra	Paddler Crab	*Metopograpsus messor*
Kankra	Violet Vinegar Crab	*Episesarma versicolor*
Kata Kankra	Freshwater Crab	*Potamon woodmasoni*
Chimta Kankra	Spiny Crab	*Potamon martensi*
Pati Kankra	Sartotina Crab	*Paratelphusa lamellifrons*
Holdepa Kankra	Fiddler Crab	*Uca urvillei*
Kankra	Ghost Crab	*Uca annulipes*
Lal Kankra	Horned-eyed Ghost Crab	*Ocypode ceratophthalmus*

* indicates commercially exportable species (Source: Reference 21)

Table 3: Commercially important seaweeds in Bangladesh

Species	Type
Caulerpa racemosa	Green seaweed
Enteromorpha sp	Green seaweed
Gelidiella tenuissima	Red seaweed
Gelidiella pusillum	Red seaweed
Halymenia discoidea	Red seaweed
Hypnea pannosa	Red seaweed
Clathratus sp	Brown seaweed
Sargassaum sp	Brown seaweed

(*Source*: Reference 26)

Prospects of inland culture fisheries

56% fish production comes from inland culture fisheries [3]. But, inland culture fish production almost saturated in condition. Aquaculture industry has the prime responsibility to increase in production to maintain current aquatic food consumption levels within the next 5 decades. For this reason, we need new technology. As a result, bio-floc technology and recirculating aquaculture systems can be used in a wide scale to increase the inland culture fish production. Bio-floc technology has self-nitrification process and generate nutrient cycle by maintaining higher C: N ratio [39]. Therefore, bio-floc technology is cost effective, control water pollution, eco-friendly, prevent diseases, gives higher productivity and consequently a sustainable production [39]. In this technology fish are cultured in high stocking density, strong aeration and biota formed by bio-floc used in aquaculture system with limited or zero water exchange under. To improve the digestibility of nutrients, increase tolerance to stress and encourage reproduction, probiotics are used [15]. In addition, recirculation aquaculture systems (RAS) represent a new and unique way to farm fish. Instead of the traditional method of growing fish outdoors in open ponds and raceways, this system rears fish at high densities, in indoor tanks with a "controlled" environment.

Prospects of inland capture fisheries

Only 28% fish production comes from inland capture fisheries [3]. But we have huge open water resources. The productivity in the river-estuary and beel is 318 and 859 Kg/ha, respectively [3]. If we want to increase this value either 1000 Kg/ha or 1200 Kg/ha we should increase the water area under pen and cage culture system. Only 1.29 lakh cubic meter and 5294 ha area are under cage and pen culture system, respectively. Therefore, to increase inland capture fisheries production and conserve biodiversity, various approaches such as community based fisheries management, beel nurseries, stocking fingerlings of endangered species, establishment and maintenance of fish sanctuaries, cage and pen culture systems can be adopted [5]. Additionally, existing banning rules and regulations of catching fish during breeding season from inland capture water bodies like rivers, haors, baors, beels etc. should be implemented properly for conserving biodiversity and increasing fish production, as banning of 22-days in rivers and 65-days in marine water have significantly increased hilsha fish production [13]. If we apply this ban period during the spawning season of fish in the other capture water bodies like haors, baors, beels will increase the capture fisheries production. In addition, Daudkandi model of community floodplain aquaculture is the another opportunity and it is one kind of community-based fisheries management (CBFM). CBFM was expected to improve fisher access, livelihoods, and the sustainability of fisheries and promote an equitable distribution of benefits from fisheries to community people [28]. So, we can apply this approach in the different open water bodies in the country such as haors, baors and beels (chalan beel, arial beel etc.) to increase the capture fisheries production in Bangladesh.

Prospects of marine fisheries

Blue economy has recently gained impressive attention in Bangladesh due to getting huge marine water resources from Myanmar in 2012 and India in 2014 [16]. Ecological importance of blue economy includes ecosystem functioning, water quality preservation, biodiversity maintenance, stock improvement, stabilizes the shoreline, pollution reduction and CO_2 removal from the atmosphere. In addition, socio-economic importance includes food security, economic security, empowerment, human health, knowledge transfer, cultural services and capacity building [27]. Marine tourism could be one of the important sources of income in Bangladesh. It is estimated that in 150 countries, tourism is one of the five top export earners and 60 countries it is the first earning source [29]. So, development of blue economy will open a new window for development of Bangladesh. Therefore, marine aquaculture systems for example farming of seaweed, sea bass, mullets, promfrets, mud crab etc. should be adopted for achieving the United Nations agenda on sustainable development goal 14 on conservation, sustainability and use of oceans, seas and marine resources for increasing economic benefits.

Challenges of fisheries resources management in Bangladesh

Bangladesh is most at risk from climate change. The country will face the greatest danger from global warming in the next 3 decades. In addition, poverty and large low-lying coastal regions prone to annual floods and cyclones were among factors making Bangladesh the number 1 exposed country to climate change [30]. Climate change have devastating impacts on fishery-based livelihoods and on domestic food supply. World's biggest mangrove can be smeared out by a one- meter rise in sea level [31]. In addition, erratic and irregular rainfall as well as temperature change will affect the readiness, maturity and gonad development of fishes in breeding season. As a result, the production of eggs and carp fry has been declined in Halda river [32]. In the same time, changes in temperature and dissolved oxygen affect plankton productivity in the water bodies [2]. The deteriorated water quality is tended to escalate disease outbreaks, reduce fish growth, production and species composition [33, 34]. Total number of freshwater fish species in Bangladesh ranges from 250 to 260 [23, 35], but IUCN assessed 253 fish species of which 64 species are under threatened category. 9 species are critically endangered, 30 species are endangered and 25 species are vulnerable [36]. Moreover, the marine fisheries were constrained mainly by lack of awareness about modern aquaculture techniques like cage culture, lack of inadequate facilities in relation to information, communication, transportation and market, lack of skilled manpower in this field, lack of financial support and loan facilities to the sector [5, 37].

Solutions for inland fisheries resources

The government of the Bangladesh should develop appropriate policy and take proper initiatives for protection and conservation of inland fisheries resources. To realize the problems, there is a need to control pollution, prevent further

deterioration of water flows and shrinkage of water-bodies through infrastructures, like embankment, roads, urban housing projects, and industrialization. Moreover, to overcome these problems, it is important to maintain good quality brood fish (indigenous and exotic carp species) with conserving the natural breeding, spawning, nursery and grow-out areas. In addition, establishment and maintain fish sanctuaries in certain eco-sensitive areas like the sundarbans, kaptai lake, rivers, floodplains. Training facilities should be provided to the fishermen and maintain quality fish seed and supply good quality fish feed at any time. The conservation strategy includes the seasonal ban, gear restriction, species restriction.

Solutions for marine fisheries resources

The initiatives have to be taken by the government and private sector for developing the Mariculture [37, 38]. These are: (a) for ensuring the economic security of marine fisheries conservation and management can be divided into three categories, short-term, mid-term and long-term strategies; (b) prevention of harvesting hilsha juveniles will significantly improve the recruitment that will ultimately increase the production of the species in the area; (c) develop appropriate technologies for coastal and marine aquaculture expansion of coastal aquaculture like sea bass, mullet, seaweeds, crabs, mollusks also could be an important alternative option; (d) develop and coordinate with the regional and international networks and (e) water areas in the Sundarbans and adjacent island shall be declared as Marine Protected Areas.

1. For ensuring the economic security of marine
2. fisheries conservation and management can be
3. divided into three categories, short-term, mid-term
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7. divided into three categories, short-term, mid-term
8. and long-term strategies.Management of gravid mother of the tiger shrimp (*Penaeus monodon*) for optimization of the catch and use of gravid mother of the tiger shrimp for hatcheries.

Conclusion

Inland culture fisheries production has increased over the recent years, but inland capture and marine fisheries production has not yet attained to its optimum level. Therefore, to increase inland capture fisheries production and conserve biodiversity, stocking fingerlings of endangered species, establishment and maintenance of fish sanctuaries, cage and pen culture systems can be adopted. Blue economy has recently gained impressive attention in Bangladesh due to the technological advancement, and providing offers of multiple benefits, like marine aquaculture, marine tourism and transport etc. Natural ecosystems are decreasing rapidly due to various human interferences and natural causes, which increasing challenges to conserve the remaining fish biodiversity. To realize the potential, the government departments, non-government organizations, researchers and development partners can play important role in the formulation of management plans. So, proper utilization of the marine resources can boost up the total fisheries production of Bangladesh. Indeed, this review will help researchers, academicians, policy makers of Bangladesh to formulate appropriate plan to utmost utilization of fisheries resources.

Declaration

All authors would like to declare that they have read and agreed to the content of the submitted article and there is no conflict of interest among the authors and/or with the publication ethics of the journal.

Authors Contribution

This work was carried out in collaboration among all authors. Authors JH and DCS designed and performed relevant reviews and wrote the first draft of the manuscript. Author RAL rewrote the manuscript. All authors read and approved the final manuscript.

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