1. WRITTEN IN WATER: FISHERIES AND AQUACULTURE IN BANGLADESH

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1.1 Introduction

Water and manpower are the two most abundant resources of Bangladesh. While developing these resources are seminal to the nation's economic development, achievement so far has been minimal [1]. The nation, however, depends heavily on its fisheries sector (which is a direct beneficiary of the water resources) for employment, protein nutrition and export revenue. Most of the fish produced in the country at present is captural in origin and fish capture is in the decline. Aquaculture has not been successful in adequately boosting fish production. The preservation of the environment, which is directly linked to fisheries and aquaculture, is also an important issue. The government and non-government organizations (NGOs) have various plans to make the fisheries sustainable and improve aquacultural productivity while the involvement of the private sector remained erratic. The purpose of this essay is to analyze some of these activities and offer some suggestions. The status and potential of fisheries and aquaculture, which have been adequately reviewed [2-4] and many other areas such as, government policies, role of donor agencies, flood action plan, socioeconomics of traditional fisher folk, small-scale cooperatives, global warming, etc., are not elaborated here. We plan to treat fisheries research, development and management in a separate article. To keep the reference list short, secondary sources have been widely cited in this report. The article starts with an explicit look on the importance of fisheries, followed by a brief review of fishery and aquaculture with implications and concludes with remarks emphasizing the requirement of new approach and technology for the protection and development of fisheries resources.

1.2 Importance of fishery

1.2.1 Fish in public nutrition

The average per capita calorie intake in Bangladesh is too low for a productive life [5,6]. The diet is protein deficient and dominated by cereals (which provide 85% of the calorie intake) and pulses. Arguably, Bangladesh is self-sufficient in rice, but it imports wheat (700,000 metric tons or mt), and bulk of its needed diary products (65,000mt), animal meat (as live cattle) and edible oils (550,000mt) [7]. According to BBS [8], per capita per day protein consumption in Bangladesh is 63gm, which is lower than the recommended 125gm (1.6gm/kg body weight). Protein deficiency in diet may inflict growth retardation and physical deformities in growing children and indeed, 43% of Bangladeshi children suffer from adverse effects of protein

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deficiency [8]. As much as 94% of the protein consumed in Bangladesh come from grains and pulses [3], however, unlike animal proteins, plant proteins may not provide all the essential amino acids. Fish provides 74% of animal protein consumed. As fish is consumed in Bangladesh almost in its entirety (excepting scales, portion of the alimentary canal, spines, fins and a few large bones), fish diet provides calcium, phosphorus, some essential fatty acids, vitamins and minerals. Certain fatty acids implicated as health food are abundant in fishes. Vitamin A deficiency is an important public health problem in Bangladesh evidenced by a very high incidence of blindness among growing children and expectant mothers. Certain freshwater fishes (such as Mola) contain high concentrations of fat soluble vitamins. Since these relatively cheaper fishes are within the purchasing power of the rural poor, fish diet may be preventing even more acute vitamin A deficiency in Bangladesh. Marine fishes contain higher concentrations of iodine and some other minerals. Table salt is not iodized in Bangladesh and endemic goiter is prevalent in the northern region of the country. Increase in the consumption of marine fishes may help solve this important public health problem too.

1.2.2. Fish in Bangladesh economy

The fisheries sector comprises 2.8% of the GDP of Bangladesh and eight percent of export income [3]. Many fish farms, particularly shrimp farms, are now being established exclusively for export and fish export income is likely to increase. At present the fisheries sector employs over five to eight percent of Bangladeshi work force. Hilsa fishery alone employs 200,000 full time fishermen, almost two percent of the nation's total work force [9]. A fraction of the work force in the fishery sector is represented by various middlemen, craftsmen, businessmen, researchers and officers. The rest is dominated by the traditional fisher folk mostly from the lower cast Hindus. Landless and uneducated, these people are virtually enslaved to the fishing profession who have few other options to make a living. Over the years, economic hardship had forced many poor (Muslim) peasants to join the fishing folk. Fishing in public water is free in Bangladesh and all large water bodies (irrespective of the ownership of the land) are owned by the state. As a result, over 77% of rural household freely engage in harvesting wild fish for food every month [10]. Evident is the discrepancy that the fisheries sector constitutes only 2.8% of the GDP but employs a huge work force. The fisheries resources of the country are truly under drastic strain.

1.3 The water resource

1.3.1 Surface waters

Bangladesh is endowed with ample water resources. Over 200 rivers and canals totaling an area of 1,032,000 hectare (ha) traverse the country. The natural depression of various origins and the Kapati reservoir comprise another 175,000ha. Bangladesh has over 1,949,000 ponds and ditches covering 152,000ha. The flood plain which remains under water for as long as 6 months each year due to the annual welcome monsoon flood provides a seasonal water resources of about 2,800,000ha [see references 3 and 8 for more detailed statistics]. The estuarine ecosystem,

which is one of the most productive ecosystems of the world [11], constitutes another 552,000ha [3]. The drainage of the Ganges-Brahmaputra-Meghna river system makes the continental shelve in the Bay of Bengal highly productive. Considering 200 miles offshore water as the country's economic zone, Bangladesh claims exclusive fishing right over a sea surface 31% of its total land area [10].

Bangladesh's water resources, however, are seasonal and undeveloped. The soil of the country is made of sandy clay with poor water retention capacity [10]. The surface water is exposed to the tropical sun and evaporates rapidly. While the country was primarily a lowland monsoon forest and everglades a few scores of years ago, most of its leftover wooded areas has been cleared in last 20 years. Currently, only six percent of the land is forested [9]. Such exposed land is under the continuous assault of deep-tilling agriculture, as much as 3504mm of annual rainfall [8], frequent droughts and seasonal high winds. As a result, the top soil is being eroded at a very rapid rate and is being deposited into the low lands, natural depressions, rivers and canals. Such deposit is in addition to the huge amount of alluvium that is routinely carried by the major rivers. The major rivers of Bangladesh are international which travel through India, Nepal, China or Burma and deforestation in those countries (particularly Nepal) also adds additional loads of silt in the water flow. The overall result of silt deposition is reflected in the major waterways, which at present are barely navigable. The oxbow lakes created due to the shift in the course of the major rivers are the major freshwater fish habitats. These resources are temporary in nature. However, in the past these water bodies used to disappear after a long ecological succession. At present, the disappearance is rather quick. In some cases, oxbow lakes are deliberately connected to the rivers to accelerate silting, to reclaim the land for agriculture.

The upstream partners of some of Bangladesh's international rivers, particularly India, had intensified the use of water. Such diversion of water affects Bangladesh in very unpredictable ways. The Ganges, the life line of western Bangladesh, and its tributaries, flows across Nepal, India and Bangladesh. The deforestation in Nepal has caused widespread silting across the Ganges. India has erected many dams on the Ganges and its tributaries for irrigation and other purposes. The diversion of water and silting have caused a multitude of problems in Bangladesh, including, bank erosion, flooding, water table depression, deterioration in navigation, habitat damage, intrusion of salinity and xeric transformation of land. Other international rivers like the Brahmaputra may encounter similar fate in the future [12]. Deforestation induced soil erosion and silting have damaged the Kaptai reservoir to such an extent that in the dry season, the water level of the reservoir is not sufficient to operate all the turbines of the hydroelectric power station [13].

The ponds and ditches of Bangladesh are relatively small in size and vulnerable to drying, flood, rain water runoff and silting. Besides, the ponds often have multiple owners and fish raising is not the principle cause to own them. Ponds are generally not created for aquaculture but for soil to elevate land over the flood levels to construct houses, markets and streets. The ditches are left to the mercy of the flood to be refilled with silt. The relatively large holes are left alone; water from these holes are used for various household usage, particularly for cooking,

washing, bathing, and animal consumption (water of shallow tubewells used for drinking is often hard and iron laden and not good for cooking and bath). Changes in odor, color or taste of pond water (due to manuring, for example) are seldom welcome.

There are over a hundred flood control embankments in Bangladesh and many more are in the planning stage. The embankments, though may have served their primary purpose, are often made without considering the ecosystem of the land. The embankments are not constructed with adequate numbers of sluice gates. As a result, it prevents the free flow of the welcome flood water (and the alluvium) and dispersion of aquatic wildlife. It is estimated that the existing embankments had already caused reduction of fish production by five percent and at the end of the implementation of the current flood control plan by the year 2005, inland fish production may be reduced by as much as 13% [14].

The shore areas of Bangladesh are very low and flood prone. Several tidal waves have caused millions of deaths in Bangladesh in the present (twentieth) century. Except for a patch near Cox's Bazar, the shore line of Bangladesh is muddy. The loose soil of the shore can be damaged irreversibly if the mangrove cover is removed for say, mariculture. Over 41% of the mangrove growth of Chakoria Sundarbans in Chittagong, however, has been removed for low productivity shrimp culture [9]. Bangladesh has very few in-shore and offshore islands to be used as fishing docks. A few in existence are young coral or alluvium formations which are low and erosion prone. The weather pattern of Bangladesh is also unfavorable for sea going. Formation of low pressure in the Bay of Bengal is all very common and the sea is rough for as much as six months of the year.

1.3.2. Ground water

Water table of Bangladesh is very close to the surface on which the country’s ecosystem has been established over the last few million years. In last few decades, however, the ecosystem has experienced inauspicious changes in terms of water table. Increase in ground water usage started in the 1960s. Millions of hand pumped shallow tubewells were installed to get clean drinking water in the countryside. Deep tubewells were later installed in the cities for the same purpose. Bangladeshi artisans were the first to invent bamboo tubewells. Shallow as well as deep tubewells are used for irrigation and aquaculture since 1970s. Many shallow tubewells have since dried up. Many localities are not getting enough clean drinking water and many irrigation projects had failed. Ponds and ditches, including many private and public fish (seed) farms regularly dry up in the summer.

Water diversion from the Ganges may have affected the ground water levels of Bangladesh. All the branches of the Ganges in the western Bangladesh (including Madhumati, Shibsha and Pashur) had reduced to mere canals. Xeric transformation in western Bangladesh has been reported [12] and salinity intrusion in the south-western Bangladesh has been so severe in the dry season that water is required to be carried from upstream in barges to keep the factories

operational in Khulna. High levels of arsenic has been recently reported in many districts of West Bengal [15]. Arsenic has also been detected in tubewell water in Sylhet [16]. Arsenic poisoning has caused severe dermatitis and various types of cancers in human and animals in West Bengal. The extent of arsenic problem in Bangladesh is yet to be fully assessed.

1.3.3. Water pollution

The data on pollution in Bangladesh is scanty but suspicion is high regarding its presence due to a complete lag in the enforcement of any regulation [9]. Bangladesh is one of the few remaining nations in the world which still uses leaded gasoline, manufactures and uses DDT, allows marine ships and tankers to dispose ballast water and bilge washings in the inner harbors of its sea ports and releases all its raw municipal sewage and industrial effluent directly to its surface water. Since water is a universal solvent, pollutants released in the air and soil also find their ways to water in the long run. Bangladesh is not heavily industrialized and the volume of industrial effluent may not be very large. However, effluent from paper and pulp, leather, chemical fertilizer, and dyeing industries contain highly toxic ingredients including mercury, lead, arsenic, chromium and various hydrocarbon derivatives [9]. In the recent past, Bangladeshi businessmen attempted to import industrial waste from western countries to process and dispose in Bangladesh [13]. It is hoped that the attempt was permanently blocked and Bangladesh is not receiving additional loads of foreign pollutants.

Bangladesh is an agricultural country but it uses relatively lower amounts of chemical fertilizers and pesticides per acre [10] compared to the industrialized nations. However, use of pesticides is not much regulated and pesticides such as DDT, endrin and dieldrin are still being used. Endrin, although is not available in the open market, can be obtained illegally from the neighboring countries. As a beneficiary of the Green Revolution, the use of chemical fertilizers and pesticides in Bangladesh will significantly increase in the future to increase and maintain the levels of agricultural productivity. Since the aquatic wildlife of Bangladesh is in a decline, it is possible that water pollution may be affecting the ecosystem. Some levels of research are needed right now to determine the present status of pollution in the country. Without actual data, politicians, businessmen, scientists, external donors and environmentalists must not take sides and long term policies should not be sought.

1.4 Aquatic Wildlife: Species Diversity

1.4.1 Endogenous species

The aquatic wildlife of Bangladesh contains over 500 species [9]. The fresh water fishes are dominated by carps, catfishes, shads, freshwater shark, air breathing catfishes, snakeheads, spiny eels, loaches, gobies, feather backs and perches. Various types of prawns and shrimps are the shell fishes of commercial importance. The fresh water bivalves and crabs are abundant but are not commercially harvested. Mud crab (Scylla serrata) however, is now being collected by artisanal fishers for export [17]. A few freshwater bivalves and snails are harvested (for shells)

to make calcium oxide for household consumption. Pearls are now collected from bivalves [4,18]. Frogs and toads are not consumed in the country but bull frogs are commercially hunted for export. Among the reptiles, cobras and probably some other land snakes are harvested for illegal export, boas and monitor lizards are killed for pelt and several species of turtle are harvested for consumption and export. Bangladesh is one of the largest exporters of reptile leather [9]. Almost all of the large lizards (alligators, crocodiles and gavials), which were previously abundant, are now in the brink of extinction. There are several species of river and marine dolphins in Bangladeshi waters but fortunately, few are harvested for commercial purpose [19]. All aquatic wildlife other than fin-fishes and shrimps are harvested exclusively for export. However, little is known about the biology and population dynamics of the organisms such as crab, frog, monitor lizard, boa, turtle and dolphin and exploitation of these organisms at this point can be risky. Amphibian populations are showing a sharp decline worldwide for various reasons [20]. It is claimed that further exploitation of bull frog, an important pest controlling agent, could be disastrous to agriculture in Bangladesh [21]. The same can be true for the reptiles which control important agricultural pests such as rodents. Interestingly, commercial bullfrog farming is now in the experimental stage in Bangladesh [22]. Turtle population is also reported to be in the decline and the United States is considering a ban on shrimp import from Asian countries (including Bangladesh) to protect turtles since many turtles got killed during shrimp fishing [23].

The diversity of marine fauna is not completely investigated yet. Several fin fishes such as pomfrets, snappers, cat fishes, tunas, shads, herrings, ribbon fishes, bombay duck, whiting, perch like fishes and shrimps are caught commercially. A sizable fraction of the marine catch, an estimated 30,000mt/year, is considered trash-fish and is discarded, although, the trash could be utilized to manufacture fish feed and other value-added commodities [24]. Several species of shrimps are harvested mostly for export. Mollusks are not consumed but shallow water marine shells and stony corals are harvested for making handicraft to be sold at a nominal price. In the recent years, large jelly fishes are harvested for export by the Beximco industrial group. Crabs (other than mud crab), and mollusks (including valuable seafood species such as octopuses, squids, scallops, clams and cockles, etc.) are yet to be fully utilized although the potential of these non-traditional fishes is under discussion [25].

The bionomics of only a handful of endogenous species of Bangladesh has been studied so far. A number of the endogenous species, viz., rohu (Labeo rohita), kalobaush (L. calbasu), catla (Catla catla) and mrigal (Cirrhinus mrigala), tiger shrimp (Penaeus monodon) and giant freshwater prawn (Macrobrachium rosenberghi) have been selected for aquaculture in Bangladesh. Several other species such as the common snakehead (Channa punctatus), striated snakehead (C. striatus), giant snakehead (C. marulius), air breathing catfishes (Clarias batrachus and Heteropneustes fossilis) and climbing perch (Anabas testudineus) are currently under consideration for aquaculture [4]. Several other species such as Pungus (Pangasius pangasius), cock-up (Lates calcarifer), fresh water shark (Wallago attu), river catfish (Mystus aor), spotted feather back (Notopterus chitala) and mahseer (Tor tor) could also be considered for aquaculture.

Bangladesh have only one migratory anadromous fish, the Padma shad (Hilsa ilisha), of economic importance. The anadromous fishes grow for years grazing in the vast feeding grounds in the seas and then migrate by the millions back to their birth-rivers for breeding. Countries like Canada, United States, Britain and Japan have large fisheries of migratory fishes such as salmon, trout, plaice and eels. These countries can sea-ranch (i.e., release farm-raised fingerlings to the open seas for future capture in the inland waters) with high degrees of certainty. The detailed biology of these species have been worked out and millions of fries of the fishes can be raised under controlled conditions. Although hilsa fishery in Bangladesh constitutes 14% of the total capture and employs 11% of the work force in the sector [9], Bangladesh is completely incapable of launching a program of hilsa ranching at this time. Although biology of Hilsa species has been studied to some extent [26], little is known about physiology and reproductive biology of the species. Tagging and other related studies on hilsas of the Padma river are yet to be performed.

1.4.2. Introduced exotic species

The genetic endowment in terms of aquatic wildlife for a small country like Bangladesh, is relatively large, but by no means, exceptional. Bangladesh has only a few species (a few air breathing fishes) suitable for aquaculture that naturally breed in captivity to quickly extend species diversity in aquaculture. Asiatic fin fish culture is largely traditional which prefers culture species at the base of the food chain and which grows rapidly in captivity. The filter feeders, such as the carps, are the primary consumers which depend on plankton and detritus and therefore, are the species of choice. Bangladesh has only four relatively fast growing filter feeders (i.e. the major carps). Quite naturally, Bangladesh has introduced several exotic fishes such as bighead carp (Aristicthys nobilis), black carp (Mylopharyngnodon piceus), common carp (Cyprinus carpio), grass carp (Ctenopharyngodon idella), java and nile tilapia (Oreochromis mossambicus and O. niloticus), mirror carp (C. carpio var specularis), silver minnow (Puntius gonionotus), and silver carp (Hypopthalamicthys molitrix), which has been adopted elsewhere for aquaculture and have been introduced in almost all of the east and south Asian countries, to improve aquacultural production [see 27 for details]. To date, no exotic species has been deliberately released to the open environment of Bangladesh. Biologists and environmentalists are still unsettled regarding the acceptance of the introduced species in Bangladesh [3]. However, no serious ill-effect due to the introduction of the exotic fishes in last three decades has so far been reported, indicating the concerns over ecological invasion unfounded.

1.5 Fishery

1.5.1 Freshwater fishery

Freshwater is the mainstay of Bangladesh fishery. Harvest from the rivers, canals, natural depressions, reservoirs, oxbow lakes, inundated flood plains and unstocked ponds (covering a

total of area of about 4,200,000ha) was 431,000mt in 1987 [3] . Fresh water fish production from wild stock has been sliding since mid 70's and it is unlikely that production will increase from this source without strenuous intervention. Freshwater fishery can be divided into riverine and oxbow lake/flood plain fisheries. The inundation that interconnects the rivers, the flood plains and the oxbow lakes is of cardinal importance to the sustainability of Bangladesh fisheries. Majority of the oxbow lakes completely dries up in the summer or become extremely shallow for large fishes to hide away from predators and fisherman, particularly, during prolonged droughts. Only a few of the natural depressions are large enough to conceal a breeding stock from the tremendous fishing pressure. Relatively larger rivers are the only places where the breeding stock can sustain and early stage recruits can grow out. It can be assumed from the available data and descriptive accounts [28] that most of the inland fishes of Bangladesh breed during some part of the flood season (May to September). Such a timing provides the breeding stock from the rivers and larger natural depressions to disperse to a suddenly widened habitat created by the flooding. At the end of the flood season, the habitat shrinks quickly. A fraction of the dispersed fishes return back to the rivers while others find themselves in the impounded paddy fields, ditches and oxbow lakes of various sizes which had been already disconnected from the rivers. Such a cycle has been operational from time immemorial and continuation of the cycle is essential for the sustainability of the inland fishery of Bangladesh

Importance of flood, however, is highly under-appreciated in Bangladesh. The effect of the ecologically unsound flood control plan on fishery has been discussed earlier. During flood season, many canals and channels are completely obstructed by fishermen and peasants for tarp and bag-net fishery. Such obstruction fishery may deplete breeding stock, disrupt timing of fish migration and spawning and prevent dispersion of young fishes. A large fraction of the catch of the obstruction fishery is carp fingerlings and berried freshwater prawn. Several fishing regulations preventing obstruction fishery particularly, fishing of gravid fishes and fingerlings do exist but the regulations are seldom enforced.

Riverine fishery is dominated by the hilsa fishery. Hilsa migrates through most of the large rivers and both fishermen and peasants engage in fishing hilsas. Although accurate data is missing, hilsa catch in the rivers has dropped significantly in recent years [2]. At present more hilsas are probably caught in the estuaries or the open seas than in the rivers. Some smaller rivers such as the Madhumati, receives only a few hilsas to sustain a fishery (causing widespread migration of the traditional fisher folk). The smaller rivers in western Bangladesh, such as Barashia, Chitra, Ichamati and Fotik, become so shallow in the summer that most of its inhabitants are cleared off by the local fishermen and peasants as if the rivers are drying oxbow lakes. Management of these rivers during the dry season is urgently needed.

The fishing gears used in the fresh water fishery in Bangladesh have been reviewed [29]. Human hands [30] are still the most widely used fishing gears in the oxbow lakes and shallow rivers. Beside hands, various kinds of rods and lines, hooks, spears, traps, and nets are used. Hand capturing is facilitated by impounding whole or part of the water body by bamboo splits, nets or earthen dike. Prior to impounding, fishes are lured to small areas by providing shelters

made of tree twigs. The shelters probably provides extra food due to microbial growth in the rotting twigs. Ponds and impoundment are often exhausted manually (by using irrigation boats) or by power pumps prior to catching each and every beast in the water and in the clay underneath [31]. Although water exhaustion is a destructive method of fishing, few other methods provide the effectiveness of fishing in the eutrophic water bodies. Beside pond exhaustion, cast nets, framed nets and gill nets are used by the peasants while drag nets, bag nets, seine nets, and framed nets are used by the traditional fishermen. Synthetic fibers are now widely used for net making and net-weaving has been mechanized. With the sharp decline of the fresh water fishery, the mesh size of the bag and seine nets has shrunk radically. Some seine nets used are indeed mosquito nets of mesh size of about 0.5mm which can retain the smallest of the fishes. Various manually dragged country boats of keel length of 15-150 feet, made of ply wood are the principle fishing (and fish transporting) crafts. Some of the boats are now motorized by power pump engines. Paradoxically, improvement in fishing technology (such as, more durable nets, motorized boats and power pumps for pond exhaustion) may have increased fishing efficiency but concomitant management measures have not been implemented to maintain resource sustainability.

1.5.2. Estuarine and marine fishery

The total coastal area of Bangladesh is about 2,500,000ha [3]. The central area of Bangladesh coast (from Barisal to Noakhali) is an expanding young delta. Majority of hilsa is caught from this area of the coast. The soil of eastern and western wings of Bangladesh coast is acidic and the central region is alkaline [10]. The eastern and western wings of the coast have vegetation typical of the mangrove forests (named Sundarbans in Khulna and Chakoria Sundarbans in Chittagong). The exact areas in the coast covered by Brackish water, its species diversity and its effect on inland and open sea fishery are not well studied. It is estimated that about 400 species of fishes make use of the Sundarban habitat for part of their life cycle [9]. The potential of the coastal areas has been appreciated only recently and 87,000ha of it has been already taken for traditional shrimp culture [3].

The effective size of the marine fishery of Bangladesh comprises of only about 15,000sq km, of which about 5,000sq km is termed as shrimp water [32]. A series of surveys performed during 1968-71 charted three fishing grounds, namely, the South patches (6,200sqkm), middle ground (4,600sqkm) and swatch of no ground (3,800sqkm). The water depth in the outer margins of the fishing grounds approaches about a hundred meters. The standing (fish) crop beyond this margin is not profuse enough to sustain a profitable capture operation by the relatively inefficient Bangladesh offshore fishing fleet. However, fishing boats from other south and east Asian countries regularly capture fishes beyond 100 meters depth limit in the Bay of Bengal and one can assume that those boats are not incurring operating losses. Sometimes those boats intrude Bangladeshi territorial waters and several of them have been intercepted by Bangladesh Navy in the recent years [13]. Many south Asian nations including Japan and Thailand have commercial fishing fleet operating in the international waters. In Japan, fish harvest from international waters constitutes over 72% of total fish production [33]. Considering

its high population density, Bangladesh needs the bounties of the seas more than any other nation and it should have an outer sea fishing fleet. The private sector could be involved in this sector with international partnership if necessary. The total marine harvest, mostly from within the territorial waters, was only about 250,000mt in 1993 [8]. Marine catch has increased slightly over the last decade.

Several species of hilsa are now captured in large scales in the estuaries of the Bay of Bengal and salt water catch of hilsa has surpassed the reverine catch [2]. One important problem that anadromous fisheries are suffering today is the large scale capture of the grazing stock in the seas. Since open seas are open to fishing for every nation, one nation may be fishing anadromous fishes which were born in the rivers of another nation and the stock would have migrated back to that country for spawning. Large scale capture of the grazing stock of anadromous fishes may severely affect inland capture of the species. The seasonal migration of the anadromous fishes is important not only to the traditional fisher folk of each countries involved but also to the species itself and many other species which are linked to the migrating schools through the food chain. Since open sea fishery is highly mechanized and effective, uncontrolled fishing can destroy the breeding stock leaving few to migrate back to the rivers for spawning. Many nations actively regulate the catch of grazing stocks of anadromous fishes to keep the fishery sustainable. However, data on hilsa stock assessment is scanty or lacking and how the marine hilsa fishery is affecting the riverine hilsa fishery and the well-being of the species is unknown.

The artisanal fishermen catch over 95% of the total marine harvest using various nets such as, seine nets, gill nets and set bag nets [34]. The rest is harvested by the trawlers owned by Bangladesh Fisheries Development Corporations (BFDC). Fin-fishes constitute 97% of the marine harvest. Only 2.5% of total catch are shrimps and most of it is exported [3]. Bangladeshi trawl boats are not as efficient in fishing compared to the boats from other south and east Asian countries. The fleet size has not grown appreciably over the years. To increase capture, attempts were made in the past to set up joint fishing operations with the fishing fleet of Thailand and Kuwait [10]. It is argued that the marine fisheries have reached their maximum sustainable levels of production [35], which if true, left only one option to increase marine harvest: to modernize the fishing fleet to operate in the international waters. The manpower should be mobilized for sea fishing and the private sector should be involved in the marine fishery.

1.6 Aquaculture and extension

1.6.1 Aquaculture

Aquaculture in Bangladesh is still in its infancy. Decades ago, availability of wild fish was too high to consider pisciculture seriously. Indeed fish supply was so high that Rathindra Nath Tagore (son of poet Rabindra Nath Tagore), who established an agricultural farm at Patishar, used hilsas to fertilize land. However, many large ponds were constructed by land lords for charity (for drinking water). Ponds were also constructed near the temples, mosques and shrines and various aquatic organisms, including fishes were stocked in it. Notable of such

ponds are the ones present in the dominions of Shah Jalal of Sylhet (where the airbreathing snakehead Channa marulius is kept), Bayezid Bistami at Chittagong (where the tortoiseTryonix nigricans is kept) and Khan Jahan Ali of Bagerhat, Khulna (where marsh crocodile Crocodylus porosus was once housed). Various species of carps were stocked in many temple ponds. The stocking was not necessarily meant for human consumption. Consumption of pond-raised carps was almost a vice, as described in Ramer Shumati [36]. However, pond full of fish (and barn full of rice) were considered the signs of self-sufficiency of the Bengal countryside and naturally grown pond fishes probably supplemented the diet of the villagers. During the British era, malaria became a threat to the colonial power and fish (such as Gambusia) culture was attempted to control mosquito larvae [37]. The Colonial Government enacted a law in 1939 prescribing all ponds to be stocked with fish or else the local government would siege the property to lease them out. This was the time when S.L. Hora, the director of Fisheries of Bengal (1932-47) and a prominent scientist in his own right, initiated the modern pond culture in India. His assistant, Nazir Ahmed, who later become the director fisheries in East Pakistan, was to develop an improved method for hatching carp fries in 1948.

As the major carps grow quite large in the ponds (without any husbandry), they become the obvious choice for aquaculture in the independent south Asian nations. The choice is albeit logical since Indian carps are relatively fast growing filter feeders. The selected carps are never cannibalistic during their life cycles and a large supply of seed of the species can be obtained in almost pure form from the local rivers. Moreover, the local people have developed quite a bit of knowledge base to handle, rear and market the eggs, embryos and fingerlings of major carps [38]. The carps if grown in cold and unpolluted water are quite tasty and the Bengalis highly esteem Indian carps. Carp meat is lean and preserved carp meat may develop rancidity much slower than oily fishes such as hilsa or pomfrets. Incidentally, China, the first nation to domesticate fishes and culture fish for consumption and the largest producer of freshwater fish in the world, has also adopted major carps for aquaculture. Carps, however, are not the most ideal fishes for aquaculture because of their high bone/muscle ratio, the coarseness of their meat and for their susceptibility to develop repugnant flavor if reared in polluted and warm water ponds. Major and Indian carps are seldom consumed in the developed countries (except the immigrants therein) and thereby, major carps can not be expected to earn large export revenues. Time is ripe for Bangladesh to start adopting fish species such as C. batrachus, H. fosslis, C. striatus and P. pangasius for commercial aquaculture. Induced spawning of some of these species has been highly optimized. In some of these species, even multiple ovulation can be induced to a single female in a year [37], thereby eliminating dependency on wild fish seed completely. The former three species are more suited to grow in warmer shallow ponds and can be stocked at a very high density. These species can be fattened by providing pellet feed and can be transported live to domestic and international fish markets. These species are now commercially produced in some south Asian countries. Interestingly, farm-raised C. striatus and P. pungasius are now familiar fishes in the fish markets throughout the United States.

The pinch of lower production of freshwater fish was felt immediately after the independence of the Country in 1947 as the population increased rapidly, more and more wet

lands were reclaimed for agriculture, the green revolution was welcomed and water was used more to grow rice than to let fish grow in the ponds, more roads and railways were constructed and flood control embankments checkered the vast flood plains. The vastness of the water resource was, however, appreciated and aquaculture was targeted to boost fish production. In 1967, Yusuf Ali introduced induced spawning of carps and in the same year fisheries science was organized as a filed of instruction in the Bangladesh Agriculture University. At this time, many thanas were staffed with fisheries extension officers and over a hundred fish seed farms were established by the government. Several foreign fishes (such as tilapia and common carp) were introduced to increase aquaculture production and fish protection regulations (1950) were organized. The Bangladesh Government had further emphasized the fisheries (and livestock) sector by separating it from the ministry of agriculture and had reenacted the Bengal Tanks Improvement Act (1939). Former president Ziaur Rahman enthusiastically targeted aquaculture to double fish production through his failed 'canal digging revolution' in the early 1980's. Several large fish seed farms have since been established to make fish seed available to the farmers and shrimp culture has been on the upswing.

Aquaculture in Bangladesh, however, is still a poorly developed traditional process. The practices involved in aquaculture, in short, are:

1. Catching fish eggs and larvae from rivers by bag net: Over 97% of fish fry used in aquaculture is collected from the wild stock [3]. Fish seeds are collected by seasonal fishermen and peasants using set bag nets. The collection is kept in earthen or tin pots, aerated by occasional hand splashing and the water is buffered by mud. Water is changed occasionally to reduce mortality. Mortality may vary from 10-70%. The seeds are sold immediately or transferred to hatching pits. The buyers include government fish seed multiplication farms, private fish hatchery owners and various traders.

2. Transporting fish spawn to the hatching pits: This is done in earthen or tin pots using boats, rickshaws or motorized vehicles. Aeration and buffering/cleaning of water during transportation are similar as above. Recently, cellophane bags and oxygenation are available for fish seed transport to a limited extent [39].

3. Hatching eggs and rearing embryos to fingerling stage: This is done in small earthen pits which is prepared as described in the next section. No aeration is provided and supplementary food if added are household byproducts such as rice fine and oil cakes. The fries and fingerlings are then transported by the fish seed traders to the pond owners in the remote villages. Gregory and coworkers [38] provide a very illuminating account of fish seed trade in Bangladesh. Fish disease appears to be not a problem up to this stage and mortality is caused mostly due to the archaic transport system.

4. Fish stocking: Stocking (and hatchery) ponds are prepared after drying the ponds to eliminate fish eating organisms. Many booklets have been developed covering pond preparation and fish culture issues [39] and the following description is partly from those booklets. The

pond-bottom is then ploughed (to kill hidden fish eaters, to release bottom nutrients and probably to decontaminate toxic materials; however, it also reduces water retention capacity of the pond). Lime is then applied to the bottom to make it slightly alkaline (pH range of soil in most areas of Bangladesh is 6.0-7.0; however, liming helps). Compost, particularly decomposed cow dung and inorganic fertilizers are then added and water is allowed to enter the pond. If water can not be completely drained, fish eaters are killed by poisoning with rotenone (which is expensive and rarely available) or endrin, followed by liming and fertilization. When pond water is bluish, fingerlings are stocked in it. The ponds are then fertilized by compost, domestic byproducts (including cow dung and poultry waste if available) and oil cake to encourage growth of plankton. No supplementary food is added, although, oil cake and kitchen waste may very well be nibbled by the fishes. Human waste, used regularly in China, is not used in Bangladesh. Fish is reared for 1-3 years prior to harvest, first by netting and then by pond exhaustion. The produce is sold to middlemen or fishermen (or BFDC if production exceeds 2000kg). Although little husbandry is needed to raise the stock, a person has to attend the pond round the clock to prevent fish theft. In some estimates, stealing and deliberate fish poisoning by vandals are found to be the major obstacles to aquaculture expansion in Bangladesh [40]. Fish disease particularly, gill disease and ulceration are encountered occasionally and additional lime is applied to control the outbreak. Fish farmers become helpless in the outbreak of fish disease as no curative agent is available in large scale. Large scale fish deaths are, however, rare. Fish loss to otters and birds appeared not to be significant. The average fish production in Bangladesh is 700-1200kg/ha, far lower than other south and east Asian countries (production is 2,000-3,500kg/ha in India and 2,000-9,500kg/ha in China). Production of carps in experimental ponds had approached 1200-3500kg/ha, depending on the intensity of husbandry [3].

The government effort on rural aquaculture expansion seems to be focused on supplying fish seed. However, only about 2-3% of fish seed is produced by the government fish seed farms through induced spawning. Despite the nations heavy dependence on wild seed for aquaculture, little has been done on modernizing fish seed collection and transport. Although oxygenation and cellophane bags for fish seed transport is available in the semi-urban setting, they are yet to be available in the remote seed collection stations. The government can arrange (or encourage the private sector) to make mobile oxygenation stations with dechlorinated pure water, rental oxygen cylinders, fiber glass fish tanks with aerators and other necessary equipments available to every major seed harvest stations to insure transport of wild fish seed with highest survival rate. With the wide availability of cellular phones in the country, a few mobile stations could cover a wide area to aid safer seed collection and transport.

Some progress has been made in induced spawning of carps. Over a dozen government fish seed farms have the capability installed. Induced spawning is done by extracts of pituitary glands from live carps and human chorionic gonadotrophin [3]. Non-carp pituitaries and synthetic hormones used elsewhere [37] are yet to be used in large scale. The Government fish seed farms rear their fish fry to the fingerling stage before marketing. Only a few government fish farms maintain brood stock while none grows market size food fish. Some government fish farms produce seeds of introduced carps and tilapias. Introduced carps are stocked together with

endogenous carps at various ratios but the impact had not been high. Recently introduced minnows, P. gonionotus, become marketable in a year and availability of its fingerling may help small farmers. Tilapia reproduces in the pond and farmers can perpetuate its stock. However, managing tilapia is difficult because of its prolific reproduction. A monosex culture of tilapia could be much more manageable but sex selected fingerlings are not available in large scale. Although the governmental fish seed multiplication farms were established with a view that the farms would be self-sustaining, only a few of the farms actually produce enough revenue to pay for itself or make some profit. The majority of the farms actually earn less income than the annual government appropriations (employee salary excluded). Many fish seed farms were established without much of feasibility analysis and many are actually not suitable for fish seed production. A number of fish seed farms are in the remote areas and the management can not protect the farms from thieves and thugs. In fine, the government project on fish seed multiplication appears to be a failure and it has not helped expand fish culture in Bangladesh adequately.

Paddy cum fish culture has been in the experimental stage in Bangladesh for quite a while. Fish culture in flood plain paddy fields seems not feasible since suitable water levels in the paddy fields last for a very short time and the plot sizes are extremely small. Fish production from paddy field is extremely low (65kg/ha without stocking and 350kg/ha with stocking of large fingerlings, but no additional husbandry) [3]. Water levels in high yield variety paddy fields may be maintained for longer time but high use of pesticides and fertilizers prohibit fish co-culture. Deep water rice culture, another perpetual project in the experimental stage, can be integrated with paddy cum fish culture. Much work is needed before expecting any significant output from Paddy cum fish culture. Integrated fish culture, where fish, crops, poultry and cattle are raised in a self-sustained highly productive system, practiced in the commercial scale in China and other countries, has not been targeted in Bangladesh in the real context. Pen culture and case culture (culture of fishes within impound constructed in the open water) had been successful in China and Japan but test projects on case culture had been unsuccessful in Bangladesh [3]. The smaller rivers and canals of Bangladesh provide enormous opportunities of pen culture and private investors may approach this avenue.

Unlike industrialized countries, public waters are not stocked by the Bangladesh government agencies except in certain oxbow lakes and the Kaptai reservoir where the government keeps exclusive fishing rights. These release programs, called 'lake culture' had increased fish production from about 150kg/ha to over 200kg/ha in the oxbow lakes and further increase is expected [3]. Stocking the Kaptai reservoir has not improved fish production and the cause of the failure has not been investigated. Large scale release of fingerlings may be necessary to keep the fresh water fishery sustainable in the future.

One area that has seen much expansion in aquaculture in last decade is the crustacean culture in fresh and brackish waters. Shrimp culture has been emphasized since 1972 as the international demand of shrimp went high. However, the practice remained traditional, i.e., limited to capturing wild shrimp/prawn larvae in fields with earthen dikes (with sluice gates in

some cases), then harvesting the grown-outs 3-6 months later with a yield of about 200 kg/ha of shrimp and about 50kg/ha finfish [3]. Again, the production rate is the lowest in the east and south Asia. However, most of the land used for shrimp culture are also used to produce rice and/or salt. Furthermore, shrimp is produced with minimum husbandry and low yield is not of much concern. Intensive shrimp culture (giving up salt or rice and supplying feed for shrimp) has shown promise of significant increase in shrimp production as two to three crops can be harvested each year [3]. The demand of crustacean post-larvae is high but not much work has been done to expand its capture area. Shrimp hatcheries are needed to be established in eastern and western wings of Bangladesh coastal areas. Several mini and a small scale shrimp hatcheries have been established in Bangladesh [41]. However, production capacity of the hatcheries is yet too low to make a real impact. Much research is needed on reproduction, nutrition and disease of shrimps and prawns to take the progress to industrial scale. Interestingly, several articles [42] were encountered during this search on feed of shrimp larvae. Shrimp culture had stirred interest among the international investors and suitable projects may attract foreign investment. However, one note of caution is that many ill-planned investments on shrimp farming had collapsed in other countries [43]. Toady, about 100,000ha of brackish water is about to be allocated under low yield shrimp culture in Bangladesh. With a projected increase of yield of as much as five fold, shrimp culture in Bangladesh may gross $375m in the near future [44].

1.6.2 Aquacuture extension

Agricultural extension service is needed to transfer knowledge and technologies to the framers. Low literacy among the peasants in Bangladesh demands extensive extension services and the country indeed has an overgrown extension service [10]. As in many other minor agriculture sectors, fisheries has its own network of extension workers from the government and the NGOs. The main target of the aquaculture extension workers is to convince the owners of the nation’s 1,949,000 ponds to culture fish of various species at certain ratios. The extension workers have to advice the farmers to kill unwanted fishes, put compost and lime on pond bottom and in water, stock sizable fingerlings and then throw domestic waste and oil cake for the fishes to eat. They also tell the farmers to add even more lime if fishes get sick. Many booklets, posters and pamphlets have been published by the extension services [39] and most farmers should have grasped the canons of fish culture by now. Agricultural financing is under a separate extension network and the government fisheries extension workers have little authority on loans for their clients (in rare cases, NGOs may arrange internal loan for their clients). Aquaculture extension work is, therefore, advising fish farmers without any material support, insurance and credit incentives. Such 'trickle down extension service' has lead the farmers only to practice aquaculture in their own ways and within their means [45]. Farmers often follow their own instinct on important decisions such as species selection and stocking density, even while being overseen by extension project personnel [46], reflecting their reluctance to take financial risk on the words of a government official or an NGO employee. The real extension work is probably done by the fish seed traders who provide fish seed and often share the risk of seed survival as they advise the end users, the pond owners [38]. The agriculture extension work in Bangladesh has been ineffective for multitude of reasons and a thorough overhaul of the system is overdue

[10]. It has been argued that aquacultutre extension work should be indigenized [47], i.e., performed by the people such as the seed traders, who are directly related to fish farming. However, indigenous extension workers may not be able to bring new technologies. It will be better if the professional extension workers become indigenized (i.e., have practical experience on rearing food fish in ponds to make profit in Bangladesh). It is mentioned earlier that operations of government fish farms are limited to fry production while rearing food fish for profit is a completely different process. Beside advice, the extension workers should also be able to ensure at least the capital of the farmers so that the farmers can share the risk of adopting new and untested technologies. Bangladeshi farmers welcomed the Green Revolution long time ago and they can not be blamed for the poor progress in the fisheries sector. The extension services must be responsive to the specific demands of the farmers.

1.7 Fish preservation and marketing

1.7.1 Fish transport

Fish is a highly perishable commodity. Without any measure of preservation, fish stays fresh only for a short while and then enters a phase called rigor mortis which is followed by rapid spoilage. In Bangladesh, which is a hot and humid country, fish is considered fresh if it is marketed live or dead but without any manipulation. Ice preserved fish is getting acceptance as fresh fish in the recent years. There is no institutional inspection for the freshness of fish and ice chilling is not required to sell dead fish. Ice preservation is practiced by the fish traders who transport fish to cities. However, fishes are not gutted or cleaned before adding ice and thereby the full benefit of chilling is seldom achieved. Road communication in general and fish transport in particular, are poorly developed in Bangladesh. Fish is transported by country boats, rickshaws and covered and uncovered trucks and even passenger buses. The fishing fleet of BFDC have refrigerated chambers to preserve marine catch. In the recent years, Bangladesh railway has added refrigerated cars exclusively for fish transport. A small industry for production and distribution of ice and refrigerated vehicles may thrive in Bangladesh.

1.7.2 Fish preservation and processing

Fish is a seasonal commodity. Supply of many fishes, such as hilsa and bombay duck is highest in the rainy season (July-September) and low in rest of the year. Fishes dispersed during the flood season are caught at the end of rainy season (October and November). Fishing operations in the seas also considerably subside during the summer months when the Bay of Bengal becomes extremely rough. However, fish is marketed immediately after catch which causes significant price variation over the months. Fish become almost unavailable in the markets at the height of the dry season and fish price multiplies at this time. Such fluctuations in the availability and price of fish harm both the consumers and the producers. Preservation of fish for long-term storage is necessary but still lagging. Technology for long-term preservation of fish has become generic in the industrialized countries and is easily available. Long-term

preservation of potato has been commercially successful in Bangladesh and it is likely that long-term fish preservation may also be successful.

Bangladesh exports quick chilled frozen fishes. Thus the private sector has established some capacity in quick chilling and long-term fish-freezing facilities. Such installed capacity is not readily available in published reports presumably because of the lack of interest of the consumer to purchase preserved fish. It is likely that thawed frozen fish is sold as 'fresh' or 'ice chilled' in the internal markets to make the fishes readily acceptable to the consumers. A survey of the installed capacity is necessary before expanding freeze preservation capabilities. Such survey would prevent installing under-utilized over-capacity as it has happened in the machine tools and urea fertilization manufacturing industries.

Salting and drying are practiced in Bangladesh to some extent. Hilsa and some other herrings are occasionally salted using traditional methods by fishermen when catch supersedes market demand (August-September). No official figure is available for the amount of fish salted in Bangladesh. Salting is usually done in empty kerosene tins. The fishes are sliced vertically and salt is sprinkled over the layers of fish slices. The amount of salt used per tin is arbitrary and quality of processed product is seldom uniform. Kerosene tins quickly get oxidized in brine and preserved fish gradually turn reddish due to the absorption of iron oxides. Salted fish can not be kept for long and usually marketed before summer. Salt supply in Bangladesh is unpredictable and ironically, price of salt sometime may exceed price of the fish. Salted hilsa is highly esteemed in many parts of Bangladesh and availability of salt and appropriate salting cans may help expand hilsa salting.

Fish drying in Bangladesh is mostly traditional. Fish drying is performed by artisanal fishermen in the boats or on the sandy shores in the peak fishing season when the whole catch can not be marketed at a fair price. Sea fishes such as, anchovies, butter fishes, bomabay ducks, sea catfishes, herrings, mackerel, pomfrets, tuna and ribbon fish are preserved by drying. Slender fishes are dried whole, while small perch like fishes are sliced longitudinally along the vertical fin before drying. Large fishes such as tuna and snapper are sliced longitudinally but keeping the slices joined at the head and tail ends. Fishes are seldom properly gutted, dressed, filleted and washed before drying. The entire pre-drying processes are performed in a hurry, presumably to save labor cost and time. In addition, fishes are dried in open sun and is subjected to dust, bird droppings and rain. At what stage drying should be concluded is determined arbitrarily or by the availability of sunshine. As a result, the quality of product is usually very low. The dried products are then stored at ambient temperature in baskets or gunny bags and the quality deteriorates even further and rapidly (fish become discolored, smelly, stringy and rancid). A significant fraction of the stock is then consumed by insects (particularly Dermestes sp.) and other pests. As consumers prefer fresh fish, preserved fish has to be competitive in price but not necessarily in quality. Such an unusual situation has prevented innovation in fish drying in Bangladesh. However, in the past, research to develop appropriate technology for fish drying

had been attempted by the government and the NGOs [48]. Such efforts have resulted in the process of tent drying (drying of fish initially in open sun, then in plastic tents, see reference 45 for details). Use of gamma irradiation to control pest, use of cellophane sheets to vacuum package dried fishes and cold storage of dried fish have been suggested. Large scale modern fish drying (such as hot-air drum drying) is not a topic of discussion yet. The price of fish in Bangladesh is high enough for preserved fish to be competitive if a quality product can be offered on a regular basis. Only an industrial rather than artisanal process can ensure supply of such a quality product. Fish (hilsa) canning started in Bangladesh in the late seventies [49] but canning industry has not expanded appreciably.

1.7.3 Fish marketing

Fish marketing in Bangladesh is dominated by several layers of completely unregulated middlemen. A snap shot of fish marketing can be traced in the Padma Nadir Majhi [50]. The fisher folk often have to be engaged in fishing almost continuously to make a living. As a result, various types of middlemen buy and sale the fish several times before it reaches the consumers. Such a series of transfers prolong the time of distribution of the perishable commodity. The middlemen may lack the knowledge of proper fish handling. In the absence of any regular inspection, quality of fish depends on the mercy of the middlemen. While the middlemen in fish trade must also have to earn a living, an excess number of them in the sector has not served any good purpose. At present, BFDC provides a service to large fish farmers by purchasing their produce. Similar large scale fish trading operations could be developed in the private sector. There is no modern fish market in the country except for a few sales stations of BFDC. The lack of participation of private investors in fish marketing is evident.

The private sector, however, is very much involved in fish export marketing. After initial setback in quality control, the export of shrimp, prawn, frog legs and fin fishes is on the rise. Although the consumers of exported fish (particularly fin fishes) are dominated by the expatriate Bengalis, the quality of the exported fishes is essentially of international level. Very recently, Bangladesh is exporting fresh fish (not quick-frozen) to middle eastern countries, Britain and USA. These fishes are gutted, properly dressed and cleaned and then covered by ice. This success indicates that Bangladeshi traders can market quality fishes. A spill-over of this tendency to the internal market is necessary.

1.8 Concluding remarks

The fisheries sector in Bangladesh should have been targeted by the government to mass produce animal protein, preserve environment, maintain and create employment and increase export revenue. Those objectives could have been achieved through developing other sectors. However, the intuition that Bangladesh has a large water resource may have contributed to the special attention to the fisheries sector. The past performance of fishery sector, however, has been discouraging. In 1969-70, the government targeted fish production increase from

810,000mt to 1,002,000mt, but actually, production declined to 643,000mt. The causes of the failure as described at that time were reduced investment, lack of infrastructure for aquaculture, over fishing, environmental effects of irrigation and pesticides [10]. In 1978-80 two year plan, the new production target was set to 808,000mt and the actual production remained about 644,000mt [10]. The reasons of the failure remained the same as above. Total fish production remained under a million metric tons till 1993 [8] and reached to 1,373,000mt in 1996-97 of which 42,000mt was exported [13]. The internal demand of fish is estimated at 2,000,000mt [13]. It is clear that growth in fisheries sector has been painfully slow. In terms of fish availability, there is no positive growth since present fish availability (25gm/person/day) is about 25% lower than the base line of 1963 (33gm/person/day). It is all evident in the previous sections that much improvement is needed in almost every areas just to maintain the present status of fishery and aquaculture in Bangladesh. Fisheries sector still is an area the nation feels to have a growth potential and the reason is the perception of abundant water resources.

It is pertinent here to discuss if Bangladesh really has abundant water resources. As elaborated earlier, many of the natural depressions have been silted and reclaimed for agriculture, many rivers have been relegated to shallow canals, the welcome flood has became more unpredictable due to dams and embankments and the ground water has been depleted to such an extent that further increase in its use may jeopardize the country's environment [9]. The nation’s estuaries are experiencing deforestation, soil erosion and a reduced flow of freshwater. In the dry season, when pond bottom cracks and shallow tube wells dry up, many villagers find shortages in drinking water. Bangladesh may have a million ponds and even if a fraction of them may contain water year round, those are the last resorts to the villagers. It is often argued that a nation's progress is demonstrated by the availability of clean water to its citizen. With less than 10% of the population with access to running water, actual per capita water availability in Bangladesh may be well below the world average. If targeted for national development, it is to be known that fishery and aquaculture are exploitation and cultivation of water and plenty of water is necessary for sustainable fishery and aquaculture. Bangladesh certainly does not have perennial 'abundant water'.

It should now be realized that 'abundant water' in Bangladesh is largely a seasonal commodity. The rain and the seasonal flood are, in effect, the major water resources of the country. As the resources are seasonal, they need to be preserved to be utilized off seasons. In other words, Bangladesh needs to build large water reservoirs to conserve water for the dry seasons. However, construction of water reservoirs needs land and land is in short supply in the country. A close examination would reveal that the rivers, canals and the natural depressions, on which the government claims right, can be converted to water reservoirs if the government acquire the land. Rivers and canals can be turned into reservoirs with dams and gates and natural depressions can be dredged and dyked to convert into lakes. Although our planet is remarkably wet, a very small fraction of its surface water is fresh and developed countries such as the United States put every drop of freshwater in good use. Most cities in the United States get water from local reservoirs and waste water is recycled and reused. Indeed Bangladesh is endowed with the abundance of freshwater and this resource should be developed on a priority

basis. Construction and maintenance of many water reservoirs could be expensive. However, the nation needs water not only for aquaculture and agriculture that constitute as much as 50% of its GDP, but for the maintenance of its habitat. No longer the nation could overlook such events as desertification in Dinajpur and soil-fire in Faridpur. Without proper water management, the environment of the country may change even more drastically.

The topic of land reform is beyond the scope of the present discussion. However, it is known that vast areas of the country's arable land is yet to be brought under intensive agriculture due to small size of the farms and lack of adequate capital. Much smaller land areas under intensive agriculture probably could produce more than what is produced now through extensive cultivation of the whole. The leadership of the country may have realized that collective farming is acutely necessary to expand the farm size and to accumulate the necessary capital. The failed cooperative movement may have to be replaced by incorporating modern farming industries where land owners would own stocks instead of land. Such a reform may sound revolutionary but a nation with more than seven people per hectare of land can hardly go for anything less. With such changes, however, land can be safely set aside to construct water reservoirs, dikes and dams, without affecting individual farmers.

An important freshwater resource, Flood is a natural component of Bangladesh's ecosystem. Like cyclones and tidal waves, flood may not be controlled, but it could only be harnessed to some extent. It is difficult to conceive that flood, one of the nature’s most brutal forces, can be controlled by a few earthen walls. Embankments for example, may in some instances, actually worsen flooding situation. Bangladesh must continue to live with flood and utilize its bounties such as water, alluvium and the aquatic wild life. An all-out effort of 'total flood control' may be an effort to manually reconstruct the ecosystem of the country. Any effort to control flood in the country must be ecosystem friendly. The flood control planners are obviously aware that flood control is not simply erecting dikes and embankments but an integrated effort including such activities as afforestation, dredging and digging and protection of existing resources such as fisheries resources. The flood control plan should reconsider the fisheries sector if it had inadvertently ignored it as it appears it did in the past [14].

Extreme population growth and advent of new technologies have obviated readjustments in resource exploitation worldwide. Citizens of most civilized nations are no longer allowed to hunt and fish freely. The United States of America, for example, is the most resourceful nation of the world. However, its citizens must obey the national and regional nature conservancy regulations and carry a valid license to fish or hunt. Bangladesh can no longer allow its people to continue the old fashioned 'hunt and gather' type exploitation of its scanty aquatic wild life resources. Every adult in Bangladesh should obtain a license to fish (and hunt). Likewise, fishermen should obtain commercial licenses. To obtain license, one has to master the fisheries conservancy regulations, which in turn will force the license holders appreciate the necessity of resource conservation. It may be argued that such regulations may impede poor people from obtaining fish protein. However, even poor people can not be allowed to kill the goose that lays golden eggs. The traditional fisher folk need to be emancipated through education and job

incentives. The fisheries rule and regulations have to be rigorously enforced. At present, there is no clear cut understanding who is responsible for enforcing fisheries regulations and the issue should be addressed.

Fish culture in Bangladesh has not progressed adequately despite a sizable government investment in the area. It is to be appreciated that production of animal protein is not an energy efficient process. As a result, farm-raised animal protein may not be competitive in price with animal protein simply harvested from the wild. Enforcement of wild life regulations, appropriate tax structure and special subsidy (if necessary) are sometimes required to make farm-raised protein price competitive. Bangladesh can not forever continue to harvest wild fish spawn to sustain aquaculture. There is no reliable assessment of the effect of fish seed hunting on Bangladesh fisheries. It has been shown that for every shrimp larva collected in the wild, 118 larvae of other organisms are destroyed [51]. It is highly likely that carp egg collection has similar effect on fresh water fishes. The country may establish a few large industry standard fish seed farms that can satisfy internal demand for fish seed. The failed 'cottage industry' type government fish seed farms should be closed. The government should commercially operate a few food fish farms to understand the constraints of commercial food fish farming in rural Bangladesh and to train managers and extension workers.

The government should encourage the private sector to get involved in all areas of fisheries sector, particularly, fish preservation, marketing, aquaculture, offshore marine fisheries and water reservoir industries. While poverty alleviation programs of the government may continue to support 'small scale' fisheries and aquaculture programs, real industrial development should not be ignored. Such a balanced effort is essential to protect the capital from complete dissipation. A vacuum exits for an industry on modern fish processing and marketing. However, special care must be given on coastal shrimp farming in the low lying mangrove forests where invasive foreign investment can be expected. The importance of mangrove forests can not be justified by any amount of financial gain. Professional farms rather than NGOs should be consulted on policy issues whenever necessary. More often than not, NGOs will be motivated by self-interest. For example, one NGO may suggest an all-out effort on shrimp culture in the estuaries while another may suggest a complete ban on destroying the mangrove forest [43]. The government has to focus on the long-term interest of its own people.

High illiteracy will remain the mother of all problems of Bangladesh for years to come. However, the nation’s mass communication system has the opportunity to contribute significantly to public education. Wide spread campaigning is often necessary even in the developed nations (with as much as 99% literacy rate) on issues such as, environment, nutrition, addiction and infectious disease. Bangladeshi mass, despite high illiteracy rate, has shown remarkable capacity to make correct decisions on important issues such as national independence and prevention of autocracy. If correct information can be presented on environmental, nutritional and land reform issues in a consistent way, the public will react correctly. Fish preservation and processing industries, for example, probably will not be financially viable if the

public do not accept preserved and processed fish at right price. However, proper public adjustments will improve public nutrition and create industries and new employment.

In the recent years, Bangladesh is increasingly exporting fin fishes despite acute shortage in fish availability in the country. Fin fish export was feasible because, ironically, animal meat is more expensive in Bangladesh than fish and seafood products. In the developed countries, fish and seafood are as much as four to ten fold more expensive than poultry and beef. Widespread destruction of fisheries resources due to lack of management and extreme poor performance of the livestock sector has contributed to such unusual discrepancy in Bangladesh. The neighboring countries, where cattle meat is a social taboo and killing cattle is prohibited, dump their live cattle to Bangladesh. Such disposal has established strong organized rent-seekers in Bangladesh and prevented development of a local cattle industry [9]. Similarly, dumping of sugar is about to destroy sugar industries of Bangladesh. It is recently reported that farm-raised fishes from India is 'flooding' the fish markets of Bangladesh [16] and the Director of Fisheries of Bangladesh has acknowledged the merit of the news [13]. Fish farming in India is much more developed than in Bangladesh and if such illegal activities continue, the aquacultrure movement in Bangladesh is destined to fail. Furthermore, if farm-raised fish sales cheaper, local fishermen will be forced to increase fishing activity to sustain income, resulting into a more acute overfishing. Bangladesh still counts on its water resources for national development. With due respect to free trade principles, Bangladesh or any other third world nation, must need some protection to develop its resources before competing in the free market, same as a little fish, which needs protection when threatened.

Man or fish, all are but mostly aquatic creatures and the main issue remains the water resources. Lewis, et al. [38] once came to discover that study of fish culture and trade is ultimately about people. Earlier, however, Shamsur Rahman [52] perceived people discover (itself and) its fish,

> Little fish in my hand,
> You are wilting by the minute.
>
> Kneeling by a solitary shore
> I listen a singing thrush
> And wonder who should free whom,
> You me or I you.

Acknowledgment: This work was supported in part by Bangladesh Development Initiative (BDI), Pittsburgh, Pennsylvania. The author is grateful to the library system of the University of Pittsburgh, Pittsburgh, Pennsylvania, for help during the progress of this work.

1.9 References and Notes

1. Bangladesh human resources: Literacy 32%, average life expectancy 57 years, child mortality 83/1,000 live births and population growth rate 2.2%. Yet, about 6% of the foreign exchange income is from the contribution of the expatriate Bangladeshis (figures for 1991, source ref. 8). For water resources, see this article and refs. 2, 3 and 4 and other refs. therein.
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6. According to Bangladesh Bureau of Statistics (BBS), 1994, average per person per day energy intake in Bangladesh is 2266kcal. Recommendation is 700, 2200 and 2900kcal for children, adult female and hard working adult male, respectively. As children dominate the population profile of Bangladesh, Bangladeshis seem to consume more calories than needed. This contradicts with information such as, 46% of the children went stunted and 7% of the population wasted due to severe malnutrition in the same year (see reference 8).
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