Advances in Fisheries Research in Bangladesh

Proceedings of 5th Biennial Fisheries Conference & Research Fair 2012

18-19 January 2012

Bangladesh Agricultural Research Council
Dhaka

Bangladesh Fisheries Research Forum

I

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Editorial

Fisheries activities has gradually emerged as an important livelihood options for over million of poorer people including full-time and part-time fisher folks, fish farmers, processors and traders. The primary need for animal protein intake for the overwhelming majority has spurred a range of initiatives among actors and institutions forward scientific fisheries management and aquaculture. To support the ongoing development of fisheries and aquaculture, the need for demand led research and generation of sustainable technologies cannot be ignored. It is fact that the researchers in this country have been working in isolation in different institutions, universities and other private and NGO'; and there has been a chronic lack of coordination among the researchers as well as between researchers and the extension agencies.

In order to overcome this situation, Bangladesh Fisheries Research Forum (BFRF), a professional organization, was established in 2002 with its mission of breaking the barrier and territoriality among different organization and bring about all the fisheries academics, researchers, extension agencies of both GO and NGOs and other relevant stakeholders under one umbrella so that we can make good use of resources, better serve the sector together, and thus make rapid development through benefiting the end-users of research outputs.

It is a great pleasure of us to extend our sincere greeting and felicitations to the members of the BFRF on the occasion of 'Sixth Biennial Fisheries Conference and Research Fair 2014' held on 26-27 April 2014 for their commendable contributions to the promotion of science of aquatic natural resources. We have selected about 25 articles from about 190 abstracts presented in 5th Biennial Fisheries Conference and Research Fair 2012. After finalization 16 articles are now presented in **Advances in Fisheries Research in Bangladesh: I.** In the coming days, other volumes will be published to document and of updated research in fisheries of Bangladesh. We duly acknowledge WorldFish-Bangladesh and South Asia Office for financial support to publish this first volume of the proceedings.

The Editors

Acronyms and Abbreviations

BARC	:	Bangladesh Agricultural Research Council
BARI	:	Bangladesh Agricultural Research Institute
BAU	:	Bangladesh Agricultural University
BBS	:	Bangladesh Bureau of Statistics
BCSIR	:	Bangladesh Council for Scientific and Industrial Researches
BFDC	:	Bangladesh Fisheries Development Corporation
BFRI	:	Bangladesh Fisheries Research Institute
BRAC	:	Bangladesh Rural Advancement Committee
BRRI	:	Bangladesh Rice Research Institute
DANIDA	:	Danish International Development Assistance
DOF	:	Department of Fisheries
DU	:	Dhaka University
FAO	:	Food and Agriculture Organization of the United Nations
FCD	:	Flood Control and Drainage
FCDI	:	Flood Control, Drainage and Irrigation
FGD	:	Focus Group Discussion
GDP	:	Gross Domestic Product
GIS	:	Geographic Information System
GOB	:	Government of Bangladesh
GSI	:	Gonadosomatic index
HYV	:	High Yielding Variety
ICLARM	:	International Center for Living Aquatic Resources Management
IFADEP	:	Integrated Food Assisted Development Project
IPM	:	Integrated Pest Management
MOFL	:	Ministry of Fisheries and Livestock
NGO	:	Non-Government Organization
PRA	:	Participatory Rural Appraisal
RFLDC	:	Regional Fisheries and Livestock Development Component
RU	:	Rajshahi University
SIS	:	Small Indigenous Species of fish
SRS	:	Self-recruiting Species
UNDP	:	United Nations Development Programme
UNICEF	:	United Nations Children's Emergency Fund
WFP	:	World Food Programme

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Habitat and fish diversity: Bangladesh perspective

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Hossain, M.A.R. 2014. Habitat and fish diversity: Bangladesh perspective, pp 1-26. In: Wahab, M.A., Shah, M.S., Hossain, M.A.R., Barman, B.K. and Hoq, M.E. (eds.), Advances in Fisheries Research in Bangladesh: I. Proc. of 5th Fisheries Conference & Research Fair 2012. 18-19 January 2012, Bangladesh Agricultural Research Council, Dhaka, Bangladesh Fisheries Research Forum, Dhaka, Bangladesh. 246 p.

Abstract: Bangladesh is ranked third largest in inland fisheries in Asia behind China and India. The rich aquatic biodiversity of the country has been attributed to the world's one of the largest wetlands (Bengal Delta) and three large river systems (Brahmaputra, Ganges and Jamuna) that flow from the Himalayan Mountains into the Bay of Bengal. Huge inland fisheries resources supply fish and other aquatic animals and plants to millions of people living in the Delta. Recent acceleration of production from culture fishery (1.73 million tons of fish) in Bangladesh has yet to ease fishing pressure in large rivers and other water bodies. It is expected that the demand for fish will reach over 4 million tons by year 2020. Unfortunately, over-harvesting of fish is likely to continue and exert greater pressure on most of the water bodies. The country will face the biggest risk from global warming in the next 30 years. Because of the shrinkage of the wintering habitats for the fish species due to decrease in groundwater and surface water, tremendous pressure has been exerted on wetlands to convert them to agricultural land. Fishing pressure from an ever-growing population has increased dramatically and has seriously affected the abundance of nearly half of the inland fishes of Bangladesh, particularly many small fishes. Indeed, there may be no place in the world where effects of climate change and other natural/anthropogenic activities on fish biodiversity are more apparent than in Bangladesh. In order to reverse the trend and ensure sustainability of inland fisheries resources, in recent years, the nation has placed major emphasis on fisheries conservation & management, and development of institutional framework and need-based training in this respect. This treatise reviews the present status of inland fish diversity, basis of dwindling trend, conservation actions, and attempts to identify the problems and constraints thereby to provide some recommendations in the context of overall developments of conservation approaches.

Inland aquatic ecosystem of Bangladesh

Bangladesh is situated in the northeastern part of the South Asia and lies between 20°34' and 26°38' North longitudes and 88°01' and 92°41' East latitudes. The country is bordered by India on the West, North and North-East (2,400 kilometer land frontier) and Myanmar on the Southeastern tip (193 km land and water frontier). On the south is a highly irregular deltaic coastline of about 710 kilometers, fissured by many rivers and streams flowing into the Bay of Bengal. The territorial waters of Bangladesh extend 22 km, and the exclusive economic zone of the country is 370 km. The total landmass of the country is about 144,400 km^2 and extends 820 kilometers north to south and 600 kilometers east to west. The country stretches out at the junction of the Indian and Malayan sub-regions of the Indo-Malayan zoogeographic realm.

Formed by a deltaic plain, Bangladesh is virtually the only drainage outlet for a vast complex river basin made up of the Ganges (local name the Padma), the Brahmaputra and the Meghna rivers and their network of tributaries. The Padma unites with the Jamuna (main channel of the Brahmaputra) and later joins the Meghna to eventually empty into the Bay of Bengal. The alluvial soil deposited by these rivers every year has created some of the most fertile plains in the world. Most parts of the delta are less than 12 metres above the sea level, and it is believed that about 50% of the land would be flooded if the sea level rise by a metre. Straddling the Tropic of Cancer, Bangladesh has a tropical monsoon climate characterised by heavy seasonal rainfall, high temperatures, and high humidity. There are three broad physiographic regions in the country. The floodplains occupy about 80%, terrace about 8% and hills about 12% of the land area (Table 1). Moreover, it is a country dominated by wetland having more than 50% of its territory under true wetlands that is freshwater marshes, swamps, rivers estuaries and the world's largest contiguous mangrove forest - the Sundarbans.

Table 1. Major physiographic areas of Bangladesh

Description	Area (km^2)	% of total area
Rivers, canals, streams	8,300	5.76
Estuaries, brackish- water-bodies	1,828	1.27
Floodplains	112,010	77.76
Wetlands	2,930	2.03
Freshwater ponds and tanks	794	0.55
Artificial lakes	906	0.63
Hill areas	17,286	12.00
Total Bangladesh	144,054	100

Source: Hoq (2009)

Bangladesh has a total inland water area of 6.7 million ha of which 94% is used for open water capture fishery and 6% for closed water culture fishery (Table 2). The inland open water fishery resources have been playing a significant role in the economy, culture and tradition and food habit of the people of Bangladesh. Rivers and their ramified branches cover about 479,735 ha area of land. Seasonal floodplain expands over a massive 5.5 million ha for 4-6 months of the year. Inland open water also contains estuarine areas with semi-saline waters (0-10 ppt), numerous *beels* (saucer shaped natural depressions often with permanent water) and *haors* (conglomeration of many beels making a huge expansion of water) in the north-east and the Kaptai lake – the largest lake created due to of hydroelectric dam construction in the south-east of the country. The country is blessed with 0.26 million ha of closed waters in the form of ponds, ditches, oxbow lakes (dead river portions) and brackish water shrimp farms. More than 2 million people directly or indirectly depend on inland capture fisheries for their livelihood.

Table 2. Extent of different type of water areas

Types of water areas	Area (ha)
a) Inland open waters	
1. Rivers (during dry season)	
The Ganges	27,165
The Padma	42,325
The Jamuna	73,666
The Meghna (upper)	33,592
The Meghna (lower	40,407
Other rivers and canals	262,580
2. Estuarine area	551,828
3. *Beels* and *haors*	114,161
4. Kaptai Lake	68,800
5. Inundated flood plains (seasonal)	5,486,609
Total	6,701,133
b) Closed waters	
1. Ponds and ditches	146,890
2. *Baors* (oxbow lakes)	5,488
3. Brackish water farms	108,000
Total	260,378

Source: FRSS-DoF 2008

Fish have been an integral part of life of the people of Bangladesh from time immemorial. Many aspects of the Bangladeshi culture, economy and tradition are based around fishing and fish culture activities. The sector plays a vital role in the country's economy, employment generation, animal protein supply and foreign currency earning and poverty alleviation. Fish is a natural complement to rice in the

national diet, giving rise to the adage "*Maache-Bhate Bangali*", literally meaning – 'fish and rice make a Bangladeshi'. Fisheries, second only to agriculture in the overall economy of Bangladesh, contribute nearly 5.0% to the Gross Domestic Product (GDP), 23% of gross agriculture products and 5.71% to the total export earnings (DoF 2008). It accounts for about 63% of animal protein intake in the diet of the people of Bangladesh (DoF 2005). The fisheries sector provides full-time employment to an estimated 1.2 million fishermen and an estimated 10 million households or about 64% of all households are partly dependent on fishing, e.g. part time fishing for family subsistence in flooded areas. Another 10% poor and middle class people are engaged in part-time fishing, aquaculture, fish seed production and collection of shrimp and prawn seed, fish handling, processing and marketing, net making, input supply etc.

The people of Bangladesh largely depend on fish to meet their protein needs in both the rural and urban areas. Until 70s, there was an abundance of fish in the natural waters of the country to well-satisfy the demand. In recent years, however, capture fish production has declined to about 50%, with a negative trend of 1.24 % per year (Ahmed 1995). Despite the constant depletion of the natural water bodies for years, Bangladesh still holds one of the most diverse inland fisheries in the world. However, the availability of many fish species has been drastically declined, and many are either critically endangered or extinct. Both the longitudinal and lateral breeding and feeding migrations of the river and floodplain resident fishes of the country have been drastically damaged due to flood protection embankment with serious consequence on recruitment and production tonnage.

Impact of climate change and other natural and anthropogenic dynamics

Bangladesh is at most risk from climate change. The country will face the biggest risk from global warming in the next 30 years. The poor economy and low deltaic coastal regions being prone to floods and cyclones are among the factors that make Bangladesh the number one exposed country to climate change. Climate change impacts gradually over a wide range of livelihoods in different settings. Drought and siltation together are reducing over-wintering habitats for the fish species resulting in less recruitment into the grazing field to grow open water inland fisheries. Reduced water flow in the Ganges rivers basin has resulted in a severe depletion of fisheries. Due to the decrease in groundwater and surface water, tremendous pressure has been exerted on wetlands converting them to agricultural land, resulting in a serious decline in the numbers of fish species and the fish production as a whole. Indeed, there may be no where in the world where effects of climate change and other natural/anthropogenic activities on fish biodiversity are more apparent than in Bangladesh. The floodplains of the country are now among the fastest disappearing

of all ecological systems. Fishing pressure from an ever-growing population has increased dramatically and has seriously affected the abundance of nearly half of the inland fishes of Bangladesh, particularly small fishes like minor carps, loaches, barbs, minnows, catfishes, parchlets, gobies, featherbacks, snakeheads and eels.

Other major causes

In the past the major source of fish production in Bangladesh was the inland open water capture fisheries. During 1960s, it contributed about 90% of the country's total fish production. Rapid growth of population coupled with lack of proper management policy, however, created increasing pressure on fish resources and aquatic environment. Due to over exploitation of fish including use of harmful fishing gears and system (fishing by dewatering), degradation and loss of fish habitats due to abstraction water for winter irrigation for rice cultivation, obstruction of fish migration routes by construction of flood control embankments mainly to increase agriculture production and road communication, siltation of water bodies by natural process and water pollution by industry, and agrochemicals, the natural inland fish stocks have declined significantly and fish biodiversity and poor fishers' livelihood have been affected seriously (Ali 1997).

Fish stocks in the rivers and floodplains are being declined due to a variety of reasons. Most of the indigenous fish perform both lateral and longitudinal breeding and feeding migrations and rely on seasonal flooding. Almost all dams and embankments interfere directly with the successful completion of the breeding and feeding migrations of the fish. Agriculture (excessive removal of surface water and abstraction of groundwater for irrigation), pollution (domestic and industrial), and unregulated discharge of untreated industrial and farm effluents, habitat destruction also have significant impact, as does the regular over flooding and lack of flooding rain in the last few decades. Introduced species (primarily tilapia, Chinese carp and Thai pangas) are significant contributors to aquaculture production, but their role in threatening biodiversity of indigenous fishes is not understood for, none of the species is known to have established breeding in nature. In the past, stocking of rivers and floodplain is carried out with both indigenous and introduced species by government and through different projects. The effectiveness of stocking activities has generally not been well assessed. Furthermore, the impacts of aquaculture (both commercial and small scale) have not been accurately assessed in this country.

Most of the litoral and floodplains areas are cultivated with rice and other crops, providing multiple annual harvests. Thus, government policy has always prioritized cereal food production. Consequently, most development initiatives in the country have focused on crop cultivation, rather than biological management of the rich

floodplain system for fish production, ignoring the needs of poorer people for access to renewable protein sources. Capture fisheries in inland waters which are based on natural productivity generally have reached the level of overexploitation. The inland open water fisheries, where the floodplains assume an important position in the livelihoods and nutrition of the rural poor have now been under serious threat of resource depletion due to various man-made and natural causes. The majority of the waters of this type have been depleted to an alarming state and warrant urgent interventions for conservation and sustenance. Ecosystem integrity has often been destabilized and aquatic systems now fail to support decent levels of aquatic life. As a result the livelihoods of fishers and rural Bangladeshis, previously supported by the inland open waters, are seriously compromised (Coates 1995). Some rivers and floodplains have been modified to a level where they are only recognized as narrow ditches and paddy fields.

During 1960s, the inland capture fisheries contributed about 90% of the country's total fish production. Production from inland capture fisheries has declined significantly over the years and in 2010-11 it accounted only about 42% (Fig. 1a). During 1960s, production from inland capture fisheries was almost 20 times higher compared to the then aquaculture production of the country (Fig. 1b). However, aquaculture production both in fresh water and brackish water has significantly increased during the last two and a half decades with development of technology. Due to the rapid increase of aquaculture production and sharp decrease of capture fishery production, in 2010-11, the aquaculture contributed (about 48 %) more than inland capture fisheries in total fish production of the country (DoF 2012). There has been a qualitative degradation of fish catch in terms of valued species which included cypriniforms like Indian major carps and olive barb. The Indian major carps contributed 67% of the total stock in 1967 in Sylhet-Mymensingh *haor* basin that rapidly declined to 50% in 1973 and only 4% in 1984 (Tsai and Ali 1987).

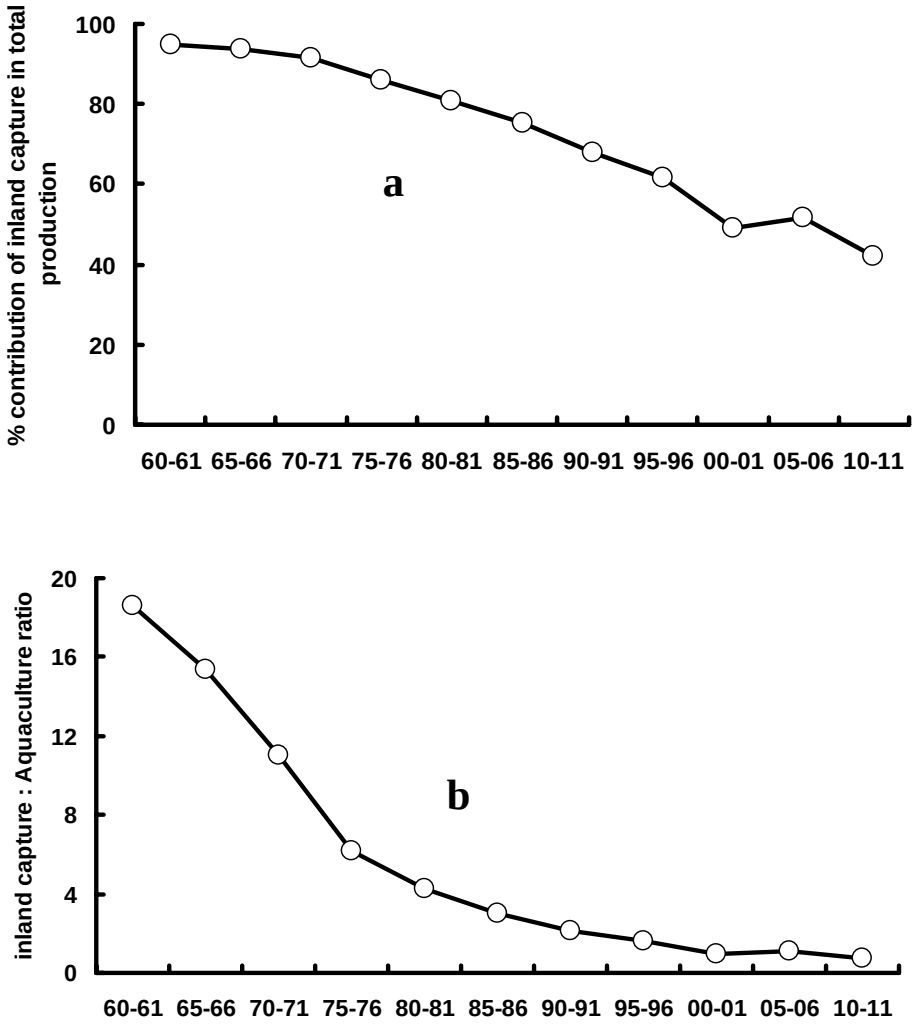

Fig. 1. Trend of fish production in Bangladesh 1960-2011
a. Contribution of inland capture (%) in total fish production, and
b. Inland capture to aquaculture ratios Source: (Ali *et al.* 2009, DoF 2012)

Effects of usage of pesticides and chemicals

Every year, there are thousands of tons of different pesticides (insecticides, herbicides, piscicide, miticides, fungicides, weedicides etc.) used around the globe that enter into aquatic systems from direct application and indirectly through

terrestrial runoff or wind-borne drift. Pesticide affects the aquatic ecosystem by interrupting the aquatic food chain of open water fish species resulting loss of natural diversity (Parveen and Faisal 2002).

The Bangladesh Pesticides Rule clearly states that "no person shall import, manufacture, formulate, repack, sale, hold in stock, or in any other manner advertise any brand of pesticides which has not been registered." The naive and illiterate farmers are, however, convinced by glib sales talk at promotional camps, and through incentive schemes, to buy new unregistered formulations that promise to protect crops against pest attacks and disease. Suppliers continue to sell many chemicals banned by the government. The increased reliance on pesticides in rice and other crop production has, in some areas, proved to be unsuitable and unsustainable due to pesticide-induced outbreaks of insect pests, development of pesticide resistant pests, rising cost of pesticide use and the negative effects of pesticide use on human health and the environment (Pingali and Gerpacio 1997).

The inundated floodplains of Bangladesh during monsoon are the seasonal habitat of the many indigenous fish. The residual effects of pesticides applied to these floodplains for agricultural purpose before monsoon lead to the fish mass mortality. Besides fish killing, there are also many other chronic effects of pesticides on fish including changes in their reproductive system, metabolism, growth patterns, food availability and population size and numbers (Rohar and Crumrine 2005). Lower abundance of phytoplankton and, consequently, lower abundance of zooplankton are observed as a result of pesticide use in the water bodies. The application of a pesticide might kill all individuals and it can be substantial perturbation to the ecosystem.

The pesticides affect the aquatic biodiversity in two ways depending on the intensity: sub lethal (chronic) effect and lethal (acute) effect. The sub lethal concentrations of pesticides can alter a wide range of individual traits including changes in neurotransmitters, hormones, immune response, reproduction, physiology, morphology and behavior including reduced foraging and changes in swimming ability, predator detection, learning and social interactions (Weis *et al*. 2001). At relatively high concentrations, pesticides become lethal and kill the organisms immediately. However, pesticides that are sub lethal for short exposure can also be lethal to aquatic organisms when they are exposed for longer durations (chronic exposure).

The indiscriminate use of insecticides and pesticides in the crop fields by the farmers is one of the major causes of disappearance of many fish from the natural waters in Bangladesh High yielding varieties (HYV) of rice have replaced the indigenous ones

resulting in substantial increase in insecticides and pesticides use and causing total disappearance of fish from many monsoon fed water bodies (Mazid 2002). Prolonged misuse of pesticides and fertilizers over the years has also halted the development of inland fisheries and aquaculture (Abdullah *et al.* 1997).

Pesticide use in Bangladesh got started from mid 1950s and gained momentum in late 1960s with the introduction of green revolution through the use of HYV rice in the country (Rahman 2004). A total of 94 pesticides, with 299 trade names of different groups and formulations have been registered for use in the crop fields. In 1999, the total use of pesticides was about 14,340 mt (active ingredient 2,462 mt) (Banglapedia 2004). In pesticide sector, farmers have been receiving extension services and considerable subsidies from the government over the years (Hossain 1988). As a result of the expansive policy and to minimize the increasing demand of staple crops, pesticide use in Bangladesh has been more than ten times increased since 1988, rising from 4,375 mt to 48,654 mt in 2008 (Fig. 2). Among the different pesticides, more than 60% are insecticides and used mainly in the paddy field.

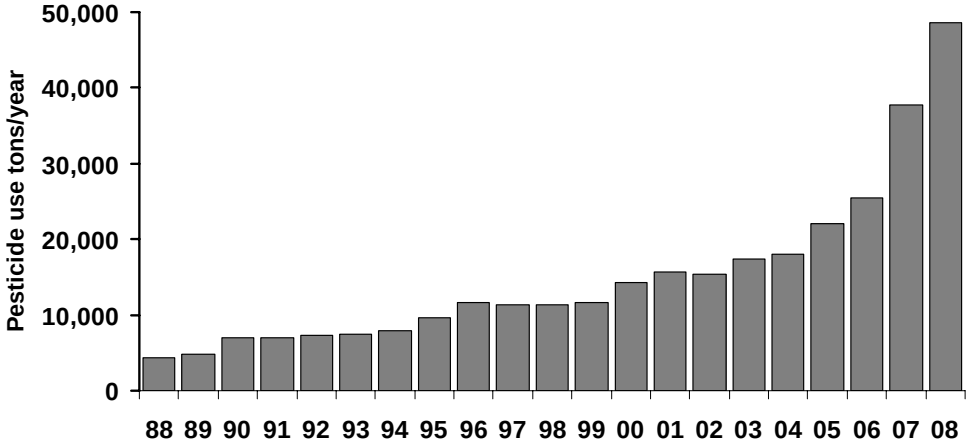

Fig. 2. Trend in pesticide use in Bangladesh during 1988-2008
Source: Bangladesh Crop Protection Association, Aziz (2005)
and www.moa.gov.bd/statistics/Table4.15CP.htm

In the inland open waters of Bangladesh, mass mortality of fish by pesticides mainly occurs due to the use of pesticides in improper doses and use of banned chemicals. The most commonly used pesticide in the crop field is organochlorine which is highly toxic to fish and other aquatic organism. In sub-lethal doses, organochlorine affects the reproductive physiology of fish and other aquatic fauna. A few drops of

endrin can kill all fish in a pond. Hossain and Halder (1996) reported that the main cause of disappearance of the fish from the inland open water of Bangladesh was the use of excessive and banned pesticide and 100% fish mortality occurred within 96 hours of the application of a number of pesticides following even recommended dose for the crop. Lethal dose and even at sub lethal dosage of chemical residues of pesticides largely attributed to cropland runoff contaminants killed fish as well as other aquatic organisms (Parveen and Faisal 2002).

Introduction of exotic fish

Allover the world the exotic species have been recognized as an agent of the loss of indigenous biodiversity. Alteration of species and ecosystem caused by exotic invasive animals and plants influence the functioning and overall health of the affected ecosystems (Ameen 1999).

As a country of rivers and wetlands, Bangladesh is very rich in fish diversity. Even then, over the last six decades a total of 24 fishes have been introduced (Table 3). The invasive species rapidly spread over the wetlands as biological explosives during the rainy seasons. Most of the introduced species were meant only for captive cultivation in closed pond systems but nobody succeeded to maintain the fish in captivity. During monsoon and/or flood the escapees easily found their ways to the rivers and floodplains throughout the country. This posed one of the major threats to the biodiversity of many indigenous fishes in this country.

Table 3. The exotic fishes introduced into the freshwaters of Bangladesh and the countries they imported from

Common name	Scientific Name	Source	Year of introduction
Siamese gourami	*Trichogaster pectoralis*	Singapore	1952
Goldfish	*Carassius auratus*	Pakistan	1953
Tilapia	*Oreochromis mossambicus*	Thailand	1954
Guppy	*Poecilia reticulata*	Thailand	1957
Common carp	*Cyprinus carpio*	India, Nepal	1960
Mirror carp	*Cyprinus carpio var specularis*	India, Nepal	1979
Scale carp	*Cyprinus carpio var communis*	India, Nepal	1965
Leather carp	*Cyprinus carpio var nudus*	India, Nepal	-
Grass carp	*Ctenopharyngodon idella*	Hong Kong,	1966
Silver carp	*Hypophthalmichthys molitrix*	Hong Kong	1969
Nilotica	*Oreochromis niloticus*	Thailand	1974

Thai sarpunti	*Barbonymus gonionotus*	Thailand	1977
Bighead carp	*Hypophthalmichthys nobilis*	Nepal	1981
Black carp	*Mylopharyngodon piceus*	China	1983
African magur	*Clarias gariepinus*	Thailand	1990
GIFT (genetically improved farmed tilapia)	*Oreochromis niloticus*	Philippines	1994
Genetically improved scale carp	*Cyprinus carpio var communis*	Vietnam	1995
Thai pangas	*Pangasius hypophthalmus*	Thailand	1990
Giant pangas	*Pangasius gigus*	Thailand	-
Mosquito fish	*Gambusia affinis*	India	-
Sucker mouth catfish	*Hypostomus plecostomus*	Hong Kong, Singapore	-
Red piranha	*Pygocentrus nattereri*	do	2003
Pirapatinga	*Piaractus brachypomus*	do	2003

Modified from Rahman (2005)

Several introduced species are highly carnivorous and predatory and eat almost everything including the small indigenous species of fish (SIS - which grow to a maximum length of 5- 25 - Felts *et al.* 1996). Several exotic species also compete with the SIS and gradually occupy their niches. The ecological, economic and biodiversity consequences of the introductions of exotic fish species have never been taken into consideration. It is very unfortunate that the long-term, and even short-term adverse effects were not considered while introducing the invasive species in Bangladesh. The excessive fecundity and growth rate of these species created pressure on the carrying capacity of the habitat, and the ecosystem balance itself by reducing the indigenous species diversity and population. Some of the negative impacts of exotic species on indigenous fishes are given in Table 4.

Table 4. The negative impacts of exotic fishes on the indigenous fishes

Exotic fish	Impact
Tilapia	Their prolific breeding surpasses the carrying capacity of the waterbody leading to stunting of tilapia and a number of SIS– mola, dhela, darkina, chela, punti, chapila, tengra, buguri, chanda, chikra etc.
Common carp	Destroy pond embankments, make water turbid by stirring up mud. Reduce the water transparency and dissolved O_2 in water. Destroy the habitat of SIS living closed to the pond dyke and loaches in the bottom.
Grass carp	High feeding competition with many herbivorous small and large indigenous fishes.
Silver carp	Strong feeding and habitat competition with– catla in both captive condition and in the wild
Thai sarpunti	Compete with local sarpunti for foods and space

African magur	Predation and voracity of this catfish is legendary, predate on almost all small and medium fishes
Thai pangas	Natural diet is finfish, crustacean and insects, periphyton and benthos. This predatory fish is the major cause of disappearance of SIS from the pond system
Mosquito fish	They live in the littoral zone of the waterbody and compete with small fishes for food and habitat
Suckermouth catfish	One of the dangerous catfish, now found in the floodplain allover the country, feeds on small crustaceans and small fishes like loaches and freshwater eel
Red piranha	One of the most dangerous and aggressive species of piranha, feeds on insects, worms and small and large fish. The cultured fish in the pond system and escapees in the wild actively predate on the indigenous fishes particularly SIS
Pirapatinga	The natural diet is terrestrial plants, fruits, insects and crustaceans, however, in captivity where the natural food is scarce the pirapatinga compete with SIS. The fish has strong, human like teeth used to crush food items.

Aquatic fauna and their present status

Bangladesh is a transitional zone of flora and fauna, because of its geographical settings and climatic characteristics. It is natural that the water resources of the existing extent and magnitude should harbor and support populations of a large variety of vertebrate and invertebrate aquatic living organisms. This country is rich in fish and aquatic resources, and other biodiversity (Table 5). Bangladesh's water bodies are known to be the habitat of 267 freshwater fishes, 475 marine fishes, 24 exotic fishes and a number of other vertebrates and invertebrates. Among the documented aquatic fauna, finfish tops the list, followed by the crustaceans and molluscs (Fig. 3).

Table 5. Diversity of aquatic animals in Bangladesh water

Animal group	Number of Species	
	Freshwater	Marine
Finfish	267	475
Shrimp	-	41
Prawn	20	-
Mollusc	26	336
Crab	4	11
Lobster	-	6
Frog	-	10

Turtle & tortoise	24	7
Crocodiles	2	1
Snakes	6	18
Otters	3	-
Dolphin	1	8
Whale	-	3
Total	353	916

Source: Ahmed and Ali (1996), Ali (1997) and Banglapedia (2004)

The total inland open water fish production of Bangladesh in the year of 2006-07 (July-June) was 1.783 million tons. The catch was dominated by major carps (30%) followed by exotic carps (16.4%) and snakeheads (5.8%) (Fig. 4).

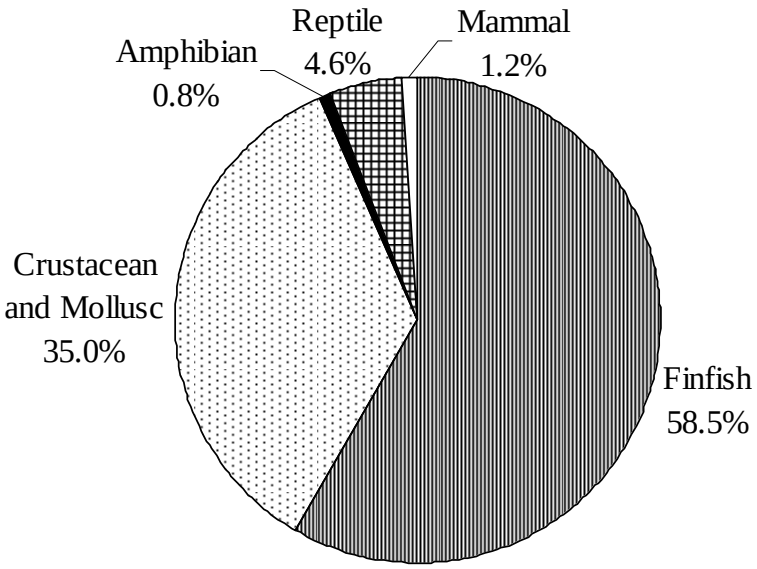

Fig.3. Percentages of major aquatic animal groups of Bangladesh.

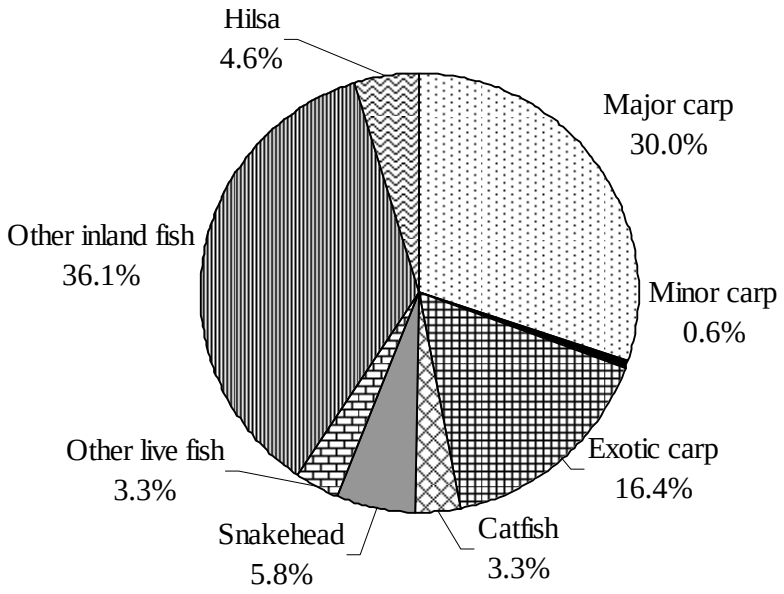

Fig 4. Group-wise catch of freshwater fishes (2006-07). Source: FRSS-DoF 2008
Major carp - Rui, Catla, Mrigal and Kalibaus; Exotic carp - Silver carp, Common carp, Mirror carp and Grass carp; Minor carp – Gonia, Reba and Bata; Catfish - Rita, Boal, Pangas, Silong and Air; Snakehead - Shol, Gazar and Taki; Other live fish - Koi, Singh and Magur; and Other Fish - all other fishes

There are serious concerns about the slow decline in the condition of open water fish stocks which have been negatively impacted upon through a series of natural and anthropogenic induced changes. These include disturbances resulting from rapid growth of population coupled with lack of proper management policy, water management programs including the large scale extraction of water for irrigation and the construction of water barrages and dams, human activity resulting in the overexploitation of fish including use of harmful fishing gears and system (fishing by dewatering, poisoning, using explosives), road communication, siltation of water bodies by natural process, the unregulated introduction of alien fish species and pollution from industry and agrochemicals. As a consequence, many Bangladeshi species have become critically endangered like – *Hemibagrus menoda*, *Barilius barila*, *Dermogenys brachynopterus*, *Botia dayi*, *Raiamas bola*, *Psylorhynchus sucatio*, *Scistura corica*, *Labeo pangusia*, *Labeo angra*, *Botia lohachata*, *Barilius barila*, *Chagunius chagunio*, *Gogangra viridescenes*, *Silonia silondia*, *Setipinna phasa*, *Laguvia shawi*, *Crossocheilus latius* or many more. Biodiversity status of many of the fishes have now changed from that listed in the IUCN Red Book almost a decade ago. The results of the survey conducted by FMBC (2011) found the following fishes as extinct from Bangladesh water - *Neoeucirrhichthys maydelli*,

Pangio pangia, *Salmostoma sardinella*, *Esomus* lineatus, *Garra annandalei*, *Neolissochilus hexagonolepis*, *Osteochilus hasseltii*, *Raiamas guttatus*, *Mystus armatus*, *Laguvia shawi*, *Pseudecheneis sulcata*, *Ailia punctata*, *Ambassis nalua*, *Channa barca* and *Pseudosphromenus cupanus* and a few more.

The fishes of Bangladesh exhibit a wonderful diversity in their size, shape, colour, habitat, feeding habits and breeding behaviour. Considering size alone, there are fish such as the rice fish which attain only an inch long at maturity and weigh less than a gram, whilst others such as the river shark or goonch reach more than two meters in length and weigh more than 100 kg. Bangladesh also possesses splendid, vibrantly coloured fish – queen loach and other loaches and those such as pipe fishes which look more like a crocodile. The male pipe fish provides all postzygotic care of its offspring by brooding embryos on its ventral surfaces, while the rice fish are live bearers.

The biodiversity of riverine fishes is presently in great danger. Many fishes are either endangered or critically endangered. Many have already become extinct from the waters of Bangladesh. The Red Book of Threatened Fishes of Bangladesh published by the IUCN-Bangladesh is already more than a decade old. According to the Red List, 54 indigenous riverine fishes of Bangladesh are threatened– vulnerable, endangered and critically endangered (IUCN-Bangladesh 2000). However, there have been massive changes in riverine fish biodiversity over the last 12 years. According to the survey conducted by the Fish Museum & Biodiversity Centre (FMBC), Bangladesh Agricultural University, Mymensingh, Bangladesh during 2009-10, more than 100 riverine fishes are presently under threat and a number of species are already lost.

Table 6. Extinct Riverine Fishes of Bangladesh

No.	Family	Scientific name	Common English name	Bangla name	Habitat
Cypriniformes					
1	Balitoridae	*Balitora brucei*	Grays Stone Loach		R
2		*Nemacheilus sikmaiensis*			R
3		*Schistura dayi*			R
4	Cobitidae	*Neoeucirrhichthys maydelli*	Goalpara Loach		R
5		*Pangio oblonga*	Java Loach	Panga	R
6	Cyprinidae	*Barilius tileo*	Tileo Baril	Pathorchata	R
7		*Salmostoma acinaces*	Silver Razorbelly Minnow	Chela	R
8		*Danio dangila*	Moustached Danio	Nipati	R

9		*Esomus lineatus*	Striped Flying Barb	Darkina	R-E
10		*Garra annandalei*	Annandale Garra	Ghorpoiya	R
11		*Labeo dero*	Kalabans	Kursa	R
12		*Labeo dyocheilus*		Ghora Machh	R
13		*Labeo nandina*	Kulta Labeo	Nandina	R
14		*Neolissochilus hexagonolepis*	Copper Mahseer		R
15		*Osteochilus hasseltii*	Silver Sharkminnow		R
16		*Raiamas guttatus*	Burmese Trout	Bhol	R
Siluriformes					
17	Amblycipitidae	*Amblyceps laticeps*	Indian Torrent Catfish		R
18	Bagridae	*Batasio tengana*		Tengra	R
19	Erethistidae	*Laguvia shawi*		Kani Tengra	R
20		*Laguvia ribeiroi*	Painted Catfish	Kani Tengra	R
21	Schilbeidae	*Ailia punctata*	Jamuna Ailia	Kajoli	R-E
22	Siluridae	*Pterocryptis gangelica*			R
23	Sisoridae	*Nangra bucculenta*		Gang Tengra	R
24		*Nangra nangra*		Gang Tengra	R
25		*Nangra ornata*		Gang Tengra	R
26		*Pseudecheneis sulcata*	Sucker Throat Catfish		R
Perciformes					
27	Ambassidae	*Ambassis nalua*	Scalloped Perchlet	Nalua Chanda	R-E
28	Channidae	*Channa barca*	Barca Snakehead	Pipla	R
29	Osphronemidae	*Pseudosphromenus cupanus*	Spiketail Paradisefish	Koi	R-E
Beloniformes					
30	Hemiramphidae	*Dermogenys brachynotopterus*	Gangetic Halfbeak	Ekthuita	E-R

Ongoing measures to reverse/slow down the trend

The government of Bangladesh and a number of non government organizations (NGOs) have taken a number of regulatory and development interventions for sustainable management of the natural fisheries. In order to reverse the loosing trend and ensure sustainability of fish biodiversity and production from inland open waters various measures for protection, conservation and management of fisheries resources have been adopted time to time. Among the measures are the implementation of Fish Protection and Conservation Act 1950 and related rules including new fisheries management policy (licensing the fishing rights directly to the true fishers),

community based fisheries management (CBFM), establishment of fish sanctuary in the strategic points of the rivers and floodplains, fish stock enhancement through releasing fish seed in seasonal floodplains, and fish habitat improvement through excavation of link canals (between rivers and floodplains) and *beels*.
The Fish Act 1950 provides regulations for: (i) restriction on capture size of some fish for a specific period, (ii) restriction on catch of any species for specific time or season, (iii) closure of fishing in any water body for any stipulated time period, (iv) restriction of fishing by dewatering or any other destructive method, (v) restriction on the use of any kind of gear and mesh size of net, and (vi) restriction on placing fixed engine in a water course, which may restrict fish migration.

Implementation of fisheries regulations has proved to be very difficult in this country due to institutional weakness of implementing authorities and the socio-economic conditions of the fishers. However, the Fish Act 1950 element – 'closure of fishing in specific area for specific period' as may be termed as 'fish sanctuary' is easier to adopt than applying other regulations of the Fish Act. Sanctuary has been tested and found as a powerful tool for protection and conservation of fish stock in Bangladesh.

The dry season is the critical time for the fishes, when water levels in the rivers, canals, *beels* etc. recede drastically leaving a very few refuges for the inland fishes. Fish are exposed to greater predation and increased susceptibility to fishing pressure as the water level drops due to water extraction for irrigation and evaporation due to persistent heat of the dry season. Loss of surface water in the dry season makes the fish populations increasingly vulnerable to intensive fishing and thereby the fish stock particularly the brood stocks deplete to such a level that cannot sustain the fisheries and gradually fish diversity and production decline. Therefore, the major issue for biodiversity conservation is to provide sufficient dry season refuges to maintain the population at sustainable level.

Among all measures, fish sanctuary has been apparently found most effective for fish biodiversity conservation, when other measures are difficult to implement in the present administrative and social contexts. With this notion, Bangladesh government has established fish sanctuaries under different development projects following a number of management approaches since 1960 and more intensively in last decade. The NGOs like BRAC, CARITAS, CNRS, PROSHIKA and WorldFish Centre (CBFM project) have also been involved in fish stock enhancement by establishing traditional sanctuaries in *beels* and rivers of Bangladesh.

In addition, a number of silted up *beels*, *baors*, dead rivers and link canals have been re-excavated by the government under the food for work programs over the years. By 2000 a total of about 8,300 ha water area of borrow pit, *baors*, dead rivers, canals and

beels had been excavated (DoF 2005). In the late 1990s the government approved a series of sectoral policies including National Fisheries Policy (1998), National Environment Policy (1995), and National Land Use Policy (2001) with a new emphasis on maintaining and protecting the moribund inland waterbodies. Under the National Fisheries Policy, government has formulated strategies for inland capture fisheries and emphasized on fisher community participation in fisheries management, along with fish sanctuaries as a key management tool (DoF 2005).

Fish sanctuaries

The massive siltation has threatened the existence of most of the inland waterbodies – rivers, floodplains, *beels*, *haors* and *baors*. Many waterbodies which were once the blessings for Bangladesh providing fishing, communication and irrigation facilities are now being dried up at an alarming rate. Most of the waterbodies are becoming empty of fish. The principal causes of the situations have been dealt with in the foregoing.

Following the provision of the Fish Act 1950, Govt. declared closed season for fishing of certain species or for all species of fish in specified water bodies under normal fisheries management programme and under different development schemes/projects of DoF. In 1952 Govt. prohibited catching of Cypriniforms - rui, catla, mrigal, kalibaus and gonia of any size in rivers and canals for different time period between mid March to 31 July every year except for pisciculture purposes. Under the Development and Management Scheme of Department of Fisheries (DoF), 23 sanctuaries were established in different floodplains during 1960-1965. Upon having good results of the established sanctuaries, 25 more sanctuaries were established under the same scheme of DoF during 1965-70. Afterwards 10 more sanctuaries were established in 1987 under the Integrated Fisheries Development Project of DoF.

Most of the fish sanctuaries now focus on the need of involvement of fisher community and local government in the management system, long tenure of lease period and also strong monitoring and supervision. Besides, to safeguard the fishers' interest, the Govt. policy now is to establish sanctuary in part of the floodplain and the remaining part to keep open for fishing by the local fishers. Based on this idea, under different development projects, government has established a number of sanctuaries involving the fisher communities with support of NGOs. In a government declared fish sanctuary, catching/killing of fishes is prohibited by law and order of competent authority for all the times to come or for a specified period mainly with objective of protecting/conserving the fish.

A total of 463 permanent fish sanctuaries covering an area of 1,745 ha have been established in 98,405 ha water bodies by 2007 (Table 7). A number of the sanctuaries have been closed after the projects ended. Management has deteriorated in many sanctuaries due to the conflict of interests among the stakeholders, lack of funding and lack of coordination among the organizations.

Table 7. Fish sanctuaries established in Bangladesh by 2007

Project/ Programme	Area of water body ha	Area of Sanctuary ha	Number of Sanctuary
Fourth Fisheries Project	12,233	1,022	63
Community Based Fisheries Project (CBFM-2)	9,602	93	182
Management of Aquatic Ecosystems through Community Husbandry Project (MACH)	785	76	65
New Fisheries Management Policy	1,698	77	21
Fisheries/ Fish Culture Development in *Beel* and Chharas project	1,294	18	29
Aqua Development Project (Faridpur)	454	11	14
Patuakhali Barguna Aquaculture Extension Project (PBAEP)	307	26	19
Fish Habitat Restoration Project	3,890	73	45
Fisheries Development in *Jabai Beel* project	75	4	4
Sustainable Environment Management Programme (SEMP-17)	50	17	12
Community Based Wetland Management Project(CBWM- 4)	17	4	7
Kaptai Lake	68,000	324	2
Total	98,405	1,745	463

Modified from Ali *et al.* (2009)

Fish sanctuary in Bangladesh was proved to be an important and efficient tool for management in protection and conservation of fishes and other aquatic organisms (Ali *et al.* 2009). Since mid 80s, concept of the involvement/participation of local fisher community in setting up and managing sanctuaries has been the government policy. However, a major problem in managing sanctuaries in public water bodies is the policy conflict between the government ministries. Although the national fisheries policy envisages establishing fish sanctuaries, there is no clear guideline for establishment and management of fish sanctuaries. To make the fish sanctuaries more effective, the following stages should be followed - mitigation of all the conflicts among the stakeholders involved, formulation of clear guidelines of sanctuary management, selecting the strategic place and size of the sanctuary, proper awareness

building among the stakeholders, ensuring proper community organization and full participation and continuous monitoring and impact assessment.

Fish breeding, domestication and gene banking

As more fish species of Bangladesh become threatened, there is tremendous need to preserve the disappearing genetic material as well as to conserve the existing gene pools. The ideal strategy for conservation of threatened and endangered fish species is through restoration of the native habitat of the species (*in situ* approach). Unfortunately, most habitat damages are irrevocable and where remediation is possible, it is costly and requires a great deal of time, as the restoration process is slow. One alternative is to maintain *ex situ* conservation (outside the natural environment) as live populations or in a cryopreserved sperm bank (Pullin *et al*. 1991).

Domestication of wild fishes in most cases benefits both the farmer and the environment. Investments in domestication have to pay off; therefore, researches should take into account the biodiversity and production scenario and overall socioeconomic and environmental outcome at a broader scale. In Bangladesh, to date about 20 fish species have been domesticated and their breeding and rearing protocols have been developed. Around 50% of the domesticated fishes are cypriniforms and now under nation-wide aquaculture (Table 8). Though there is high possibility of working with reduced gene pool, it is optimistically believed that the biodiversity of the domesticated fish are well-preserved.

Table 8. The domesticated indigenous fishes of Bangladesh

Order	Fish	Culture status
Cypriniformes	*Catla catla*	Country-wide commercial
	Labeo rohita	Country-wide commercial
	Labeo gonius	Country-wide commercial
	Labeo bata	Country-wide commercial
	Labeo calbasu	Small scale, sporadic
	Cirrhinus mrigala	Country-wide commercial
	Cirrhinus reba	Small scale, sporadic
	Tor putitora	Breeding protocol developed
	Puntius sarana	Small scale, sporadic
	Lepidocephalichthys guntea	Breeding protocol developed
	Botia dario	Breeding protocol developed
Osteoglossiformes	*Chitala chitala*	Small scale, sporadic

Siluriformes	*Ompok bimaculatus*	Small scale, sporadic
	Ompok pabda	Small scale, sporadic
	Mystus vittatus	Small scale, sporadic
	Mystus gulio	Breeding protocol developed
	Clarias batrachus	Small scale, sporadic
	Heteropneustes fossilis	Small scale, sporadic
Synbranchiformes	*Mastacembelus armatus*	Breeding protocol developed
	Macrognathus aculeatus	Breeding protocol developed
Perciformes	*Anabas testudineus*	Breeding protocol developed
	Colisa fasciata	Breeding protocol developed

Recently there has been expanded development of cryogenic sperm banks (preservation of fish sperm in liquid N_2 at -196 ^oC) for fish in Europe and North America. These sperm banks are more cost effective than maintaining live gene banks which require wide space, maintenance and high costs. Cryogenic gene banking avoids the risk of genetic contamination and requires little space and minimal facilities.

Fish sperm cryopreservation assists conservation of fish biodiversity through gene banks of endangered species, and assists aquaculture by providing flexibility in spawning of females and selective breeding through synchronizing artificial reproduction, efficient utilization of semen, and maintaining the genetic variability of broodstocks (Lahnsteiner 2004). The technique also ensures preservation of genetic materials of the genetically superior wild fish populations and the gene transfer between wild and hatchery stocks (Tiersch *et al.* 1998).

The sperm cryopreservation protocol for different fish species seems variable and species-specific. Although fish are the main protein source in Bangladesh and other countries in the sub-continent, and the fish biodiversity and production from open water are declining, little attention has been paid to cryopreservation of fish sperm. In Bangladesh, research on fish sperm cryopreservtion was started in early 2004. The studies have focused on aquacultured or commercial species and so far none of the threatened species have been considered (Table 9).

Table 9. Cryopreservation of sperm of some fish species in Bangladesh

Fish group	Indigenous	Exotic
Cypriniform	*Catla catla*	*Cyprinus carpio*
	Cirrhinus mrigala	*Hypophthalmichthys molitrix*
	Labeo rohita	*Hypophthalmichthys nobilis*

	Labeo calbasu *Puntius sarana*	*Barbonymus gonionotus* *Oreochromis niloticus*
Others	*Ompok bimaculatus* *Mastacembelus armatus* *Channa striatus* *Rita rita*	

Genetic stock conservation for wild and domesticated fishes is very important, as the genetic diversity of every species develops through a long evolutionary process over millions of years. Cryogenic techniques can assist in the conservation of biodiversity, to bring back the threatened species to natural environment with restocking programmes, as well as in improving aquaculture production. Cryogenic sperm banks for more fish need to be established as means of germplasm conservation in Bangladesh.

Recommendations

A renewable resource like fish, when under intense exploitation, needs a management regime as it is not inexhaustible. Therefore, management measures should be applied in such a way that young fish are protected to grow before capture and enough are left as breeding stock for future generations. The management measures should include – regulation of fishing intensity at sustainable level, control on gear selectivity, gear type and size of fish caught, closed season implementation, prohibition of destructive fishing, closed fish sanctuary, and allocation of resources to different types of fisheries.

For sustainable and well-protected fish diversity for present and for future, the country should go for -

- Rational use of inorganic fertilizers and pesticides, and proper management of industrial effluents,
- Maintenance of minimum water depth (at least 1 m) during water extractions in dry season natural water bodies,
- Regulation of selective fishing gears, mesh sizes, and fishing by dewatering,
- Establishment of more fish sanctuaries and natural *beel* nurseries in strategic points,
- Stock enhancement programs,
- Establishment of community-based organizations (CBO) among the fishers,
- Zero tolerance to new exotic fish introduction, and
- Strict application of existing fisheries rules and regulations.

This is the high time to care for the biodiversity of the most valuable Cypriniform and other indigenous fishes – the pride, heritage and livelihood of Bangladesh before they are lost forever. The researchers, policy makers, GOs and NGOs and national and international bodies should come forward to conserve the fish species using both *in situ* and *ex situ* approaches.

Conclusions

The biodiversity of indigenous fishes of Bangladesh has come under grave threat in recent years. Due to manifold reasons, many species of fish are disappearing from the country's water bodies. The day is not too far when many of our fishes will be extinct in our waters. Therefore, documenting all the indigenous fishes of the country carries an enormous value. In this treatise, I have attempted to record all the fishes documented between 1822 and the present day. The key reason for doing so is this: if we do not know what we had, how will we realize what we are loosing now and what else we are going to lose in the coming days. I believe that the checklist presented here will provoke the thought of the people of all strata – consumers, fishers, fish farmers, researchers, donors, policy makers and others, and will encourage them to come forward to find effective ways to preserve fish biodiversity - the pride, heritage and livelihood of Bangladesh - before many species are lost forever.

There is a crying need to adjust the existing laws and legislation of the country for integrated resource management to save the fisheries resources. Although much of the damage to the habitat and biodiversity of the inland water of Bangladesh over recent decades is likely to be irreversible, there is still time to act. From now on, Bangladesh government, the NGOs and national and international bodies should help fostering a social and technical environment in which the enormous richness of the fisheries resources can stabilize and eventually rebuild so as to continue to feed people of today and tomorrow. Poverty in fishing communities should be reduced in part by ensuring a stable supply of fish; something can only be achieved through improved knowledge, integration of fisheries and freshwater management, and greater public involvement. In case of fishing closure in areas or for certain time, the fishers should be provided with alternative income generating activities, credit with low interest and other sustainable means. Creating public awareness of the importance of maintenance of fish diversity in Bangladesh is extremely necessary and should be the first priority for a lasting change. Sustenance of fish diversity can only be achieved with public support. Bangladeshi fishers, fish farmers, traders, processors, and general people as a whole need to understand the issues, to be involved in the formulation of management plans and to benefit from the whole process. A key step in building fisheries co-management and fish biodiversity conservation with community participation is to bring all the various stakeholders in

a common front with a view to sharing resource and knowledge, creating an environment for meaningful discussion on cross-cutting themes and valuing each other.

In recent years, GoB and the donors have placed major emphasis on capture fisheries, conservation, management, and development of institutional framework and need-based training. All concerned and those are working for the betterment of the fisheries sector of Bangladesh – the fishers, fish farmers, general people, local leaders, researchers, policy makers, GO and NGO workers should come forward to conserve the precious fish and ecosystem diversity of the country and to increase the fish production through effective coordination, long-term program and sustainable approaches. This is the high time to care for the aquatic biodiversity. The national and international bodies should come forward to help conserving aquatic ecosystems and organisms using both *in situ* and *ex situ* approaches.

References

Abdullah, A.R., Bajet, C.M., Matin, M.A., Nhan, D.D. & Sulaiman, A.H. (1997). Ecotoxicology of pesticides in the tropical paddy field ecosystem. *Environmental Toxicological Chemistry*, 16, 59-70.

Ahmed, A.T.A. (1995). Impact of Other Sectoral Development on the Inland Capture Fisheries of Bangladesh. Proceeding of the Fourth Asian Fisheries Forum. The Fourth Asian Fisheries Forum. China Ocean Press. Beijing, China.

Ahmed, A.T.A. & Ali, M.L. (1996). Fisheries Resources Potential in Bangladesh and Manpower Development for Fisheries Activities. In: Population Dimension of Fisheries Development and Management Policies of Bangladesh. Dhaka, Bangladesh.

Ali, M.Y. (1997). Fish, water and people, Reflections on inland openwater fisheries resources in Bangladesh. The University Press Limited, Dhaka, 154 p.

Ali, M.L., Hossain, M.A.R. & Ahmed, M. (2009). Impact of Sanctuary on Fish Production and Biodiversity in Bangladesh. Final Project Report. Bangladesh Fisheries Research Forum (BFRF), Dhaka, Bangladesh. 80 p.

Ameen, M. (1999). Development of guiding principles for the prevention of impacts of alien species. Paper presented at a consultative workshop in advance of the 4th meeting of SBSTTA to the CBD, organized by IUCN Bangladesh at Dhaka on 25 May 1999.

Aziz, M.A. (2005). Country Reports, Bangladesh. In the Proceedings of the Asia regional workshop on the implementation, monitoring and observance of the international code of conduct on the distribution and use of pesticides. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. 26-28 July 2005 RAP Publication - 2005/29. 258.

Banglapedia. (2004). National Encyclopedia of Bangladesh, Asiatic Society of Bangladesh, 1st edn. February 2004. Dhaka, Bangladesh. Available from URL: www.banglapedia.org.

Coates, D. 1995. Inland capture fisheries enhancement: status, constraints and prospects for food security. Report of the International Conference on the Sustainable Contribution of

Fisheries to Food Security, 4-9 December, 1995. Kyoto, Japan. Government of Japan. Document # KC/ FI/95/TECH/3. 85 p.

DoF (Department of Fisheries). (2005). Matshya Pakkhya Saranika-2005. Department of Fisheries, Ministry of Fisheries and Livestock. The Government of the Peoples Republic of Bangladesh, Ramna, Dhaka. Bangladesh. 109 p.

DoF (Department of Fisheries). (2008). Matshya Pakkhya Saranika-2008. Department of Fisheries, Ministry of Fisheries and Livestock. The Government of the Peoples Republic of Bangladesh, Ramna, Dhaka. Bangladesh. 96 p.

DoF (Department of Fisheries). (2012). Matshya Saptaha Saranika-2012. Department of Fisheries, Ministry of Fisheries and Livestock. The Government of the Peoples Republic of Bangladesh, Ramna, Dhaka. Bangladesh. 144 p.

Felts, R.A., Rajts, F. & Akhteruzzaman, M. (1996). Small Indigenous Fish Species Culture in Bangladesh. Technical Brief, EC & DoF, Integrated Food Assisted Development Project, Gulshan, Dhaka, Bangladesh. 41.

Hoq, M.E. (2009). Fisheries Resources and Management Perspectives of a World Heritage Site- Sundarbans Mangrove, Bangladesh. In: Fisheries: Management, Economics and Perspectives (N. F. McManus, & D. S. Bellinghouse, Eds.)., Published by Nova Science Publishers Inc., New York, USA. (ISBN 978-1-60692-303-0). 199-227.

Hossain, M. (1988). Nature and Impact of the Green Revolution in Bangladesh. Research Report No. 67. International Food Policy Research Institute, Washington DC, USA. 146.

Hossain, Z. & Halder, G.C. (1996). Impact of pesticide on environment and fisheries. In: Fisheries Fortnight publication: Technologies and management for fisheries development. (M. A. Mazid, Ed.), Bangladesh Fisheries Research Institute, Mymensingh, Bangladesh. 160.

IUCN Bangladesh. (2000). Red Book of Threatened Fishes of Bangladesh. IUCN- The World Conservation Union. 116.

Lahnsteiner, F. (2004). Cryopreservation of semen of the Salmonidae with special reference to large-scale fertilization. *Methods in Molecular Biology*, 253:1-12.

Mazid, M.A. (2002). Development of Fisheries in Bangladesh: Plans and strategies for income generation and poverty alleviation. Nasima Mazid Publications, Dhaka, Bangladesh. 176.

Parveen, S. & Faisal, M.I. (2002). Open Water Fisheries in Bangladesh: A critical Review. Environmental Studies, North South University, Dhaka, Bangladesh. 20.

Pingali, P. L. & Gerpacio, R. V. (1997). Living with reduced insecticide use for tropical rice in Asia. *Food Policy*, 22, 107-118.

Pullin, R.S.V., Eknath, A.E., Gjedrem, T., Tayamen, M., Julie, M. & Tereso, A. (1991). The genetic improvement of farmed tilapias (GIFT) Project. *Naga, the ICLARM Quarterly*, 14(2), 210-315.

Rahman, M.M. (2004). Uses of persistent organic pollutants (POPs) in Bangladesh. Paper presented at the Inception Workshop of the Project Bangladesh: Preparation of POPs National Implementation Plan under Stockholm Convention (POP NIP), Department of Environment, held at Hotel Sonargaon, Bangladesh.

Rahman, A.K.A. (2005). Freshwater Fishes of Bangladesh. Second edition, Zoological Society of Bangladesh, Dhaka, Bangladesh. 394.

Rohar, J.R. & Crumrine, P.W. (2005). Effects of an herbicide and an insecticide on pond community structure and processes. *Ecological Applications*, 15(4), 1135-1147.

Tiersch, T.R., Figiel, C.R., Wayman, W.R., Williamson, J.H., Carmivhael, G.J. & Gorman, O. T. (1998). Cryopreservation of sperm of the endangered razorback sucker. *Transactions of the American Fisheries Society*, 127, 95-104.

Tsai, C. & Ali, L. (1987). The Changes in Fish Community and Major Carp Population in Beels in the Sylhet-Mymensingh Basin, Bangladesh. *Indian Journal of Fisheries*, 34(1), 78-88.

Weis, J.S., Smith G., Zhou T., Santiago-Bass, C. & Weis, P. (2001). Effects of contaminants on behavior: biochemical mechanisms and ecological consequences. *Bioscience*, 51, 209-217.

Aquaculture development under the DANIDA Aquaculture Extension Projects in Bangladesh, with special reference to Regional Fisheries and Livestock Development Component (RFLDC), Noakhali

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Abstract: DANIDA has been engaged in aquaculture development in Bangladesh for almost 30 years, beginning in 1984 with support to what was then the Fisheries Research Institute in Mymensingh and continuing with successive aquaculture development projects, MAEP (1989-2003), PBAEP (1997-2006) and GNAEP (1998-2006). This long experience has provided a good deal of learning over time, notably involving a shift away from the notion of standard technical models which can be applied for the development of small-scale aquaculture to a realization of the need for adaptations to the environmental and socio-economic conditions of particular geographic areas and groups of farm households. This was sharply highlighted in the expansion of support from MAEP to PBAEP and especially GNAEP after 2002, when a range of livelihood interventions were introduced focusing upon resource-poor households. The latest manifestation of this trend in development thinking has been in the Regional Fisheries and Livestock Development Component (RFLDC), in which the extension mode has been the adoption of the Farmer Field School (FFS) approach. This is a highly participatory form of group learning in which farmers are encouraged to analyze their resource base, jointly assess appropriate technical options and test out these options through so-called 'study plots/ponds' before moving to adoption of those alternatives which best suit their own situation. A continuing focus of such developments seems to be addition of giant freshwater prawn to add value to the system, as well as the stocking of sex-reverse tilapia in short-cycle ponds. However, the focus of the FFS is the whole farm and the use of pond water depends upon the emphasis of the household in aquaculture, animal husbandry and homestead gardening. In this approach, it has frequently been realized that the most important part of the resource base for aquaculture is not

managed by the individual farm household, but by the community. Noakhali has two such resource systems: the waterlogged paddy lands (*dogis*) of the north-central part of the region and community ponds in new villages in the char lands in the south. Both these systems require particular management practices, not so much in technical terms, but also in terms of organization within the community. This is particularly the case with the waterlogged paddy land, since management involves both land owners who cultivate rice in the *boro* season and landless households who once harvested wild fish and aquatic plants from the waterlogged lands. If these two groups can be brought together in a common purpose, the waterlogged paddy lands can be turned into a highly productive resource, which may be a model for other parts of the country in the context of water logging associated with climate change.

Introduction

As many people are aware, Danish International Development Assistance (DANIDA) has been involved in aquaculture development in Bangladesh for well over two decades. This involvement began with support to the then Fisheries Research Institute in Mymensingh in 1984 and continued through a series of aquaculture extension projects, beginning with the Mymensingh Aquaculture Extension Project (MAEP) in three phases from 1989-2003, followed by the Patuakhali-Barguna Aquaculture Extension Project (PBAEP 1997-2006) and the Greater Noakhali Aquaculture Extension Project (GNAEP 1998-2006). The latter two projects were incorporated as Components of the Agricultural Sector Programme Support, Phase I, from 2002-6.[1] From 1989-2006 support for the three aquaculture extension projects in Bangladesh amounted to some DKK145 million and addressed approximately 200,000 farm households.

The primary target group throughout the intervention period in all areas was men and women with access to ponds with special attention to landless, marginal farmers, and people with access to fish and prawn cultivation through leased or own ponds or ghers (modified rice fields with a combined production of vegetables, rice, fish and prawns). Secondary target groups include fishermen and traders, entrepreneurs involved in hatchery development, and landless laborers who would become engaged in related services, e.g. net-making, nursery, harvesting, etc. Each of the projects – MAEC in its later stages and PBAEC and GNAEC from the outset - followed a largely top-down transfer of technology approach organized through training and credit provided by contracted NGOs

[1] Thus, although they remained as projects to the Government of Bangladesh, PBAEP and GNAEP were renamed PBAEC and GNAEC as Components of the ASPS.

Impact evaluation of DANIDA aquaculture extension projects

An Impact Evaluation of these various Danida-funded projects was carried out in 2008 (Orbicon and Lamans, 2008). This recorded a generally positive impact from the interventions (although the study was ultimately limited to MAEC and GNAEC because Cyclone Sidr had badly affected the Patuakhali region). Both MAEC and GNAEC had a statistically significant and positive impact on the value of fish production. In Mymensingh this was in the range of Tk 944 to 3858, while in Noakhali the average effect of GNAEC participation on HH income ranged from Tk 787 to 1982 Tk per capita. The average increases in the value of fish production were found to be highest for households either switching into prawn cultivation or cultivating it throughout the whole period. Nevertheless, in Mymensingh aquaculture was on average a relatively small contributor to overall HH income, generally not exceeding 20% of the total. However, aquaculture did become the main source of HH income for a minority of GNAEC participants (18.5%) but much fewer non-participants (3.3%). For GNAEC participants the proportion of household income from aquaculture did increase, with the survey data showing a change from 14% to 21% of total household income.

MAEC and GNAEC were found to have had both direct and indirect but limited, impacts, on nutrition and health. The direct impact was to increase the intake of fish, improving diet, nutrition, and health for participants. Indirectly, increases in income from aquaculture were used to purchase more nutritional food and for access to health care services, which also lead to improved HH health. MAEC and GNAEC were successful in engaging women as participants. In Mymensingh the target of 30% was surpassed by 15% and in Noakhali the 50/50 targeted split between men and women was marginally in favour of women (52%). MAEC and GNAEC appear to have resulted in increased empowerment and participation among those women who were involved in the interventions compared to women who were not. These changes were the result of participation in the activities of MAEC and GNAEC rather than the application of technical skills and knowledge gained from training or from increased control of credit. Analysis of the 2006/07 survey data indicated that training and credit provided to women through GNAEC had a statistically significant and positive average treatment effect impact on women's mobility in Noakhali.

MAEC and GNAEC faced challenges in targeting the poorest of their target beneficiaries. This was shown in project documentation and supported by the survey data which showed that participants were better off economically, better educated, owned more land, and had larger ponds than non-participants. The ease of

implementation, desire to work with pond owners, credit-worthiness, and perceived "better/larger" results, all served to bias selection by the NGO implementors away from the poor of those qualified to participate.

At the pond level the skills and knowledge from training were still very much being practiced by men, although less so by women. However, the ongoing support for aquaculture production to the farmers was seen less sustainable. Extension from Government and NGOs has decreased since 2004 in Mymensingh. The inputs that are required for aquaculture production are largely in place and are being maintained on a sustainable basis. Feed, PL, fingerlings, fertilizer, and labor were all available, with possible issues identified by participants about fertilizer availability.

In Mymensingh the proximity to Dhaka provided a strong ongoing source of demand. At the time of the evaluation, in Noakhali, Danida and DoF were still working on improving access to markets, especially for prawn. Reported price decreases were identified as playing a potentially negative role with respect to sustainability. Flooding and disease were critical risks, more important for prawn, but also of concern for carp polyculture.

The Impact Evaluation identified the following lessons learnt:

- In the right context, with relatively small amounts of training and credit, poor people with pond access can make significant improvements in fish production.
- If the scale of the intervention is large enough a development intervention can successfully catalyse a significant change in an economic sub-sector and the lives of the people active in that area.
- Practical changes in women's lives such as receiving credit, going to meetings, and learning about aquaculture were able to influence strategic improvements in mobility and HH decision-making. Thus the Evaluation recommended working with women regardless of the restrictions they may face with respect to the use of credit and application of training for the empowerment benefits it brings them.

Perhaps more importantly, however, the Evaluation drew attention to the need to examining the context and means of the poor through innovative programming that addresses those needs in a real way and involves them in the sector being targeted. In

this context, the Evaluation it supported in particular the type of learning and innovation displayed in GNAEC that improved the targeting of the poor. The Evaluation also identified that sustainability was enhanced when private sector forces and actors are brought into implementation without necessarily making them beneficiaries. The Evaluation thus recommended the use of the private sector in an extension capacity

Development of the approach into RFLDC

Although the Impact Evaluation of the DANIDA aquaculture projects was completed in 2008, some of its recommendations had already been incorporated into the ongoing projects and were the basis of the more specific recommendations. Following the Joint Annual Sector Reviews of 2002 and 2003 GNAEC in particular had widened the target group to the hard core poor, shifting from an approach which was largely technology driven to one which focused how aquaculture to support the livelihoods of the poor based upon their available resources. Thus from 2003, new interventions were introduced including promotion of integrated prawn farming in *ghers*, nursing of prawn post-larvae to juveniles in micro-scale ponds in the charlands, cage culture in multiple ownership ponds for share-croppers and development of community ponds. Positive results from these interventions were identified in a consultant study contracted by this Component (Akteruzzaman *et al.* 2006).

Under the so-called Agricultural Sector Programme Support, Phase II, the aquaculture extension activities were combined with activities for the promotion of smallholder livestock (mainly poultry) into the Regional Fisheries and Livestock Development Component, which continued to work in the same southern coastal districts of Bangladesh as PBAEC and GNAEP. The immediate objective of RFLDC has an explicit pro-poor focus and aims to improve the livelihood of resource-poor households through improving the productivity of and returns from their fishery and livestock systems. To reach that objective, RFLDC has four main outputs which reflect some of the innovations introduced in the Greater Noakhali Aquaculture Extension Project (Fig. 1). In particular

a) It emphasizes a decentralized, integrated and demand-driven extension approach through the participatory mechanism of the Farmer Field School, which does not include provision of credit;

b) It addresses the needs of farmers in terms of service provision through the establishment and development of farmers' (community-based organizations); and
c) It seeks to link these organizations with the local and national corporate private sector in ensuring quality inputs and access to markets

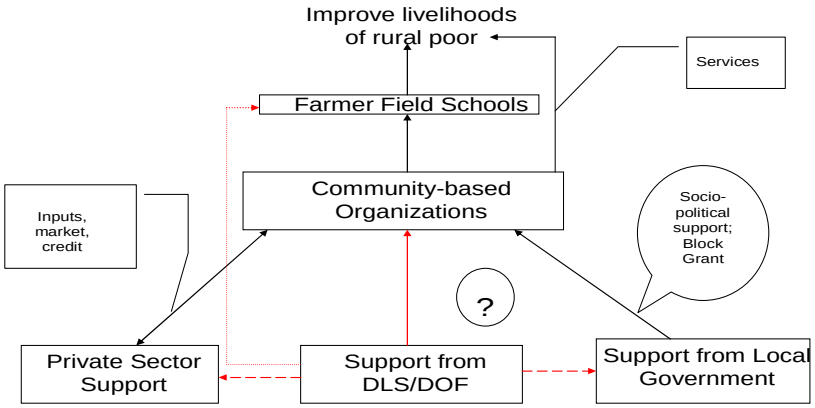

Fig. 1. Strategic Framework of RFLDC.

Farmer field schools as a learning mode

The Farmer Field School approach has been associated with DANIDA's support to the agricultural sector in Bangladesh for several years through the promotion of Integrated Pest Management for rice and vegetable cultivation by the Department of Agricultural Extension. It is characterized by what is known as experiential learning, in which groups of farmers analyze their resource base and discuss how to improve its use by comparing alternative technical options, both through dialogue within the group and field trials. This process is supported by a young, local facilitator, who goes through a practical Season-long Learning (SLL) offered by Project staff on the various technical options as well as in the FFS approach. Participants assess their own situation pre and post training by Participatory Monitoring techniques.

In RFLDC, this approach has been extended to the fisheries and livestock sector, covering a range of modules (aquaculture, poultry rearing, goat, sheep and cattle rearing, homestead gardening and nutrition), as well as special sessions on social issues, conducted on a fortnightly basis over a period of 12-18 months. In the aquaculture sector, there are usually six sessions involving culture system preparation, stocking mix and density, feeding and fertilization, hazard management, harvesting and marketing and perhaps nursing if required. These sessions may apply to individual household culture systems or to community managed systems and the curriculum adapted accordingly. Thus, in Noakhali, the aquaculture module in the Farmer Field School may focus on the waterlogged paddy lands in the north of the region or on the community ponds in settlement villages in the char lands, where these are the key aquatic resources available to the group (the FFS group may be specific to the resource, which may also be the focus of livestock (e.g. duck) rearing and pond bank (as opposed to individual homestead) gardening.

Community-based organizations as service providers

It has been found that the Farmer Field School is an effective learning tool for resource-poor farmers, allowing them to select the appropriate technical options according to their resource availability in all senses of the word, including available capital. However, adoption of the preferred technology depends on the availability of key inputs. These are provided through the Farmers (Community-based) Organizations, managed by groups of local farmers many of them FFS members, who pool their regular savings and apply for grants from local government or the project to invest in inputs and facilities. In the aquaculture sector, the CBOs operate carp, tilapia and prawn nurseries, buy fish feed in bulk, hire out nets and water pumps to assist harvesting and provide advice to the individual FFS households through Community Agriculture and Aquaculture Resource Persons (CAARP) trained as technical specialists by RFLDC. In the case of the waterlogged paddy lands, the CBOs provide the grant from a revolving fund from the Project, provide inputs and help to organize the water resource management groups, which then are responsible for maintenance of the dykes, arranging nursery ponds for overwintering of carp fingerlings, guarding of the system and harvesting and marketing.

Linkages to private agribusiness

The Community-based Organizations or their Associations at District level are in turn linked to local and national corporate agribusiness who provide quality inputs in bulk and therefore at low cost. RFLDC offers technical support to local agribusiness, directly to prawn and sex-reversal tilapia hatcheries, and through a research program with the World Fish Center Bangladesh and South Asia office, to carp hatcheries to try to ensure quality fish seed and fingerlings at a fair price. The hatchery owners typically offer commission to the CAARP and the CBOs to facilitate the sale and distribution of the fingerlings through the CBO nurseries. Under the co-operation with the World Fish Center, four carp hatcheries have been selected as a focus for production of improved seed, through encouraging technical improvements in the hatcheries and improvement of brood fish management. One of these hatcheries has been selected as a nucleus for stocking of high quality brood stock, which will be distributed to other private hatcheries in the region. RFLDC and World Fish will in the first instance 'certify' the improved hatcheries as producing quality seed and encourage the CBOs and their members to stock only from these hatcheries. Through this mechanism, already other hatcheries are coming forward to seek technical assistance to upgrade their facilities.

The CBO Association in Feni District has developed contract with a local sex-reversal tilapia hatchery and a small-scale local feed mill to ensure quality and reduced cost supplies to the member CBOs and through them to individual farmers.
The network of private hatcheries and Community-based Organizations offers scope for the development of a fully certified, traceability system both for prawn and for white fish. RFLDC is now working with Winrock International under the Katalyst project to forge links between the CBOs as bulk suppliers of freshwater prawn and processing plants and a dialogue is underway with UNIDO BEST-BFQ on the possibility of developing a traceability system based on the CBOs.

Results to date

Aquaculture in farmer field schools

In 2010, the Regional Fisheries and Livestock Development Component carried out a performance and impact study of the Farmer Field Schools which had been completed up to the middle of that year. The study assessed the degree to which FFS participants had understood the learning points covered in the FFS sessions and the

degree to which this new learning had impacted upon their production and consumption of fish, as well increases in income levels. The total sample was 1,000 households involved in FFS divided between 5 different ecological zones (on the assumption that the FFS learning points might be of greater or lesser relevance in certain contexts. The learning points covered were pond preparation, including nursing, stocking mix, stocking density, feed management, risk and hazard management, and harvesting and marketing. The in-house study showed that the numbers of households engaged in aquaculture was significantly smaller than in the other two major sub-systems covered by the FFS, poultry rearing and homestead gardening. Prior to the FFS interventions, only 44.5% of farmers were involved in this practice, although after FFS the proportion had increased by an encouraging 26% to 55.9% overall. There was a particularly noticeable increased in the isolated chars in Hatiya, although this was not supported by the increase in area cultured.

The knowledge and adoption of the FFS learning points were measured by a scoring mechanism. In aquaculture was rather less satisfactory than in the case of poultry and vegetable farming, with the highest score at 2.4 for pond preparation and the scores for the other variables around 2.0. In this case, the slightly better performance in both knowledge and adoption was in the coastal and isolated chars where aquaculture has been rather less developed in the past. Perhaps naturally, the least knowledge and adoption was in the small area of the Chittagong hills in Mirsarai and Fatikchari, where so far there has been limited scope for aquaculture development (Table 1).

There was little difference between the scores on the different learning sessions for aquaculture, although pond preparation seems to be better understood than others. Thus the problems related to aquaculture development do not correlate well with the scores on the learning sessions as it did for poultry and vegetable cultivation. Only one-third of farmers say that they experience problems (Table 2), with four main issues prominent: disease, which appears to be the main problem in the chars; natural disaster, mainly overbank flooding, but also drought/lack of water which are important in the waterlogged zone and Hatiya (possibly related to Cyclone Aila?); quality of carp fingerlings, mentioned mainly in the waterlogged areas and in the chars; and, perhaps worryingly for the *dogi* intervention, theft in the waterlogged area. Most of these problems cannot easily be addressed by support services and other than training/advice, the support from CBOs is largely concentrated on ensuring quality fingerlings, mainly on the char lands and Hatiya.

Table-1

Table-2 & 3

Table-4

Overall, however, after the FFS interventions, production from aquaculture had increased to an encouraging degree by 74%, with the best performance in the waterlogged lands and the isolated chars in Hatiya (Table 2). Here too, fish consumption, had also increased markedly, by 183%, much higher than the overall average increase of 91%. The best performance in terms of net income was exhibited in the waterlogged area (again 183%), with the isolated chars also doing well. A similar pattern emerged in terms of distribution of income; Table 3 shows that two-thirds of farmers in the waterlogged paddy lands, in the isolated chars and in the foothills achieved income increases of over 100%.

A relatively small group of farmers engaged in carp polyculture with prawn were analyzed separately. The number of prawn farmers was only 5.3% of the total prior to the FFS and increased to 6.1% afterwards. However, production increased very rapidly following the learning process and income from this system more than doubled. Clearly there is a need to encourage further the incorporation of prawn through the FFS, assuming appropriate rearing conditions.

Development of waterlogged paddy lands

The data from the Performance and Impact survey suggests positive impact especially in the waterlogged paddy areas in Noakhali. These areas have long been recognized as a zone of considerable potential in the region, especially for prawn aquaculture (Karim 1989). There are over 45,000 hectares of such land in the region, covering most of the Begumgonj, Sonaimuri, Chatkhil and Senbagh Upazilas and parts of Noakhali Sadar, Kabirhat, Lakshmipur Sadar and Ramgonj. GNAEP conducted some modest trials under various mechanisms in these systems in 2005-6 (Datta, 2011), but the main focus at activities in this Project was individual household ponds and these trials largely focusing on production technology were not continued in subsequent years. RFLDC revived this initiative in 2009 with a small number of systems facilitated by the Community-based Organizations and thus with a greater emphasis on management structures. The new trials were highly promising (Datta *et al.* 2011) and local community groups have been encouraged to expand the area via the Farmer Field School approach. In 2010, the number of dogi tracts expanded to 37 and in 2011 to 110, including a small number in Lakshmipur (Table 5). Data is still being gathered on the performance of these systems in 2011 (an in-house workshop will be held on January 26, 2012), but in 2010 from a total of 326 hectares, yields of 357 kgs of carp, 4 kgs of prawn and 18 kg of small indigenous species per hectare

were recorded offering a gross return of Tk38,250 and a net profit of Tk9,143 per hectare.[2]

Table 5. Summary of Development of Dogi Aquaculture under RFLDC, 2009-2011

Year	No Dogis	Total Area (Ha)	Average Size (Ha)	No Beneficiaries	Average Profit per Ha (Taka)
2009	7	58.94	8.42	264	19,183
2010	37	326.25	8.82	1,149	9,143
2011	106	748	7.06	3,247	Not yet available

Key features of the system are:

- A process of community meetings involving all stakeholders, both landowners and landless members of the community;
- Formation of a Dogi Management Committee, followed by regular meetings to supervise management;
- Lease agreements with the land owners;
- Shareholders for all stakeholders, with landless households paying their share in labour contributions for maintenance of the system and guarding;
- Tillage of dogi, which increases fertility and reduces costs of boro rice cultivation for land owners
- Overwintering of Indian major carp fingerlings and nursing of prawn PL and other carp species;
- Low density sticking of prawn to add value;
- Wide variety of species stocked including fast-growing species for early harvest;
- Integrated systems, including duck rearing and vegetable growing within and around the dogi;
- Supply of inputs from the Community-based Organizations; and
- Careful record keeping to ensure transparent management.

[2] Compared with 522 kgs of carp, 29 kgs of prawn and 20 kgs of SIS per hectare in 2009. In 2010, not all dogis stocked prawn because of a shortage of PL.

Development of community ponds in the char lands

Another example of community-based aquaculture is the culture of community ponds in settlement villages in the Noakhali char lands. In Subornachar Upazila and the adjoining area of Boyar Char (administratively in Hatiya), there over 300 such ponds at the center of various settlement villages established by government and foreign aid projects for the systematic settlement of these newly accreted lands. The ponds typically vary in size from 0.5 – 2 hectares (although some are substantially larger); the ponds in Subornachar and Boyar Chat total 550 acres. They are surrounded by the houses of between 25-50 settler households, who are vested with ownership of the ponds. Most are quite deep and were excavated to ensure domestic water supply, but most are 'naturally fertile' through domestic waste. Arguably they form the most important resource for the community if they can be properly managed. Unfortunately until recently, as far as fish culture was practiced, it was done in a largely unplanned manner, with no systematic relationship with service providing organizations and often by one or two influential person in the community.

Parallel to the effort to develop the waterlogged paddy lands in the north of Noakhali, RFLDC has attempted to support the poor settler communities by promoting aquaculture in these community ponds. In 2011, the Project worked with 50 such ponds with a total of 90 acres and a settler population of 2,538 households. The Project intervention was rather similar to that of the waterlogged land with the key features being once again:

- Community meetings;
- Formation of Farmer Field Schools and Pond Management Committees;
- Agreements between the CBO and the PMC for supply of inputs;
- Orientation of the PMC in their roles;
- Pond preparation, including dyke repair and re-excavation where necessary;
- Regular PMC meetings and record keeping to ensure transparency;
- Annual meeting for profit distribution

In 2011, the PMC invested Tk1.8 million in the community ponds and the total return was Tk4.5 million from a production of 29.54 tons of carp (67% in terms of value), 6.92 tons of tilapia (10% by value), 3.75 tons of small indigenous species (7% by value) and 0.84 tons of prawn (10% by value). The best ponds offered a net income of around Tk 120,000, giving an average per household of Tk 3,000-4,000.

Lessons learnt from the 2010-11 cycle were quite similar to those of the waterlogged paddy land:

- The need for overwintering of carps, but preferably through maintaining a nursery pond from the previous season because of the high price of overwintered fingerlings;
- Stocking of prawn juveniles, if necessary through the development of a nursery system;
- Release of monosex tilapia to reduce competition if tilapia are stocked;
- Maintenance of green water and feeding of kitchen waste to reduce feed costs;
- Such ponds are surprisingly suitable for prawn, which adds value; but
- The need for strong leadership in the pond committee; and
- Problems of harvest at the period of peak prices during the autumn because of the depth of water.

In some respects, the waterlogged paddy systems and the community ponds in the char area are complementary in terms of their characteristics. The waterlogged paddy dries up at the end of the rainy season and harvesting takes place between September-December. On the other hand, the deeper community ponds are difficult to harvest during the rainy season and may retain water right through the dry season, even to the time of restocking. Thus harvest may be as late as May-June. This is an important in terms of marketing, especially of a commercial crop like freshwater prawn, where buyers need a regular supply of produce for the international market. From the 2010-11 season, the waterlogged paddy land produced approximately 1.3 tons of prawn, although with relatively few systems stocking and only at low density, and the community ponds 0.8 tons. With the area of waterlogged paddy cultured in 2011 increasing by more than twice and the intensity of stocking increasing, the potentials here are significantly greater than in the community ponds, the area of which is limited. Nevertheless such a complementarily may be valuable, especially since both systems offer quite large size prawn (U10) which command a good price and for which Bangladesh has a comparative advantage.

Conclusions

DANIDA has been involved in aquaculture development in Bangladesh for over twenty years. Over time its approach to aquaculture extension has undergone quite significant changes. The later phases of MAEC and the earlier phases of PBAEC and

GNAEC were characterized by a conventional transfer of technology approach through group training by NGOs focusing on carp polyculture in ponds and supported by credit. This approach had its limitations in terms of poverty focus, especially with regard to participation of women, and sustainability. Since 2003, in the later stages of GNAEC and in the successor Regional Fisheries and Livestock Development Component, DANIDA has adopted a much more explicitly pro-poor strategy, focusing on how aquaculture could contribute to improved livelihood based upon the resources available to the poor. In RFLDC, this has been manifested in the adoption of the Farmer Field School approach, a highly participatory learning mode in which technology adoption is adapted to the specific resource systems of the participants. In some cases, this leads to a focus not on the individual household system, but on community resources such as waterlogged paddy lands and community ponds.

Moreover GNAEC/RFLDC have also emphasized a total system approach to development, supporting the farmer learning process through the promotion of Community-based (Farmers') Organizations, which offer the necessary services and quality inputs through links to private agribusiness. This model appears to be a promising one for sustainable development of small-scale aquaculture in the coastal regions of Bangladesh.

References

Akteruzzaman, M., Salam, M.A., Alam, M.J. and Banu, L.J. (2006). A Consultancy Report on Impact Study of Pro-Poor Initiatives through Greater Noakhali Aquaculture Extension Project (GNAEP), Bangladesh Agricultural university, Mymensingh

Datta, Gopal Chandra, Alam, M.S., Akbar, M.T., Alam, A.K.M.R. (2011). Integrated Prawn Carp Culture in Waterlogged Paddy Land through Community Approach, Paper presented at the Asian Pacific Aquaculture Conference Giant Prawn Symposium, 2011, held at Kochi, Kerala, January 15-24, 2011.

Orbicon and Lamans S.A. (2008). Impact Evaluation of Aquaculture Interventions in Bangladesh, Ministry of Foreign Affairs, Copenhagen

RFLDC, Noakhali (2011a). Experience Sharing Workshop on Community-based Integrated Dogi Aquaculture, held at BRDB-Danida Training Center, Maijdee, February 15, 2011

RFLDC, Barisal and Noakhali Technical Support Units (2011b). Farmer Field School Performance and Impact Evaluation, Cycles 1-4 (FFS Completed by April –May 2010), Part IV: Noakhali. http://www.rfldc-noakhali.org

Table 1. Average score Knowledge and adoption on major learning points Aquaculture from FFS (Poor-1, Moderate-2and Adequate-3) by SRC

Major Learning Points	Waterlogged area N=270		Plain land, mainly irrigated N= 270		Coastal chars N=250		Isolated chars (Hatiya) N=180		Chittagong foothills N=30		All (N=1000)	
	Average score		Average score		Average score		Average score		Average score		Average score	
	Know ledge	Adop tion	Know ledge	Adop tion	Know ledge	Adop tion	Know ledge	Adop tion	Know ledge	Adop tion	Know ledge	Adop tion
Pond preparation (Nursery)	2.4	1.8	2.3	1.6	2.5	2.1	2.5	2.0	0.9	0.7	2.4	1.8
Stocking	2.2	1.7	2.0	1.5	2.1	1.9	2.0	1.7	0.7	0.6	2.0	1.6
Stocking density	2.0	1.6	2.0	1.5	2.0	1.7	2.2	1.8	0.7	0.6	2.0	1.6
Feed management	2.1	1.6	2.1	1.5	2.2	2.1	2.1	1.7	1.0	0.7	2.1	1.7
Risk and hazard	2.0	1.6	1.9	1.5	1.8	1.5	2.0	1.6	0.8	0.6	1.9	1.5
Harvesting and marketing	2.1	1.6	1.9	1.5	1.8	1.7	1.9	1.5	0.8	0.6	1.9	1.6

Table 2. Production, Consumption and Income Changes of Poly-culture without prawn by SRC

	Waterlogged land (N=270)			Plain lands, mainly irrigated (N=270)			Coastal chars (N=250)			Isolated chars in Hatiya (N=180)			Chittagong foothills (N=30)			All (N=1000)		
	Before	After	Change	Before	After	Change	Before	After	Change	Before	After	Change	Before	After	Change	Before	After	Change
No. of farmers	114	136	19	114	141	24	183	207	13	31	70	126	3	5	67	445	559	26
Area (Deci)	15	18	15	16	19	12	17	17	0	15	17	11	12	18	44	16	17	6
Sale (Taka)	5984	9250	55	2225	3663	65	2167	3307	53	1797	5272	193	1000	920	-8	3126	5067	62
Consumption (Taka)	4772	13510	183	3820	6087	59	3642	5188	42	3545	6026	70	4167	10940	163	3974	7596	91
Production (Kg)	149	308	106	84	132	57	81	115	42	74	153	106	72	160	123	99	171	74
Gross income	10757	22760	112	6045	9750	61	5809	8495	46	5342	11298	111	5167	11860	130	7100	12663	78
Expenses	4249	4376	3	2003	3428	71	1497	2532	69	1585	2265	43	1833	1440	-21	2340	3163	35
Net income	6507	18384	183	4042	6322	56	4312	5963	38	3756	9033	140	3333	10420	213	4760	9500	100

Table 3. Range of Income Changes of Poly-culture without prawn by SRC

Income changes	Waterlogged Area (N=270)	Plain lands, mainly irrigated (N=270)	Coastal charlands (N=250)	Isolated charlands in Hatiya (N=180)	Chittagong foothills (N=30)	All (N=1000)
	n=117	n=129	n=184	N=58	n=3	n=491
Up to 50%	19	28	30	17	0	25
50%-99%	15	20	15	8	33	16
100% & above	66	52	55	75	67	59
Total	100	100	100	100	100	100

Table 4. Type of problem faced on fish culture

	Waterlogged lands N=270		Plain lands, mainly irrigated N= 270		Coastal chars, N=250		Isolated chars in Hatiya N=180		Chittagong foothills N=30		All (N=1000)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Response	139	51	179	66	190	76	113	63	6	20	627	63
Problem faced	14	10	59	33	68	36	69	61	0	0	210	34
Type of problems												
Disease	3	21	2	3	35	51	33	48	0	0	73	35
Carp fingerling /PL	2	14	13	22	17	25	4	6	0	0	36	17
Feed crisis	1	7	3	5	4	6	2	3	0	0	10	5
Theft	0	0	25	42	1	1	0	0	0	0	26	12
Financial	1	7	3	5	1	1	2	3	0	0	7	3
Pond crisis	0	0	9	15	1	1	2	3	0	0	12	6
Natural disaster (Drought / Flood)	5	36	22	37	5	7	16	28	0	0	48	23
Decrease water level	3	21	3	5	7	10	13	19	0	0	26	12

Advances in Fisheries Research in Bangladesh: I

Production of inbred lines of *Labeo rohita* and *Cirrhinus mrigala* by gynogenetic technique

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Abstract: The present study was aimed at the identification of treatment optima to induce gynogenesis in two different stocks of *Labeo rohita* (rohu) and *Cirrhinus mrigala* (mrigal) by UV irradiation and heat shock treatment. Sperms were exposed under UV lamp (254 nm wave length emitting capacity) from 3 different distances viz., 10 cm, 15 cm and 20 cm. Two different sperm dilutions were tested viz., sperm: Cortland salt solution = 1:5 and 1:10. For each dilution rate and distance, sperm solution was exposed under UV lamp for 2, 5 and 10 minutes duration. To induce meiotic gynogenesis, heat shock was applied 4 minutes after fertilizing the eggs with UV irradiated sperm for both species. Heat shock treatment was applied 15 minutes after fertilization to induce mitotic gynogenesis. In both the cases, heat shock treatment was applied at 40 ^{o}C for 1 minute duration to induce meiotic gynogenesis and 10 minutes duration for mitotic gynogenesis. Among the various treatment combinations tested, UV irradiation from 15 cm distance at 1:10 sperm dilution rate with different durations for meiotic and mitotic gynogenesis was considered to be the best combination. The treatment combinations revealed 28% and 27% hatching rates in rohu and mrigal, 80% and 90% gynogenesis induction rates in rohu and mrigal in case of meiotic gynogens. In case of mitotic gynogenesis, 15% and 18% hatching rates were obtained in rohu and mrigal whereas 85% and 80% gynogenesis induction rates were obtained. Chromosome counting revealed that the haploids have 25 chromosomes and diploids have 50 chromosomes in both species. Haploid gynogenesis was also induced but the haploids did not survive after 3 days. Survivability of the gynogens was tested with the normal diploids for a period of 30 days. Survivability rates of the meiotic gynogens, mitotic gynogens and normal diploids were 18%, 15% and 64% respectively for rohu; and 14%, 11% and 65% respectively for mrigal. As gynogenesis was induced successfully in this experiment, this technique can effectively be introduced in Bangladesh to produce inbred lines of different fishes for the production of faster growing seeds by performing intra-specific hybridization between two inbred stocks.

Introduction

Inland aquaculture in Bangladesh is mainly consisted of some faster growing and larger indigenous as well as exotic carps including: Indian major carps *viz.*, catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), the Chinese carps viz., silver carp (*Hypophthalmichthys molitrix*), black carp (*Mylopharyngodon piceus*), grass carp (*Ctenophryngodon idella*), bighead carp (*Hypophthalmichthys nobilis*) and common carp (*Cyprinus carpio*). The Indian major carps are commercially important fish species widely cultured in the entire Indian sub-continent because these three species satisfy all the important requirements of ideal species for culture (Ahmed *et al.* 2008). Thus, rohu and mrigal are the major contributors and potential candidate species to the aquaculture and inland fisheries production of Bangladesh and have a high demand in the domestic market (Simonsen *et al.* 2005, Ahmed *et al.* 2008). The two Indian major carp species contribute to 23% of total inland fisheries production in Bangladesh (FSY 2012). Seeds for aquaculture were used to be collected from nature until mid 1980s but natural resource depletion reduced the availability of seeds in nature. As a result, quite a large number of private and governmental hatcheries have already been established in Bangladesh in order to meet the growing demand of seeds for aquaculture. However, in an attempt to produce more seeds the seed producers did not pay attention to the genetic attributes and inbreeding inevitably occurred in hatchery populations; and resulting in reduced growth and survival. In order to achieve more profit and production, fish culturists are still inquisitive to collect riverine seeds. Hence, it has become imperative to carry out research on genetic improvement of the species through various approaches. Chromosome engineering technology can provide a tool for rapid genetic improvement of fish, in particular, growth and survival by gynogenesis, androgenesis and polyploidy (triploidy and tetraploidy). Gynogenesis is an all maternal type of inheritance which is of two types: mitotic and meiotic; depending on the induction timing during the stage of cell division process. Hybridization can provide quick outcome in the form of intra or inter species crossing but it needs some degree of genetic variation. Hybridization has already gained a considerable interest in aquaculture for achieving a wide variety of commercial traits, particularly, growth, disease resistance and survivability. Intra-specific hybridization or crossing is an effective option for increased growth in aquaculture but works efficiently if the strains or stocks used are inbred. Thus, crossing between two homozygous or inbred lines could be a plausible option in hatcheries of Bangladesh. Inbred production

through normal breeding program is undoubtedly a long time consuming process, takes several generations of selection. In contrast, gynogenesis technique can provide inbreed lines of fishes within a short time and even after only one generation. Considering the facts, the present experiment was conducted to induce mitotic and meiotic gynogenesis in two different species of Indian major carps: rohu and mrigal.

Materials and methods

Collection and maintenance of broods

The sexually mature brood fishes of "Fish Seed Multiplication Farm", Gollamari, Khulna, were used for the present experiment. The broods were maintained in the brood rearing ponds of the hatchery with supplied feed at 3% of total body weight.

Hypophysation and collection of gametic material

The mature brood fishes were collected from brood stock ponds of the hatchery and kept under a 12 hour photoperiod in conditioning tank for the study. Induced breeding was performed by using carp pituitary hormone injection intramuscularly. The doses were 2mg kg^{-1} and 6mg kg^{-1} body weight for female administered at 6 hour interval while male was given only one injection at 2mg kg^{-1} body weight at the time of second dose to the female. The mature male and female of rohu and mrigal were taken and inseminations were performed after UV irradiation of sperm. UV irradiated sperm was then mixed with normal eggs for fertilization. Heat shock treatment was applied after a certain period of fertilization to induce meiotic and mitotic gynogenesis.

UV irradiation, heat shock treatment and gynogenesis induction

Collected sperms were diluted 10 times with Cortland Salt solution (0.9% NaCl + 5% dextrose) before UV irradiation. For this a sample of 2ml fresh sperm was taken and diluted by Cortland salt solution in a petri dish. This diluted sperm was then exposed to UV irradiation under an ultraviolet lamp (UVBGL- 58) having capacity of emitting short wave length, 254nm. Irradiation was performed at a distance of 10cm, 15cm and 20cm from the lamp filter. Irradiation duration was maintained for 2 minutes, 5 minutes and 10 minutes with continuous shaking of the petri dish. Two different sperm dilutions were tested, sperm: Cortland solution = 1: 5 and 1: 10. The irradiated sperm was then mixed well with the eggs collected by hand stripping. The

eggs fertilized with UV treated sperm were placed batch wise by scoop net in a thermostatically controlled water bath (HHS 4: WS2-133-75, China). Heat shock treatment was applied 4 minutes after fertilization for 1 minute duration to arrest the second polar body for the induction of meiotic gynogenesis which was found optimum by Rahi and Shah (2012) and Reddy *et al*. (1997). For inducing mitotic gynogenesis, heat shock treatment was applied 20 minutes after fertilization for 1 minute duration which was optimized by Mia *et al*. (2001). In both the cases, heat shock treatment was applied at 40 ^{o}C temperature. During each trial, one batch of eggs was kept as normal control and was not treated under UV lamp. Moreover, one batch of eggs was kept as haploid control on which heat shock was not applied.

Incubation of eggs, fertilization and hatching rates

The fertilized eggs were incubated in some round fiber made hatching jars of 15 liter water holding capacity connected to water circulating system. Eggs were hatched within 18 to 24 hours. The rates of fertilization and hatching of fertilized eggs were recorded. After complete hatching of eggs, the larvae were reared in the jars for three days. Supplementary feed, egg yolk was given in the jars twice daily after 24 hours of hatching. To count the fertilization rates, fertilized eggs were easily separated from the unfertilized eggs by the presence of transparent shell with gray spot within the egg shell, while the unfertilized eggs were opaque. Then the fertilized eggs were counted and rate was determined by using the following equation:

$$\text{Fertilization rate (\%)} = \frac{\text{No. of fertilized eggs}}{\text{Total no. of eggs}} \times 100$$

To count hatching rate exactly, 250-500 fertilized eggs were isolated and kept in some small hatching jars of 6 liter water holding capacity with 3 replications and continuous water flow. Then the actual hatching rate was determined by counting the number of hatchlings in the jars.

Assessment of survival rate up to yolk sac absorption stage

At first total number of spawns were counted from the time of starting of hatching. After complete removal of yolk sac of the spawns, total number was counted again. Then the survival rate of the larvae was measured by the following equation:

$$\text{Survival rate (\%)} = \frac{\text{No. of larvae after complete yolk sac absorbtion}}{\text{No. of hatchlings just after hatching of eggs}} \times 100$$

Karyological analysis

Newly hatched (one day old) larvae were taken for karyological analysis in the laboratory for counting the haploid and diploid chromosome numbers of rohu and mrigal. The karyological analysis was done according to Rahi and Shah (2012).

Survivability analysis

The larvae of 3 different fish groups (normal diploid larvae, diploid meiotic and mitotic gynogens) were reared in the earthen nursery rearing ponds of Khulna University for a period of 35 days. In each pond, 3 different net hapas were settled. In total 15 hapas were settled in 5 different ponds indicating that each treatment had 5 replications. For survivability analysis, 300 larvae were stocked in each hapa. Total number of larvae stocked and the number of fry obtained by the end of the rearing period were counted to count survival rates.

Statistical analysis

The results of the survival rate of larval groups were statistically compared using One Way ANOVA followed by Duncan's Multiple Range Test (DMRT) with the aid of SPSS (Statistical Products for Service Solution). Test of significance was done at 5% level.

Results and discussion

The experiment was conducted in two distinct phases for a period 6 months from April to September, 2010. The 1st phase included induced breeding, UV irradiation, gynogenesis induction, assessment of fertilization and hatching rates, survivability

analysis up to yolk sac absorption stage and karyological analysis throughout the production season of the hatchery. The 2nd phase included survivability analysis of 3 different spawn groups for a period of 35 days.

UV irradiation, heat shock treatment and gynogenesis induction

Different treatment combinations with the success for meiotic gynogenesis induction are presented in the Table 1. Heat shock treatment was applied 4 minutes after fertilization at 40°C. Table 2 shows the different treatment combinations and success of mitotic gynogenesis induction. In case of mitotic gynogenesis, heat shock was applied 20 minutes after fertilization.

Table 1. Different treatment combinations for induction of meiotic gynogenesis in Rohu and Mrigal

Distance between UV lamp and petri-dish	Dilution rate (Sperm: Courtland Solution)	Duration of UV irradiation (min.)	Hatching Rate (%)		Gynogenesis obtained (%)	
			Rohu	Mrigal	Rohu	Mrigal
10 cm	1: 5	2	30±1.6	25±1.2	25	10
		5	21±1.1	23±1.7	35	25
		10	19±1.8	19±2	50	40
	1: 10	2	25±2.2	20±2.7	50	30
		5	18±2	18±3	60	50
		10	15±1	12±1.1	90	90
15 cm	1: 5	2	35±2.8	32±2.8	20	0
		5	26±2.3	29±2.1	25	5
		10	23±1	23±1	40	20
	1: 10	2	33±2.9	17±2	45	10
		5	30±1.3	15±1.3	60	20
		10	28±2.2	25±2.2	80	70
20 cm	1: 5	2	38±3.3	32±3	10	15
		5	26±2.1	28±2.1	20	17
		10	24±1.8	27±1.7	40	30
	1: 10	2	34±1.7	31±2.3	30	25
		5	19±1.3	24±2	40	25
		10	17±1	23±1.9	60	45

The present experiment revealed that UV irradiation from shorter distances (10 cm better over 15cm and 20cm; 15cm over 20 cm) was more effective in inactivating the

genetic material of sperm. Percentage of gynogens obtained also varied significantly on the basis of sperm dilution rates. Sperm dilution at 1:10 was found better than 1:5 in all cases for gynogenesis induction but hatching rates showed the reverse result. Lower hatching rate with 1:10 sperm dilution was due to lower sperm concentration at this dilution rate. UV irradiation for higher durations was found better for the inactivation of sperm providing with higher percentages of gynogens obtained. In all cases, UV irradiation duration for 2 minutes resulted in the lowest rate of gynogenesis induction but higher rate of hatching percentages. In this experiment, the best treatment combination was considered on the basis of hatching rate and percentage of gynogens obtained. In case of meiotic gynogenesis, the highest hatching rate was obtained at 38% for rohu and 32% for mrigal when UV irradiation was performed for 2 minutes duration, from 20cm distance with 1:5 sperm dilution rate. But this treatment combination revealed only 10% and 15% of gynogenesis induction in rohu and mrigal respectively. About 90% gynogens were obtained for both species when UV irradiation was performed for 10 minutes duration from 10cm distance with 1:10 sperm dilution rate. But these two treatment combinations were not considered the best. In this experiment the best treatment combination was considered as 10 minutes UV irradiation duration from 15cm distance at 1:10 sperm dilution rate. This treatment combination revealed comparatively better result in terms of both the hatching rates (28% in rohu and 25% in mrigal) and gynogens induced (rohu= 80% and mrigal= 70%).

Table 2. Different treatment combinations for the induction of mitotic gynogenesis in Rohu and Mrigal

Distance between UV lamp and Petri-dish	Dilution rate (Sperm: Courtland Solution)	Duration of UV irradiation (min.)	Hatching Rate (%)		Gynogenesis obtained	
			Rohu	Mrigal	Rohu	Mrigal
10 cm	1: 5	2	15±1.6	17±0.8	20	8
		5	11±1.2	11±1.1	35	25
		10	12±1.8	9±1.3	50	50
	1: 10	2	13±2.2	16±2.1	40	35
		5	10±1.1	13±2	60	60
		10	09±0.6	10±1.0	85	80
15 cm	1: 5	2	19±2.8	26±2.9	20	5
		5	18±2.3	24±2.3	30	20
		10	17±1	20±1.4	40	40
		2	15±2.9	19±1.5	45	20

	1: 10	5	12±1.3	15±1.1	50	25
		10	11±0.7	13±2	85	70
20 cm	1: 5	2	22±3.3	21±2	15	16
		5	20±2.1	23±1.8	20	25
		10	16±1.8	15±1.4	50	40
	1: 10	2	23±1.7	24±2.2	40	30
		5	14±1.3	11±1	40	40
		10	11±0.8	9±0.6	50	60

On the other hand, the same treatment combination and heat shock for 1 minute duration after 20 minutes of fertilization revealed 11% hatching rate and 85% gynogenesis induction rate in rohu but 13% hatching and 70% gynogenesis induction rates in mrigal which were considered the best in case of mitotic gynogenesis. It is well recognized that success of gynogenesis induction depends on several factors including: distance between the UV lamp and sperm solution, light intensity/ wave length, sperm dilution rate (concentration of sperm: cortland salt solution) and duration of UV irradiation (Mia *et al*. 2001, Francescon *et al*. 2004, Komen and Thorgaard 2007, Rahi and Shah 2012).

Fertilization and hatching rates

The mean fertilization and hatching rates of haploid, diploid meiotic and diploid mitotic gynogens as well as normal diploids are presented in the figures 1 and 2. Normal diploid control showed the highest fertilization rate and diploid meiotic gynogens showed the lowest fertilization rate because of UV irradiation and heat shock treatment at earlier stage (4 minutes after fertilization) of embryonic development.

The mitotic gynogens showed 2nd highest fertilization rate in this experiment because of later application (20 minutes after fertilization) of heat shock treatment. At this stage fertilization has taken place properly and the embryo was able to tolerate more or less an adverse situation. But the zygotes of diploid meiotic gynogens are incapable of tolerating an adverse situation because fertilization has just taken place. The normal diploid zygotes showed the highest rate of fertilization because no treatment was applied on them neither UV irradiation nor heat shock treatment. Thus the situation was totally favorable for the normal diploids. In case of the most fish species, mixing of gametes for 1 to 2 minutes duration is enough for effective

fertilization (Reddy *et al.* 1997, FAO 2006, Komen and Thorgaard 2007, Marx and Sukumaran 2007).

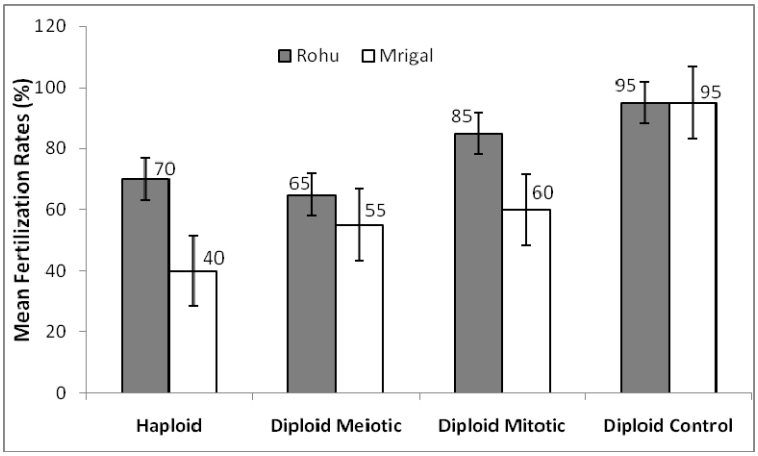

Fig. 1. Mean fertilization rates of the zygotes of rohu and mrigal.

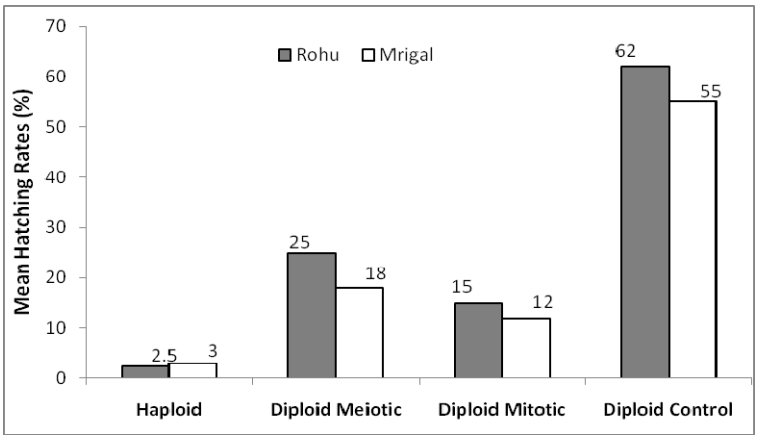

Fig. 2. Mean hatching rates of 4 different zygotes of rohu and mrigal.

Fig. 2 reveals that the haploids showed the lowest hatching rate because of lack of a chromosome set in their nucleus that ensured the half of genetic materials compared to the diploids that might lead to improper embryonic development. The diploid gynogens showed lower hatching rates than the normal diploids because of higher

rate of inbreeding in the gynogens as well as two different shocks (UV irradiation and heat shock) that might create problem in embryonic development providing small percentages of hatching rates. UV-irradiation can have severe effects on development of oocytes and early embryos. The critical effect of temperature in fish chromosome set manipulation has been stressed by several authors (Palti *et al*. 1997, Li *et al*. 2000, Paschos *et al*. 2001).

Survivability rate up to yolk sac absorption stage

Survival rate up to yolk sac absorption stage (up to 3rd day) for the spawns varied considerably among the treatments and controls. The haploids did not survive after 2 days of hatching. Survivability of diploid meiotic gynogens (rohu= 13% and mrigal= 10%) was found to be better than that of the mitotic gynogens (rohu= 8% and mrigal= 5%). But the normal diploids showed the highest survival rate (rohu= 55% and mrigal= 50%) up to this stage. Usually the haploids do not survive because of their lack of 50% genetic materials (Li *et al*. 2000, Komen and Thorgaard 2007) as they have only one set of chromosome (Chakraborty *et al*. 2006, Fopp-Bayat *et al*. 2007).

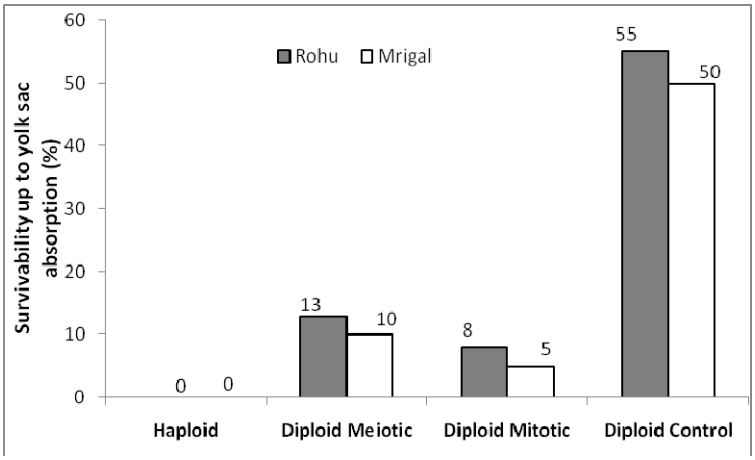

Fig. 3. Mean survivability rate of spawns up to yolk sac absorption stage.

Karyological analysis

Karyological analysis revealed that the haploid gynogens have only 25 (n) chromosomes and diploids have 50 (2n) chromosomes (Fig. 4 a and b) for both of the

species. The haploid and diploid chromosome numbers of this species were found to be 25 and 50 by other authors as well (John *et al*. 1984, Reddy *et al*. 1997, Rahi and Shah 2012).

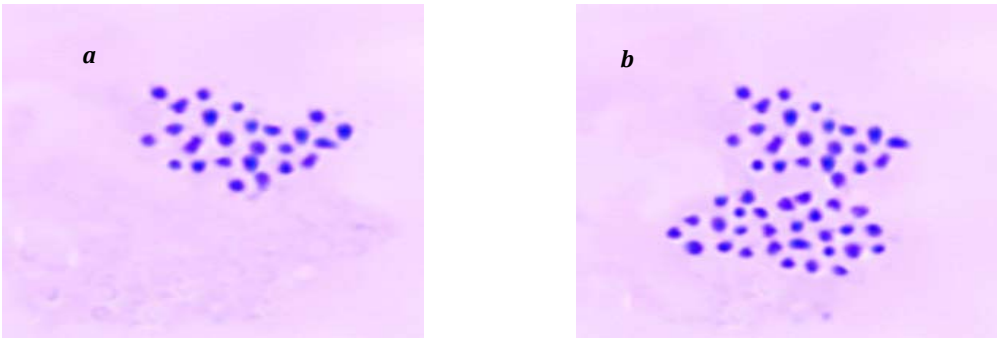

Fig. 4. Metaphase preparation of chromosomes of rohu and mrigal: a) haploid and b) diploid.

Survivability analysis

Fig. 5 shows that the mean survival rates of meiotic diploid, mitotic diploid and normal diploid larvae of rohu and mrigal up to 35 days. The lowest survivability in the mitotic gynogens was due to higher rate of inbreeding as both the chromosome sets are the same. On the other hand meiotic gynogens are obtained by arresting the extrusion of second polar body and increased heterozygosity than the mitotic gynogens. On the other hand, heterozygosity of normal diploids is generally far higher than the gynogens and provided with very high survival rates than the gynogens. No significant difference ($p = 0.07 > 0.05$) between meiotic and mitotic gynogens was observed in the present study. But significant difference ($p = 0.00 < 0.05$) was observed between the survival rates of normal diploids with the gynogens.

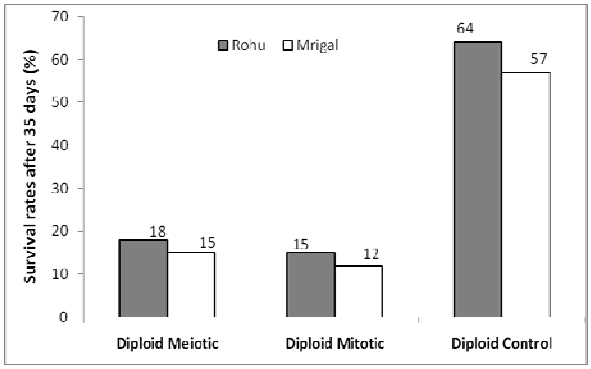

Fig. 5. Mean survivability rates of normal and gynogenetic larvae

Conclusions

In the present study the gynogenesis has been successfully induced in two different species of Indian major carps, rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) using UV irradiation and heat shock at proper treatment combinations. There has been an explosive increase in aquaculture production in the last few decades through several traditional and modern means, especially through the application of several genetic technologies. However, still the enterprise is being confronted with severe challenges from pollution, inbreeding and spread of diseases and loss of biodiversity. For creation of appropriate manpower in aquaculture genetics in Bangladesh, many crucial issues of technological, biological, ecological and economics are waiting to be resolved. Fish culture and fisheries, in general, play a very vital role in the socio-economy of the country. A large number of people are engaged in the sector for livelihoods and nutrition. Inland aquaculture production is suffering from genetic degradation arising out from seed quality produced from hatcheries. Intra specific hybridization between two inbred lines can provide increased aquaculture production which can effectively combat the problem of lower growth performance of hatchery produced seeds. Thus, the results of the present study could play a significant role in the increase of fish production from culture sector of the country.

References

Ahmed, V.P.I., Chandra, V., Shukla, R. Bhonde, R. and Hameed, A.S.S. (2008). A new epithelial-like cell line from eye muscle of catla *Catla catla* (Ham.): development and characterization. *Journal of Fish Biology*, 72: 2026-2038.

Chakraborty, B.K., Miah, M.I., Mirja, M.J.A. and Habib, M.A.B. (2006). Induction of gynogenesis in endangered Sarpunti *Puntius sarana* (Hamilton) and evidence for female homogamety. *Aquaculture*, 258: 312-320.

FAO, (2006). Conservation of the genetic resources of fish: Problems and recommendations. Report of the Expert Consultation on the Genetic Resources of Fish. Rome, Italy 9-13 June: 43.

Francescon, A., Libertini, A., Betotto, D. and Barbaro, A. (2004). Shock timing in mitogynogenesis and tetraploidization of the European sea bass (*Dicentrarchus labrax*). *Aquaculture*, 236: 201-209.

FSY, (2012). Fisheries Statistical Yearbook of Bangladesh, 26th edition. Department of Fisheries, Ministry of Fisheries and livestock, government of the People's Republic of Bangladesh.

Fopp-Bayat, D., Kolman, R. and Woznicki, P. (2007). Induction of meiotic gynogenesis in starlet (*Acipencer ruthenus*) using UV irradiated bester sperm. *Aquaculture*, 264: 54-58.

John, G., Reddy P.V.G.K. and Gupta, S.D. (1984). Artificial gynogenesis in two Indian major carps, *Labeo rohita* (Ham.) and *Catla catla* (Ham.). *Aquaculture*, 42: 161–168.

Komen, H., and Thorgaard, G.H. (2007). Androgenesis, gynogenesis and the production of clones in fishes: a review. *Aquaculture*, 269: 150-173.

Li, Q., Osada,, M., Kashihara, M., Hirohashi, K. and Kijima, A. (2000). Cytological studies on artificially induced gynogenesis in the pacific abalone. *Fisheries Science*, 66: 701-707.

Marx, K.K. and Sukumaran, N. (2007). Comparison of effectiveness of heat and cold shocks applied in the induction of gynogenesis in *Clarias gariepinus* (Burchell). *Bangladesh Journal of Fisheries Research*, 11(2): 131-140.

Mia, M.Y., Islam, M.S. and Shah, M.S. (2001). Radiation induced heat shocked gynogenesis in mrigal, *Cirrhinus cirrhosus* (Hamilton). *Indian Journal of Fisheries*, 48(4): 353-359.

Palti, Y., Li, J.J. and Thorgaard, G.H. (1997). Improved efficiency of heat and pressure shocks for producing gynogenetic rainbow trout. *Progressive Fish Culturist*, 59: 1–13.

Paschos, I., Natsis, L., Nathanailides, C., Kagalou, I. and Kolettas, E., (2001). Induction of gynogenesis and androgenesis in goldfish *Carassius auratus* (var. ornda). *Reproduction of Domestic Animals*, 36: 195–198.

Rahi, M.L. and Shah, M.S. (2012). Triploidization in rohu x mrigal hybrid and comparison of growth performance of triploid hybrid. *Aquaculture Research*, 43(12): 1867-1879.

Reddy, P.V.G.K., Mohapatra, K.D., Saha, J.N., Barat, A., Barman, H.K., Jana, R.K. and Meher, P.K. (1997). Induction of Mitotic gynogenesis in *Catla catla*, *Cirrhinus mrigala* and *Labeo calbasu*. *Journal of Aquaculture in Tropics*, 12 (1): 65-72.

Simonsen, V., Hansen, M.M., Mensberg, K.L.D., Sarder, R.I. and Alam, S. (2005). Widespread hybridization among species of Indian major carps in hatcheries, but not in the wild. *Journal of Fish Biology*, 67: 794-808.

Inheritance of sex and sex-linked markers in Nile tilapia (*Oreochromis niloticus* L.)

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Abstract: Sex determination system in tilapia is fairly complex. This study analysed the sex determining mechanism using markers from recently developed linkage map. A series of crosses were performed involving clonal line of females and a range of males. Three groups of fish each consisting of three families were used for linkage study: type 'A' (normal XY males x clonal XX females), type 'B' (putative YY males x clonal XX females) and type 'C' (unknown groups of males x clonal XX females), for sex linkage study. For type 'A', inheritance of DNA markers and phenotypic sex were investigated using screened markers from tilapia linkage group 1 (LG1) to confirm the LG1-associated pattern of inheritance of phenotypic sex and the structure of LG1. Screened markers from LG1, LG3 and LG23 were used to investigate the association of markers with sex in families of type 'B' and 'C'. In addition, a genome-wide scan of markers from the other 21 LGs was performed to investigate any association between markers and sex, in families of cross type 'B'. LG1 associated pattern of inheritance of phenotypic sex was confirmed by genotype and QTL analyses in families of cross type 'A'. Analyses of genotypes in families of type 'B' and 'C' showed strong association with LG1 markers but no association with LG3 and LG23 markers. Genome wide scan of markers from all other LGs did not show any significant association between any markers and the sex. The allelic inheritance of two tightly linked LG1 markers (UNH995 and UNH104) in families of type 'B' and 'C' identified polymorphism in the sex determining locus: one of the alleles was associated mostly with male offspring whereas another was associated with both progeny (mostly males in type 'B' families, and approximately equal numbers in type 'C' families).

Introduction

Teleost fish display an amazing variety of sex determination systems. The primary sex determination in most species is genetic (Valenzuela *et al.* 2003); nevertheless, the sex differentiation of fishes is remarkably plastic and is determined by both genetic and environmental factors in many species (Baroiller and D'Cotta 2001). In tilapia, a variety of evidence suggests that sex determination is principally monofactorial (Wohlfarth and Wedekind 1991). The genetic sex of Nile tilapia is thought to be an XX/XY male heterogametic system (Jalabert *et al.* 1975; Penman *et al.* 1987, Mair *et al.* 1991) controlled by a major gene. However mass spawning and interspecies cross-breeding shows unexpected sex ratios based on a simple monofactorial sex determination model (Mair *et al.* 1987, Rosenstein and Hulata, 1994). A clear understanding of the genetics of sex is therefore important to help producing genetically male Nile tilapia against the conventional approach of sex reversal using hormones.

DNA markers have been used in a number of studies to identify association between markers and the QTL (for sex) in different tilapia species and their hybrids (Shirak *et al.* 2002, Lee *et al.* 2003 2004, Cnaani *et al.* 2004, Ezaz *et al.* 2004a, Karayucel *et al.* 2004, Cnaani *et al.* 2008). In Nile tilapia, notable works on sex-linkage using DNA markers are those of Lee *et al.* (2003) and Lee and Kocher (2007). Mapping of a functional gene close to QTL for sex determination has also been performed but based on hybrid crosses (Shirak *et al.* 2006). Some work suggests there may be autosomal modifiers in establishing sex of tilapia (Cnaani *et al.* 2008). Another model of sex determination, in the absence of any interaction (or in inconsistent pattern of interaction) between two such sex chromosomes is the segregation of an allelic series (multiple alleles) at the sex determining locus (Wohlfarth and Wedekind 1991) which was partially supported by Cnaani *et al.* (2008) because of the apparent differences among families of the same species. However, they did not have evidence for multiple alleles segregating at the same sex determining locus across crosses. Therefore, the current state of knowledge on the sex determination system of Nile tilapia is indistinct. The present study investigates the association of microsatellite DNA markers with sex in a variety of crosses involving XX clonal females as reference line and different types of males to get a further understanding of the genetic sex determination mechanism in Nile tilapia in a controlled environment.

Materials and methods

Screening of broodfish and PIT tagging

Five putative XY and 16 putative YY male tilapia were taken from stock tanks at Tropical Aquarium Facilities (TAF), Institute of Aquaculture, University of Stirling, and kept at individual tanks following PIT (Passive Integrated Transponder) tagging. The basic maintenance of the experimental stock rigorously followed working procedures under ASPA (Animals Scientific Procedures Act 1986) and monitored by the Home Office in the United Kingdom.

Breeding of fish

Three randomly chosen putative XY and 14 putative YY fish were successfully bred with the females that were fully inbred clonal line.

Selection of different types of families for sex linkage study

A total of nine crosses of three groups (each group consisting of three families) were selected from those described in previous section. The first type of cross (Type A) was selected from the apparent normal males giving sex ratios not significantly different from 1:1. Type 'B' included the families giving high frequencies of males (with >90 % male). The third type consisted of families giving intermediate sex ratios (~60-80% males), considering them as neither normal XY males nor putative YY males. This type was designated as group 'C'.

Fin biopsy and DNA extraction and amplification

Fin samples were biopsied from the parents and offspring and DNA was extracted using REAL kit (REAL laboratories, Spain), quality checked and quantified by Nanodrop spectrophotometer. PCR was carried out in 15 µl master mix (1X TAE buffer, 1.5 mM $MgCl_2$, 0.2 mM of dNTPs, 0.3 µM of labeled and FW/RV primers, 0.02µM tailed primer, 0.05U/µl Taq, 0.05µg to 1 µg DNA) using different fluorescent primers; M13 blue (ggataacaatttcacacagg), CAG tag green (cagtcgggcgtcatca) and Godde black (catcgctgattcgcacat). PCR was performed at 95 ºC for 14 min followed by 40 cycles of 95 ºC for 1 min, one or two-step annealing temperatures for markers from LG1, 3 and 23, 72 ºC for 1 min, with a final elongation step of 72 ºC for 30 min. For the rest of the markers from genome wide selection, annealing temperatures of 57 ^{o}C, 58 ^{o}C and 60 ^{o}C were used for primers having M13 tail, CAG tag green and Godde black, respectively.

Genotyping and fragment analyses

The labeled PCR fragments were genotyped using the CEQ™ 8800 capillary sequencer. Bulk segregant analyses (BSA) were performed to reduce the amount of genotyping of large number of samples considering the cost. If BSA suggested an association with sex, individual samples were run to allow statistical analysis and build linkage maps. The analyses of fragments were performed using Beckman-Coulter software. The CRI-MAP software v 2.4 (Green and Crooks 1990) was used to construct linkage maps. The graphical representation of linkage maps was done by MapChart version 2.2 (Voorrips 2002). Chi-square (goodness of fit) statistics were performed to test for significant difference of observed sex ratios in each cross from 1:1 ratios.

Results

Sex ratios from breeding of clonal females with a range of males

The cross details of the selected families and sex ratios from various crosses are presented in Table 1.

Table 1. Selection of three types of crosses (consists of nine families) for sex linkage study

Designated group/type of cross for sex linkage study	Designated Family	Tag no. of Sire x Dam	No. of male/ female	% male	Inferred Sire genotype	Basis of selection
Type A	Fam 1	00 068C D9E3 x 00 0633 EA38	71/75	48.6	XY	Sex ratios do not significantly differ from 1:1 (Table 4.1), ($P(\chi^2_{[1]})>0.05$)
	Fam 2	00 068C FBE2 x 00 0633 EA38	61/57	51.6	XY	
	Fam 3	00 064E 46A8 x 00 068C F2E0	60/62	49.2	XY	
Type B	Fam 4	00 068C E167 x 00 068D 0073 and 00 064E 4714	206/15	93.2	Putative YY	Sex ratios differ significantly from 1:1 (Table 4.1), ($P(\chi^2_{[1]})<0.001$); High frequency of males (91-100%, Figure 4.2)
	Fam 5	00 013E 315C x 00 068C F2E0, 00 068D 0B19 and 00 064C FDF1	404/36	91.8	Putative YY	
	Fam 6	00 068C F8BB x 00 064E 4714 and 00 068C DD59	76/4	95.0	Putative YY	

	Fam 7	00 064E 44F0 x 00 068D 0073 and 00 068C D9B1	87/49	64.0	??	Sex ratios differ significantly differ from 1:1 (Table 4.1); intermediate frequency of males (64-80%)
Type C	Fam 8	00 064C F99B x 00 068D 0073 and 00 068C D9B1	120/46	72.3	??	
	Fam 9	00 064C F5FC x 00 068C F2E0 and 00 068C F5C9	86/21	80.4	??	

Analyses of marker genotypes in different groups of fishes

Heterozygosity was detected in seven loci (out of 11) in LG1 in the sires of type 'A' families. The segregations of alleles with individual progeny DNA with polymorphic markers are presented in Table 2. Six loci were found to be significantly linked (LOD>3.00) following linkage analyses. The order of the linked markers from the individual genotype results of three families of type 'A' are given in Table 3 (QTL positioning at 9 cM).The sires of type 'B' families were heterozygous at seven loci in LG1, four loci in LG3 and seven loci in LG23. Four markers (UNH995, GM258, UNH719 and UNH846) from LG1 were polymorphic in sires of all three families. Only UNH995 seemed to show a strong association with sex during BSA and individual genotyping in type 'B' families (Table 4). The sires of type 'C' families were heterozygous at nine loci in LG1, six loci in LG3 and all of the eight loci in LG23. Markers only from LG1 showed association with sex in BSA (Table 5-7). Analyses of QTLs using the genotype information from cross type 'C' with 4 markers and using the genotype information, collectively, from three families of type 'C' and from three families of type 'A', with 4 markers are given in Table 8 and 9 respectively.

Table 2. Segregation of LG1 markers in individuals of type 'A' families

Marker name	Sire tag code	Sire genotype	Dam genotype	Possible genotypes in progeny	No. of progeny with different genotypes	
					Male (N=23)	Female (N=23)
UNH985	D9E3	144/154	144/144	144/144	2	23
				144/154	21	0
	46A8	144/154	144/144	144/144	1	22
				144/154	22	1
	FBE2	144/154	144/144	144/144	0	23
				144/154	23	0

UNH931	D9E3	227/261	227/227	227/227 227/261	1 22	22 1
	46A8	227/261	227/227	227/227 227/261	1 22	22 1
	FBE2	227/261	227/227	227/227 227/261	4 19	21 2
UNH213	D9E3	190/211	211/211	211/211 190/211	2 21	22 1
	46A8	190/211	211/211	211/211 190/211	1 22	22 1
	FBE2	190/211	211/211	211/211 190/211	6 17	22 1
UNH995	D9E3	184/236	184/184	184/184 184/236	4 19	21 2
	46A8	184/236	184/184	184/184 184/236	3 20	21 2
	FBE2	184/236	184/184	184/184 184/236	0 23	23 0
UNH104	D9E3	147/197	147/147	147/147 147/197	4 19	21 2
	46A8	147/197	147/147	147/147 147/197	2 21	22 1
	FBE2	147/197	147/147	147/147 147/197	0 23	23 0
UNH719A	D9E3	121/127	121/127	121/121 121/127	2 21	1 22
	46A8	121/121	121/127	121/121 121/127	1 22	0 23
	FBE2	121/127	121/127	121/121 121/127	5 18	5 18
UNH719B	D9E3	141/null	Null/null	Null/null 141/null	7 16	17 6
	46A8	141/143	Null/null	141/null 143/null	18 5	9 14
	FBE2	141/null	141/null	Null/null 141/141	0 23	3 20

Table 3. Male-specific map of Nile tilapia LG1 produced from offspring genotypes of XY males x XX clonal females (type 'A' families)

#	**1**	**2**	**3**	**4**	**5**	**6**
Marker	UNH931	UNH213	UNH985	UNH995	UNH104	UNH719B
Distance cM	0.0	2.9	5.8	5.1	0.7	30.0
Position cM	0.0	2.9	8.7	13.8	14.5	44.5
# Sires Genotyped (%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)

# Dams Genotyped (%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)
# HS Genotyped (%)	138 (100 %)	138 (100 %)	138 (100%)	138 (100%)	138 (100%)	138 (100%)
# Het Sires	3	3	3	3	3	3
# alleles	2	2	2	2	2	3

Table 4. Association between UNH995 (LG1) and phenotypic sex in individual progenies of family type 'B' (putative YY males x clonal females)

Cross type	Sire tag code	Sire genotype	Dam genotype	Male progeny		Female progeny	
				Genotype	No.	Genotype	No.
Type 'B' YY x XX (producing > 90% male in progeny sex ratios)	Fam 4 00 068C E167	184/236	184/184	184/184	11/20	184/184	10/10 *
				184/236	9/20 ns		
	Fam 5 00 013E 315C	184/236	184/184	184/184	9/20	184/184	10/10 *
				184/236	11/20 ns		
	Fam 6 00068C F8BB	184/236	184/184	184/184	15/28	184/184	4/4
				184/236	13/28 ns		

*χ^2 (against expected ratio of 1:1 of each genotype in female progeny): P<0.05; ns: Not significant: P>0.05

Table 5. Segregation of LG1 polymorphic markers in family 7 (00 064E 44F0 male x clonal XX female) of cross type C (unknown sire genotype producing ~60-80% male progeny)

Cross type	Marker and LG	Unknown Sire (44F0) genotype	Dam (0073 clonal ♀) genotype	Male progeny		Female progeny	
				Genotype	No.	Genotype	No.
Type C Family 7	UNH931 (LG1)	227/240	227/227	227/227	10/23	227/227	21/23
				227/240	13/23 ns	227/240	2/23 ***
	UNH995 (LG1)	236/252	184/184	184/236	12/23	184/252	23/23
				184/252	11/23 ns		**
	UNH104 (LG1)	190/210	147/147	147/190	12/23	147/210	23/23
				147/210	11/23 ns		**

***χ^2 (against expected ratio of 1:1 of each genotype in female progeny): P<0.001; ** P<0.01; ns: Not significant: P>0.05

Table 6. Segregation of LG1 polymorphic markers in family 8 (00 064C F99B male x clonal XX female) of cross type C (unknown sire genotype producing ~60-80% male progeny)

Cross type	Marker and LG	Unknown Sire (F99B) genotype	Dam (0073 clonal ♀) genotype	Male progeny Genotype	No.	Female progeny Genotype	No.
Type C Family 8	UNH104 (LG1)	147/190	147/147	147/147 147/190	11/23 12/23 ns	147/147	23/23 ***
	UNH719 (LG1)	127/141	127/127	127/127 127/141	10/23 13/23 ns	127/127 127/141	19/23 4/23 **

***χ^2 (against expected ratio of 1:1 of each genotype in female progeny): P<0.001
**χ^2 (against expected ratio of 1:1 of each genotype in female progeny): P<0.01. ns: Not significant: P>0.05

Table 7. Segregation of LG1 polymorphic markers in family 9 (00 064C F5FC male x clonal XX female) of cross type C (unknown sire genotype producing ~60-80% male progeny)

Cross type	Marker and LG	Unknown Sire (F5FC) genotype	Dam (F2E0/F5C 9 clonal ♀) genotype	Male progeny Genotype	No.	Female progeny Genotype	No.
Type C Family 9	UNH931 (LG1)	227/245	227/227	227/227 227/245	6/18 12/18 ns	227/227 227/245	4/20 16/20 **
	UNH995 (LG1)	236/252	184/184	184/252 184/236	10/18 8/18 ns	184/252	20/20 ***
	UNH104 (LG1)	190/210	147/147	147/190 147/210	8/18 10/18 ns	147/210	20/20 ***

***χ^2 (against expected ratio of 1:1 of each genotype in female progeny): P<0.001
**χ^2 (against expected ratio of 1:1 of each genotype in female progeny): P<0.01. ns: Not significant: P>0.05

Table 8. QTL analyses for type 'C' families (QTL for sex positioned at 28 cM)

#	1	2	3	4
Marker	UNH931	UNH995	UNH104	UNH719
Distance cM	0.0	27.5	0.0	11.0
Position cM	0.0	27.5	27.5	38.5
# Sires Genotyped (%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)
# Dams Genotyped (%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)
# HS Genotyped (%)	138 (100%)	138 (100%)	138 (100%)	138 (100%)
# Het Sires	2	2	3	1
# alleles	2	3	3	2

Table 9. QTL analyses for genotypes of 6 families, combining crosses of type 'A' and 'C' (QTL for sex at 17 cM)

#	1	2	3	4
Marker	UNH931	UNH995	UNH104	UNH719
Distance cM	0.0	16.2	0.4	18.6
Position cM	0.0	16.2	16.6	35.2
# Sires Genotyped (%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)
# Dams Genotyped (%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)
# HS Genotyped (%)	276 (100%)	276 (100%)	276 (100%)	276 (100%)
# Het Sires	5	5	6	4
# alleles	3	3	5	3

Genome wide scan (GWS)

The genotyping of individual samples in genome wide scan did not show any significant association between markers and sex.

Discussion

Sex ratios in crosses of clonal females and different males

The sex ratios in the three families of cross type 'A' (Table 1) were not significantly different ($p>0.05$) from 1:1 and there was a strong association between polymorphic sex and LG1. Therefore it can be postulated that a monofactorial model of sex determination is at work in all three families with female homogamety (XX) and male heterogamety (XY). The sex ratios in the three families of cross type 'B' (producing >90% male) were significantly different ($p<0.001$) from 1:1. The sex ratios in three families of cross type 'C' (producing 64-80% male) were significantly different from 1:1 ($p<0.01$or $p<0.001$). In contrast to the arbitrary designations of the families by Mair *et al.* (1997), where potential YY genotypes producing sex ratios significantly not different from 1:1 or only significant at the 5% level ($0.01<p<0.05$) were designated as XY and sex ratios significantly different at a probability level of 0.1% ($p<0.001$) were designated as YY, the current study assigned a criteria of $p<0.001$ with >90% male progeny in the families as putative YY (cross type B). The other type of families (type 'C' families) had no such specific criteria (one family with $p<0.01$ and two families $p<0.001$, against 1:1 in progeny sex) and selected from the frequency distribution with a criterion of up to ~80% male progeny. Thus the genetic class is more precisely characterized in the present study reflecting the sires of type 'C' group as neither putative XY nor putative YY.

The basic sex determination mechanism of some species of *Oreochromis* has been proposed to be 'predominantly' monofactorial by several authors. Jalabert *et al.* (1971) studied the sex determination of *O. niloticus* and *O. macrochir* by evaluating the sex ratios of hybrid progeny and concluded that *O. niloticus* had a basic XX: XY sex determination. However the sex ratios from the back cross of the male hybrid to a female *O. niloticus* did not conform to the expected ratios. There are some other studies where significant variations were observed from predicted sex ratio of 1:1 in this species. Shelton *et al.* (1983) reported sex ratios from mass spawnings of *O. niloticus* that ranged from 31 to 83% male. Progeny sex ratios from normal XY males and XX females varied from 34.2 to 70% with a mean close to 50%, with a slight but significant overall excess of males (Mair *et al.* 1997). Tuan *et al.* (1999) reported a range of 15 to 100% male among 95 families of *O. niloticus*. Calhoun and Shelton (1983) examined the sex ratios within individual spawns of Nile tilapia. Numerous spawns significantly deviated from 1:1 sex ratios. Some females produced as high as 90% male progeny and others as high as 70% female progeny. Calhoun and Shelton (1983) reported that the female component of variation was responsible for 13-fold more variation in progeny sex ratios than the male component of variation suggesting the possibility that the modifying loci may actually lie on the X chromosome rather than the autosomes (Dunham 2004). This would result in variants of the X chromosome of varying strength, if there was genetic variation at these modifying loci or at the X allele itself. However, where an appropriate XX: XY pattern of inheritance is assumed, the fertilization of the egg with a Y sperm should result in male progeny if no autosomal factors influence sex ratios, or no variation exists at the XY locus, This would be particularly evident in a highly inbred population (Phelps and Warrington 2001). The highly inbred clonal line of females used as dams in the present experiment may also account for such uniform sex ratios provided that the male component did not have such variants (autosomal or XY locus) in the three families (type 'A') concerned in the current study.

There are a number of studies where significant variations were observed from predicted sex ratios concerning the YY nature of the male parents, like the sex ratios in family type 'B' and 'C' in the current study. The sex ratios produced by the males that were designated as YY genotypes in a study by Mair *et al.* (1997) were not quite in accordance with those predicted by the hypothesis of simple monofactorial sex determination, many of them being somewhat lower than the expected 100% male. Mair *et al.* (1991) observed a single female in the progeny of one of four YY males progeny tested. YY male genotypes of Nile tilapia sired a mean of 95.6% males when mated with XX females (Beardmore *et al.* 2001). However, Scott *et al.* (1989) observed no females in the sexing of 285 progeny of a single putative YY male crossed to 10 separate females.

The families of type 'C' in the current study showed sex ratios significantly different from 1:1, but approximately intermediate sex ratios (% male) between the other two groups (XY and putative YY). Significant overall excess of male progeny (as in type 'C' of the present study) has also been observed in a number of studies on Nile tilapia where an arbitrary designation of the sires was hypothesized. Mair *et al.* (1997) observed 70% male offspring in one family of Nile tilapia, but did not designate the sires as putative YY on the basis of an arbitrary designation ($p>0.01$ but <0.05 against 1:1 denoted as XY) for a range of sex ratios obtained from such families. Such criteria can be set to designate inferred genotypes in the absence of genetic markers. The present experiment did not categorize such families in either YY or XY, and attempts to identify if families of such group (type 'C' crosses) possess any genetic variation (at single sex determining locus or any autosomal locus/loci) that can be identified by a sex linkage study.

Study on the seven loci from LG1 and segregation of alleles in individual progeny samples in cross type 'A' and QTL analyses of the genotypes revealed six loci to be significantly linked (LOD> 3.00). The order of the markers produced by Crimap 'Build' showed that the genetic map length from the present study considering six loci was 44.5 cM (Fig. 1). Considering those six markers, a very close and comparable genetic map is what was produced by Lee and Kocher (2007) (42.2 cM). In LG1, the map distance (Lee *et al.* 2005) between UNH931 and UNH719 was shorter (33 cM) compared to the LG1 map of Lee and Kocher (2007) and that in the current study. The linkage and order of markers in the present study are largely congruent except the double flip of UNH985 with previous maps (by Lee and Kocher 2007, Lee *et al.* 2005). Such flipping of the markers was also evident in the male-specific map produced by Lee *et al.* (2004) for *Oreochromis aureus*. Although the basic karyotype seems to be very similar and each linkage group can represent each chromosome by a series of DNA markers, the small scale difference of map orders could be due to a number of factors, for example number of individuals genotyped, genotyping accuracy/errors, as well as different strains and species.

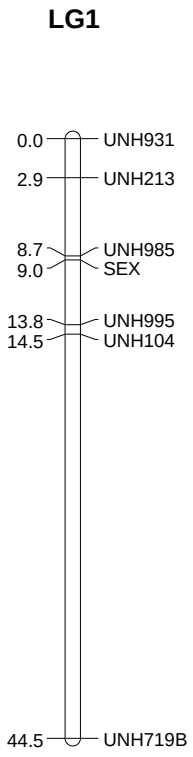
The distance of the QTL for SEX in the study of Lee and Kocher (2007) was 3.4 cM from UNH995. The flanking marker on the other side of the QTL in their study, Wt1b, was closer to SEX, only 2.5 cM away but excluded as candidate for sex determination because of the two recombinants identified in breakpoint analyses. In the present study, the SEX was positioned in between UNH985 and UNH995, being 4.8 cM away from UNH995.

The current study was designed to extend the analyses (using intraspecific Stirling Nile tilapia) of the segregation of markers in various families including type 'C' (as

unknown type) for a precise understanding of the sex determining mechanism. The map distance from the three families of cross type 'C' was 38.5 cM considering four loci (Fig. 2). SEX (28 cM) was positioned only 0.5 cM away from UNH995 and UNH104 (both positioned at 27.5 cM). The male specific map of Lee *et al.* (2003) on *O. niloticus* also shows very similar positions of these two markers.

The genetic map from the six families considering type 'A' and type 'C' cross shows a map length of 35.2 cM considering four loci (Fig. 3a) which can be compared to that produced by using genotypic data of three putative YY families of type C cross (38.5 cM) (Fig 2). This map length is much closer to that of Lee et al. (2005), 33 cM. The marker orders are congruent with those of Lee et al. (2003, Fig 3b), Lee *et al.* (2005, Fig 3c) and Lee and Kocher (2007, Fig 3d). SEX (17 cM) was positioned only 0.8 cM away (Fig 3a) from UNH995 (16.2 cM) and 0.4 cM away from UNH104 (16.6 cM) in the current study. This genetic map produced by the genotypic data of 6 families (consisting of family 'A' and 'C'; offspring N=276) supports the highest correspondence of phenotypic sex with two of three microsatellite markers as shown by Lee et al. (2003) and also an evidence for the two markers (UNH995 and UNH104) to be tightly linked (only 0.4 cM, comparable to the 0.7 cM by Lee and Kocher, 2007) and on the same side of the QTL for sex, which maps closer to these markers in the current study (0.8 cM from UNH995) compared to the distance of 3.4 cM in the study of Lee and Kocher (2007). The linkage maps from Lee *et al.* (2003), Lee *et al.* (2005) and Lee and Kocher (2007) are presented for a comparison of marker order and position of sex compared to that in the present study (Fig 3,a-d). The higher similarity of the map orders using different groups of families and mapping the QTL very close to UNH995 and UNH104 refines the location of the major sex determining region in LG1 in *Oreochromis niloticus*.

Analysis of the inheritance of marker UNH995 and UNH104 in F7 (cross type 'C') in the current study showed that progeny that inherited one of the UNH995 alleles (i.e., 236) and UNH104 alleles (i.e., 190) from the male parent were all male, while inheritance of the other allele (allele 252 in case of UNH995 and allele 210 in case of UNH104) was associated with a mixture of male and female progeny. In the case of UNH931, allele 240 was predominant in male progeny of family 7. In family 8, only UNH104 showed such a pattern of allelic association with sex. In family 9, inheritance of marker UNH995 as well as UNH104 alleles followed the same pattern of allelic segregation with sex as that in family 7. This finding suggests that the alleles of the sex determining system in this species could have different strength for producing male or female phenotype. A summary of LG1 haplotypes using UNH995 and UNH104 is given in Table 10 for type 'B' and 'C' families.



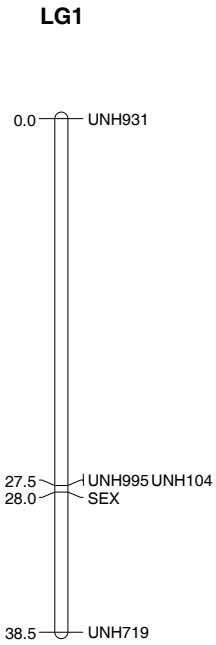


Fig 1. **Fig 2.**

Fig 1. The location of sex on linkage group (LG) 1 in Nile tilapia (from XY males x clonal females XX).

Fig 2. The location of sex on LG1 in Nile tilapia using genotype data from type 'C' families.

It is apparent from this work that the departures from the sex ratios predicted by using a "simple" XX/XY model were strongly associated with the XX/XY system itself, rather than being associated with loci in other LGs. The allelic variation in this XX/XY model demonstrates some alleles could be stronger in effect while some others are weaker giving intermediate sex ratios in the progeny. Generation of additional polymorphic sex-linked markers and potentially sex-specific markers could enhance MAS in this species, both for mapped loci known to influence sex ratio and potentially to locate others in the genome.

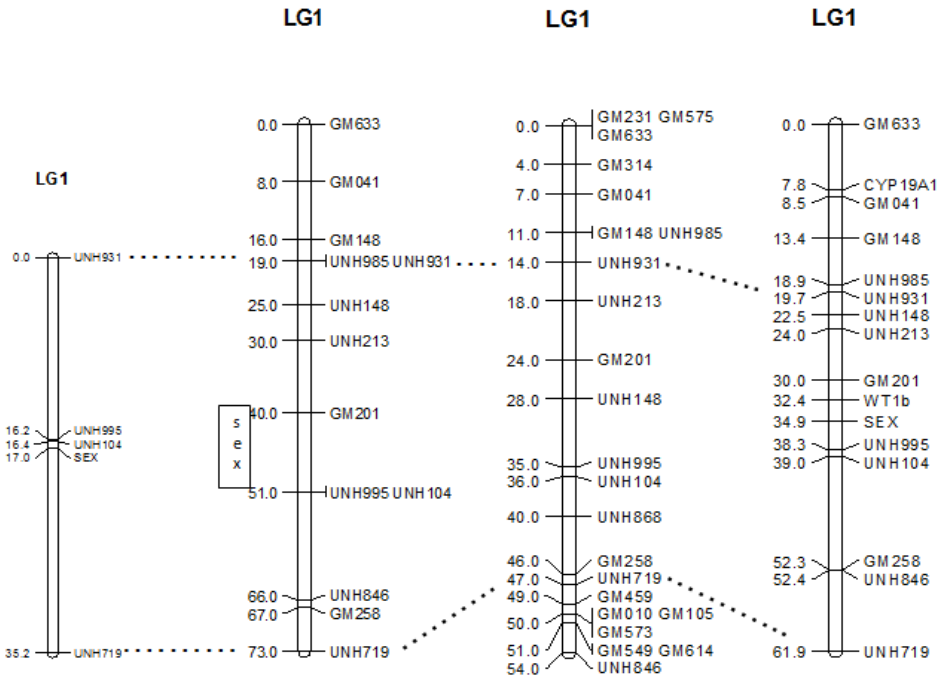


Fig 3. Location of SEX in the present study (a) using four informative markers in six families (type 'A'+ type 'C') and comparing orders of map and/or location of sex with other works: b) Lee *et al*. (2003), c) Lee *et al.* (2005) and d) Lee and Kocher (2007)

Table 10. Summary of segregation of UNH995 and UNH104 alleles in families of type 'B' and type 'C'

Marker	Cross type	Sire genotype	Dam genotype	Male progeny Genotype	No.	Female progeny Genotype	No.
UNH995	Type B (all families)	184/236	184/184	184/184	35/68	184/184	22/22
				184/236	33/68	184/236	0/22
	Type C (2 families)	236/252	184/184	184/236	22/41	184/236	0/43
				184/252	19/41	184/252	43/43
UNH104	Type C (fam 7)	190/210	140/140	140/190	12/23	140/190	0/23
				140/210	11/23	140/210	23/23
	Type C (fam 8)	140/190	140/140	140/140	8/16	140/140	23/23
				140/190	8/16	140/190	0/23
	Type C (fam 9)	190/210	140/140	140/190	12/23	140/190	0/23
				140/210	11/23	140/210	23/23

Acknowledgement
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References

Baroiller, J.F., D'Cotta, H. (2001). Environment and sex determination in farmed fish. Comp. Biochem. Physiol., C Toxicol. Pharmacol. 130, 399–409.

Calhoun, W.E., Shelton, W.L. (1983). Sex ratios of progeny from mass spawnings of sex-reversed broodstock of *Tilapia nilotica*. Aquaculture 33, 365–372.

Cnaani, A., Zilberman, N., Tinman, S., Hulata, G., Ron, M. (2004). Genome-scan analysis for quantitative trait loci in an F(2) tilapia hybrid. Mol. Genet. Genomics 272, 162–172.

Cnaani, A., Lee, B.-Y., Zilberman, N., Ozouf-Costaz, C., Hulata, G., Ron, M., D'Hont, A., Baroiller, J.-F., D'Cotta, H., Penman, D.J., Tomasino, E., Coutanceau, J.-P., Pepey, E., Shirak, A., Kocher, T.D. (2008). Genetics of sex determination in tilapiine species. Sex. Dev. 2, 43–54.

Dunham, R.A. (2004). Aquaculture and Fisheries Biotechnology: genetic approaches. CAB International Publishing, ISBN 0-85199-596-9.

Ezaz, M.T., Harvey, S.C., Boonphakdee, C., Teale, A.J., McAndrew, B.J., Penman D.J. (2004a). Isolation and physical mapping of sex-linked AFLP markers in Nile tilapia (*Oreochromis niloticus* L.). Mar. Biotech. 6, 435–445.

Green, P., Falls, K., Crooks, S. (1990). CRI-MAP. Version 2.4 [computer program]. Washington University School of Medicine, St. Louis, Mo., U.S.A.

Jalabert, B., Kammacher, R., Lessent, P. (1971). Determination de sexe chez les hybrids entre *Tilapia macrochir* et *Tilapia nilotica*. Etude du sex-ratio dans les recroisements des hybrids de premiere generation par les especes parentes. Ann. Biol. Anim., Biochim., Biophys. 11(1), 155–165.

Jalabert, B., Billard, R., Chevassus, B. (1975). Preliminary experiments on sex control in trout: production of sterile fishes and self fertilization of hermaphrodites. Ann. Biol. Anim., Biochim., Biophys. 15, 19–28.

Karayücel, I., Ezaz, M.T., Karayücel, S., McAndrew B.J., Penman, D.J. (2004). Evidence for two unlinked sex reversal loci in the Nile tilapia, *Oreochromis niloticus*, and for linkage of one of these to the red body colour gene. Aquaculture 234, 51–63.

Lee, B., Penman, D.J., Kocher, T. (2003). Identification of a sex-determining region in Nile tilapia (Oreochromis niloticus) using bulked segregant analysis. Anim. Genet. 34, 379–383.

Lee, B., Hulata, G., Kocher, T. (2004). Two unlinked loci controlling the sex of blue tilapia (*Oreochromis aureus*). Heredity 92, 543–549.

Lee, B.Y., Lee, W.J., Streelman, J.T., Carleton, K.L., Howe, A.E., Hulata, G., Steffan, A., Stern, J.E., Terai, Y., Kocher, T.D. (2005). A second generation linkage map of tilapia (Oreochromus spp.). Genetics 170, 237–244.

Lee, B.Y., Kocher, T.D. (2007). Exclusion of *Wilms tumour* (*WT1b*) and *ovarian cytochrome P450 aromatase* (*CYP19A1*) as candidates for sex determination genes in Nile tilapia (*Oreochromis niloticus*). Anim. Genet. 38, 85–86.

Mair, G.C., Penman, D.J., Scott, A., Skibinski, D.O.F., Beardmore, J.A. (1987). Hormonal sex reversal and the mechanisms of sex determination in *Oreochromis*. in: Tiews, K., (Ed.) Proceedings of the World Symposium on Selection, Hybridization and Genetic Engineering in Aquaculture, Vol. II, Heenemann Verlagsgesellschaft, Berlin, pp. 289–300.

Mair, G.C., Scott, A.G., Penman, D.J., Beardmore, J.A., Skibinski, D.O.F. (1991). Sex determination in the genus *Oreochromis*: 1. Sex reversal, gynogenesis and triploidy in *O. niloticus* (L.). Theor. Appl. Genet. 82, 144–152.

Mair, G.C., Abucay, J.S., Skibinski, D.O.F., Abella, T.A., Beardmore, J.A. (1997). Genetic manipulation of sex ratio for the large-scale production of all-male tilapia, *Oreochromis niloticus*. Can. J. Fish. Aquat. Sci. 54, 396–404.

Penman, D.J., Shah, M.S., Beardmore, J.A., Skibinski, D.O.F. (1987). Sex ratios of gynogenetic and triploid tilapia, in: Tiews, K., (Ed.), Proceedings of the World Symposium of Selection, Hybridization, and Genetic Engineering in Aquaculture, Vol. II, Heeneman, Berlin, pp. 267–276.

Phelps, R.P., Warrington, R.L. (2001). Methods for the contribution from the male and female genome to sex inheritance. in: Gupta, A., McElwee, K., Burke, D., Burright, J., Cummings, X., Egna, H., (Eds.), Eighteenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, pp. 37–42.

Rosenstein, S., Hulata, G. (1994). Sex reversal in the genus *Oreochromis*: optimization of feminization protocol. Aquacult. Fish. Manage. 25, 329–339.

Scott, A.G., Penman, D.J., Beardmore, J.A., Skibinski, D. (1989). The "YY" supermale in *Oreochromis niloticus* (L.) and its potential in aquaculture. Aquaculture 178(34), 237–251.

Shelton, W.L., Meriwether, F.H., Semmens, K.J., Calhoun, W.E. (1983). Progeny sex ratio from intraspecific pair spawnings of *Tilapia aurea* and *Tilapia nilotica*. in: Fishelson, L., Yaron, Z. (Eds.), Proceedings of the International Symposium on Tilapia in Aquaculture, Tel Aviv University, Israel, pp. 270–280.

Shirak, A., Seroussi, E., Cnaani, A., Howe, A. E., Domokhovsky, R., Zilberman, N., Kocher, T. D., Hulata, G., Ron, M. (2006). *Amh* and *Dmrta2* genes map to tilapia (*Oreochromis* spp.) linkage group 23 within quantitative trait locus regions for sex determination. Genetics 174, 1573–1581.

Valenzuela, N., Adams, D.C., Janzen, F.J. (2003). Pattern does not equal process: Exactly when is sex environmentally determined? Am. Nat. 161, 676–683.

Voorrips, R.E. (2002). MapChart: Software for the graphical presentation of linkage maps and QTLs. J. Heredity 93 (1), 77–78.

Wohlfarth, G.W., Wedekind, H, (1991). The heredity of sex determination in tilapias. Aquaculture 92, 143–156.

Impact of aqua-drugs and chemicals on fish health

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Abstract: The present study was conducted in farmer ponds of Muktagacha, Fulbaria, Gouripur, Fulpur upazillas of Mymensingh region and experimental ponds (0.65 d each) under the Faculty of Fisheries, BAU to study the impact of aqua-drugs and chemicals on fish health and diseases. Fish samples were taken from both the systems of aqua drugs treated and control ponds at monthly intervals. Fishes between aqua-drugs treated and control ponds at both the BAU and farmer's level did not show any remarkable changes clinically. Histopathology in the fishes of control ponds revealed that skin, muscle, liver, kidney and gill of fish with almost normal structure. However, in the chemical treated ponds, the above mentioned organs of fishes had remarkable pathological changes like necrosis, hemorrhages, vacuums, pyknosis, partial loss of organs and hypertrophy.

Introduction

Aquaculture is the fastest growing food-producing sector in the world. It is growing more rapidly than all other animal food producing sectors. Aquaculture in Bangladesh is also under heavy expansion. Over the last decade it has been expanded, diversified, intensified and technologically advanced. In aquaculture, among others, the external inputs required for successful fish production is chemical, which has been used in various forms for centuries (Subasinghe *et al.* 1996). Sodium chloride is an old treatment used for fungal and parasitic diseases of fish. Formalin is used primarily as an external parasiticide on fish and fish eggs. Potassium permanganate is good for treating external protozoa and external bacterial infections (Plumb, 1992). Malachite green is an organic dye that has been popular as a parasiticide and fungicide on fish. It is principally used in hatcheries rather than

grow-out systems (Alderman 1992). Common group of pesticides are organo-phosphates, organotin compounds, rotenone and saponin. Dichlovos, trichlorfon, diptarex, melathion and dursban are the widely used organophosphate applied to control ectoparasitic crustacean infections in finfish culture. Fertilizers are also widely used in the management of fish ponds to stimulate phytoplankton bloom. Although Reilly (1992) opined that fertilizers pose minimal risk to food safety in aquaculture, when used appropriately and any misuse could lead to hazard in aquaculture products. There is potential for some chemical compounds used in aquaculture to pose health risks to fish and site workers. Unfortunately, there is a lack of information regarding the impact of aqua-drugs and chemicals used in Bangladesh aquaculture industry. The present study would be aimed to investigate the impact of aqua-drugs and chemicals on health of fish in Muktagacha, Fulbaria, Gouripur, Fulpur Upazilas and in BAU campus.

Materials and methods

Study area and sample collection

The present study was conducted in aquaculture ponds at field level and experimental ponds at Department of Aquaculture under Bangladesh Agricultural University, Mymensingh. Muktagacha, Fulbaria, Fulpur and Gouripur of Mymensingh district was considered as study area for freshwater fishes at culture ponds. The study was carried out for six months during January to June, 2011.

In Mymensingh regions farmers culture mostly Thai pangus, Thai koi, tilapia and shing. Fish health between culture systems using aqua-drugs and chemicals and without chemicals were compared. For this purpose, two possible culture systems - Thai Pangus and Thai Koi were chosen and fish samples were collected from ponds those used aqua-drugs and chemicals and without chemicals.

Experiment at BAU campus

Eight equal sized ponds situated in the north side of the Faculty of Fisheries, BAU, were selected and prepared for experiment. Two sets of experiments - one with Thai Pangus and the other with Thai Koi were carried out using aqua-drugs and chemicals and without chemical treatment. Aqua-drugs (Zeo fresh, Aqua kleen, Sea weed and Square aqua premix) were applied following fish farmers schedule from pond preparation up to fish culture. Samples for health check and histology were collected three times during the experiment from both BAU ponds and farmer’s ponds.

Clinical and histopathological observation

During the experimental period, clinical changes were recorded monthly. From each pond, fishes were examined by naked eyes to observe the external signs and color changes, injury, infection in fin and muscle, appendage damage and other abnormalities. Samples for histology were collected from skin, muscle, gills, liver and kidney and fixed in 10 % buffered formalin. The samples were then dehydrated, cleared and infiltrated in an automatic tissue processor (SHANDON, CITADEL 1000), embedded and sectioned (5 micrometers) using a microtome (Leica JUNG RM 2035). The sections were then stained with haematoxylin and eosin stains. After staining the sections were mounted with Canada balsam and covered by cover slips. The prepared sections were examined under a compound microscope (Olympus). Photomicrograph of the stained sections was obtained by using a photomicroscope (OLYMPUS, Model CHS, Japan). Effect of Aqua drugs on disease recovery of fishes were also investigated through questionnaire interview and FGDs.

Results and discussion

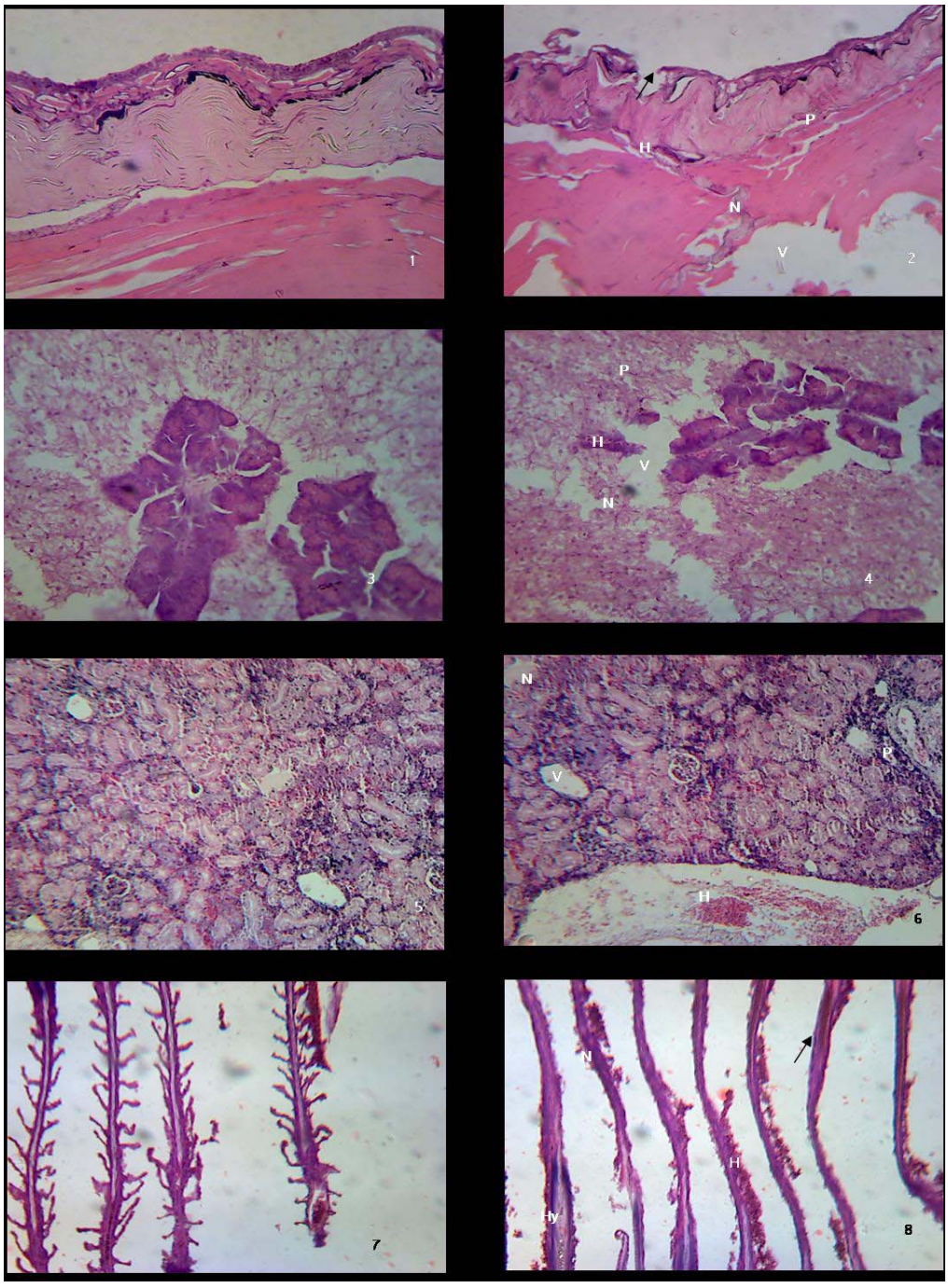
Ten different categories of chemicals were found to be used in aquaculture activities - antibiotics, disinfectants, gas removal, oxygen supplier, vitamins and minerals, growth promoter, insect killer, algae killer, predator killer and pH balance. In pharmacy of investigated areas, 50 different types of aquaculture drugs and chemicals were recorded. Among those, 15 types were widely used by the farmers such as Renamycin, Amoxifish, Ossi-C, Timsen, Aquamysine, Aquamycine, Virex, Aquakleen, Geolite gold, Oxy Dox F, Polgard plus, Charger gel, Seaweed, Bactisal and Deletix.

Clinically the fishes reared in aqua drugs treated ponds and control ponds did not show any remarkable changes. Rahman (2012) observed that fishes of Jamalpur and Sherpur region of Bangladesh did not show any significant clinical changes raised in aqua drugs treated and control ponds. In the control treatments at both the BAU ponds and farmer's ponds, skin, muscle, liver, kidney and gill of fish had almost normal structure histopathologically (Figs.1, 3, 5, 7, 9, 11, 13, and 15). However, in the chemical treated ones, the above mentioned investigated organs of fishes had remarkable pathological changes like necrosis, hemorrhage, vacuum, pyknosis, necrosis, hypertrophy and partial loss of some parts (Figs. 2, 4, 6, 8, 10, 12, 14 and 16) which were in accordance with the findings of Rahman (2012). Loss of epidermis, necrosis, vacuum, haemorrhage and pyknosis were found in the skin and muscle layer of aqua-drugs and chemical treated fishes (Figs. 2 and 10). Ahmed *et al*

(2011) also mentioned that pathological signs such as epidermis lost, broken dermis into few parts, vacuoles and melanomacrophage were noticed in the affected skin and muscle of *Cyprinus carpio* collected from NGO fish farm. In skin and muscle of *Monopterus cuchia*, Ahmed *et al.* (2009) observed severe necrosis and huge vacuums in December and January. Ahmed *et al.* (2007) found that during December and January, epidermis and dermis were totally lost and necrotic. Hatai *et al*. (1994) also reported that fungal hyphae and fungal granulomas in the internal organs and musculature of *Colisa lalia* suffering from an invasive mycosis in Japan.

In the present study some important pathological changes such as haemorrhage, necrotic hepatocytes, pyknotic cells and vacuum were recorded in the liver of chemical treated fishes (Figs. 4 and 12). According to Rahman (2012) liver of chemical treated fish had some important pathological changes such as hemorrhage, necrosis, pyknotic cell and vacuums in treated ponds during December and January. Ahmed *et al.* (2009) also found similar result for freshwater eel in winter season. Fish liver had highly necrotic hepatocytes, pyknotic and inflammatory cells during the months of December and January (Roy *et al*., 2006). Hossain *et al*. (2009) reported that severe necrosis of hepatocytes, pyknosis, vacuoles, fat droplets and hemorrhage were observed in small indigenous species during December and January. In the study vacuums, necrosis and pyknosis were found in the month of June, July and August. Thus pathological changes in liver at treated ponds could be due to application of aqua-drugs and chemicals.

In the present study haemopoeitic necrosis, hemorrhages, vacuolation in haemopoeitic cell were common pathological changes in kidney of chemical treated fishes (Figs. 6 and 14). According to Ahmed *et al.* (2011) swollen kidney tubules, necrosis, hemorrhage and ruptured haemopoietic tissue observed in kidney of fishes. Ahmed *et al*. (2009) also observed necrosis, vacuums, hemorrhage and blood cells in kidney tubule of *Anabas testudineus* during the month of November and degenerated kidney tubules, many pyknotic nuclei, hemorrhage and inflammatory cells were found in December and January,. In case of gills of aqua-drugs and chemical treated fish exhibited pathological changes which included hypertrophy, haemorrhage, missing of secondary gill lamellae and necrosis (Figs. 8 and 16). The gills of aqua drugs and chemical treated fishes exhibited pathological changes such as hypertrophy, hemorrhage, lamellar missing, hyperplasia, clubbing and necrosis especially during December and January as observed by Rahman (2012). Ahmed *et al.* (2007) mentioned that necrosis, pyknosis, inflammation, hypertrophy, hyperplasia, missing of gill lamellae in the months of December and January in *Anabas testudineus*. Akter *et al*. (2009) found that gill structures of *Anabas testudineus* exhibited few abnormalities during summer.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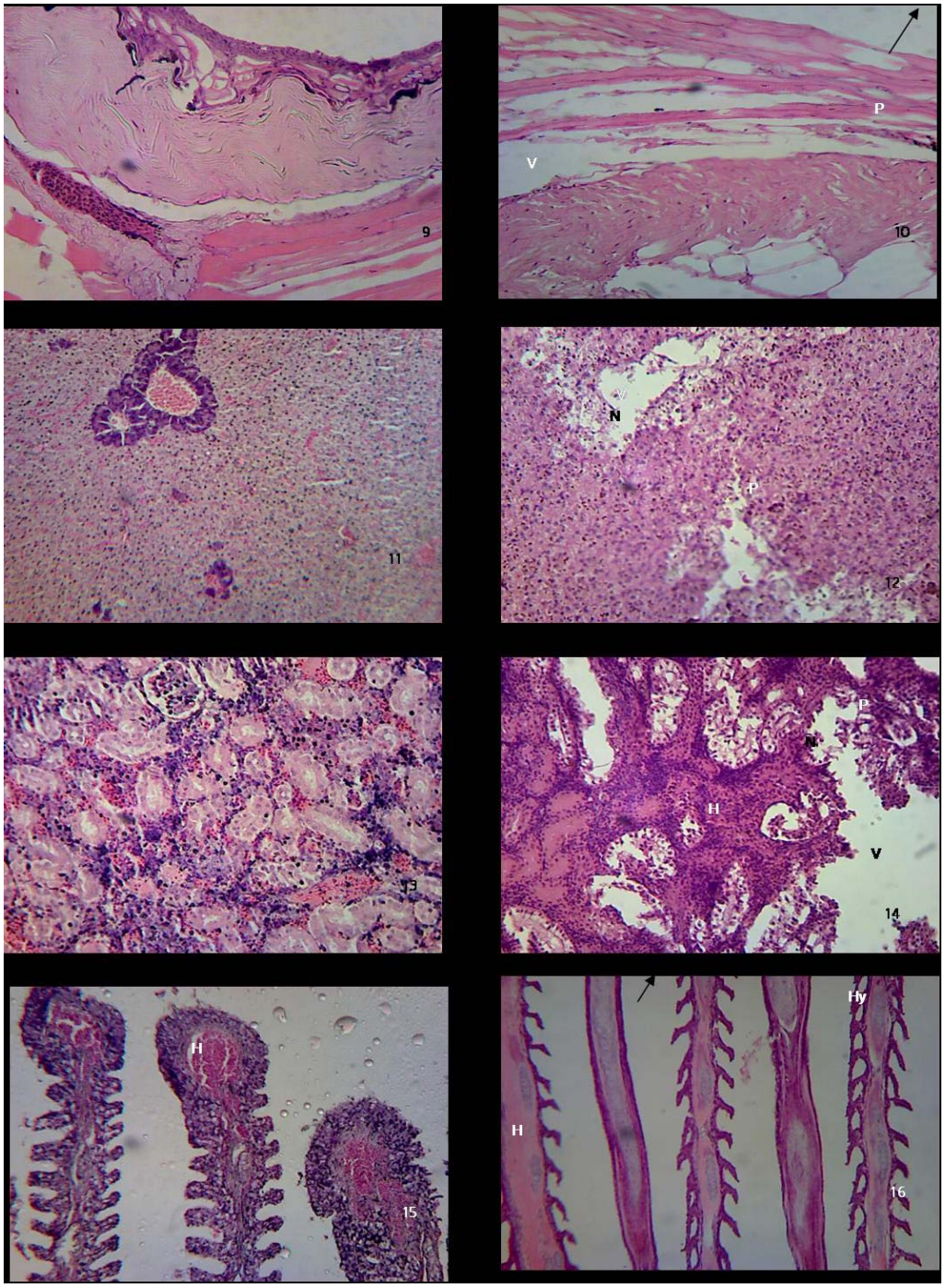
Figs. 1, 3, 5 and 7. Sections of almost normal skin, muscle, liver, kidney and gill of Thai Pangus from Gouripur and Muktagacha.
Fig. 2. Section of affected skin and muscle of Thai Pangus from Gouripur showing loss of epidermis (↗), necrosis (N), vacuum (V), haemorrhage (H) and pyknosis (P).
Fig. 4. Section of affected liver of Thai Pangus from Gouripur showing necrosis (N), vacuum (V), haemorrhage (H) and pyknosis (P).
Fig. 6. Section of affected kidney of Thai Pangus from Muktagacha showing pyknosis (P), vacuum (V), necrosis (N) and haemorrhage (H).
Fig. 8. Section of affected gill of Thai Pangus from Muktagacha showing loss of secondary gill lamellae ( ), necrosis (N), hypertrophy (Hy) and haemorrhage (H).
(All the sections: H and E x 150).

In Mymensingh region farmers culture mostly Thai pangaus, Thai koi, tilapia and shing. In upazillas like Fulpur, Muktahacha and Fulbaria EUS, dropsy, edwardsiellosis were observed in pangus and tilapia. Shing had 90-100% mortalities within very short period from unknown diseases with no obvious symptoms but swollen abdomen and spots and treatment with drugs resulted 30-00% recovery.. Farmers used Renamycin, Ossi-C in Fulpur and Polgard plus and Polgard plus and Bactisol in Fulbaria for the treatment of shing. To treat EUS affected tilapia in Fulpur (20%) and Muktagacha (30%) farmers used Renamycin, Polgard plus and Ossi C with a result of 95-80% recovery. In Edwardsiellosis affected pangus in Fulpur (80%) and Fulbaria (50%), farmers used Renamycin, Timsen, Polgard plus and Ossi C in Fulpur and Geolite and Timsen in Fulbaria having 80% recovery in both upazillas. Dropsy was seen with tilapia in Fulpur upazilla (10%) where farmers used Aquamycin and Ossi C as drugs with a result of 95% recovery. In Fulpur (50%) and Fulbaria (50%), Zoothamnium and various spots on skin, scales dropped in some parts of koi, where farmers used Renamycin, Aquamycine, Ossi-C and Polgard plus drugs as treatment and achieved 70-80% recovery. Sharpunti, rui, catla and mrigal were also affected by EUS in Muktagacha and farmers achieved good recovery by applying drugs like Renamycin and Ossi C. It was thus observed that aqua drugs played an important role in recovery of fish from diseases and maintenance of health. In a drug treated pond of BAU, plankton bloom was recovered within one week by seaweed (Algicide) application. This encourages farmers of Mymensingh to uses frequent aqua drugs against fish diseases and ill health. In many cases it was observed that farmers used more than one drugs for similar case, which needs to be stopped. Whatever prescriptions farmers received from other farmers, neighbors and drug store, they follow that in order to prevent diseases and overcome economic loss. Thus steps should be taken by government and private organizations to arrange trainings on proper and controlled use of safe aqua drugs for aquaculture and health management practices.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Figs. 9, 11, 13 and 15. Sections of almost normal skin, muscle, liver, kidney and gill of Thai Koi from BAU pond.
Fig. 10. Section of affected skin, muscle showing split of dermis (↗), vacuum (V) and pyknosis (P).
Fig. 12. Section of affected liver of Thai Koi from BAU experimental pond showing necrosis (N), vacuum (V) and pyknosis (P).
Fig. 14. Section of affected kidney of Thai Koi from BAU experimental pond showing necrosis (N), vacuum (V) and haemorrhage (H).
Fig. 16. Section of affected gill of Thai Koi from BAU experimental pond showing totally missing of secondary gill lamellae (↗), hypertrophy (Hy) and haemorrhage (H).
(All the sections: H and E x 150).

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References

Ahmed. G.U., Akter, M.N., Islam, M.R. and Rahman, K.M.M. (2011). Health condition of juvenile exotic carp *Cyprinus carpio* from various fish farms of Mymensingh area, Bangladesh. *Int. J. Nat. Sic*., 1 (4): 77- 81.

Ahmed, G.U., Dhar, M., Khan, M.N.A. and Choi, J.S. (2007). Investigation of disease of Thai Koi, *Anabas testudineus* (Bloch) from farming conditions in winter. *J. Life Sci.*, 17 (10): 1309-1314.

Ahmed, G.U., Hossain, M.M. and Hassan, M.M. (2009). Seasonal variation of disease and pathology of a perch, *Nandus nandus* (Hamilton) from Oxbow Lake fisheries of Bangladesh. *Eco-friendly Agril. J.*, 2 (8): 761-767.

Akter, M.N., Ahmed, G.U. and Hossain, M.S. (2009). Seasonal variation of gill pathology of a climbing perch in lake fisheries of Bangladesh. *Int. J. Anim. Fish. Sci.*, 2 (3): 208-213.

Alderman, D.J. (1992). Malachite green and alternatives as therapeutic agents. *Europ. Aquacult. Soc. Spec. Pub*., 16: 235-44.

DoF (Department of Fisheries). (2011). Jatiyo Matshya Soptaho. Ministry of Fisheries and Livestock, The Government of People's republic of Bangladesh, Dhaka. pp: 56.

Hatai, K., Nakamura, K. Yuasa, K. and Wada, S. (1994). Aphanomyces infection in Dwarf Gaurami (*Colisa lalia*). *Fish Pathol*., 29: 95-99.

Plumb, J.A. (1992). Disease control in aquaculture. In: Shariff, I.M., R.P. Subasinghe and J.R. Arthur. Disease in Asian Aquaculture. Asian Fisheries Society, Philippines. pp: 3-17.

Rahman, H. (2012). Effects of Aqua Drugs on the health condition of farmed fishes of Jamalpur areas. M.S. Thesis. Department of Aquaculture. BAU. Mymensingh. 58 pp.

Reilly, P.J.A. (1992). Review of the occurrence of Salmonella in cultured tropical shrimp. FAO Fisheries Circular No. 851. FAO, Rome. pp: 19.

Roy, M.K., Ahmed, G.U., Akter, S. and Akter, N. (2006). Study of health condition of small indigenous fishes of Ailee beel in Mymensingh. *Progress. Agric.*, 17 (1): 201-209.

Subasinghe, R.P., Barg, U. and Tacon, A. (1996). Chemicals in Asian Aquaculture: Need, usages, issues and challenges. In: Arthur, J.R., C.R. Lavilla-Pitogo and R.P. Subasinghe (eds.). Use of chemicals in Aquaculure in Asia. Southeast Asian Fisheries Development Center, Aquaculture Department. Tigbauan, Iloilo, Philippines. pp. 1-6.

Probiotic technology for sustainable aquaculture

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Abstract: Aquaculture products especially shrimp is a major export item in Bangladesh. A significant limitation to the industry is loss of productivity owing to the emergence of a large variety of pathogenic bacteria and viruses, and their resistance to chemotherapeutic drugs that cause mass mortality and consequent crop failure. The application of traditional methods in shrimp industry to combat microbial diseases, like use of broad-spectrum antimicrobial drugs and chemicals, many of those have already been banned globally often causes health concern locally and rejection of exportation in international markets, hence finding a public health and environment-friendly alternative has become a timely need. Probiotics– the friendly bacteria with a host of benefits can be an alternative to address the demand. This review highlights a comprehensive summary of probiotics in aquaculture with special reference to shrimp culture in Bangladesh in order to prevent illegal drug use in shrimp industry, and construct the probiotic technology as a crying need for the industry as well as for other aquaculture sectors.

Introduction

Aquaculture, also known as aquafarming, is the farming of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants (1, 2). It has been practiced since ancient times and has played a significant role in food production. It is one of the fastest growing food-producing sectors throughout the world. Resembling many countries Bangladesh too has achieved credibility in aquaculture because of its amiable agro-climatic conditions and unique geographic location that provides the world's largest deltaic basin rich in nutrients, and thereby makes it suitable for fish firming. Therefore, aquaculture has become an inevitable part in escalating the

country's economy contributing 4% to GDP, 10% to export earning, 73% to animal protein intake, in addition to providing 1.4 m people full time and 11 m part time employment opportunities (3). Nevertheless disease outbreaks are being increasingly recognized as a noteworthy impediment on aquaculture production and trade, affecting the economic development of the sector in Bangladesh like many other countries. Various infectious diseases caused by bacteria, virus and protozoa are now a primary concern in aquaculture. Diseases caused by *Vibrio* spp. and *Aeromonas* spp. are commonly implicated in episodes of mortality (4). For instance vibriosis is currently one of the main diseases affecting shrimp culture and outbreaks lead to dramatic crop failures in the major shrimp-producing countries (5, 6). So as to avert and control diseases, antibiotics, pesticides and other toxic chemicals are used presumably in an uncontrolled fashion. Such an usage appears to upset the ecological balance among fish gut dwellers known as normal flora, diminishing the benefits being brought by them, and creating antibiotic resistant bacteria with the consequent environmental pollution that threatens food safety and food security.

Presently it has become an important issue to improve the ecological environment of aquaculture throughout the world without creating any environmental pollution and health hazards. So definitely it has forced us to look for a number of better alternatives to overcome these threats to environment along with us. Strategy like using antimicrobials in disease control has been proposed and has already been applied very successfully in aquaculture [7]. The use of effective vaccine or enhancing the nonspecific defense mechanisms to the hosts by immunostimulants, alone or in combination with vaccines, is another very promising approach (8-11). The most promising approach, as literature suggests is the use of probiotic bacteria as a biological control agent to control pathogens causing disease outbreaks. (12). This review aims to provide an outline of the work done on bacteria as biological control agents for aquaculture environments throughout the world along with in Bangladesh and the future prospect of probiotic technology in Bangladesh. Furthermore, a rationale for the search for probiotics is presented and directions for further research are proposed.

Probiotics- the pursuit

A maxim says "prevention is better than cure". Apropos preventive measures will be practicable for managing diseases than the curing and herein probiotic can be a good candidate to fight against aquaculture bugs. Hence the use of beneficial bacteria (probiotics) to displace pathogens by competitive processes is being used in the animal industry as a better remedy than administering antibiotics and is now gaining acceptance for the control of pathogens in aquaculture [13]. So what is a probiotic?

As new findings emerged, several definitions of probiotics have been proposed. A widely accepted definition proposed by Fuller (14) suggesting a live microbial feed supplement which beneficially affects the host animal by improving its intestinal balance. This definition was broadened by Havenaar and Huisin't Veld (13) to a 'mono- or mixed-culture of live microorganisms which benefits man or animals by improving the properties of the indigenous microflora'. According to Food and agricultural organization and world Health Organisation "probiotics are live microorganisms, which, when administered in adequate amounts, confer a health benefit on the host." (WHO/FAO, 2011) (15)

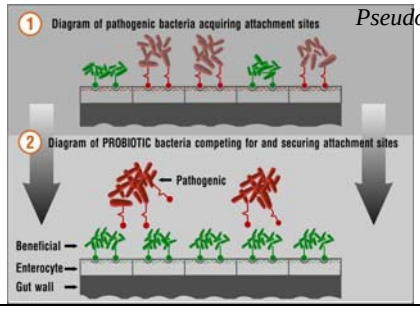
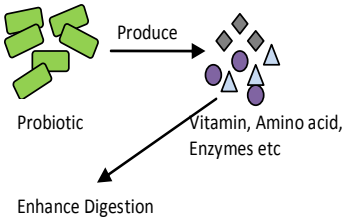
The ways probiotics work

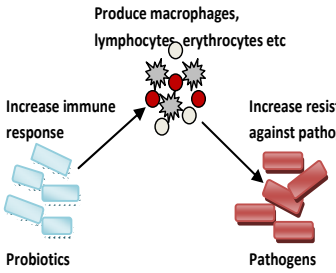
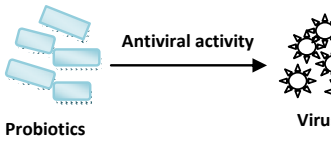
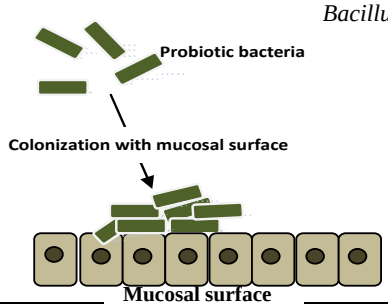
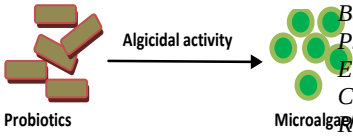
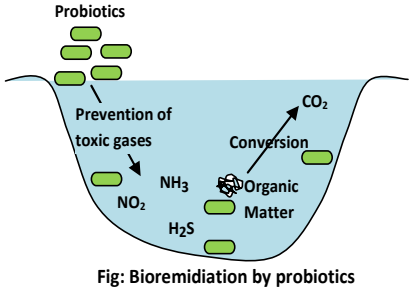
Several studies on probiotic show different mechanisms of probiotic action directed against host pathogens or they provide better environment for host. The modes of action of probiotic bacteria can be summarized as:

Competitive exclusion: Competitive exclusion as it applies to the gastrointestinal tract is a phenomenon whereby an established microflora prevents or reduces the colonization of a competing bacterial challenge for the same location in the intestine (16). Bacterial antagonism is a common phenomenon in nature, and thus microbial interactions play a major role in the equilibrium between competing beneficial and potentially pathogenic microorganisms. It is well known that the microbiota in the gastrointestinal tract of aquatic animals can be modified, for example by ingestion of other microorganisms. Microbial manipulation, therefore, constitutes a viable tool to reduce or eliminate the incidence of opportunist pathogens (17). Selected microorganisms are able to produce substances that can inhibit or kill other potential pathogenic bacteria such as antibiotics, antibacterial substances, siderophores, bacteriolytic enzymes, proteases and protease inhibitor, lactic acid, and other organic compounds including bacteriocins and hydrogen peroxide (18).

Digestion enhancement: Some researchers have suggested that microorganisms have a beneficial effect on the digestive processes of aquatic animals, particularly by supplying fatty acids and vitamins. In addition, some bacteria may participate in the digestion processes of bivalves by producing extracellular enzymes such as proteases and lipases and by providing necessary growth factors (19, 20). Microbiota may serve as a supplementary source of food, or microbial activity in the digestive tract may be a source of vitamins or essential amino acids (21). Bairagi *et al*. 2002 (22) assessed aerobic bacteria associated with the GI tract of nine freshwater fishes. They determined that selected strains produced digestive enzymes, thus facilitating feed utilization and digestion.

Immune response enhancement: One of the potential characteristics of some probiotic bacteria is to stimulate the immune system of host against pathogenic agents [23]. Some studies show that *B. pumilus*, *B. sphaericus*, *B. subtilis*, *V. fluvialis* (strain PM 17, Alavandi *et al*. 2004), *Pseudomonas sp*. (strain PM 11, Alavandi *et al*. 2004), *S. cerevisiae*, *S. exigus*, *P. rodozoma* are used as probiotic with immune response on *P. monodon* and *L. vannamei* [24-26]. Rengpipat *et al*. [24] showed that *Bacillus sp*. (strain S11) can provide disease protection for activating immune defenses of *P. monodon*. Gatesoup reported that feeding with Gram-positive as well as Gram-negative selected probiotics helped increase cellular parameters such as the number of erythrocytes, lymphocytes, and macrophages while also enhancing lysozyme activity (18). In shrimp, a mixture administration of *Bacillus* and *Vibrio* sp. to *Litopenaeus vannamei* aided an increase in resistance against *Vibrio harveyi* and white spot syndrome that was correlated with an increase of the phagocytosis and antibacterial activity (27). Addition of *Bifidobacterium thermophilum*-derived peptidoglycan to kuruma shrimp helped significant increase of their survival when they were challenged with *V. penaeicida* (28). They attributed this to an immunostimulatory effect, as the phagocytic activity of shrimp granulocytes was significantly higher in the treated shrimp compared with those of the control animals.

Mode of Action	Illustration	Probiotic strain	Reference
Competitive Exclusion		*Thalassobacter utilis*; *Pseudomonas* I2	Nogami and Maeda, 1992, Nogami *et al.*, 1997; Chythanya *et al*., 2002
Digestion Enhancement		*Bacteroides* and *Clostridium* sp. *Agrobacterium* sp. *Pseudomonas* sp. *Brevibacterium* sp. *Microbacterium* sp. and *Staphylococcus* sp.	Sakata, 1990; Ringo *et al*. 1995

Immune Response Enhancement		*Clostridium butyricum*, *Bacillus* sp. (strain S11), *Lactobacillus thermosus*	Sakai *et al*., 1995; Rengpipat *et al.* 2000; Nikoskelainen *et al.* 2003
Antiviral Effects		*Pseudomonas* sp., *Vibrios* sp., *Aeromonas* sp., *Moraxella*	Kamei *et al*., 1988; Girones *et al*. 1989
Colonization		*Bacillus* sp.	Gullian and Rodrı´guez, 2002
Interaction with phytoplankton		*Bacillus, Nitrobacter, Pseudomonas, Enterobacter, Cellulomonas*, and *Rhodopseudomonas* spp.	Boyd *et. al*. 1984
Effective means for Bioremediation	 Fig: Bioremidiation by probiotics	*Bacillus* spp.	Stanier *et.al.* 1963

Antiviral effects: The production of antagonistic compounds may also be active against viruses as documented by Balcazur *et al.* (2006) (19) who reported antiviral activity from *Pseudomonas* sp., *Vibrio* sp., *Aeromonas* sp., obtained from salmon hatcheries against infectious hematopoietic necrosis virus (IHNV) with more than 50% plaque reduction.

Colonization: Probiotics make up part of the resident microflora and contribute to the health or well-being of their host [29]. The ability of some strain of adhesion to mucus, GI tract, epithelial cell and other tissues is a common characteristic used in the probiotic selection because it is associated with bacterial colonization [30-32]. According to Gatesoup (2008) (18), a microorganism is able to colonize the GI tract when it can persist there for a long time, possessing a multiplication rate that is higher than its expulsion rate. For example, *Vibrio* sp. normally colonize the hepatopancreas of juvenile white shrimp; this normal microflora, however, can artificially be replaced and dominated by *Bacillus* sp. (up to 50% of the total) if it is added to the water for 20 days (18). The process of colonization is characterized by attraction of bacteria to the mucosal surface followed by association within the mucous gel or attachment to epithelial cells. Adhesion and colonization of the mucosal surfaces are possible protective mechanisms against pathogens through competition for binding sites and nutrients, or immune modulation (19).

Interaction with phytoplankton: Probiotic bacteria have a significant algicidal effect on many species of microalgae, particularly of red tide plankton [33]. Bacteria antagonistic towards algae would be undesirable in green water larval rearing technique in hatchery where unicellular algae are cultured and added, but would be advantageous when undesired algae species are developed in the culture pond (34).

Effective means for bioremediation: Bioremediation agents serve to modify or manipulate the microbial communities in water and sediment such that they reduce or eliminate selected pathogenic microbes and generally improve growth and survival of the targeted species (35). Usage of probiotics reduced and prevented the accumulation of organic sludge at pond bottom as well as formation of toxic gases like NH_3, NO_2, H_2S etc., it was also effective in controlling *Vibrio* population and thus helped improve water quality and subsequently shrimp health (36). Improved water quality has especially been associated with *Bacillus* sp. The rationale is that gram positive bacteria are better converters of organic matter back to CO_2 than that of gram-negative bacteria. During the production cycle, high levels of gram-positive bacteria can minimize the buildup of dissolved and particulate organic carbon. It has been reported that use of *Bacillus* sp. improved water quality, survival and growth rates and increased the health status of juvenile *Penaeus monodon* and reduced the

pathogenic vibrios (37). There are approximately 15 species *of Bacillus*, which are the main components of commercial probiotic (bioremediation) products for pond aquaculture (35). According to Jory (1998) (35) there are several characteristics that make *Bacillus* an ideal bioremediation agent in aquaculture (see Table 1).

Table 1. *Bacillus* as an agent for bioremediation (Jory 1998) (35)

• *Bacillus* can easily move around (motile) because they have a whip like flagella.
• *Bacillus* form endospores, which are useful under stressful conditions.
• Endospores allow *Bacillus* to reproduce when conditions are favourable.
• *Bacillus* produces antibiotics, for example, bacitracin, polymyxin, trycodin, gramicidin and circulin.
• *Bacillus* produce special compounds (enzymes) that can break down polysaccharides, nucleic acids and lipids.
• *Bacillus* are easily transformable (free DNA is easily incorporated to change its
• genetic make-up). This is very useful in making 'designer" bacteria.
• *Bacillus* are thermophilic, growing at high temperatures (50-70 °C).
• *Bacillus* are easy to isolate from soil or air. They grow well on synthetic media.
• Ammonium can be its sole nitrogen source. Few isolates require vitamin supplements.

Probiotics strains studied in aquaculture

A good number of probiotics considered as biological control agents in aquaculture arena belong to the lactic acid bacteria (*Lactobacillus* and *Carnobacterium*) (38), or to the genus *Vibrio* (*V. alginolyticus*) (39), *Bacillus (40-42)*, *Pseudomonas* (43), *Saccharomyces(26)*, along with other genera viz. *Aeromonas* and *Flavobacterium* (44, 45). The first probiotics discovered long time ago was *Lactobacillus* sp., the lactic acid producing bacteria. Afterwards, many probiotics such as *Aeromonas hydrophila* [46], *A. media* [47], *Micrococcus luteus* [46], *Pseudomonas fluorescens* [43], *Altermonas* sp [48], *Bacillus subtilis* [49], *B. polymyxa*, *B. licheniformis* (40), *Saccharomyces cerevisiae* [26], *S. exiguous* [26], *Carnobacterium inhibens* [50], *Debaryomyces hansenii* [51], *Enterococcus faecium* [52], *Lactobacillus helveticus* [53], *L. plantarum* [53], *L. rhamnosus* [54], *Roseobacter* sp. [55], *Streptococcus thermophilus* [53], *Vibrio alginolyticus* [56], *V. fluvialis* [46], *Vibrio* sp. (strain P62, P63) (59) *Tetraselmis suecica* [57] and *Weissella helenica* [58] were considered for using in aquaculture.

Mounting probiotics for aquaculture

In order to develop or select new, effective and safe probiotic bacteria, it is very important to ensure some criteria of probiotic bacteria which are listed below according to Verschuere *et al*. 2000a (34):

I. The probiotic should not be harmful to the host it is desired for,
II. It should be accepted by the host, e.g. through ingestion and potential colonization and replication within the host,
III. It should reach the location where the effect is required to take place,
IV. It should actually work *in vivo* in accordance to *in vitro* findings, and
V. It should preferably not contain virulence resistance or antibiotic resistance genes.

A common way to select probiotics is to perform *in vitro* antagonism tests, in which pathogens are exposed to the candidate probiotics or their extracellular products in a liquid (60, 61) or solid (62, 63) medium. Currently there are four methods commonly employed to screen for inhibitory substances *in vitro*; the double layer method, the well diffusion method, the cross-streak method, and the disc diffusion method. All methods are based on the principle that a bacterium (the producers) produces an extracellular substance which is inhibitory to another bacterial strain (4).

Probiotics research in Bangladesh

In Bangladesh a good number of studies dedicated to probiotic technology have been reported. Putative probiotic bacteria isolated from rearing environment of shrimp aquaculture with potential bactericidal activity *in vitro* had been isolated (64, 65). Two approaches, the well diffusion method and co-culture experiments confirmed their probiotic nature. Their non-hemolytic property also ensured their safe mode for application in shrimp aquaculture (65). Moving forward, the identified probiotic bacteria, *Bacillus licheniformis* exhibited vibriocidal activity *in vitro* against 60% of the *Vibrio* species isolated from the same water samples. Further characterization of the isolate unveil that higher activity was recorded in the neutral and alkaline pH, at 30°C, and the antagonistic property was refractory to the surfactants used (66). The metal chelator, EDTA nullified the antagonistic property even at 0.01 mM concentration, indicating the presence of a metal active group in the active fraction (66). Earlier, a study by Rahman *et al* (67) recognized the prevalence of *Vibrio* spp in the coastal waters of Bangladesh, and identified the existence of *V. harveyi, V. metschnikovii, V. nereis, V. alginolyticus* and some unidentified colonies of *Vibrio* spp. Such a diverge presence of vibrios and their high level of abundance are

presumed to be attributed from the commercial brands of brine shrimp, *Artemia* cysts, imported from foreign origin, popularly used as shrimp feed in the rearing system (68). These bacteria are associated with *Artemia* during its encapsulation stage, which is released once the cysts are hatched. This is a cause of concern of introducing bacterial diseases in shrimp hatcheries of Bangladesh during feeding the shrimp larvae (68). The regular existence of vibrios in rearing waters indicates the failure of medication and treatments offered in the hatcheries for known vibriosis. An *in vivo* study using brine shrimp *Artemia franciscana* to analyze the cytotoxic effect of some putative probionts revealed that four bacteria, identified as *Pseudomonas* and *Bacillus* spp. exhibited the lowest inhibition to *Artemia* and were considered safe (69). Another study attempted to use *Lactobacillus* spp as probiotic bacteria, isolated from curd samples. The isolates clearly outcompete the growth of pathogenic bacteria: *Vibrio* spp and *Shigella* spp that caused mass mortality in post larvae of *Macrobrachium rosenbergii* during the period of May 2012 in Khulna and Sathkhira region (70). Further study need to be done to test their efficacy in culture environment of Bangladesh in order to understand their effectiveness of controlling bacterial diseases in shrimp aquaculture.

Limitation of probiotics use

Probiotics can be used in advance as prevention tools. They can prevent the disease, not to be used as a treatment strategy. They can be established well in static or low water exchange systems (re-circulatory system). They are effective if applied as soon as the water medium is sterilized before populated by other microbes [71]. In the process of application of probiotics, no other chemical or drug should be used for treating other diseases like fungal and protozoan diseases caused by those other than bacteria. These probiotics can easily be destroyed by any other chemical or drug which generally interferes with the establishment of useful microbes (72).

References

1. Environmental Impact of Aquaculture; http://en.wikipedia.org/wiki/Aquaculture
2. Aquaculture’s growth continuing: improved management techniques can reduce environmental effects of the practice.(UPDATE)." Resource: Engineering & Technology for a Sustainable World 16.5 (2009): 20-22. Gale Expanded Academic ASAP. Web. 1 October 2009. <http://find.galegroup.com/gtx/start.do?prodId=EAIM

3. Dr. M.A. Mazid and Mr. M.G.M. Alam: Appropriate Technologies for Sustainable and Environmentally Compatible Aquaculture Development in Bangladesh; Proceedings of the UNESCO - University of Tsukuba International Seminar on Traditional Technology for Environmental Conservation and Sustainable Development in the Asian-Pacific Region, held in Tsukuba Science City, Japan, 11-14 December, 1995, pp. 95-105
4. Aditya Kesarcodi-Watson, Heinrich Kaspar, M. Josie Lategan, Lewis Gibson; Probiotics in aquaculture: The need, principles and mechanisms of action and screening processes, Aquaculture 274 (2008) 1–14
5. Lightner, D.V., 1988. Vibrio disease of penaeid shrimp. In: Sindermann, C.J., Lightner, D.V. (Eds.), Disease Diagnosis and Control in North American Marine Aquaculture. Elsevier, Amsterdam, The Netherlands, pp. 42– 47.
6. Lin, C.K., 1995. Progression of intensive marine shrimp culture in Thailand. In: C. L. Browdy and J.S. Hpkins (ed.), Swimming through troubled water. Proceedings of the special Session on Shrimp farming, Aquaculture' 95. World Aquaculture Society, Baton Rouge, La, pp. 13–23.
7. Laurent Verschuere, Geert Rombaut, Patrick Sorgeloos, and Willy Verstraete; Probiotic bacteria as biological control agents in aquaculture; Microbiology and Molecular Biology Reviews Dec. 2000, p. 655–671 Vol. 64, No. 4
8. Lunestad, B. T. 1998. Impact of farmed fish on the environment, presentation by representative of Norway. *In* Notes of the Workshop on Aquaculture/ Environment Interactions: impacts on microbial ecology. Canadian Aquaculture Society, Halifax, Nova Scotia, Canada.
9. Raa, J. 1996. The use of immunostimulatory substances in fish and shellfish farming. Rev. Fish. Sc. 4:229–288.
10. Sakai, M. 1999. Current research status of fish immunostimulants. Aquaculture 172:63–92.
11. Subasinghe, R. 1997. Fish health and quarantine, p. 45–49. *In* Review of the State of the World Aquaculture. FAO Fisheries circular no. 886. Food and Agriculture Organization of the United Nations, Rome, Italy.
12. Browdy, C. 1998. Recent developments in penaeid broodstock and seed production technologies: improving the outlook for superior captive stocks. Aquaculture 164:3–21.
13. Havenaar, R, Ten Brink, B, Huis in't Veld, J H J (1992) Selection of strains for probiotic use. In: R. Fuller (ed), Probiotics: the scientific basis, Chapman and Hall, London. pp 209-224.
14. Fuller, R**.** 1989. A review: probiotics in man and animals. J. Appl. Bacteriol. 66**:**365–378.
15. FAO/WHO Expert Consultation, 2001. "Health andNutritional Properties of Probiotics in Food including Powder Milk with Live Lactic Acid Bacteria" Cordoba (Argentina). (available at http://www.who.int/foodsafety/publications/fs_management/probiotics/en/).
16. Maurilio Lara-Flores and Gabriel Aguirre-Guzmán The use of probiotic in fish and shrimp aquaculture. A review Research Signpost 37/661 (2), 2009
17. SCD Probiotics, *Application of SCD Probiotics Technology In Aquaculture, 2010*
18. Gatesoupe, F.J. 2008. Updating the importance of lactic Acid bacteria in fish farming: natural occurrence and probiotic treatments. J. Mol. Microbiol. Biotechnol. 14, (1-3), 107-14.

19. Balcázar, J.L., De Blas, I., Zarzuela-Ruiz, I., Cunningham, D., Vendrell, D., Múzquiz, J.L. 2006. The role of probiotics in aquaculture (Review). Veterinary Microbiology 114, 173-186.
20. Vine, N.G., Leukes, W.D., Kaiser, H. 2006. Probiotics in marine larviculture. FEMS Microbiol. Rev. 30(3), 404-27.
21. Wang, X., Li, H., Zhang, X., Li, Y., Ji, W., Xu, H., 2000. Microbial flora in the digestive tract of adult penaeid shrimp (*Penaeus chinensis*). J. Ocean. Univ. Qingdao 30, 493–498.
22. Bairagi, A., Sakar Ghosh, K., Sen, S.K., Ray, A.K., 2002. Enzyme producing bacterial flora isolated from fish digestive tracts. Aquaculture International 10, 109–121.
23. Song, Y.L., and Huang, C.C. 2000. Aplications of immunostimulant to prevent shrimp diseases. 173. Fingerman, M., and Negabhusanam, R. (Ed). Science Publishers Inc. Playmouth, UK.
24. Rengpipat S, Rukpratanporn S, Piyatiratitivorakul S and Menasaveta P (2000) Immunity enhancement in black tiger shrimp (*Penaeus monodon*) by a probiont bacterium (*Bacillus* S11). Aquaculture 191:271–288
25. Alavandi S.V., Vijayan K.K., Santiago T.C., Poornima M., Jithendran K.P., Ali S.A., and Rajan J.J.S. 2004. Fish Shellfish Immunol. 17, 115.
26. Scholz, U., Garcia-Diaz, G., Ricque, D., Cruz-Suarez, L.E., Vargas-Albores, F., Latchford, J., 1999. Enhancement of vibriosis resistance in juvenile Penaeus vannamei by supplementation of diets with different yeast products. Aquaculture 176, 271– 283.
27. Balcázar, J.L. 2003. Evaluation of probiotic bacterial strains in *Litopenaeus vannamei*. Final Report, National Center for Marine and Aquaculture Research, Guayaquil, Ecuador.
28. Itami, T., Asano, M., Tokushige, K., Kubono, K., Nakagawa, A., Noboru, T., Nishimura, H., Maeda, M., Kondo, M., Takahashi, Y., 1998. Enhancement of disease resistance of kuruma shrimp, Penaeus japonicus, after oral administration of peptidoglycan derived from Bifidobacterium thermophilum. Aquaculture 164, 277–288.
29. Gatesoupe FJ (1999) The use of probiotics in aquaculture. Aquaculture 180:147–165
30. Crittenden, R., Bird, A.R., Gopal, P., Henriksson, A., Lee, Y.K., and Playne, M.J. 2005. Curr Pharm Des. 11, 37.
31. Verschuere, L., Rombaut, G., Sorgeloos, P., Verstraete, W., 2000. Probiotic bacteria as biological control agents in aquaculture. Microbiology and Molecular Biology Review 64, 655–671.
32. Farzanfar, A. 2004. FEMS Immunol. Med. Microbiol. 48, 149.
33. Vandenberghe, J., Verdonck, L., Robles-Arozarena, R., Rivera, G., Bolland, A., Balladares, M., Gomez-Gil, B., Calderon, J., Sorgeloos, P., and Swings, J. 1999. Appl. Environ. Microbiol. 65, 2592.
34. Verschuere, L., Rombaut, G., Sorgeloos, P., Verstraete, W., 2000a. Probiotic bacteria as biological control agents in aquaculture. Microbiology and Molecular Biology Review 64, 655–671.
35. Jory, D.E., 1998. Use of probiotics in penaeid shrimp growout. Aquacult. Mag. 24(1): 62-67.
36. Arun kumar jha, Probiotic technology : an effective means for bioremediation in shrimp farming ponds *Journal of Bangladesh Academy of Sciences, Vol. 35, No. 2, 237-240, 2011*

37. Dalmin, G., Kathiresan, K., Purushothaman, A., 2001. Effect of probiotics on bacterial population and health status of shrimp in culture pond ecosystem. Indian J. Exp. Biol. 39, 939–942.
38. Gatesoupe, F.J., 1994. Lactic acid bacteria increase the resistance of turbot larvae, Scophthalmus maximus, against pathogenic Vibrio. Aquat. Living Resour. 7, 277–282.
39. Austin, B., Stuckey, L., Robertson, P., Effendi, I., Griffith, D., 1995. A probiotic strain of Vibrio alginolyticus effective in reducing diseases caused by Aeromonas salmonicida, Vibrio anguillarum and Vibrio ordalii. J. Fish Dis. 18, 93–96.
40. Queiroz, F., Boyd, C., 1998. Effects of a bacterial inoculum in channel catfish ponds. J. World Aquacult. Soc. 29, 67–73.
41. Rengpipat, S., Phianphak, W., Piyatiratitivorakul, S., Menasaveta, P., 1998. Effects of a probiotic bacterium in black tiger shrimp Penaeus monodon survival and growth. Aquaculture 167, 301–313.
42. Moriarty, D., 1998. Control of luminous Vibrio species in penaeid aquaculture ponds. Aquaculture 164, 351–358.
43. Gram, L., Melchiorsen, J., Spanggaard, B., Huber, I., Nielsen, T., 1999. Inhibition of Vibrio anguillarum by Pseudomonas fluorescens strain AH2, a possible probiotic treatment of fish. Appl. Environ. Microbiol. 65, 969–973.
44. Gibson, L.F.,Woodworth, J., George, A.M., 1998. Probiotic activity of Aeromonas media on the Pacific oyster, Crassostrea gigas, when challenged with Vibrio tubiashii. Aquaculture 169, 111–120.
45. Suminto, K., Hirayama, K., 1997. Application of a growth-promoting bacterium for stable mass culture of three marine microalgae. Hydrobiologia 358, 223–230.
46. Irianto A and Austin B (2002) Use of probiotics to control furunculosis in rainbow trout, *Oncorhynchus mykiss* (Walbaum). J Fish Dis 25:1–10
47. Gibson LF, Woodworth J and George AM (1998) Probiotic activity of Aeromonas media when challenged with *Vibrio tubiashii*. Aquaculture 169:111–120
48. Douillet PA and Langdon CJ (1994) Use of probiotic for the culture of larvae of the Pacifi c oyster (*Crassostrea gigas Thurnberg*). Aquaculture 119:25–40
49. Vaseeharan B and Ramasamy P (2003) Control of pathogenic *Vibrio* spp. by *Bacillus subtilis* BT23, a possible probiotic treatment for black tiger shrimp *Penaeus monodon*. Lett Appl Microbiol 36:83–87
50. Joborn A, Olsson JC, Westerdahl A, Conway PL and Kjelleberg S (1997) Colonization in the fi sh intestinal tract and production of inhibitory substances in intestinal mucus and faecal extracts by *Carnobacterium* sp. K1. J Fish Dis 20: 383–392
51. Tovar D, Zambonino J, Cahu C, Gatesoupe FJ, Vazquez- Juarez R and Lesel R (2002) Effect of yeast incorporation in compound diet on digestive enzyme activity in sea bass (*Dicentrarchus labrax*) larvae. Aquaculture 204:113–123
52. Chang CI and Liu WY (2002) An evaluation of two probiotics bacterial strains, *Enterococcus faecium* SF68 and *Bacillus toyoi*, for reducing edwardsiellosis in cultured European eel, *Anguilla anguilla*, L. J Fish Dis 25:311–315
53. Gatesoupe FJ (1991) Siderophore production and probiotics effect of *Vibrio* sp. associated with turbot larvae, *Scophthalmus maximus.* Aquatic Living Resources 10: 239–246

54. Nikoskelainen S, Ouwehand A, Salminen S and Bylund G (2001) Protection of rainbow trout (*Oncorhynchus mykiss*) from furunculosis by *Lactobacillus rhamnosus*. Aquaculture 198:229–236
55. Ruiz-Ponte C, Samain JF, Sanchez JL and Nicolas JL (1999) The benefit of a *Roseobacter* species on the survival of scallop larvae. Mar Biotech 1:52–59
56. Austin B, Stuckey LF, Robertson PAW, Effendi I and Griffi th DRW (1995) A probiotic strain of *Vibrio alginolyticus* effective in reducing diseases caused by *Aeromonas salmonicida*, *Vibrio anguillarum* and *Vibrio ordalii*. J Fish Dis 18:93–96
57. Austin B, Baudet E and Stobie MBC (1992) Inhibition of bacterial fi sh pathogens by *Tetraselmis suecica*. J Fish Dis. 15:55–61
58. Byun JW, Park SC, Benno Y and Oh TK (1997) Probiotic effect of *Lactobacillus* sp. DS-12 in fl ounder (*Paralichthys olivaceus*). J Gen Appl Microbio 43:305–308
59. Gullian, M., Thompson, F., Rodrı´guez, J., 2004. Selection of probiotic bacteria and study of their immunostimulatory effect in Penaeus vannamei. Aquaculture 233, 1–14.
60. Sotomayor, M.A., Balca´zar, J.L., 2003. Inhibition of shrimp pathogenic vibrios by mixture of probiotic strain. Rev. Aquat. 19, 9–15.
61. Vine, N.G., Leukes, W.D., Kaiser, H., 2004a. In vitro growth characteristics of five candidate aquaculture probiotics and two fish pathogens grown in fish intestinal mucus. FEMS Microbiol. Lett. 231, 145–152. f probiotic strain. Rev. Aquat. 19, 9–15.
62. Dopazo, C., Lemos, M., Lodeiros, C., Bolinches, J., Barja, J., Toranzo, A., 1988. Inhibitory activity of antibiotic-producing marine bacteria against fish pathogens. J. Appl. Bacteriol. 65, 97–101
63. Chythanya, R., Karunasagar, I., Karunasagar, I., 2002. Inhibition of shrimp pathogenic vibrios by a marine Pseudomonas I-2 strain. Aquaculture 208, 1–10.
64. Sarker A, Khan SN, Naser MN and Karim MM. 2008. Isolation of probiotic bacteria from natural sources to control diseases in shrimp aquaculture. *In*: *Food Safety and Hygiene*. N Choudhury, CR Ahsan and MM Karim (eds.), Bangladesh Academy of Sciences, Bangladesh. pp 129-135.
65. Rahman S, Khan SN, Naser MN and Karim MM. 2009. Application of probiotic bacteria: A novel approach towards ensuring food safety in shrimp aquaculture. *Journal of Bangladesh Academy of Sciences*, **33** (1) 139-144.
66. Sarker A, Rahman S, Khan SN, Naser MN and Karim MM. 2010. Optimization and Partial Characterization of a Putative Probiotic Bacterium Antagonistic to Vibrios in Shrimp Larval Rearing System; Dhaka Univ. J. Pharm. Sci. **9** (1): 23-29.
67. Rahman S, Khan SN, Naser MN and Karim MM. 2010. Isolation of *Vibrio* spp. from Penaeid Shrimp Hatcheries and Coastal Waters of Cox's Bazar, Bangladesh ; Asian J. Exp. Biol. Sci. **1** (2): 288 – 293.
68. Fahmi T, Karim MM, Rahman S, Naser MN and Khan SN. 2010. Abundance and community structure of bacteria associated with *Artemia* cysts of commercial brands commonly used in hatchery operations of Bangladesh. Bangladesh Journal of Zoology. **38** (1) 41-49.
69. Rahman S, Khan SN, Naser MN and Karim MM. 2011. Safety issues of isolated probiotic natured bacteria from Bangladesh coastal waters for controlling shrimp diseases. *Journal of Scientific Research*, **3** (3) 659-668.

70. Ramim AM, Rahman S, Naser MN and Karim MM. 2012. The application of probiotic technology to prevent prawn (*Macrobrachium rosenbergii*) mortality in the south-west coastal region of Bangladesh. *In*: Proceedings of the 1st International Exhibition on Dairy, Aqua and Pet animals. Published by Animal Health Companies Association of Bangladesh. pp 204-10.
71. Nageswara PV and Babu DE (2006) Probiotics as an alternative therapy to minimize or avoid antibiotics use in aquaculture. Fishing Chimes 26 (1):112–114.
72. Maloy Kumar Sahu · N. S. Swarnakumar · K. Sivakumar · T. Thangaradjou · L. Kannan Probiotics in aquaculture: importance and future perspectives Indian J. Microbiol. (September 2008) 48:299–308 DOI: 10.1007/s12088-008-0024-3
73. Nogami, K., and M. Maeda, 1992. Bacteria as biocontrol agents for rearing larvae of the crab *Portunus trituberculatus. Can. J. Fish. Aquat. Sci*., **49**: 2373-2376.
74. Nogami, K., K. Hamasaki, M. Maeda, and K. Hirayama, 1997. Biocontrol method in aquaculture for rearing the swimming crab larvae *Portunus trituberculatus*. *Hydrobiologia*, **358**: 291-295.
75. Sakata T (1990) Microfl ora in the digestive tract of fi sh and shell-fi sh. In: Microbiology in Poecilotherms (Lesel R ed.), Elsevier, Amsterdam, pp 171–176
76. Ringo E, Strom E and Tabacheck J (1995) Intestinal microflora of salmonids: a review. Aquacult Res **26**:773–789
77. Sakai, M., T. Yoshida, S. Astuta, and M. Kobayashi, 1995. Enhancement of resistence to vibriosis in rainbow trout, *Oncorrhynchus mykiss* (Walbaum) by oral administration of *Clostridium butyricum* bacteria. *J.Fish Dis*., **18**: 187-190.
78. Nikoskelainen, S., A. C. Ouwehand, G. Bylund, S. Salminen, and E. M. Lilius, 2003. Immune enhancement in rainbow trout (*Oncorhychus mykiss*) by potential probiotic bacteria (*Lactobacillus rhamnosus*). *Fish Shellfish Immunol*., **15**: 443-452.
79. Kamei Y, Yoshimizu M, Ezura Y and Kimura T (1988) Screening of bacteria with antiviral activity from fresh water salmonid hatcheries. Microbiol Immunol 32:67–73
80. Girones R, Jofre JT and Bosch A (1989) Isolation of marine bacteria with antiviral properties. Can J Microbiol 35: 1015–1021
81. Gullian, M., Rodrı´guez, J., 2002. Immunostimulant qualities of probiotic bacteria. Global Aquacult. Advocate 5, 52–54.
82. Stanier, R. Y., M. Doudoroff, and E. A. Adelberg. 1963. The microbial world. Prentice-Hall Inc., Englewood Cliffs, N.J.

Transportation of mola (*Amblypharyngodon mola*) brood fish for stocking in the homestead ponds of North West Bangladesh

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Abstract: Collection and transportation of small fish- mola (*Amblypharyngodon mola*) in live condition from different water bodies for stocking in ponds and wetlands is a major problem for expansion of its culture potentials in carp polyculture. The purpose of this study was to develop effective methods to reduce mortality and stress on mola during transportation . The IFAD funded Small Fish and Nutrition project took initiatives to device effective methods of transportation of mola in order to stock in ponds of 1500 households in North West Bangladesh during November 2010 - May 2011. The sources used for collection of mola brood fish were- ponds connected with *beel* (natural depression), seasonal ditches inside the dead rivers, rice field connected ponds and grow-out (carp polyculture) ponds. The devices used for transportation of mola were; aluminum pot ; mini tank developed using thick polythene sheet inside a pickup van/ engine van and plastic barrel. The mola fish transported were grouped under two categories (1) mola transported through properly conditioned and (2) mola transported with minimum or not conditioned. Proper conditioning included keeping mola fish in separate ponds as single species, regular netting, and use of good quality supplementary feeds. Under minimum or without conditioning, no particular initiatives were taken to pre-conditioned mola before harvest. Careful and sensible handling, adding saline solution, using oxygen releasing agents, agitating of water, hand splashing and using aerator during transportation showed better result for mola broods. The study showed that transportation of 1,655.5 kg of properly conditioned mola on 131 occasions using different devices were with very high survival of 91%. The transportation of mola brood fish with proper conditioning was found to be effective up to 62 km distance in about 2 hr journey. The method developed here is found to be very effective for transportation of mola and might be useful for its promotion for culture in ponds and wetlands.

Introduction

About 150 species among 280 freshwater fishes available in Bangladesh can be considered as small indigenous fish species (SIS), which play a vital role in respect to household nutrition supply in Bangladesh. SIS are highly valuable sources of macro and micro nutrients which play an important role to provide essential bio-available nutrients for the rural people. In the past, in carp polyculture, as a part of the pond management fish poisons from organic and inorganic origin have been prescribed to the farmers to eradicate SIS from the culture ponds (Wahab *et al.* 2003). Little attempts has been taken to culture these SIS commercially. Now nutritional value of these species has put emphasis for large scale culture and production of SIS in the country (Rahman *et al.* 2002).

A large proportion of the population in Bangladesh suffers from malnutrition and about 30,000 children become night blind each year from vitamin A deficiency (Parvin *et al.* 2012). The low intake of vitamin A and other micronutrients has caused an increase evidence in night blindness, anemia and stunted growth, which can be mitigate through intake of vitamin A rich small fishes like mola (*A. mola*), calcium rich punti (*Puntius sophore*) and other micronutrient rich fishes (Thilsted *et al.* 1997). Among the fish available in the inland water of Bangladesh, mola contain the highest amount of vitamin A (Kawarazuka 2010). On the other hand, mola is very tasty and has high market demand in North West Bangladesh as well as all over the country. No significant difference in total fish production has been observed between ponds stocked with mola and those without mola stock (Thilsted 2010). Moreovere, mola reproduced in the pond several times over a single production season (Roos *et al.* 2003).

Although there is high demand and market potential, the culture of mola is not well established. Even in the homestead ponds, the production of mola is decreasing day by day. The lack of seed supply of mola is one of the major cause that hinders its culture Collection and transportation of mola in live condition is not a easy task. Considering the importance of mola culture, the study was undertaken to develop an effective method for mola transportation to reduce mortality and stress and to incorporate the nutrient rich mola fish in the homestead pond culture of North West Bangladesh.

Materials and methods

The study was conducted at three Upazilas (Sadar, Chirirbandar and Parbatipur) of Dinajpur and two Upazilas (Kaunia and Pirgachha) of Rangpur districts during November 2010 to May 2011.

Mola brood were collected to incorporate the fish into carp polyculture system in homestead ponds of 1500 house holds. Various containers were used for collection and transportation of the mola fish (Table 1) and theywere collected from water bodies like pond connected with *beel* (natural depression), seasonal ditches inside dead river (The Ichhamoti, located at Chirirbandar, Dinajpur), alternative rice fish systems, large grow-out ponds etc. (Table 2). These sources were identified through communicating with local fisher groups, fish traders, DoF personnel, fish markets (*arot*), Lead Entrepreneur (LE) of RIU-DSP project and through a number of on-site visits. Aluminum pot was used to carry the fish from the water sources to pick into another container and to release the fish into pond from that container. Transportation mode was developed like as open system tank using polythene sheet into engine van or pickup van for transportation the mola brood fish (Fig. 1). Rickshaw van (up to 10 km), power tiller/trolley (up to 40 km), engine van locally called *votvoti* (up to 40 km) and pickup van (up to 62 km) were used as transport for mola brood in short and long distances (Table 3).

Table 1. Containers used for fish transport

Sl.	Name of container	Quantity of water (L)	Water holding capacity (L)
1	Aluminum pot (*Patil*)	25-30	40-45
2	Plastic barrel	120-130	200-210
3	Mini Tank developed by polythine sheet into engine van	300-500	1000-1200
4	Mini Tank developed by polythine sheet into pickup van	800-1000	2000-3000

Table 2. Sources of mola brood fish collection

Sl.	Types of sources	Mola (kg)					%
		Dinajpur	%	Rangpur	%	Total	
1	*Beel* connected pond	50	8	918	72	968	51.1
2	Large grow-out pond	45	7	356	28	401	21.2
3	Alternate rice fish system	329.5	53			329.5	17.4
4	Seasonal ditches inside dead river	110	18			110	5.8

5	Ponds connected to rice field	52.5	8		52.5	2.8
6	Borrow-pits connected to rice fields	11	2		11	0.6
7	Canal beside railway	7	1		7	0.4
8	Small homestead pond	16	3		16	0.8
	Total	621		1274	1895	

Fig. 1. Mini tank developed by polythene sheet installed on engine van.

Table 3. Survival rate of transported mola brood fish

Container used	Without conditioning				Conditioned			
	No. of occasions	Amount of mola (Kg)	Survival amount (kg)	Survival rate (%)	No. of occasions	Amount of mola (Kg)	Survival amount (kg)	Survival rate (%)
Mini Tank (Pickup Van)	2	19	5.5	29	9	403	395	98
Mini Tank (Engine Van)	12	106	71.5	67	17	211.5	184	87
Barrel (Power tiller/ trolley)	1	5	2	40	17	230	221.5	96
Aluminum pot, *Patil* (Van/ manually)	10	109.5	34.5	32	88	811	698	86
Total	25	239.5	113.5	47	131	1655.5	1498.5	91

The collected mola brood fish were reared in the collection ponds before distributing to the farmers (Fig. 2). Mola brood fish were stocked in a thirteen collection ponds (seven in Rangpur and six in Dinajpur). The collection ponds were located at the premises of the target farmers where the mola brood fish were distributed or closed to the collection sites.. Pre-nursery and nursery feed, rice bran, wheat bran, maize bran and mustard oil cake were used for feeding @ 1-2% body wt. in the collection ponds. Collection ponds were used for different purposes like (1) to collect mola brood fish where the fish is more available, (2) to manage only mola fish for preparing brood, (3) to uniform condition/hardening the mola brood fish for transportation properly and (4) to distribute mola brood fish to the farmers in a plan way.

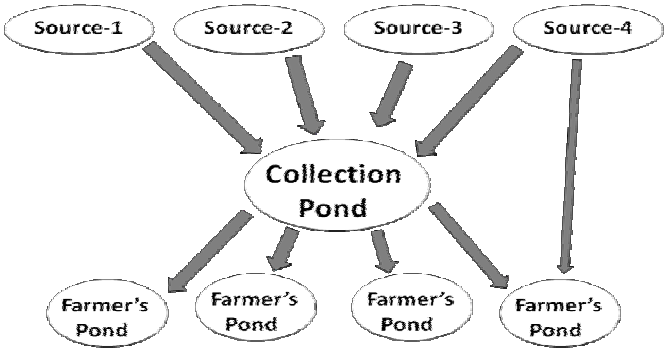

Fig. 3. Transportation system of mola brood fish.

Oral saline (ORSaline-N of Reneta Limited: Sodium Chloride, Potassium Chloride, Trisodium Citrate and Glucose) was used into *patil* during fish carrying. One packet of 10 g saline was used for 30 liter water into *patil*. Oxygen releasing agents (Calcium per oxide, Sodium per oxide, Sodium per carbonate etc.) and Quick-Oxygen (Sodium per carbonate: marketed by Organic Pharmaceuticals Limited, Agro-Vet Division), Oxy-A (Sodium per carbonate of ACME Laboratories), Oxyflow (Novartis), were used @ 30-50 g for 300-500 liter water during transportation of brood fish. Mechanized aerator was used only at Rangpur during brood fish transportation.

Two categories of Mola brood fish transportation was grouped into two ways.. One was properly conditioned and another was without or less conditioned (Table 3). Conditioning was done through isolating of mola and stocking into a separate pond where possible. Fish were fed with mustard oil cake and rice bran at least 7 -10 days followed by the separation. Netting and releasing the fish back into pond by splashing water was done for 2-3 times with 1-3 days interval before mola brood

transportation to collection ponds from sources. For without-conditioned fish, no feeding and no netting was done to harden the fish.

Feeding was stopped at the day of netting and transportation day. Soft and sensible handling was followed during fishing and carrying the brood fish. Screening net of large mesh size (*Katai jal*) was used for isolating mola from the large fish at sources. Mostly, soft seine net was used and the blue mosquito net was used for few times at Rangpur as well. Mola brood fish were generally transported early in the morning. Action research model (Susman 1983 and O'Brain 2001) was followed for the study (Fig. 4). Data was recorded after each practice. Statistical measures like number, percentage were used for analyzing using MS Excel 2007 for showing the relationship between variables of the study.

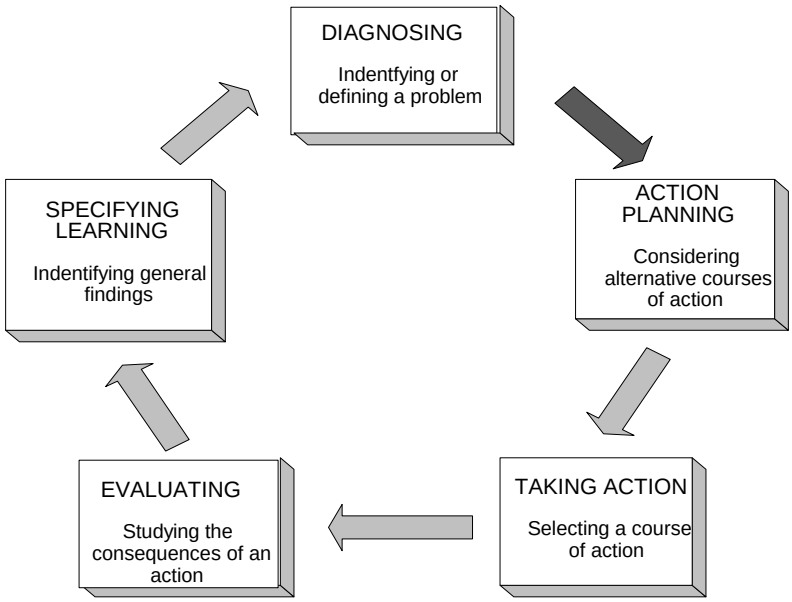

Fig. 4. Detailed Action Research Model (adopted from Susman 1983 and O'Brain 2001)

Results and discussion

A total of 1,895 kg mola fish were collected from different water sources. Inr Rangpur, site, 1,274 kg mola was collected, where 72% was collected from *beel* connected ponds and 28% from large grow-out ponds and in Dinajpur, 621 kg mola was collected, where 53% was from alternative rice fish systems, 18% from seasonal ditches inside dead rivers, 8% from ponds connected to rice field and 8% from *beel*

connected ponds, 7% from large grow-out pond and only 3% from small homestead ponds. Only a total 16 kg of mola was collected from 22 small homestead ponds and the small amount indicates that mola is very less available into homestead ponds (Table 2). Among the alternate rice fish system, 195 kg (59%) mola fish was collected from the water sources of Nilphamari district, which were *beel* adjacent culture system. On the other hand, 71% of total collected amount of mola from open water or open water adjacent culture system and only 22% of mola was collected from the pond culture systems, which showed the primary source of mola is open water or open water adjacent culture system.

Survival rate of mola brood after transportation was observed in 156 occasions (Table 3). The survival of fish transported by the same way for conditioned and without-conditioned fish was 91% (1498.5 kg out of 1655.5 kg, 131 occasions) and 47% (113.5 kg out of 239.5 kg, 25 occasions), respectively. The distance covered during transportation using various ways and carrying vehicles increased in trials from short distances (<1 km for 5-15 min.) to long distances (up to 62 km for 2 hrs and 10 min). Fig. 5 shows the comparative survival rate of after transportation of mola for conditioned and without conditioned. Engine van performed with better survival (67%) for withou conditioned fish transportation, because it vibrates a lot by which oxygenation occurs during transportation.

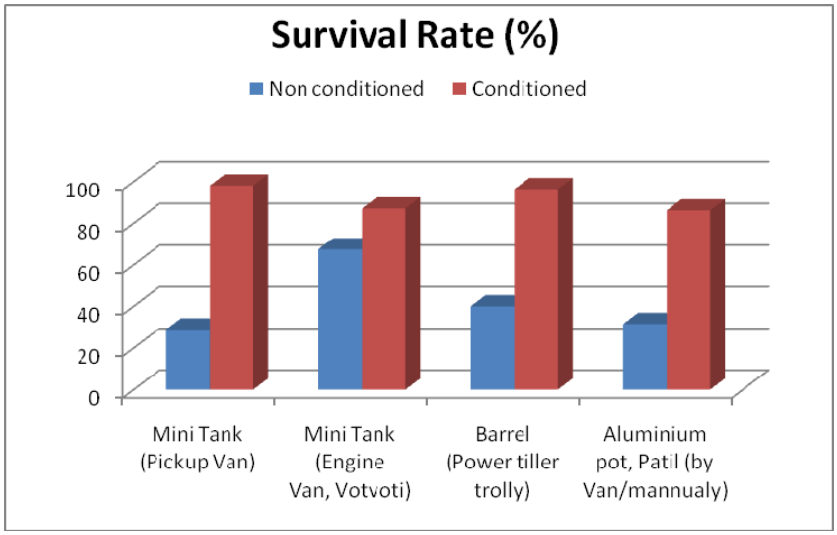

Fig. 5. Survival rate of mola after transportation using different containers.

The practices of separation of mola as a single species for hardening and conditioning was very effective even for long distance and large amount of fish transportation (235 kg in 5 occasions with 99% survival). Good survival rate (97%, 485 kg out of 499.5 kg) was also observed when soft net was used. However, using rough/harsh net (blue net) resulted comparatively less survival rate (88%, 1013.5 kg out of 1156 kg). Proper conditioning, better handling and stress alleviating approach for transportation of mola were found to be very effective for obtaining good survival rate (86% - 98%) in mola transportation. By the invented successful technology of mola transportation, farmers can include the mola fish as a cultivable species in their homestead ponds which will increase the farmers income and improve their household nutrition.

References

Kawarazuka, N. (2010). The contribution of fish intake, aquaculture and small scale fisheries to improving nutrition: A literature review. The WorldFish Center Working Paper No. 2106. The WorldFish Center, Penang, Malaysia, P 51.

O'Brien, R. (2001). Um exame da abordagem metodológica da pesquisa ação [An Overview of the Methodological Approach of Action Research]. In Roberto Richardson (ed.), Pessoa, Brazil: Universidade Federal da Paraíba. (English version). http://www.web.ca/~robrien/papers/arfinal.html (Accessed 20/1/2002)

Pervin, R., Wahab, M.A., Fatema K., Khan., M.S.R. (2012). Effects of addition of mola at different densities on production of giant fresh water prawn. *J. Bangladesh Agril. Univ.* 10(1): 163-167.

Rahman, S.M., Asaduzzaman, M.D., Saha, M.K., Siddique, M.A.B., Hossain, M.M. (2002). Proximate composition of some small indigenous fish in Bangladesh. *Khulna University Studies* 4(1): 683-688.

Roos, N., Islam, M., Thilstead, S.H. (2003). Small fish is an important dietary source of vitamin A and calcium in Bangladesh. *International J. Food Sci. and Nutrition*. 54: 329-339.

Susman, Gerald I. (1983). "Action Research: A Socio-technical Systems Perspective." Ed. G. Morgan. London: Sage Publications. 95-113.

Thilsted, S.H. (2010). The potential of nutrient-rich small fish species in aquaculture to improve human nutrition and health. In Global Conference on Aquaculture. Phuket, Thailand.

Thilsted, S.H., Roos, N., Hasan, N. (1997). The role of small indigenous fish species in food and nutrition security in Bangladesh. NAGA Newsletter, July –December (Supplement) 13 pp.

Wahab, M.A., Thilsted, S.H., Hoq, M.E (eds.). (2003). Small Indigenous Species of Fish in Bangladesh. Proceedings of BAU-ENRECA/DANIDA Workshop on 30-31 October, 2002, BAU, Mymensingh, Bangladesh Agricultural University, Mymensingh, Bangladesh. 150 pp.

Inclusion of prawn in polyculture: effects of stocking density of tilapia on environment and production

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Abstract: An experiment was conducted to evaluate the effects of stocking density of tilapia on environmental parameters and production in organic prawn farming system over a period of 122 days at the Fisheries Field Laboratory, Bangladesh Agricultural University, Mymensingh. There were three treatments T_1, T_2 and T_3 with 10,000, 15,000 and 20,000 tilapia. ha^{-1}, respectively. A fixed density of freshwater prawn and silver carp at 30,000 and 1,250 indiv. ha^{-1}, respectively, was maintained in all treatment ponds. The area of each pond was 130 m^2 and water depth 1.5 m. Bambooo branches (*Kanchi*) with mean diameter of 2.8 cm were posted at a density of 15 poles m^{-2} vertically into pond bottom as periphyton substrates. Water quality parameters were within the suitable ranges for fish culture among all the treatments. The mean weight of tilapia at harvest decreased significantly ($p<0.05$) with increasing stocking density, but survival rate did not differ significantly. The net production of prawn was higher (668 $kg.ha^{-1}$) in T_3 than in T_2 (648 kg ha^{-1}) and T_1 (640 kg ha^{-1}). Similarly, the net production of tilapia was significantly higher in treatments T_3 (2,118 kg ha^{-1}) and T_2 (1,779 kg ha^{-1}) than in treatment T_1 (1,422 kg ha^{-1}). When combined production of all three species were compared, it was found that treatment T_3 resulted in significantly higher net production (3,196 kg ha^{-1}) than those of T_1 (2,797 kg ha^{-1}) and T_2 (2,393 kg ha^{-1}). The results revealed that an addition of tilapia at a density at 20,000 ha^{-1} increased the production of prawn as well as silver carp, and thus contributed to earn higher net profit (Tk. 1,78,321 ha^{-1}) with a BCR of 0.53.

Introduction

Organic aquaculture is the production of fish and other aquatic products without the use of synthetic pesticides, chemicals, fertilizers, antibiotics, growth hormones and

genetic manipulation. It aims to produce ecologically, economically and socially more acceptable fish and other aquatic products. As most of the cultured fishes are reared with a number of chemicals, there has been an increasingly high demand for organically farmed fish, without the application of any chemical both inside the country and in abroad. In the international and domestic markets, both prawn and tilapia have tremendous prospects to be considered as superior food item.

Due to fast-growing nature and ability to adapt in almost all aquatic systems allover the world, Nile tilapia and a number of other tilapias have been known as "aquatic chicken" (Dey 2001). Tilapia has high resistance to poor water quality and disease, tolerance to a wide range of environmental conditions, the ability to convert efficiently the organic and domestic waste into high quality protein, rapid growth rate and tasty flavour (Ballarin and Hallar 1982).

Bangladesh has entered into the commercial prawn farming since early 90s and has become a world player as one of the seven major export countries (Wahab 2009). Freshwater prawn is contributing 30% of total shrimp export, which is about US $ 135 million share out of the total US $ 445.41 million export (Khondaker 2009). The increase in world aquaculture production has recently seen the negative impacts of unsustainable production methods in many countries with regard to the environment and, in some cases, consumers' safety. Due to the increased awareness, in many EU countries, consumers are becoming more anxious about the food they eat and are increasingly concerned with food production issues such as food safety (Haung 1995), food quality (Haglund *et al,* 1999), human health (Beharrel and MacFie 1991), the environment (Cudjoe and Rees 1992; Haglund *et al.* 1999) and animal welfare (Fearne and Lavelle 1996). Consumers from more and more developed countries are turning their interest to the organically produced aquatic products.

Polyculture can improve water quality by creating a better balance among the microbial communities of the pond, resulting in enhanced production. Organic farming of prawn and silver carp with tilapia in pond may be a likely option and can be a source of extra income for the poor fish farmers. In view of the above facts, the present study has been undertaken to determine the effects of stocking density of tilapia on environment and production in organic farming system.

Materials and methods

The experiment was carried out for a period of four months from 15th April to 15th August, 2010 at the Fisheries Field Laboratory, Bangladesh Agricultural University,

Mymensingh. Nine rectangular earthen ponds with an area of 130 m^2 and an average depth of 1.5 m each were used for this study.

The trial was conducted in a completely randomized design into three different treatments with three replications each. Stocking density of prawn (*Macrobrachium rosenbergii*) and silver carp (*Hypophthalmichthys molitrix*) was same in all treatments. The differences of different treatments were stocking density of tilapia (*Oreochromis niloticus*). The stocking densities of tilapia (*O. niloticus*) were 10,000; 15,000 and 20,000 ha^{-1} in treatment T_1, T_2, T_3, respectively. Feed for prawn was supplied in all treatments and bamboo *kanchi* were provided for developing periphyton.

All ponds were drained out and prepared by removing weeds, predators and other fishes from the ponds. Afterwards, the ponds were treated with agricultural lime @ 1kg/dec. (250 kg ha^{-1}). Prawn juvenile (5.27 g), tilapia fry (0.42 g) and silver carp fingerlings (9.21) were stocked on 15 April 2010. Prior to the formulation of a diet, the proximate composition of feed ingredients was analyzed in triplicates according to AOAC (1990). A diet was formulated containing C/N ratio close to 20 using fishmeal (15%), soybean meal (20%), mustard oil cake (20%), rice bran (20%), maize flour (20%), vitamin-mineral premix (1%) and molasses (4%). Feeding rate was calculated from the average weight of prawn after each sampling. The feed was applied at a daily feeding rate of 10% body weight at the beginning the experiment (up to 30 days), and assuming 80% survival feed application was gradually reduced (3% of body weight for 2nd month, 2% of body weight for 3rd month and 2% of body weight for 4th month) to 3% body weight at the end of the culture period. The pre-weighed maize flour was uniformly distributed over the pond's surface directly after the feed application.

Throughout the experimental period, the water quality parameters were recorded weekly and monthly. Transparency and temperature determined on the spot. Transparency (cm), water temperature (^oC), pH and dissolved oxygen (mg l^{-1}) were measured every week in the late morning. Total alkalinity, Ammonia-nitrogen (mg l^{-1}), Nitrate-nitrogen (mg l^{-1}), Nitrite-nitrogen (mg l^{-1}), Phosphate-phosphorous (mg l^{-1}) and Chlorophyll- *a* (µg l^{-1}) were measured monthly at Water Quality and Pond Dynamics Laboratory of the Faculty of Fisheries, and were also measured on monthly basis in Central Laboratory, Bangladesh Agricultural University, Mymensingh. Plankton, benthos and periphyton abundance were also measured monthly basis. For the calculation of feeding rate, sampling was done monthly using a cast net and hand picking.

All the fishes were harvested after completion of the experiment on 15 August, 2008. They were weighed, measured and counted separately to evaluate the growth performance and survival rate. Individual weight gain was calculated by deducting the average initial weight from the average final weight. Specific growth rate was calculated as follows:

Specific growth rate (% bw day^{-1}):

$$\text{SGR (\% per day)} = \frac{\log_e W_2 - \log_e W_1}{T_2 - T_1} \times 100$$

Where,
W_1 = Initial live prawn body weight (g) at time T_1 (day)
W_2 = Final live prawn body weight (g) at time T_2 (day)

For statistical analysis of collected data, one-way analysis of variance (ANOVA) and Duncan Multiple Range Test was performed using the SPSS (Statistical Package for Social Science, version-11.5). Significance was assigned at the 0.05% level.

Results and discussion

Water quality parameters

Temperature of pond water was found to be more or less similar in different treatments and was not varied significantly (Table 1). The range of water temperature varied from 25.9 to 34.5 ºC in all the treatments and found to be more or less similar with the observation of Rahman (2005) and Kunda *et al.* (2008) who recorded temperature ranges from 26.0 to 35.0 and 22 to 34^{o}C, respectively.

Water transparency ranged from 24to 64cm which was more or less similar with the findings of Uddin (2002) who recorded transparency of 11 cm - 63.5 cm from the ponds in BAU campus. A significant difference ($p<0.05$) in transparency was observed among the treatments (Table 1). Dissolved oxygen concentration in different treatments varied from 3.0 to 9.0 mg l^{-1} was more or less similar to the findings of Ahmed (2004) who recorded DO ranged from 3.4 to 8.1 mg l^{-1}.

The range of pH value varied from 6.9 to 8.9 was more or less similar to findings of Alam *et al.* (1997) who found pH values ranges from 7.0 to 9.0. During the study, other water quality parameters such as total alkalinity (50-190 mg L^{-1}), chlorophyll-*a* (44.03-201.11µg L^{-1}), NO_3-N (0.01-0.53 mg L^{-1}), NO_2-N (0.00-0.15 mg L^{-1}), NH_3-

N (0.08-0.30 mg L^{-1}) and PO_4-P (0.05-2.09 mg L^{-1}) were within the suitable range for fish culture and more or less similar among the treatments.

Table 1. Mean (±SD) values of measured water quality parameters

Variables	Treatments			ANOVA (*P* value)
	T_1	T_2	T_3	
Temperature (^oC)	29.49 ± 1.64	29.31 ± 1.54	29.44 ± 1.55	NS
Transparency (cm)	38.70 ± 7.13^b	40.22 ± 7.46^{ab}	42.19 ± 8.20^a	*
pH range	7.57 ± 0.40	7.73 ± 0.44	7.69 ± 0.40	NS
DO (mg L^{-1})	5.31 ± 1.37	5.75 ± 1.36	5.53 ± 1.39	NS
Total Alkalinity	109 ± 45.13	119 ± 47.52	109 ± 42.52	NS
Total NH_3-N (mg L^{-1})	0.17 ± 0.06	0.16 ± 0.05	0.17 ± 0.06	NS
NO_3-N (mgL^{-1})	0.11 ± 0.13	0.08 ± 0.05	0.09 ± 0.07	NS
NO_2-N (mg L^{-1})	0.02 ± 0.01	0.03 ± 0.04	0.04 ± 0.03	NS
PO_4-P (mgL^{-1})	0.70 ± 0.30	0.76 ± 0.39	0.82 ± 0.42	NS
Chlorophyll *a* (µg L^{-1})	144.31 ± 45.70^a	118.60 ± 40.15^{ab}	102.10 ± 50.10^b	*

NS = Values are not significantly different (*P> 0.05*)
* = Values for treatments with different superscript letters in the same row indicate a significant difference (*P< 0.05*) based on one-way ANOVA followed by Duncan test.

Plankton and benthos population

Plankton population was identified upto genus level (Table 2). About 35 genera of phytoplankton belonging to Chlorophyceae (14), Bacillariophyceae (11), Cyanophyceae (08) and Euglenophyceae (02) and 12 genera of zooplankton belonging to Crustacea (07) and Rotifera (05) were identified. Plankton (phytoplankton and zooplankton) abundance was lower in treatment T_3 than T_2 and T_1 .The mean abundance of benthos was found to range from 593 to 2,460, 741 to 2,415 and 548 to 2,133 with the mean values of 1,261 ± 541, 1,311 ± 43 and 1,096 ± 458 for treatments T_1, T_2 and T_3, respectively. Abundance of benthos in treatment T_3 was very low in the present study, which in accordance with th findings that, Tilapias are omnivores and capable of feeding on benthic and attached (periphyton) algal and detrital aggregates (Dempster *et al.* 1993, Azim *et al.* 2003a).

Table 2. Mean abundance ($\times 10^3$ cells L^{-1}) of plankton and benthos with their different groups among different treatments

Variables	Treatments			ANOVA significance
	T_1	T_2	T_3	
Total phytoplankton	56.93 ± 7.57	53.83 ± 11.74	49.77 ± 8.95	NS
Total Zooplankton	14.03 ± 5.88	12.93 ± 5.12	13.17 ± 5.73	NS
Total plankton	70.97± 12.50	66.77 ± 12.88	62.93 ± 12.07	NS
Chironomidae	435.56 ± 356.56	493.83 ± 277.82	350.62 ± 254.99	NS
Oligochaeta	409.88 ± 250.27	404.94 ± 209.34	386.17 ± 237.86	NS
Mollusca	352.59 ± 216.23	336.79 ± 146.82	303.21 ±108.12	NS
Unidentified	63.21± 33.35	75.06 ± 36.49	56.30 ± 19.56	NS
Total benthos	1261.23±540.60	1310.62±429.77	1096.30±458.20	NS

NS = Values are not significantly different (*P> 0.05*)
* = Values with different superscripts in the same row indicate a significant difference

Periphyton biomass

The quantitative production of periphyton was determined as dry matter (DM), ash free dry matter (AFDM) and chlorophyll- *a* (Table 3). The periphyton biomass increased in the first month followed by a continuous decrease until the end of the experiment may be accounted for by changes in the prawn and tilapia grazing pressure on periphyton. The low biomass of prawn and tilapia initially exerted low grazing pressure allowing periphyton to grow. As prawn and tilapia grew, their increased grazing pressure led to reduced periphyton biomass.

Table 3. The recorded monthly mean values of periphyton biomass (± SD) in different treatments

Variables	Treatments			ANOVA (*P* value)
	T_1	T_2	T_3	
Dry matter (mg cm^{-2})	3.04 ± 0.68^a	2.26 ± 0.88^b	1.48 ± 0.90^c	*
Ash (mg cm^{-2})	1.20 ± 0.29^a	0.91 ± 0.39^b	0.63 ± 0.43^c	*
Ash free dry matter (mg cm^{-2})	1.83 ± 0.69^a	1.35 ± 0.65^b	0.85 ± 0.62^c	*
Chlorophyll-*a*	13.78 ± 3.97^a	10.25 ± 3.88^b	6.88 ± 5.36^c	*
Autotrophic index	134.00±44.32	132.67±52.23	132.43±40.18	NS

NS = Values are not significantly different (p> 0.05)
* = Values for treatment with different superscript letters in the same row indicate a significant difference

Growth and production performance of freshwater prawn, silver carp and tilapia

Average individual weight of tilapia at harvest differed significantly ($p<0.05$) among the treatments with higher value (235.46g) in the T_1 followed by T_2 (199.17g) and T_3 (178.83g). Survival rate of tilapia did not differ significantly among the treatments and ranged from 59.66 to 60.51%. The specific growth rate (SGR) of tilapia was significantly higher in treatment T_1 (5.19%) than T_2 (5.08%) and T_3 (4.96%). Gross and net yield of tilapia (kg ha^{-1}) were 1,425 and 14,22, 1,782.437 and 1,779, and 2,123 and 2,118 in treatments T_1, T_2 and T_3, respectively. Both these parameters differed significantly ($p<0.05$) among the treatments with higher value in treatment T_3 followed by treatments T_2 and T_1. On the contrary, Growth and yield parameters including individual harvesting weight, individual weight gain, specific growth rate, gross and net yields of prawn and silver carp did not vary significantly ($p>0.05$) among the treatments. However, the net production of organic prawn was higher (668 kg ha^{-1}) in T_3 than in T_2 (648 kg ha^{-1}) and T_1 (640 kg ha^{-1}). In addition, when combined production of all three species were compared, it was found that treatment T_3 resulted in significantly higher net production (3,196 kg ha^{-1}) than those of T_1 (2,797 kg ha^{-1}) and T_2 (2,393 kg ha^{-1}).

Production and growth performance of freshwater prawn silver carp and tilapia showed that treatment T_3 achieved best results in terms of total yield and survival rate. Production of tilapia increased with increasing density although the individual weight decreased. Asaduzzaman *et al.* (2006a) reported that annual production of freshwater prawn was 412 kg ha^{-1} in monoculture and 390 kg ha^{-1} in polyculture with finfish (660 kg ha^{-1}) in the southeast region of Bangladesh which was lower compared to the present study. However, Kurup and Ranjeet (2002) reported that production from polyculture system ranged between 70 to 500 kg ha^{-1} of freshwater prawn and 200 to 1200 kg ha^{-1} of fish.

Economic analysis

Total input cost (fixed cost and variable cost) with bank interest of the fish culture under the experiment were Tk. 332,114± 40, 342,571 ± 27 and 353,096 ± 28 ha^{-1} 122 d^{-1} in treatment T_1, T_2 and T_3, respectively. The total cost was significantly higher in treatment T_3 than in treatment T_1 and T_2 .The total net return were significantly higher in treatment T_3 (178,321 ± 7,441) than in T_2 (155,551 ± 5,423) and T_1 (133,861 ± 6,502). It is hypothesized that the periphyton grown on bamboo surface was a readily available feed, which might have enhanced the growth and production rate of tilapia and freshwater prawn. Higher BCR was obtained in treatment T_3 (0.53

± 0.02) followed by T_1 (0.42 ± 0.02) and T_2 (0.48 ± 0.02), respectively, which indicated that stocking density of tilapia affected the economic return positively.

Table 4. Growth and production performance (Mean ± SD) of prawn, tilapia and silver carp in different treatments

Variables	Treatments			ANOVA Sig. (*P* value)
	T_1	T_2	T_3	
M. rosenbergii				
Individual stocking weight (g)	5.27 ± .00	5.27 ± 0.00	5.27 ± 0.00	NS
Individual harvesting weight (g)	34.0 ± 1.05	34.40 ± 0.80	34.80 ± 1.31	NS
Individual weight gain (g)	28.73 ± 1.05	29.13 ± 0.80	29.53 ± 1.31	NS
Specific growth rate (% bw d^{-1})	1.53 ± 0.03	1.54 ± 0.02	1.55 ± 0.03	NS
Survival (%)	75.56 ± 2.07	74.10 ± 1.18	74.27 ± 1.55	NS
Gross yield (kg ha^{-1} 122 d^{-1})	757.42 ± 20.53	764.62 ± 13.47	787.67 ± 27.83	NS
Net yield (kg ha^{-1} 122 d^{-1})	640.00 ± 20.26	647.46 ± 13.55	668.35 ± 27.00	NS
O. niloticus				
Individual stocking weight (g)	0.42 ± 0.00	0.42 ± 0.00	0.42 ± 0.00	NS
Individual harvesting weight(g)	235.46 ± 2.63[a]	199.17 ± 6.52[b]	178.83± 5.71[c]	*
Individual weight gain (g)	235.04 ± 2.63[a]	198.75 ± 6.52[b]	178.41 ± 5.71[c]	*
Specific growth rate (% bw d^{-1})	5.19 ± 0.01[a]	5.05 ± 0.03[b]	4.96 ± .03[c]	*
Survival (%)	60.51 ± 1.18	59.66 ± 1.07	59.36 ± 0.80	NS
Gross yield (kg ha^{-1} 122 d^{-1})	1424.91 ± 35.0[c]	1782.47 ± 73.44[b]	2122.52 ± 43.04[a]	*
Net yield (kg ha^{-1} 122 d^{-1})	1422.36 ± 34.95[c]	1778.71 ± 73.40[b]	2117.53 ± 43.09[a]	*
H. molitrix				
Individual stocking weight (g)	9.21 ± 0.00	9.21 ± 0.00	9.21 ± 0.00	NS
Individual harvesting weight(g)	267.49 ± 34.43	312.60 ± 54.92	330.46 ± 59.91	NS
Individual weight gain (g)	258.28 ± 34.43	303.39 ± 54.92	321.25 ± 59.91	NS
Specific growth rate (% bw d^{-1})	2.76 ± 0.10	2.88 ± 0.15	2.93 ± 0.15	NS
Survival (%)	98.04 ± 3.40	94.12 ± 5.88	98.04 ± 3.40	NS
Gross yield (kg ha^{-1} 122 d^{-1})	341.92 ± 31.49	382.36 ± 51.31	422.05 ± 62.86	NS
Net yield (kg ha^{-1} 122 d^{-1})	330.11 ± 31.90	371.02 ± 51.79	410.24 ± 63.21	NS
Combined				
Gross yield (kg ha^{-1} 122 d^{-1})	2524.25 ± 16.64[c]	2929.44 ± 75.86[b]	3332.24 ± 70.02[a]	*
Net yield (kg ha^{-1} 122 d^{-1})	2392.47 ± 17.97[c]	2797.19 ± 78.35[b]	3196.13 ± 73.15[a]	*
Contribution to yield				
Prawn net yield (kg ha^{-1} 122 d^{-1})	26.75 ± 0.67[a]	23.16 ±.0.86[b]	20.93 ±.1.21[c]	*
Tilapia net yield (kg ha^{-1} 122 d^{-1})	59.46 ± 1.86[b]	63.59 ± 1.96[a]	66.26 ± 0.61[a]	*
Silver carp net yield (kg ha^{-1} 122 d^{-1})	13.79 ± 1.23	13.65 ± 1.68	12.82 ± 1.77	NS

NS = Values are not significantly different (*P> 0.05*)
* = Values for treatments with different superscript letters in the same row indicate a significant difference (*P< 0.05* based on one-way ANOVA followed by Duncan test.
* bw = Body weight
* d = day

There was no adverse change on the water quality parameters due to different stocking of tilapia during study period. Inclusion of tilapia did not affect the growth and production of silver carp and prawn. The results revealed that an addition of tilapia at a density at 20,000 ha^{-1} increased the production of prawn as well as silver carp, and thus contributed to earn higher net profit (Tk. 1,78,321 ha^{-1}) with a BCR of 0.53. It may be concluded that the polyculture of prawn, tilapia and silver carp at the stocking densities of 30,000, 20,000 and 1,250 ha^{-1}, respectively provided the higher net production and economic benefit, and may be recommended for on-farm periphyton-based pond polyculture.

References

Ahmed, H. (2004). Promotion of small indigenous fish species (SIS)-mola based carp polyculture technology at Gazipur area of Bangladesh. M.S. dissertation, Dept. of Fisheries Management, Bangladesh Agricultural University, Mymensingh, 85 pp.

Alam, M.J., Hoq, M.E., Jahan, D.A. and Mazid, M.A. (1997). Nursery rearing of *Macrobrachium rosenbergii* (de Man) using hapa-nets: effects of stocking density. *Bangladesh J. Fish. Res.,* 1(1): 09-16.

AOAC (Association of Official Analytical Chemists). (1990). Official Methods of Analysis of the Association of Official Analytical Chemists. 13th edition, Washington, D. C. 1018 pp.

Asaduzzaman, M., Yang Yi, Wahab, M. A., James S. Diana and Ahmed, Z. F. (2006a). Farming system of giant freshwater prawn *Macrobrachium rosenbergii* in Bangladesh: a combination of tradition and technology. Proceeding of the WAS Conference (AQUA 2006) held on 9-13 May in Florence, Italy.

Azim, M.E., Verdegem, M.C.J., Singh, M., van Dam, A.A. and Beveridge, M.C.M. (2003a). The effects of periphyton substrate and fish stocking density on water quality, phytoplankton, periphyton and fish growth. *Aquaculture Research,* 34: 685-695.

Balarin, J. D. and Haller, R. D. (1982). The intensive culture of tilapia in tank, race ways and cages. *In*: Muir, J. F. and R. J. Roberts (ed.). Recent advances in Aquaculture, West view press, Boulder, Colorado, USA. pp. 265-355.

Beharrell, B. and MacFie, J. H. (1991). Consumer attitudes to organic foods. *British Food Journal,* 93 (2): 25-30.

Cudjoe, F. and Rees, P. (1992). How important is organic farming in Great Britain? Rijdschrift voon Econ. En. Soc. Geografie, 83 (1): 13-24.

Dempster, P.W., Beveridge, M.C.M. and Baird, D.J. (1993). Herbivory in the tilapia *Oreochromis niloticus*: A comparison of feeding rates of phytoplankton and periphyton. *J. Fish Biol.,* 43: 385-392.

Dey, M.M. (2001). Tilapia production in South Asia and the Far East. *In*: Subasinghe, S. and T. Singh (eds), Tilapia production, marketing and technological development. International Technical and Trade Conference on Tilapia, 28-30 May 2001, Kuala-lumpur, Malaysia. pp. 17-26.

Fearne, A. and Lavelle, D. (1996). Segmenting the UK egg market: results of a survey of consumer attitudes and perceptions. *British Food Journal,* 98 (1): 7-12.

Haglund, A., Johannson, L., Berglund, L. and Dahlstedt, L. (1999). Sensory evaluation of carrots from ecological and conventional growing systems. Food Quality and preference, 10 (2): 23-29.

Haung, C. L. (1995). Consumer preferences and attitudes towards organically grown produces, European Review of Agricultural Economics, 23 (3): 331-342.

Khondaker, H.R. (2009). Prawn (golda), hatchery development in Bangladesh: problems and potentials. National workshop on freshwater prawn farming in Bangladesh: Technologies for sustainable production and quality control. 9 July, 2009. Dhaka, Bangladesh. p.11.

Kunda, M., Azim, M.E., Wahab, M.A., Dewan, S., Roos, N. and Thilsted, S.H. (2008). Potential of mixed culture of freshwater prawn (*Mascrobrachium rosenbergii*) and self-recruiting small species mola (*Amblypharyngodon mola*) in rotational rice-fish/prawn culture systems in Bangladesh. *Aquaculture Research,* 39: 506-517.

Kurup, B.M. and Ranjeet, K. (2002). Integration of Freshwater Prawn culture with rice farming in Kuttand, India. Naga, 25: 16-19.

Rahman, S.M.S. (2005). Effect of stocking density of gift strain of nile tilapia (*Orechromis niloticus*) and freshwater prawn (*Macrobrachium rosenbergii*) in periphyton based production system. M.S. dissertation, Dept. of Fisheries Management, Bangladesh Agricultural University, Mymensingh. 84 pp.

Uddin, M.M. (2002). Effects of addition of small fish on pond ecology and production in polyculture. M.S. thesis, Depat. of Fisheries Management, BAU, Mymensingh. 99 pp.

Wahab, M.A. (2009). Freshwater Prawn (Golda Chingri) Farming in Bangladesh: Technologies for Sustainable Production and Quality Control. *In:* Wahab M.A. and M.A.R. Hossain (eds). Abstracts. National Workshop on "Freshwater Prawn (Golda Chingri) Farming in Bangladesh: Technologies for Sustainable Production and Quality Control". 9 July 2009, Dhaka, Bangladesh. 32 pp.

Community based fish sanctuaries: improving fish biodiversity and protects inland fisheries of Bangladesh

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Abstract: The knowledge has been applied to conserve fish production and reduce the climate change threats to fisheries biodiversity, and has been successfully adopted over 500 waterbodies under co-management in Bangladesh. The majority of surveyed sites with established sanctuaries indicated that the fishing effort of fishers and other destructive activities has decreased while there is a reasonable increase in their total fish catch. Generally, this has led to a higher biodiversity and to an increasing trend on the abundance of critically endangered, endangered and vulnerable fish species in the sanctuary sites. The co-management initiatives have achieved a positive acceptance of fish sanctuaries establishment and management at community level. Based on consensus, concerned communities formed Community Based Organizations (CBOs) to implement wetland resource management and conservation activities to reduce the climate change threats to fisheries biodiversity. Local government and administration also responded positively towards wetland resources in order to sustain biodiversity and support livelihoods. However, there is lack of national legislation pertinent to fish sanctuaries in the country . The key challenge during the initial stages of the co-management initiative was to convince the community to participate and invest their time and effort in setting up and managing fish sanctuaries. This was done through massive awareness raising campaign with MACH, CBFM, CBFM-SSEA, FFP, SCBRMP, SEMP and DWMP projects. Present study reveals that sanctuaries provide protection and play a significant role in reducing effect of climate change. Scale up of sanctuary program would reduce climate change threats for hundreds of water bodies in Bangladesh and stability in nutritional security of the poor people. Simultaneously, biodiversity of fish species would also increase and that might ensure resource sustainability at water body level. There is also a need to work at the transboundary level to implement biodiversity management policies to protect aquatic resources and mitigate climate change threats.

Introduction

In Bangladesh, human activities and annual environmental effects e.g., dry season and flooding continue to cause considerable damage to the production of inland freshwater ecosystems. Among the human activities, fishing activities is more likely to damage fish stocks and habitats and some fishing methods have been criticized as being environmentally damaging (Andrew and Pepperell 1992). The collection of fish fry during pre-monsoon season is one example of a fishing method which negatively impacts the inland open water fisheries production. In addition, rivers, which are open access and lease-free and have many poor fishers depending on its resources for livelihood, are affected with heavy siltation during the rainy seasons. Oversiltation destroys the natural fish habitat and is known to be detrimental to the growth and development of major carp species. In 2000, a study by IUCN revealed that fifty-four of the major inland fish species in Bangladesh are threatened at varying degree. Among the commonly cited causes for the deterioration of the fishery resources is the loss of fish habitat, largely caused by the construction of roads, embankments, drainage, flood control and occurrences of natural siltation, along with over fishing (Hughes *et al.* 1994, Ali 1997).

Through the Community Based Fisheries Management (CBFM) project, pilot-scale community-managed fish sanctuaries were established. The goal of the project is to empower communities by giving them the means to make informed and appropriate decisions on how the fisheries they depend on day to day are to be safeguarded for ongoing productivity. Under the project, 164 fish sanctuaries were established in 81 of the total 116 project water bodies covering a total area of almost 91 hectare (Malcolm and Usha 2007) (Fig. 1). Number of fish sanctuaries established was 27, 14, 60 and 63 for open *beel*[1], closed *beel*, floodplain and river habitats respectively. These sanctuaries covering a total area of 33.11 ha, 11.45 ha, 10.65 ha and 36.15 ha for open *beel*, closed *beel*, floodplain and river habitats respectively.

Present study covers the types of fish sanctuaries found in Bangladesh and the ecological and social condition which promotes the adoption of fish sanctuaries as a management strategy. Fish sanctuaries are not panaceas for solving all the inland fisheries problems, but if the sanctuaries are implemented with full support from local community, in tune with local ecological conditions, and are appropriately scaled, then it could be useful for assisting in the management and protection of freshwater fish stocks (Baird 2006).

[1] Floodplain usually with a permanent water body in lowest part

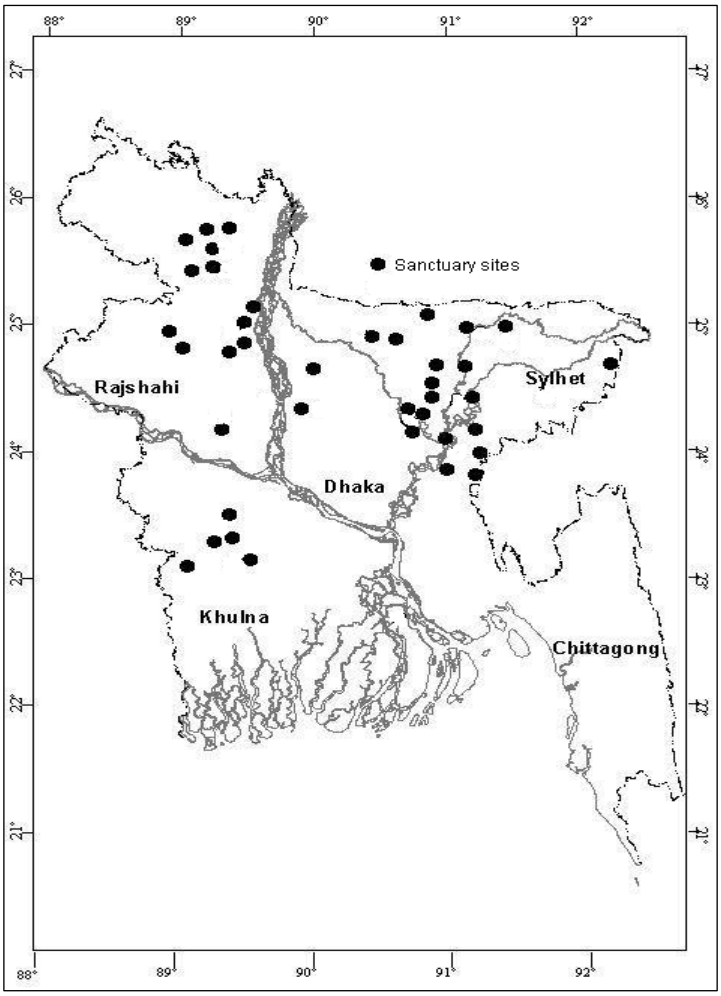

Fig. 1. Distribution of sanctuary sites under CBFM project in Bangladesh.

Community managed fish sanctuaries

Fish sanctuaries play an important role in the development of inland water bodies as they positively contribute to the production of inland fisheries. A previous study indicate that the small scale fish sanctuaries established in small ditches have demonstrated a 6 fold increase in fish production and icthyodiversity during the first year and species diversity increased from 46 to 59 percent (CNRS Annual report 1996).

The challenge was to convince the community that fish sanctuaries will benefit them in long term, mainly through the increase of fish production and the revival of native fish species. Through the CBFM project, a community led approach was adopted in establishing and managing fish sanctuaries in selected project sites. This approach includes the involvement and delegation of responsibilities to communities at all stages of the sanctuary establishment and its operation.

In Bangladesh, there is lack of national legislation specifically related to fish sanctuaries. Many of the fish sanctuaries have been established through various community action projects which aims to restore fish habitat for conservation and resource enhancement purposes, namely, the CBFM project of the WorldFish Center and DoF, USAID supported Management of Aquatic Ecosystems through Community Husbandry (MACH) project in Kaliakoir, Sherpur and Sreemangal; Dampara Water Management Project (DWMP) in Netrokona, to name a few. Some study sites have demonstrated that fish sanctuaries have led to the improvement in open water fisheries production (Khabir and Munir 2002) and this will benefit the poorer section of the community whom mainly depend on subsistence fishing from these common property resources.

Traditional fish sanctuaries are indigenous structural devices constructed using bamboo, tree branches and water hyacinths which serve to protect and support a high diversity of fish species. These fish sanctuaries are mainly constructed in the deeper water areas of the rivers, *beels*, or reservoirs as large number of fingerlings (baby-fish) and other fish species is known to congregate in these sections of the water bodies for breeding (Jingran 1984). In Bangladesh, traditional fish sanctuaries are constructed during the raining season for when the flood water begins to recede, and as the winter season begins, the fishes will move to the deeper areas of the water (Khabir and Munir 2002). The average cost of setting up a sanctuary is Taka 400 per decimal (approximately US$ 6.00 for every 0.01 hectare). Some areas could be 25 decimal and some as large as 200 decimal. As part of rehabilitating earlier established sanctuaries, tree trunks have been placed in to create a better and more convenient artificial habitat during the dry season as well as providing more spawning areas for many fish species.

Fish sanctuaries are aquatic protected areas to mitigate key biodiversity threats, which generally require the restriction of some or all fishing activities, either year round or seasonally. These sanctuaries have specific rule and norms, either written or non-written, and these are often enforced through local institutions able to apply sanctions to punish violators. Through the CBFM project, partner organizations of the project which includes the WorldFish Center, 9 local NGOs and the DoF were

responsible for establishing community groups, locally called as Community Based Organizations (CBOs). Under the CBOs, specific water body management committees, e.g. *Beel* or River Management Committees (BMC or RMC) had the responsibility to form and manage the fish sanctuaries and develop a trust-base relationship with fishers to adhere the fishing restriction call in the protected areas.

The CBFM project played a major role in promoting the importance and purpose of fish sanctuaries through various trainings related to awareness, regulation and enforcement of fish sanctuaries for CBO members. In addition, public awareness in the form of posters, sign boards, news letters and folk theatres were used to promote the benefits of establishing and sustaining fish sanctuaries. Ideally, majority of the study site communities are currently supporting the idea or concept of sanctuaries and this is proven through the minimum or nil presence of enforcement in all the CBFM project sites with established fish sanctuaries.

Materials and methods

Most of the fish sanctuaries established under the CBFM project was constructed on government owned water bodies. However, some of the sanctuaries were also constructed on leased or sub-leased water bodies by the project beneficiaries. Typical, in Bangladesh fish sanctuaries are marked with the presence of red flags surrounding the sanctuaries.

Fish sanctuary impact data were collected from three predominantly types of sanctuaries under CBFM projects areas. These are *beel* sanctuaries, floodplain sanctuaries and river sanctuaries.

Assessing the changes in total and type of fish caught and the effort used to fish during pre-sanctuary and post-sanctuary is important as it will indicate if sanctuary establishments are beneficial to the community. Hence, several assessments on the productivity of fish sanctuaries in selected CBFM sites were conducted.

Fish sanctuaries versus non-sanctuaries

Fish sanctuary monitoring was conducted in 7 beels under CBFM project, namely i) Kaheterdia beel, ii) Masti beel, iii) Neula beel, iv) Patlakuri beel, v) Kai beel, vi) Pabda beel and vii) Bannait beel as project sites in sub-district Pakundia of Kishorganj district. Simultaneously monitoring also conducted in 3 non-project beels namely i) Agartallai beel, ii) Bejurnala beel and iii) Gorabate beel in Pakundia of Kishorganj district. A comparative analysis of the impact of fish sanctuaries was

conducted between seven project sites, all of which had fish sanctuaries established for at least one year and three non-project sites which had no sanctuaries established. Specific data on the type and number of fish species was collected using a standard push net. Push net is a type of fishing gear commonly used to collect juvenile and small fishes. The data included catch from different water depth around the submerged sanctuary areas during the pre-monsoon season (March to May).

Before and after the establishment of fish sanctuaries

Catch monitoring is a survey which records the total fish caught by each gear used in a fishing operation over a period of time. Based on these data, the fishing effort of fishers fishing in the water bodies with sanctuaries is estimated. The catch monitoring data was collected one year before the establishment of fish sanctuaries and one year after the establishment of fish sanctuaries.

A comparison of catch per unit effort (CPUE) and fish production was made during pre-sanctuary and post-sanctuary periods (one year for each period). The study sought to determine the impact of sanctuary on key management performance indicator of fish production and CPUE. Three approaches were adopted; firstly an examination of catch and CPUE trends, secondly production comparison before and after sanctuary establishment and thirdly a control comparison of catch and CPUE (performance indicators) using general linear models (GLM).

Using observations for 8 sites (Titas River G-G part, Titas River Ka part, Pagla nodi (River, Arial kha river, Kali nodi (River), Moisharkandi River, Kutir beel and Goakhola-Hatiara) during pre-sanctuary and post sanctuary, the response on fish abundance (CPUE) was examined.

Results and discussion

Fish sanctuaries versus non-sanctuaries: a comparative analysis

In addition, a comparative analysis of the impact of fish sanctuaries was conducted between seven CBFM water bodies, all of which had fish sanctuaries established for at least one year and three water bodies which had no sanctuaries established. Specific data on the type and number of fish species was collected using a standard push net. The data included catch from different water depth during the pre-monsoon season (March to May).

The average weight of juvenile fish caught in the water bodies with sanctuaries was 174 g per sample compared to 24g per sample in water bodies without sanctuaries, suggesting that juvenile fish are much more abundant in protected sanctuaries. This was further proven when an average count of 799 specimens of various fish species per sample were caught in water bodies with sanctuaries compared to 167 specimens of fish species in water bodies without sanctuaries (table 1). Highest abundance of juvenile was observed between size class 1-10 mm and 11-20 mm.

Table 1. Abundance of juvenile fish species in sites with sanctuaries and without sanctuaries

Species length class (mm)	Number of species		Number of specimens	
	Site with sanctuaries	Site without sanctuaries	Site with sanctuaries	Site without sanctuaries
01 – 10	45	21	352	69
11 – 20	47	24	335	54
21 – 30	47	23	83	30
> 30	45	15	29	13
All classes	48	25	799	167

Species composition also varied. A total of 48 species was recorded in the water bodies with sanctuaries and 25 species in non-sanctuary water bodies which indicating higher abundance of juvenile species in the sites with established fish sanctuaries. Among the identified juvenile species - small prawns (*Nematopalaemon tenuipes, Macrobrachium malcolmsonii, Macrobrachium birmanicum* and other unidentified *Macrobrachium spp.*) represented by 46.97 percent of the total catch in sites with sanctuaries. In non-sanctuary sites, the total catch of small prawns represented by 78.88 percent, indicating sanctuary plays better aquatic habitat when compared with non-sanctuary sites with lower abundance of fin fishes (M. Julian Caley *et al*. 2001). The poor quality of fish habitat in non-sanctuary sites is further established with the very low presence (0.01 percent) of the highly environment-sensitive fish species - *Channa punctatus* (Taki) compared to a higher presence (29.31 percent) in sites with established fish sanctuaries.

Before and after the establishment of fish sanctuaries

Increase in fish productivity

In two of the *beels* sanctuaries the average annual fish production during the baseline year (June to Dec 2002) was 22.74 kg/hectare which then increased by almost 148% by the 2nd year (June 2004 to Dec 2004) of the sanctuary establishment. Simultaneously, the average annual fish production in two of the surveyed river

sanctuaries was 86 kg/ha during the baseline year (June to Dec 2002), which than increased to 140 kg/ha by the 2nd year and increased by 63% (figure 2). The increasing production trend suggest that fish species are likely to benefit from the establishment of sanctuaries in the water bodies, as they are protected during particularly important or vulnerable parts of their life cycle.

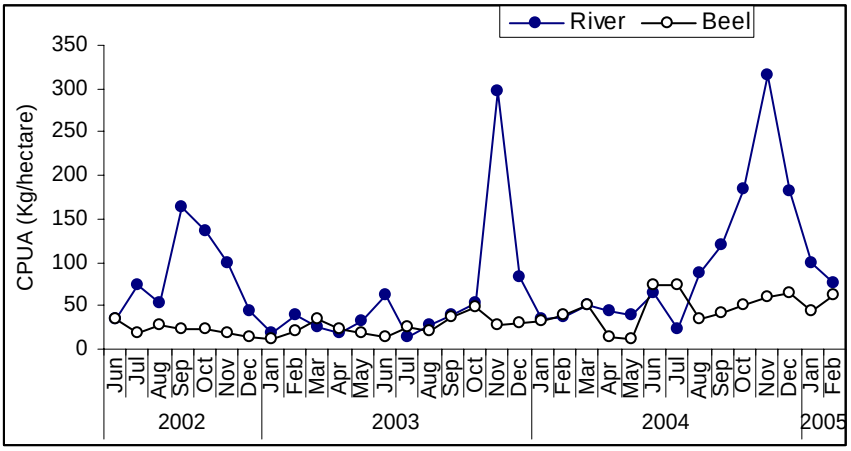

Fig. 2. Estimated fish catch (kg) trend in both *beel* and river sections (2002 is the sanctuary establishment year; 2003 and 2004 is the 1st and 2nd impact year.

Improvement in fish biodiversity and composition

The eight surveyed sites (Titas River G-G part, Titas River Ka part, Pagla nodi (River, Arial kha river, Kali nodi (River), Moisharkandi River, Kutir beel and Goakhola-Hatiara) indicated that 44 different species of fish had benefited from the establishment of fish sanctuaries, the most commonly reported ones being the Tengra (*Batasio tengara*), Pangus (*Pangasius pangasius*), Golda Icha (*Machrobrachium rosenbergii*), Batasi tengra (*Batasio batasio*), Sharputi (*Puntius sarana*), Tepa (*Tetraodon cutcutia*), Kalibaus (*Labeo calbasu*), Anju (*Danio reio*), Gachua (*Channa oriantalis*), Ekthota (*Dermogenys pusillus*)), closely followed by the (Chanda (*Parambassis ranga*), Khalla (*Rhinomugil corsula*), Kajuli (*Ailia panctata*), Dimua Icha (*Macrobarchium birmanicum*), Baghair (*Bagarius bagarius*), Bara Baim (*Mastacembalus armatus*), Foli (*Notopterus notopterus*), Kholisa (*Colisa fasciatus*), Pabda (*Ompok pabo*), Dogra Balia (*Apocryptes bato*), Lona icha (*Peneaus spp.*), Chatka Icha (*Macrobarchium macolmsonii*), Vagna Bata (*Labeo boga)*, Banspata (*Aillichthys panctata*), Lal kholisha (*Colisha lalius*), Gang tengra (*Gagata youssofi*), Chuna Koalisa (*Colisa chuna*), Madhu Pabda (*Ompok pabda*), Boal (*Wallago attu*),

Goina (*Labeo gonius*), Teri puti (*Puntius terio*), Chapila (*Gudusia chapra*), Bata (*Labeo bata*), Ghora maach (*Labeo pangusia*), Cheng (*Channa oriantalis*), Shing (*Heteropneustes fossilis*), Chatka Icha (*Macrobarchium macolmsonii*), Ekthola (*Dermogenys pusillus*), Kuicha Baim (*Monopterus cuchia*), Shol (*Channa striatus*), Ayre (*Mystus aor*), Chala puti (*Puntius chola*), Guji Ayre (*Mystus seenghala*), Gang Magur (*Plotosus canius*),.

Nine of the 16 species reported to have benefited were in the family (Cyprinidae), followed by family (Schilbaidae) and (Silurinidae). In all, 19 families of fishes, as well as small prawns, benefited from the establishment of fish sanctuaries in the *beels* and rivers.

Impact to production and biodiversity

Increase in CPUE were observed at 6 sites, but this increase was significant ($p<0.05$) only for 2 sites (Table 2). One site exhibited no change and one site exhibited decline but not significant. Using the response of fish production (Estimated monthly average production) was also examined for 8 sites during pre-sanctuary and post-sanctuary. Fish production has clearly increased during post-sanctuary periods at 7 sites, and this increase was significant ($p<0.05$) for 3 sites (Table 3). One site exhibited decline but not significant.

Eight project and 4 control sites with similar habitats were also examined during post sanctuary, using the response on CPUE and fish production only for gill net. Estimated mean fish abundance (CPUE) for project sites was 2.78 kg/day compared to 2.27 Kg/day for control sites, but the difference was not significant (P=0.135). Estimated mean fish production for project sites was 1977 Kg/month compared to 523 Kg/month for control sites and the difference was highly significant (P=0.001 and Power = 93%).

Table 2. GLM test for 8 sites during pre-sanctuary and post-sanctuary periods. Dependent variable: CPUE per day

Name of Water body	Habitat type	CPUE (Pre-sanctuary)	CPUE (Post-sanctuary)	Significant	Power (%)
Titas River G-G part	River	3.64	5.13	0.043	0.173
Titas River Ka part	River	2.03	2.006	0.933	0.0001
Pagla nodi (River)	River	3.95	4.48	0.503	0.021
Arial kha river	River	0.75	0.92	0.192	0.08
Kali nodi (River)	River	3.61	3.74	0.834	0.002

Moisharkandi River	River	2.64	2.99	0.349	0.098
Kutir beel	Open beel	1.11	2.37	0.009	0.273
Goakhola-Hatiara	Floodplain	3.85	1.63	0.297	0.077

Table 3. GLM test for 8 sites during pre-sanctuary and post-sanctuary periods (Dependent variable: Estimated average production per month)

Name of WBs	Habitat type	Est. catch (Before)	Est. catch (After)	Significant	Power (%)
Titas G-G	River	3059	5135	0.096	0.121
Titas Ka	River	242	630	0.015	0.252
Pagla nodi	River	3158	4922	0.135	0.099
Arial kha river	River	87	311	0.003	0.357
Kali nodi	River	1941	2277	0.626	0.011
Moisharkandi	River	277	423	0.291	0.123
Kutir beel	Open beel	333	1350	0.027	0.204
Goakhola	Floodplain	1039	344	0.388	0.054

Preliminary assessment of the introduction of fisheries management and habitat restoration through CBFM approaches show significant increases in fish production and trends in fish production through time were upwards at 77% of the 64 project water bodies that were monitored for at least three years without data gap (Mustafa and Halls 2007). Trends in fish abundance, indicated by annual average daily catch rates by fishers, were also upwards at 72% of monitored water bodies. Changes in biodiversity index (H') with time were found to be positive and significantly greater than in control water bodies. Species assemblages are richer and more abundant at CBFM compared to control water bodies. Trends in biodiversity were also upwards at 70% of monitored water bodies (Mustafa and Halls 2007). Preliminary assessment also show increasing trend on Critically Endanger (8), Endanger (16) and Vulnerable (12) fish species in the project sites. Impact of fish sanctuary study conducted by CNRS (Center for Natural Resource Studies) a CBFM partner NGO also indicated that along with fish catch, species diversity also increased compared to baseline year. A total of 54 species was recorded during baseline year and species diversity increased to 62 in the 1st year and 65 in the 2nd year in the beel sites. Species diversity showed no changed in the river sites during 1st year, however substantially increased from 58 to 78, occurred in the 2nd year. Results indicated that species diversity correlated with periods of sanctuary in the aquatic habitat.

Case study: Ashura beel- a community managed water body with fish sanctuary

Ashura *beel* is a perennial waterbody in Dinajpur district. Fish Sanctuary in Ashura beel under CBFM project has been established to protect inland fisheries resources and ensure more catch for fishers. BMC and local stakeholders reach consensus and formed sanctuary management committee to maintain sanctuary, protection from fish poaching and fishing in Ashura beel. In mid- 1997 to protect natural brood fish the fishers abandoned private *katas* (fish aggregating device) and made a permanent 8 hectare fish sanctuary in the deepest part of the beel, they also stopped fishing in the early monsoon to allow native fish to breed. The impacts were expected to be apparent from 1998 onwards. A total of 79 species of fish/prawn were recorded from Ashura beel during study period 1997 to 2005. Total number of species was 34 in 1997 and increased to 57 in 2005. Results indicate that three species (Jatputi- *Puntius sophore*, Bajari tengra- *Mystus tengara* and Taki- *Channa punctatus*) have increased and overall contribute 45% of catch. Another five species (Guchi biam- *Macrognathus pancalus*, Ranga chanda- *Parambassis ranga*, Katri chela- *Salmostoma acinaces*, Shing- *Heteropneustes fossilis* and Gutum- *Lepidocephalichthys guntea*) have more stable over the study periods (Figure 3). Boal- *Wallago attu* catch raised most from sanctuary during 1998 to 2001. The fish sanctuary becomes protected by the BMC and local fishers. Fishers are very happy to see fish species appearing once more when it was assumed that they had disappeared forever. These include valuable species such as meni- *Nandus nandus*, pabda- *Ompok pabda*, Batashi- *Batasio batasio* and Dhela- *Osteobrama cotio*.

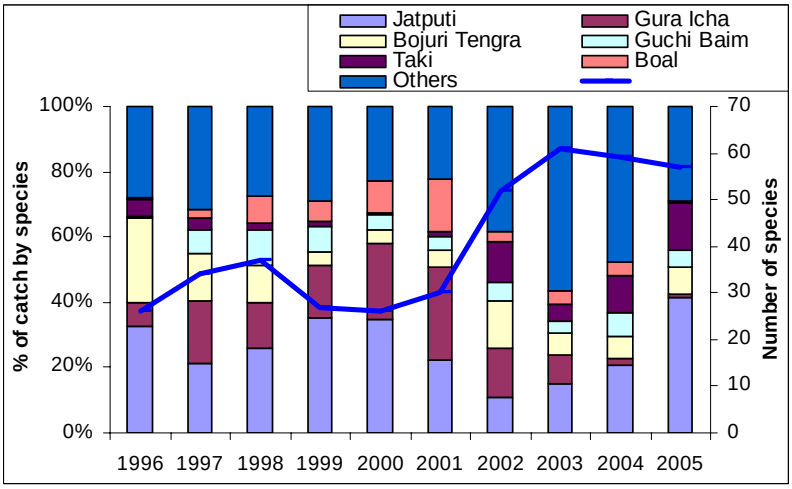

Fig. 3. Key species distribution (%) of the catch at Ashura beel.

Consensus building: Open water fishery resource systems hold multiple stakeholders in its utilization and management. So, consensus among stakeholders is an important step towards achieving sustainable fishery management. Reaching at a community consensus is considered as an important task before starting conservation or management interventions in project water bodies. CNRS (Centre for Natural Resource Studies) has used Participatory Action Plan Development (PAPD) methods to build community or stakeholders consensus over the management of project water bodies. The reflection of PAPD was that primary and secondary stakeholders of water bodies are reached in consensus to protect and conserve their fishery resources in a sustainable manner. The PAPD findings reveal that community people agreed and strongly suggested to establish fish sanctuaries in project water bodies to ensure annual replenishment of fish stock and draw an outline of resource management committee.

Community response: Positive response in both establishing and managing fish sanctuary has been found from community people. Based on consensus, concern communities formed River Management/Village Committee to implement wetland resource management and conservation activities. In Beel bhora cluster, local communities permanently contributed lands for establishing fish sanctuary and playing active role in reducing harmful fishing activities in both sites. According to local people, they did not know about the sanctuaries and its role in enhancing fish production but now almost all villagers are aware about its importance and willing to protect fish sanctuaries from any undesirable situation. For instance, local community with the help of *union parishad* protected their fish sanctuary from *bauth* fishing (force fishing) which once used to happen annually.

Community guarding: To protect fish sanctuary from fishing and stealing, concerned CBOs have been looking after their sanctuaries. Besides, community people are also taking care of there fish sanctuaries who have been motivated from massive awareness campaign.

Views of local government (Union Parishad or Upazila): Local government and local administration has a great role to play in managing wetland resources in a sustainable way. In both sites, local government and local administration responded positively towards project implementation.

Problems and constrains

There is no enough area to establish sanctuary in all water bodies. Adequate water height is also found not available in some places. These small scale fish sanctuaries are not sufficient to support large size fish species like fresh water shark (*Wallago*

attu). Sometimes over fishing in the areas poses threat to sanctuary stock. Siltation, high velocity of river current etc are physical problems to keep *katha* in the river section round the year. Regular money required to maintain fish sanctuaries. Management committees should have fund for the said purpose. Tree branches are costly and have low stabilities. Tree branches should be refilled again into the sanctuary during post-monsoon. When water area becomes squeezed, predation increased, causes total fish stock decreasing in sanctuary.

Conclusions and recommendation

Fishers often report that fish and other aquatic resources have declined due to siltation, habitat degradation and loss of connections between *beels* and rivers (Hossain *et at* 1998) hence projects like the CBFM 2 provide means to reverse this trend by helping communities to establish fish sanctuaries, which is one way to restore fish habitat. Payne and Cowan (1998) also suggest that habitat restoration may be more appropriate in improving the availability of resources of fishes.

The construction of traditional fish sanctuaries is based on the structure of the destructive *katha* fishing gear. This knowledge has been converted into positive information with the aim to conserve fish production and diversity and has been successfully adopted in 81 of the CBFM project water bodies covering 20 districts in Bangladesh. Majority of the surveyed sites which had established sanctuaries indicated that the fishing effort of fishers have decreased while there is reasonable increase and improvement in their total fish catch. The improvement of fish productivity in small scale fish sanctuaries in the floodplain have also helped to enhance the fish productivity in the surrounding floodplains. The challenge during the initial stages of the project was to convince the community to participate and invest their time and effort in setting up and managing fish sanctuaries. This was done through massive awareness raising campaign.

- Small-scale fish sanctuary contributed positively both on Ichthyodiversity and fish production of open water fisheries resources.
- There should be strong management committees for sanctuary management.
- There should have follow up awareness raising program for the local communities for fish sanctuaries.
- Operational fund for sanctuary should be ensured by the Management Committee through beneficiaries participation
- Sanctuary should be established permanently according to fish sanctuary legislation (in preparation).

References

Ali, M.Y. (1997). *Fish, Water and People*, University Press, Dhaka.

Andrew, N. L., and Pepperell, J.G., 1992. The bycatch of shrimp trawl fisheries. Oceanogr. Mar. Biol. Annu. Rev. 30:527-565.

Baird, I.G. (2006). Strength in diversity: Fish sanctuaries and deep-water pools in Laos. *Fisheries Management and Ecology* 13(1): 1-8.

CNRS Annual Report, (1996). Community-based Fisheries Management and Habitat Restoration Project, Center for Natural resource Studies (CNRS) pp 12-15.

Hossain, M.M., Rahman, S.A., Thompson, P.M., (1998). Building government-non-government organiastion-fisher partnerships for fisheries management in Bangladesh. In: Proceedings of the Seventh Annual Conference on the International Association for the Study of Common Property, Vancouver, Canada, June 10-14, 1998. http://www.indiana.edu/~iascp/Drafts/hossain.pdf.

Hughes, R., Adnan, S. and Dalal-Clayton, B. (1994). Floodplains or Flood Plans? International Institute for Environment and Development, and Research and Advisory Services, London.

Jingran, V.G. (1984). Fish and Fisheries of India. Hindustan Publishing Corporation, New Delhi, 663pp.

Khabir, A. and Munir, A. (2002). Fish sanctuary Book. TARA (Technological Assistance for Rural Advancement), 141pp.

Malcolm and Usha (2007). Turning the Tide. Community Based Fisheries Management Project, WorldFish Center, Bangladesh.

M. Julian Caley, Kathryn A. Buckley and Geoffrey P. Jones, (2001). Separating Ecological Effects of Habitat Fragmentation, Degradation, and Loss on Coral Commensals. **Ecology,** Vol. 82, No. 12 (Dec., 2001), pp. 3435-3448.

Mustafa, M.G. and Halls, A.S. (2007). Impact of the Community-Based Fisheries Management on sustainable use of inland fisheries in Bangladesh. Proceeding of the CBFM-2 International Conference on Community Based Approaches to Fisheries Management [2007-Quarter2; Dickson, M. and ***A. Brooks*** (eds.); Dhaka, Bangladesh, 6-7 March 2007. The WorldFish Center - Bangladesh Office].

Payne, A.I., Cowar, V. (1998). Review of stock enhancement in the floodplains of Bangladesh. In:Petr, T. (Ed.), Inland Fishery Enhancements. Papers Presented at the FAO/DFID Expert Consultation on Inland Fishery Enhancement, Dhaka, Bangladesh, April 7-11, 1997. FAO Fish Tech. Pap. 374, pp. 153-212.

Poverty and food insecurity in Bangladesh: Evidence from *haor* areas

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Abstract: The present study was to explore the poverty status and adopted coping strategies during food insecurity of haor people by analyzing the data of 4,065 households collected from 30 haor areas under a FAO funded project. Using the Costs of Basic Needs method, it was found out that about 29.6% of the households were below the lower poverty line and about 43% households were below the upper poverty line. Using the lower and upper poverty lines, the poverty gaps were estimated at 7.6% and 12.4%, respectively measuring the depth of poverty by the two lines; while the squared poverty gaps were obtained at 3.0% and 5.2%, measuring the severity of the poverty. Main reasons of food insecurity were landlessness, mono-crop cultivation, seasonal unemployment and natural calamities. The extent of food insecurity was found to vary significantly according to the occupation of the household head, landholdings and location (district). The specific and immediate measures for overcoming the food insecurity situation were debt from anywhere (84.1%), borrowing food items from relatives (60.2%) and reduction of the familial expenses (66.7%). As general strategies to cope with poverty and food insecurity, nearly four-fifths iterated their reliance upon borrowing money, over half upon reducing food cost and over two-fifths upon needing help from relatives. It is to be noted that 8.1% households depleted their productive assets directly in terms of sold land or household assets to cope with food insecurity. The results indicated that borrowing money mostly from the local moneylenders was the most adopted measure and strategy to overcome the food insecurity situation and the consequences of this very culture were to entrap the victims into vicious cycle and to be destitute untimely. As the necessary measures for ensuring food security, most of the respondents urged for the work opportunity round the year and government support programs.

Introduction

In Bangladesh, haors are located mainly in greater Sylhet and Mymensingh regions with 7,83,939 ha arable land and about 5 million population. Haor, a corrupt form of the Sanskrit word *Sagar* (sea), is a bowl-shaped large tectonic depression, which receives surface runoff water and consequently becomes very extensive water body in the monsoon and dries up mostly in the post-monsoon period. Food insecurity arises at the individual, household, national, regional and global levels when all people, at all times, do not have physical and economic access to sufficient, safe and nutritious food to meet their needs and food preferences for an active and healthy life (FAO 1996). A micro-level study reveals that around 47.7 % fishermen of haor area live below the poverty line (Kazal *et. al.* 2006). Although the exact number of people of haor areas living below poverty line is not known, it is again assumed that a huge percentage of people living here could be described as ultra poor. Basic avenues for life and livelihood of the common people are mostly absent in the haor areas. People do not have available employment and therefore they are very vulnerable in respect to food security and this, indeed, is a matter of great concern for the policy makers. The majority of the people in haor areas are assumed to be involved in two occupations, namely crop cultivation and fishing. A very few number of people are engaged in some other occupation like small trading, petty jobs in government and non-government organizations. The people engaged in agriculture and fishing remain frequently unemployed due to flood and other natural disasters resulting in food insecurity in the areas, which sometimes creates famine-type situations. Apart from that, these areas do not have good infrastructure and communication systems and most of the people hardly have concrete connection with the people living in other cities and towns. Therefore, food insecurity becomes perpetual for these people since they can do nothing while facing unemployment situation. The haor areas lack adequate educational arrangements and accordingly the literacy rate is very low and employment-based education is almost non-existent. Therefore, it may be concluded that it is unemployment which is mostly responsible for the situation of food insecurity in the haor areas. Besides, the speciality of haors and the overall condition in which people live might cause many of the approaches considered for development in the rest of Bangladesh not to work smoothly or apply at all in these regions.

The poor, especially the ultra poor, suffer from food insecurity basically because of lack of purchasing capacity and fewer opportunities to have easy access to available food. The landless people living in the third world countries are the main victims of food insecurity because of multiple reasons. These landless people are mostly forced

to become day laborers who are dependent on casually occasional earning for their

livelihood. Millions of such people are affected and suffer from chronic and transitory food insecurity due to seasonal variation in agricultural activities and limited opportunities to have employment in non-agricultural activities. Household level food insecurity is very common among these people. When there is no earning, there is no economic access to food at home and this unfortunate situation compels these food insecure people to survive on taking cash money as loan from the money lenders at a high interest rate (Amin and Farid 2005). In many parts of Bangladesh the people living in low lying areas like haors face frequent natural disasters and lead an uncertain life because of chronic food insecurity. Household level food insecurity is accepted as a part and parcel of everyday life in these areas and the people are often forced to depend on money lenders or food lenders for very survival (Amin and Farid 2005).

Food insecurity has in fact been reduced in Bangladesh compared to the situation prevailed in 1970s. However, it is far from being over. Although people do not die of hunger these days, a considerable portion of the population always remains hungry because of lack of food security. More than 60 million people are still found suffering from chronic hunger in Bangladesh which is definitely larger than those in many other countries in the world. Bangladesh has therefore third largest poor population across the globe after China and India (UNDP, 2005). The reports prepared on Millennium Development Goals (MDGs) by the World Bank and Government of Bangladesh (GoB) suggest that much needs to be done to attain the 2015 MDG target to free the hungry population from the situation of food insecurity and malnutrition (Mishra and Hossain, 2005). Climatic and demographic changes may also adversely affect the food security of Bangladeshi people (Mishra & Hossain, 2005). It is very urgent to develop a comprehensive plan for minimizing the adverse affects of natural disasters especially in connection with food insecurity.

Apart from the qualitative measure of food insecurity situation through coping strategies, a number of researchers developed quantitative measure through constructing indices (Campbell 1991, Radimer *et al.* 1992, Haddad *et al.* 1994, Wehler 1994). In studies of food insecurity in the United States, approaches have included construction of a "hunger index" in the Community Childhood Hunger Identification Project (Wehler, 1994) and the Radimer "food insecurity scales" (Radimer *et. al.* 1992). Maxwell *et. al.* (2003) have also created a scale but they use coping strategies rather than household or individual attributes; they call it the Coping Strategies Index (CSI). The CSI was created for use in emergency aid distribution programs and as an early warning system for African countries. The pilot

study was conducted over 1999-2000 in two of the drought affected areas of Kenya.

CSI as a tool is easy to administer and analyze and provides real time information to program managers. The scale is based on assessing the severity and frequency of coping strategies used by households over time and then combining them in a single score. The higher the index score the more insecure the household is considered to be.

Because of the adverse geography of haor regions and recent trend of negative impact of climate change on life and livelihood, particularly in these areas, the haor economy has become highly prone to seasonality characterized by the caprice of nature. The feature of high seasonality of the *haor*-based economy forces local people to remain out of work for about half of the year resulting in income-poverty leading to food insecurity for them. Moreover, a tremendous lack of physical, financial and social infrastructures constrains most of these people to endeavour for off-farm economic activities to earn their livelihood as a substitute of and/or compliment to their traditional occupations mentioned earlier. On the other hand, from anecdotal evidence, it is learnt that the government, NGOs and international development partners have not extended their interventions in terms of both transfers and economic activities to a satisfactory extent in these under-privileged areas. The factors all together might have created a situation where food insecurity for haor people is deemed to be a part and parcel of their life. How these food insecure people cope with the situation is of interest and deserves to be explored for both better understanding their vulnerability to food insecurity and subsequent policy implications to address this inhuman and chronic problem. This study made an attempt to assess the poverty and food insecurity status of the haor people, and investigate the mechanisms, both short and long term, that the haor people adopt to cope with the situation.

Methodology

The study adopted both quantitative and qualitative techniques to achieve its objectives. It covered six haor districts of Bangladesh- Sunamgong, Sylhet, Moulvibazar, Habiganj, Kishoreganj and Netrokona.

Quantitative component

The study applied cluster-sampling design and haor-attached villages were counted as clusters. A total of 30 clusters were covered in the survey. The clusters were selected using systematic probability proportionate to size (PPS) sampling procedure.

Since the numbers of haors are different in the six districts, a stratified random

sampling with proportional allocation was adopted to estimate the number of haors from each district (stratum).

Therefore, following steps were adopted in order to select the clusters and sample households:

(i) The number of haors in each of the six strata was determined and defined;
(ii) The haors were selected individually from the six strata using systematic PPS sampling procedure;
(iii) The UNICEF pencil-spin method was used to select the households randomly within the cluster; and
(iv) About 135 households from each cluster were selected for interview and the study finally covered 4065 households in total.

Qualitative component

The study conducted FGDs and PRAs in one-third randomly selected clusters where household interviews were done. For conducting FGD and PRA, the households were classified according to the three main household occupations: agriculture, fishing and 'other'. The FGDs were conducted separately from each occupational group. Thus, a total of 30 FGDs and 10 PRAs were conducted.

Analytical techniques

Cost of basic needs (CBN) method: The Bangladesh Bureau of Statistics uses the CBN method for analyzing the data of Household Expenditure Survey (HES) 1995-96 in order to estimate poverty line (BBS, 2001). The CBN method estimates the poverty level in a year in three steps. First, the cost of a bundle of fixed food items is estimated. The food items are rice, wheat, pulses, milk, oil, meat, fish, potato, vegetables, sugar and fruits, which provide minimal nutritional requirements corresponding to 2,122 K.cal per day per person (same threshold is used by the direct calorie intake method to identify the absolute poor). Required quantities in food bundle is denoted by (F_1, F_2,...,F_N) to meet calorie requirement; that is, F_j is the required per capita quantity of the food item j. The food poverty line is computed as $Z_f=\Sigma P_j F_j$, where P_j is the unit price of j-th food item.

In the second step, two non-food allowances for non-food consumption are computed. First one was obtained by taking the amount spent on non-food items by those households whose total consumption is equal to their food poverty line Z_f. These households spend lesser amount on food than the food poverty line and spend only on the essential items in non-food consumption. Algebraically, if the total per capita consumption is denoted by y and food per capita consumption by x, the "lower" allowances for non-food consumption were estimated as $ZL_n=E[y_i-x_i \mid y_i=Z_f]$, where E denotes the mathematical expectation. Second one, "upper" allowances, was obtained by taking the amount spent on non-food items by those households whose food expenditure was equal to the food poverty line. These households do meet their food requirement comfortably. Mathematically, "upper" allowances for non-food items can be expressed as $ZU_n=E[y_i-x_i \mid x_i=Z_f]$. Obviously, ZU_n is larger than ZL_n, because the share of food expenditure in total consumption decreases as consumption increases.

In the third step, estimation of the poverty lines consisted simply of adding to the food poverty line with the "lower" and "upper" non-food allowances to yield the total lower and upper poverty lines.

Lower poverty line: $Z_L=Z_f+ZL_n$ where $ZL_n=E[y_i-x_i \mid y_i=Z_f]$
Upper poverty line: $Z_U=Z_f+ZU_n$ where $ZU_n=E[y_i-x_i \mid x_i=Z_f]$

Difference between two lines is due to the difference in estimation of the allowances for non-food consumption. The lower poverty line incorporates a minimal allowance for non-food goods, while the upper poverty line includes more allowance. In practice, some adjustments are necessary to estimate ZL_n and Zu_n, because it is not feasible to get desired data whose total consumption was equal to food poverty line (Z_f) or food expenditure was equal to the food poverty line. To avoid this problem, expectation should be taken for those households whose total consumption was less or equal to food poverty line, in computation of "lower" allowance for non-food consumption. Similarly, "upper" allowance can be computed by taking expectation for those households whose food expenditure was less or equal to food poverty line.

Poverty gap and squared poverty gap

Poverty gap and squared poverty gap had been estimated using Foster-Greer-Thorbecke (FGT) method (Poverty Manual, 2005).

Suppose, N_p is the number of poor of the study population;

N is the total study population;

I (.) is an indicator function that takes on a value 1 if $y_i < z$, and 0 otherwise;

y_i is the household expenditure;

z is the food poverty at household level;

The Head Count Index can be defined as

$$P_0 = \frac{N_p}{N} = \frac{1}{N}\sum_{i=1}^{N} I\,(y_i < z).$$

The Poverty Gap Index can be defined by

$P_1 = \frac{1}{N}\sum_{i=1}^{N}\frac{G_i}{z}$, where $G_i = (z - y_i).\, I\,(y_i < z)$ is known as poverty gap score.

The Squared Poverty Gap Index can be obtained as

$$P_2 = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{G_i}{z}\right)^2$$

Results and discussion

Poverty estimation

Poverty is defined in many ways, but more generally, it is lack of economic and social ability to satisfy socially determined minimum requirements. Poverty, as normally defined, means that the consumption or income level of a person falls below a certain threshold necessary to meet basic needs (Bhuiya *et al,* 2007). The incidence of poverty varies across the periods and regions not due to definitions, but also due to external factors such as social and economic opportunities. The minimum requirements, expressed in so-called poverty line are more commonly measured by income/expenditure or calorie intake. Moreover, in multi-dimensional approach, income or calorie intake is supplemented by other variables such as, health and sanitation, housing condition, security, public distribution system, participation in development and social welfare activities. This section presents the estimation and different estimates of poverty for haor population and illustrates their differentials on the basis of some selected criteria.

Generally, two methods are used in estimating poverty. The first one is based on direct calorie intake (DCI) and the other one is the cost-of-basic needs (CBN) method. According to calorie intake method, a household is considered as 'hardcore poor' with per capita calorie intake of less than 1,805 K.cal per day, and 'absolute poor' with less than 2,122 K.cal per day. Measured by the CBN, a household is poor if its per capita expenditure lies below a given poverty line. In this method, poverty

lines are used to find a poor household which represents the level of per capita expenditure at which the members of households can buy an exogenously set low-cost adequate diet plus other minimum basic requirements. In this study, both DCI and CBN method have been used to estimate the poverty line, and extent of poverty has been examined at household level. The depth and the severity of poverty have also been estimated by FGT method.

Poverty estimation using costs of basic needs (CBN) method

It is documented that an adult person in Bangladesh requires on average a minimum of 832 gm of food a day, which is equivalent to 2,112 K.cal energy (BIDS 1997). The food combination suggested by BIDS was 397 g rice, 40g wheat, 40 g pulse, 58 g milk, 20 g oil, 12 g meat, 48 g fish, 27 g potato, 150 g vegetables, 20 g sugar, and 20 g fruits. In practice, the rural people are dependent more on rice than on any other items. In a study, the BBS has used a larger combination of food and per capita per day intake of rice was suggested as 455 g (BBS, 2000). The per capita per day food combination for this study has been prepared by considering the food combination suggested by BBS (2000) and BIDS (1997). In the estimation, the per capita per day requirements of food intake were fixed as 824 grams containing 448 grams of rice, which cost Tk.25.6 at the survey point in time.

Fig. 1 shows the incidence of poverty by CBN method in terms of head count ratio. The food poverty line had been estimated as Tk 9329.4 per capita per year. The annual per capita "lower" and "upper" allowances had been estimated as Tk 1230.0 and Tk 3383.8 respectively, which were 13.2% and 36.3% of the food expenditure. The corresponding per capita "lower" and "upper" poverty lines had been estimated as Tk 10559.4 and Tk 12713.2 respectively (Table 1). The non-food expenditure was found consistent with other studies of Bangladesh. Ravallion and Sen (1996) reported that the non-food expenditure was 15 to 40 percent of food expenditure. Using the data of Household Expenditure Survey 1988-89, Rahman (1994) found non-food expenditure as 35% of food expenditure.

Table 1. Estimation of the Incidence of Poverty at Household Level by CBN Method

Per capita Food Poverty Line (Z_f)*		9329.40	
Per capita lower allowance (ZL_n)**	1230.00	Per capita lower poverty line ($ZL= Z_f + ZL_n$)	10559.40
Per capita upper allowance (ZU_n)**	3383.82	Per capita upper poverty line ($ZU= Z_f + ZU_n$)	12713.22

Per household lower poverty line expenditure	56915.17	% HH below the lower poverty line expenditure	29.60
Per household upper poverty line expenditure	68524.26	% HH below the upper poverty line expenditure	43.00

*The food poverty line is estimated by considering the price for the annual food quantity of minimal nutritional requirements corresponding to 2,122 kcal per day per person.

** $ZL_n=E[y_i-x_i \mid y_i=Z_f]$ and $ZU_n=E[y_i-x_i \mid x_i=Z_f]$, where y denotes the total per capita consumption; x denotes the food per capita consumption and Z_f denotes the food poverty line.

By converting the per capita poverty lines into household level, the "lower" and "upper" poverty lines for the study population had been estimated as Tk 56915.2 and Tk 68524.3 respectively (Table 1). The result suggests that about 29.6% households lie below the lower poverty line and about 43% below the upper poverty line. The incidence of poverty in the study population was found consistent with the national figures (28.6% by lower poverty line and 43.8% by upper poverty line for rural Bangladesh) reported by HIES-2005 (BBS 2007).

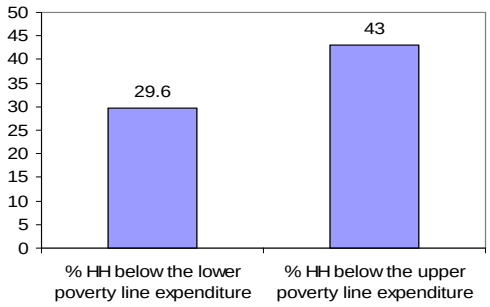

Fig. 1. Incidence of poverty by CBN method.

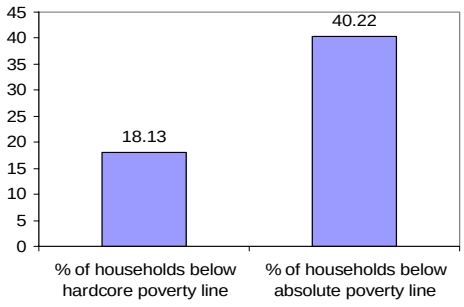

Fig. 2. Incidence of poverty by DCI method.

Poverty estimation using direct calorie intake (DCI) method

Fig. 2 presents the incidence of poverty by using direct calorie intake (DCI) method. Considering the average household consumption of food during the last three days prior to the survey, the average per capita calorie intake was estimated as 2237.0 K.cal (Table 2). However, the average per capita intake of calorie was obtained as 1578.5 K.cal and 1799.3 K.cal for the households fell below the hardcore and absolute poverty respectively. The head count ratio indicates that 18.1% households fell below the hardcore poverty line and 40.2% households below the absolute poverty line. The incidence of poverty was found remarkably lower by DCI method than the CBN method (29.6% by lower poverty line and 43.0% by upper poverty line). The difference between the rates of poverty estimated by DCI and CBN

methods was found much higher on the basis of lower poverty line than on the basis of upper poverty line. The poverty rate estimated by DCI method was found lower than that of by CBN method may be because of ingestion of more rice generally containing higher calorie value than other items of food.

Table 2. Estimation of the extent of poverty at household level by DCI method

Per capita average intake of calorie	2237.01 k.cal
Per capita average intake of calorie below hardcore poverty line	1578.54 k.cal
Per capita average intake of calorie below absolute poverty line	1799.30 k.cal
% of households below hardcore poverty line	18.13
% of households below absolute poverty line	40.22

Self-ranking of household's socio-economic status

In addition to the assessment of the poverty level of the households by CBN and DCI methods, the study adopted a complementary self-assessment. In that assessment, the households were asked to rank their socio-economic status among other households in the village, using their judgment. Fig. 3 shows their perceived position of socio-economic conditions. Of the surveyed households, about 19% identified themselves as ultra-poor and majority of them, 52.2% conceived themselves as poor. Only 8.7% wanted to put themselves as middle class and/or rich. Broadly speaking, 71% households were poor and 29% non-poor according to the self-ranking perception.

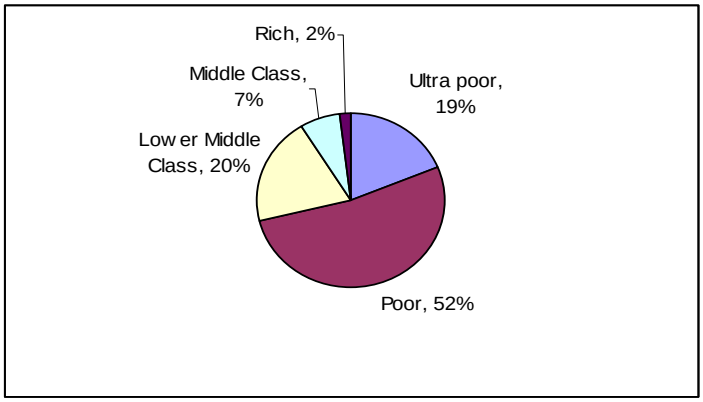

Fig. 3. self-ranking of household's socio-economic status.

Table 3. Comparison of the incidence of poverty by CBN method and DCI method with self-ranking assessment

	Self-ranking Assessment			
CBN Method (Upper poverty line)	Ultra-poor	Poor	Non-poor	Total
Poor	503	1025	218	1746
Non-poor	259	1097	963	2319
DCI Method (Absolute poverty line)	Ultra-poor	Poor	Non-poor	
Poor	355	870	410	1635
Non-poor	407	1252	771	2430
Total	762	2122	1181	4065

Table 3 demonstrates the comparison of the incidence of poverty estimated by CBN method and DCI method with that of self-ranking assessment. It is observed that 1528 households were commonly identified as ultra-poor/poor and 963 households as non-poor by both the self-ranking and CBN methods (upper poverty line), while 218 household heads ranked them as non-poor though they were identified as poor by CBN method. On the other hand, 1356 households were identified as ultra-poor/poor by self-ranking method, while they were identified as non-poor by CBN method. The incidence of poverty of these households is actually overestimated by the self-ranking method in contrast with CBN method but underestimated by the CBN method in contrast with self-ranking method. The same interpretation applies for the above mentioned 218 households but in the reverse direction. This clearly reveals that there remains some problem in estimating the incidence of poverty by both of the methods in contrast with each other. The same thing happens to the comparative analysis of the findings from DCI and self-ranking methods.

The socio-economic status of the households ranked by the household heads indicates that a larger proportion of households fell below the poverty line than that of estimated by the CBN and DCI methods. That is, the results of CBN and DCI methods may not reflect the true poverty situation of the haor people, because they are used to take more coarse rice in their food bundle - declining the cost in the CBN method and increasing the calorie intake in the DCI method. Similarly, the findings from self-ranking method are also misleading in the sense that the respondents could overestimate their poverty because of their misperception and/or manipulating attitude for some hidden reasons. The other indicators found in this study influencing the life and livelihood of surveyed people clearly revealed that the poverty situation might be different from or most probably worse than what had been estimated.

Differentials of poverty by CBN method

Table 4 shows incidence of poverty at household level by CBN method according to selected background characteristics. Result suggests that proportion of households below the lower poverty line was almost identical in all districts under study, while significant ($p<0.01$) variation was observed in the proportion of households below the upper poverty line. Proportion of households below upper poverty line was found highest (48%) in Kishoregonj district and lowest (38%) in other districts.

Table 4. Differentials of poverty using CBN method according to selected characteristics

Characteristics	% of HHs below lower poverty line	P-value	% of HHs below upper poverty line	P-value
District				
Sunamgonj	30.10	P>0.10 (χ^2=0.10)	40.40	P<0.01 (χ^2=25.0)
Other Districts of Sylhet Div.	29.60		38.00	
Kishoregonj	29.80		48.00	
Netrokona	30.20		39.40	
Landholdings (total land)				
None	38.10	P<0.01 (χ^2=157.4)	50.70	P<0.01 (χ^2=42.4)
1-10 dec	30.30		42.80	
11-49 dec	28.80		41.30	
50-199 dec	18.80		40.60	
200 dec or more	7.30		29.90	
Occupation of Household Head				
Agriculture (owner)	19.00	P<0.01 (χ^2=105.8)	38.30	P<0.01 (χ^2=26.0)
Business	29.90		41.80	
Fisherman	26.90		36.70	
Agri-labourer	34.70		45.10	
Non-agri labourer	36.40		48.00	
Job/Service	22.50		37.30	
Others	34.50		44.90	
Education of the Household Head				
No education	31.60	P<0.01 (χ^2=16.58)	43.70	P<0.05 (χ^2=6.29)
1-3 years of schooling	25.00		39.30	
4-5 years of schooling	28.30		40.20	
6+ years of schooling	23.90		39.30	
Family Size				
1-3	10.10	P<0.01 (χ^2=94.6)	21.70	P<0.01 (χ^2=108.6)
4-6	19.90		37.70	
7 & above	28.00		44.30	
Durable Assets				
No asset (score=0)	42.20	P<0.01 (χ^2=88.2)	50.00	P<0.01 (χ^2=22.2)
Poor assets (score 1-2)	32.60		44.80	
Few assets (score 3-10)	26.40		40.70	
Countable assets (score 11-74)	16.60		36.10	

Housing Condition				
Straw roof and bamboo/muddy wall	35.70	P<0.01 (χ^2=40.8)	48.10	P<0.01 (χ^2=15.96)
Tin shed roof and muddy wall	29.90		41.40	
Tin shed roof and tin wall	23.50		42.30	
Semi-pucca	20.60		34.40	
Others	38.60		54.40	
Sanitation Facilities				
Sanitary toilet	28.70	P<0.05 (χ^2=9.0)	43.40	P<0.05 (χ^2=9.62)
Pit/*pucca* toilet	26.30		39.00	
Katcha toilet	29.10		44.20	
Open field/ Others	33.00		44.10	
NGO Membership				
Yes	29.70	P<0.1 (Z=1.67)	49.00	P<0.01 (Z=3.46)
No	25.30		38.80	

Landholdings were found to have been negatively correlated with poverty. About 38% absolute landless households fell below lower poverty, whereas for the medium landholding households (200 dec or more) it was 7.3%. The incidence of poverty was found to vary significantly ($p<0.01$) across the amount of landholdings. The incidence of poverty was striking among labourer-headed households – nearly half of them in each category (agriculture and non-agriculture) fell below the upper poverty line. The incidence of poverty was found lower for the households whose heads were engaged in agriculture and job/service. There was a little variation in the incidence of poverty according to the education of the household heads may be because of the poor variation in their educational level.

Family size also appeared to have positively correlated with the incidence of poverty: about 44% of the larger households fell below the upper poverty line, but it was about 22% for small sized households (1-3 members). As expected, the incidence of poverty decreases rapidly with the increase of durable assets. About 42% households who had no asset score were found to lay below lower poverty line, whereas it was about 17% for the households with countable assets. The incidences of poverty were found to vary significantly according to the housing condition ($p<0.01$) as well as sanitation facilities ($p<0.05$). The proportion of households fell in the poverty lines decreases as the housing condition and sanitation facilities increases. The incidence of poverty was significantly higher (49%) for the households who were the member of any NGO than among non-member households (38.8%).

Differentials of poverty by DCI method

The variation of poverty according to the selected background characteristics by DCI method is shown in Table 5. The findings indicate that proportion of households below the hardcore poverty did not vary significantly across the districts, while significant ($p<0.01$) variation was observed in case of absolute poverty. Like CBN method, the incidence of absolute poverty was found to vary significantly ($p<0.01$) by DCI method and both the categories of poverty were found to be inversely related with household landholdings. The incidence of poverty by DCI method was found lower for the households with heads in agriculture, business and fishing occupations, however it was found higher for the households whose heads were engaged in job/service and non-agricultural labor. The higher incidence for job/service-holder headed households by DCI method may be due to intake of balanced diet with less amount of carbohydrate, especially rice. The incidence of poverty in both the form (hardcore and absolute) was found lowest for the households with heads of 4-5 years of schooling, while it was found highest in absolute poverty for the households with illiterate heads. Like in the CBN method, the positive impact of family size on the incidence of poverty was obviously found in the DCI method since an increasing trend was observed in the percentages of households falling below the poverty lines, both hardcore and absolute, with the increase in family size. The findings on the basis of housing condition reveal that the poverty in terms of hardcore and absolute level was observed lowest (16.0% in hardcore poverty and 37.3% in absolute poverty) for the households having housing condition with tin-shed roof and tin wall. Unlike the impact of NGO-membership on the incidence of poverty by CBN method, this very characteristic put no significant impact in terms of variation on the incidence of poverty by DCI method. The overall findings of DCI method mostly differed from those of CBN method because of substantial inclusion of rice in the diet by *haor* people, which influenced and generally inflated the value of their calorie intake.

Table 5. Differentials of poverty using DCI method

Characteristics	% of HHs below hardcore poverty line	P-value	% of HHs below absolute poverty line	P-value
Over all	18.13		40.22	
District				
Sunamgonj	21.79	P>0.10 (χ^2=2.83)	44.77	P<0.01 (χ^2= 85.51)
Other Districts of Sylhet Div.	16.35		37.51	
Kishoregonj	18.10		39.24	
Netrokona	16.31		36.68	
Landholdings (total land)				

None	23.01	P>0.10 (χ^2=2.59)	45.54	P<0.01 (χ^2=47.5)
1-10 dec	20.19		41.36	
11-49 dec	20.55		42.23	
50-199 dec	17.22		39.91	
200 dec or more	11.82		29.25	
Occupation of Household Head				
Agriculture (owner)	15.10	P<0.01 (χ^2=23.9)	36.73	P<0.01 (χ^2=100)
Business	15.55		39.93	
Fisherman	14.33		37.06	
Agri-labourer	19.39		43.79	
Non-agri labourer	22.28		44.38	
Job/Service	23.44		48.80	
Others	20.77		38.17	
Education of the Household Head				
No education	18.80	P>0.10 (χ^2=5.23)	41.19	P<0.01 (χ^2=14.2)
1-3 years of schooling	17.04		39.77	
4-5 years of schooling	14.07		36.77	
6+ years of schooling	20.14		38.86	
Family Size				
1-3	8.89	P>0.05 (χ^2=4.60)	25.70	P<0.01 (χ^2=33.9)
4-6	18.10		42.57	
7 & above	24.93		46.39	
Housing Condition				
Straw roof and bamboo/muddy wall	18.41	P>0.10 (χ^2=1.50)	40.69	P<0.01 (χ^2=4.78)
Tin shed roof and muddy wall	19.37		42.88	
Tin shed roof and tin wall	16.02		37.26	
Semi-pucca	19.57		38.09	
Others	21.05		42.10	
NGO Membership				
Yes	21.54	P>0.1 0 (Z=0.73)	40.74	P>0.1 0 (Z=0.12)
No	17.86		40.18	

The above discussion indicates that the incidence of poverty in terms of percentage of households (head count poverty index) by both CBN and DCI methods varies according to location, landholdings, occupation of the household head, family size and to some extent, the education of the household head. Therefore, policy

implications should be formulated by properly addressing these salient factors to improve the poverty and food security situation of the haor people in Bangladesh.

Poverty gap and squared poverty gap

The poverty gap and squared poverty gap have been computed by FGT method using the lower and upper poverty lines set by CBN estimation and the results are given in Table 6. The value of the poverty gap reflects the depth of poverty of the sampled households, that means, the higher the value, the deeper the poverty. Using the lower and upper poverty lines, the overall poverty gaps were estimated as 7.6% and 12.4%, respectively measuring the depth of poverty by the two lines. These values of poverty gaps can be used to estimate the total budget to raise the poor households out of poverty defined by the poverty lines[1].

Table 6. Poverty gap and squared poverty gap by FGT Method using the lower and upper poverty lines of CBN Estimation (in percent)

	Poverty Gap (%)		Squared Poverty Gap (%)	
	Lower	Upper	Lower	Upper
Overall	7.8	12.4	3.0	5.2
Districts				
Sunamgonj	6.8	1.1	2.7	4.7
Other Districts of Sylhet	6.1	10.8	2.4	4.3
Kishoregonj	7.5	12.2	3.1	5.2
Netrokona	10.2	16.1	3.9	6.8
Occupation of Household Head				
Agriculture (owner)	2.1	4.4	0.7	1.5
Business & Service	6.6	11.1	2.6	4.6
Fisherman	6.1	11.9	1.9	4.2
Agri-labourer	11.2	18.1	4.2	7.5
Non-agri labourer	12.6	19.1	4.5	7.9
Others	12.6	17.9	6.1	9.0

[1] Explanation: The result illustrates that if on an average (for the whole sample) 7.6% cost of the lower poverty line is budgeted as transfers and properly distributed to the targeted poor households, they would be able to come out from the lower poverty line, i.e. the poverty of the sample *haor* population (estimated on the basis of the lower poverty line) will be eliminated. It is estimated that Tk.17,522,911 (7.6% × lower poverty line expenditure × total sampled households) is required for the sampled poor households to bring them out of poverty measured by lower poverty line. Similar explanation applies for the upper poverty line.

The overall squared poverty gaps were obtained as 3.0% and 5.2% for the corresponding lower and upper poverty lines, measuring the severity of the poverty. The higher the value of the squared poverty gap, the more severe the poverty position of the population under consideration is. Both the poverty gap and squared poverty gap were found remarkably higher for the study population than the corresponding national figures for rural households as HIES –2005 reported that the poverty gaps were 5.3% and 9.8% for lower and upper poverty lines, respectively and the corresponding squared poverty gaps were 1.5% and 3.1%. These findings clearly revealed that the poverty level of the haor people is both deeper and more severe than that of the remaining part of rural population of Bangladesh.

Comparison by districts and household occupation

Furthermore, for making a district-wise and occupation-wise comparison of the depth and the severity of poverty, the poverty gap and squared poverty gap were estimated accordingly. The results depicted in Table 3 revealed that on the basis of the value of both the poverty gap and the squared poverty gap, Netrokona district ranks first followed by Kishorgonj district i.e., the poverty in these two districts is deeper than that in other districts under the study. On the other hand, according to the value of squared poverty gap, the poverty-stricken people of Netrokona and Kishorgonj districts are worse positioned than those of other surveyed districts in terms of the severity of poverty. It was also found out that the poverty-stricken people of other districts of Sylhet division are in the best position both in depth and severity measures. The occupation-wise comparison explores that the poverty-stricken people of labor class, both agricultural and non-agricultural, are in worse position in terms of the depth and the severity of poverty than those of other professions under consideration. In this regard, the agriculture owners are in the best position with the lowest values of both the poverty gap and the squared poverty gap. The exploration of the findings suggests for more attention and pragmatic actions from public and private sectors for poverty alleviation especially for the labor class and in Netrokona and Kishorgonj districts.

Extent and intensity of food insecurity

Three questions were asked to the respondents to understand the level of food insecurity of people living in the haor areas. This was scaled as normal (had been anxious about sufficient food), moderate (took less than 3 meals a day) and severe (slept with hunger) according to the responses. Table 7 shows the responses regarding different levels of food insecurity with respective frequency and intensity.

At first, the respondents were asked whether they had been anxious about sufficient food during the three months prior to the survey. About 45% of the respondents revealed that they were anxious about food deficit in their households. Among them, three-fifths claimed they faced the problems for sometimes and about 29% were faced the same problem for most of the times.

Table 7. Food security status with its degree

Status of Food Insecurity	No. of Households	% of Households	Frequency of Insecurity (%)		
			Very often	Sometimes	Sudden
Had been anxious about sufficient food (normal food insecurity)	1825	44.9	28.7	60.3	11.0
Had been bound to take less than three meals in a day (moderate food insecurity)	1191	29.3	10.0	57.5	32.5
Had been bound to sleep in hunger (severe food insecurity)	784	19.3	7.8	24.0	68.2
No food insecurity	2240	55.0	-	-	-
	Total=4065				

The respondents were further asked whether they had to take less than three meals in a day. About one in three of them agreed that kind of food insecurity. They reported that the moderate food insecurity situation happened most frequently for 10% cases, sometimes for 57.5% and suddenly for 32.5% (Table 7). While the respondents were questioned whether they had been bound to sleep with hunger during last three months prior to the survey, near one-fifth of them agreed to have experienced the situation (Table 7). However, this severe food insecurity situation was faced very often by about 8%, often by 24% and suddenly by 68%.

The extent of food insecurity was also analyzed according to the occupation of the household head, landholdings, location (district) and economic condition of the study households. The results are shown in Table 8. The incidence of food insecurity for the labourer-headed households were found at 56.7%, 41.6% and 27.2% for normal, moderate and severe scales respectively, while the corresponding levels for agriculture-owner-headed households were registered at 36.8%, 19.5% and 11.9% recpectively (Table 8). A wide variation in the extent of food security was observed

according to the occupation of the household head: the incidence of food insecurity in terms of percentage of households was registered to be found the highest among labourer-headed households followed by the fisherman-headed households in all the scales (normal, moderate and severe) and vice versa (the lower) for the agriculture-owner-headed and businessman and serviceholder-headed households.

Table 8. Status of food security in the last 3 months according to the occupation of household head, landholdings and location (district)

Status of Food Insecurity	% of households suffered from various types of food insecurity				
Occupation →	Agriculture	Business & Service	Fishing	Labourer	Other
Had suffered anxious about sufficient food	36.81	30.73	51.75	56.71	46.28
Had been bound to take less than three meals in a day	19.53	18.06	31.82	41.55	32.94
Had been bound to sleep in hunger	11.87	12.10	20.98	27.22	23.99
Total	1331	537	286	1319	592
Landholdings (dec.)→	None	1-10	11-49	50-199	200+
Had suffered anxious about sufficient food	65.35	51.06	44.66	38.10	14.52
Had been bound to take less than three meals in a day	49.75	35.57	27.83	18.91	5.39
Had been bound to sleep in hunger	33.91	23.66	19.74	10.92	2.07
Total	404	1847	618	714	482
District →	Sunamgonj	Other Districts of Sylhet	Kishoregonj	Netrokona	
Had suffered anxious about sufficient food	45.14	38.99	55.61	36.07	
Had been bound to take less than three meals in a day	34.69	26.20	31.62	20.37	
Had been bound to sleep in hunger	23.50	16.97	17.10	10.92	
Total	1349	813	1088	815	
Economic & Poverty Status (Self ranking) →	Extremely Poor		Poor	Non-poor	
Had suffered anxious about sufficient food	72.05		49.29	19.48	

Had been bound to take less than three meals in a day	54.46	32.28	7.71
Had been bound to sleep in hunger	41.47	20.28	3.30
Total (n)	762	2122	1181
Economic & Poverty Status (CBN Method) →	Poor (Below upper poverty line)	Non-poor (Above upper poverty line)	
Had suffered anxious about sufficient food	53.21	38.63	
Had been bound to take less than three meals in a day	36.67	23.74	
Had been bound to sleep in hunger	23.11	16.40	
Total (n)	1748	2317	

On the basis of the landholdings, the incidence of food insecurity at all the levels was found to decline monotonically with the increase of landholdings of households. Very naturally, the highest incidence was observed for the households having no land followed by the households with 1-10 decimal of land and a declining trend was found accordingly. The respective incidences were 65.4%, 49.8% and 33.9% for the no-land households at normal, moderate and severe levels, respectively and 14.5%, 5.4% and 2.1% for the households with 200 decimals or more landholdings (Table 8).

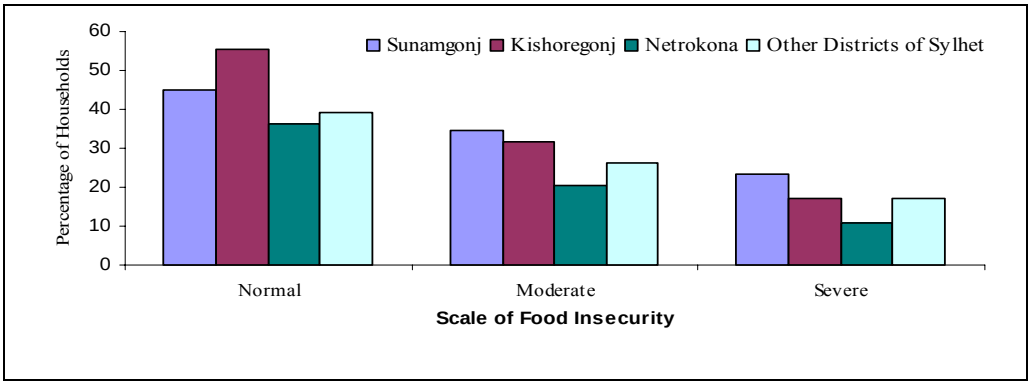

Fig. 4. Status of different scales of food insecurity by location (district).

Fig. 4 shows the incidence of food insecurity at different scales in different locations (districts). In accordance with the location, the households of Netrokona district were better off, having the lowest rates of incidence in all the scales of food insecurity. The incidence rates were somewhat fluctuating in other concerned locations according to

different scales. Other than the normal level of food insecurity, the highest incidence was estimated for the households of Sunamgonj district and the rates were 34.7% and 23.5% for moderate and severe food insecurity respectivety followed by 31.6% and 17.1% for the households of Kishorgonj district (Appendix Table 5.1). The incidence rates at normal level were recorded as 45.1% and 55.6% for Sunamgonj and Kishorgonj districts, respectively. With respect to overall grading, the households of Sunamgonj district are in worse position in terms of incidence of food insecurity followed by those of Kishoregonj district.

The extent of different scales of food insecurity was also analyzed according to the economic condition of the households, measured by both CBN and self-ranking methods (Table 8). Very reasonably, the percentages of the poor households suffering from food insecurity at all the scales were found remarkably higher than those of the non-poor households, measured by both the methods. In particular, about 53% of the poor households (measured by CBN method) reported that they suffered from normal food insecurity in contrast with 38.6% of the non-poor households. The differentials of food insecurity in terms of the percentage of the suffering households between the extremly poor and non-poor economic conditions were observed overwhelmingly higher at all levels of food insecurity.

Causes of food insecurity

The respondents were asked about the reasons of their food insecurity. They mentioned different underlying causes of their food insecurity as shown in Fig. 5.

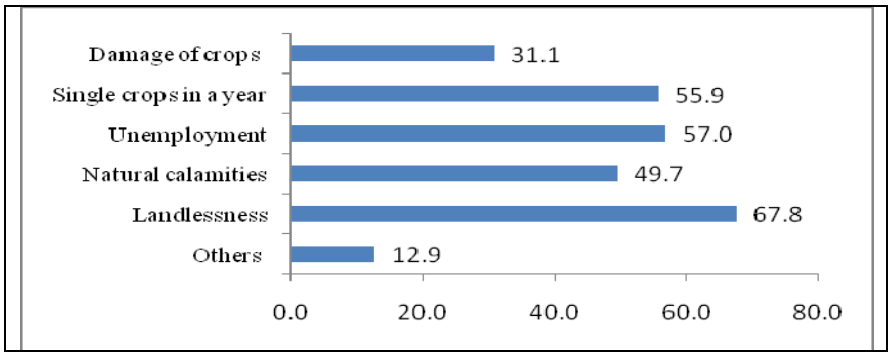

Fig. 5. Main reasons for households' food insecurity.

About two out of three respondents identified landlessness as the prime cause of their food insecurity. The other major causes identified by about half of the respondents were mono-crop cultivation, seasonal unemployment and natural calamities. About one-third of the respondents also identified the damage of crop generally caused by unexpectedly earlier heavy downpour and stone-slab as a considerable cause for food insecurity. Basically, the food insecurity problem of the *haor* people arises because of these factors as they reduce the annual cereal crop production, constrain economic access to food and limit productive resources.

Immediate measures for overcoming the food insecurity situation

The respondents reported to suffer from normal food insecurity during three months prior to the survey were asked whether they had taken some specific measures during that period. The immediate measures include taking a loan, borrowing food items from relatives, sale/mortgage of household assets and reduction of the familial expenses. Figs. 6 illustrate the measures taken for overcoming the food insecurity situation during the period mentioned earlier. Over four- fifths of the respondents admitted to resort to loans for buying food, while three-fifths to borrowing food items from kith & kin, only one in twenty to sale/mortgage of household assets and over three-fifths to reduction of other familial expenses. Selling household assets as a measure of tackling food insecurity is minimal mostly likely due to the limited ownership of assets by households. On the other hand, reliance on loans for combating food insecurity clearly indicates the scope for malpractice from money-lenders in hoar areas as this method is apparently convenient for survival but ultimately perpetuates a cycle of impoverishment overtime.

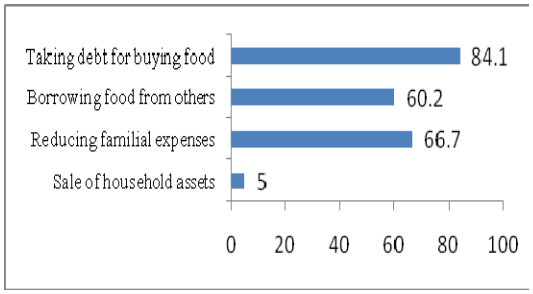

Fig. 6. Immediate coping strategies.

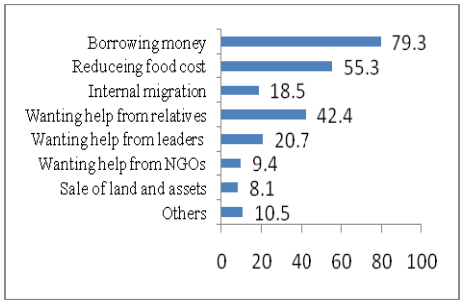

Fig. 7. General coping strategies.

General (long-run) coping strategies for food insecurity situation

The interviewees were asked about the strategies they usually adopt to cope with food insecurity. They spontaneously expressed the strategies they resorted to during different periods of time over their life span (Fig. 7). Very interestingly, here too, the highest percentage of respondents (79.3%) reiterated their reliance upon borrowing money for coping with food insecurity problem obviously bearing the testimony of pervasive existence of exploiting money-lending culture in the survey areas in almost absence of access to formal credit. The second and the third highest percentages of respondents (55.3% & 42.4%, respectively) hinged upon reducing food cost and wanting help from relatives as they reported for coping with food insecurity. Though the second largest adopted strategy is at their disposal, it results in hazards on their health in terms of hunger and malnutrition in future leading less productivity for the economy; while the third largest strategy undermines their prestige and causes indirect moral captivity to their relatives. In the midst of most of the pessimistic strategies, a highly optimistic strategy taken by a considerable percentage of respondents (18.5%) deserves special mention, which is internal out-migration to other places for livelihood adding some value to GDP through participating and/or generating temporary economic activities for food insecure people. Further, a significant percentage of respondents rely on help from communal leaders (20.7%) and from NGOs (9.4%) in resilience with food insecurity.

The adopted general coping strategies were also examined according to the households' economic condition defined by self-ranking as well as CBN upper poverty line (Table 9). The findings did not show any considerable difference in adopted coping strategies between the poor and the non-poor. However very reasonably, a slightly higher percentage of non-poor households adopted the strategies of borrowing money and reducing food cost than their poor counterparts, whereas, the poor adopted the help related strategies in a higher percentage.

Table 9. Adopted general coping strategies based on households' economic condition

General Strategies	Economic Condition of the HHs (Self-ranking)			Total
	Extremely Poor	Poor	Non-poor	
Borrowing money	77.60	82.31	69.57	1447
Reducing food cost	53.92	58.13	45.65	1009
Migration to other place of the country	18.94	19.60	12.17	337
Wanting help from relatives	45.17	43.69	30.00	774

Wanting help from community leaders	23.68	21.80	8.70	378
Wanting help from NGOs	9.65	10.42	3.91	171
Sale of land and/or household assets	7.65	8.51	6.96	147
Doing nothing/ Others	9.11	9.66	17.83	192
Total (n)	549	1046	230	1825

General Strategies	Economic Condition of the HHs (CBN upper poverty line)		Total
	Poor	Non-poor	
Borrowing money	77.53	81.12	1447
Reducing food cost	53.55	57.09	1009
Migration to other place of the country	18.39	18.55	337
Wanting help from relatives	45.70	38.99	774
Wanting help from community leaders	22.26	19.11	378
Wanting help from NGOs	11.51	7.15	171
Sale of land and/or household assets	8.28	7.82	147
Doing nothing/ Others	12.69	8.27	192
Total (n)	930	895	1825

In summary, we find that the prime strategies for coping with food insecurity for the haor people are borrowing money and food, reducing familial expenditure, specially on food, and out-migration (particularly temporarily internal migration) in both short run and long run. It is worth mentioning that the coping strategies that deplete the productive assets indirectly are reducing familial expenditures and borrowing money; moreover, the sale of land or household assets depletes the productive assets directly.

Necessary measures for household food security

The food insecure respondents were invited to express their perceptions regarding actions/measures for ensuring food security. Table 10 shows those perceived actions to be taken to maintain household food security. Over two-thirds of the respondents mentioned the need for additional work opportunities all the seasons and more than three-fourths strongly opted for government support programs. Slightly higher than two-fifths responses advocated for provision of funds for alternative income generating activities & membership under safety net food program while above one-third for introducing food-bank and appropriate actions from NGOs to ensure food

security. From the results, it can easily be inferred that provision of government interventions is a must for a secure food situation in haor areas along with private sector's, especially NGOs', complementary supportive programs. In this context, public-private partnerships can apply.

Table 10. Necessary Actions to be taken to maintain households' food security

Necessary Actions	No. of Households	% of Households
Ensuring work opportunity in all seasons	1238	67.8
Introducing food bank for ensuring food security during crisis period	681	37.3
Providing fund for alternative IGA	843	46.2
Membership under the safety net food program	732	40.1
NGOs should adopt appropriate action for tackling the situation	672	36.8
Government support program is a must	1383	75.8
Others	102	5.6
Total	1825	

Conclusions

The study draws conclusion and recommends policy interventions focusing on combating household-level food insecurity problem of haor people living in different north-eastern haor districts of Bangladesh based on key findings from household survey. It is worth mentioning that as poverty and food insecurity are intertwined, interventions addressing one aspect can be deemed to automatically address another.

Incidence of poverty by CBN method was found higher than that by DCI method, while highest incidence was observed by self-ranking method. Incidence of poverty at household level varied significantly according to some selected characteristics such as landholdings, occupation and education of the household head and family size. Depth and the severity of poverty were higher for laborer-headed households and for poverty-stricken households of Netrokona and Kishoregonj districts.

This study discovers that major coping strategies the haor people adopt are borrowing money and food, reducing familial expenses and internal out-migration both in short run and long run. The impact of borrowing sometimes renders people destitute being entrapped by a vicious cycle of debt because of their low capacity for repaying loan

and infavourable terms and conditions of the loan. Adopted general coping strategies were also examined according to the households' economic condition defined by self-ranking as well as CBN upper poverty line. The findings did not show any considerable difference in adopting coping strategies by the poor and the non-poor.

It is also observed that creation of employment opportunities throughout the year, especially in the lean season, government support, non-execution of present leasing system of waterbodies are suggested to tackle the food insecurity problems for the haor people.

Recommendations

The recommendations regarding the food security strategies of the haor people has been made from the perspective of short-run and long run plan of action.

Short-run plan of action

- Increase coverage of safety nets programs in *haor* regions, making sure that the actually needy households are included into the programs, and prioritize the haor people in the allocation and distribution of the relief materials from the government, NGOs and international organizations/communities.
- Create alternative income generating activities such as handicraft, tailoring, embroidering, poultry, livestock *etc*. through appropriate training, according to the facilities available in the locality, for the haor people, specially for women throughout the year. In this regard the participation of different NGOs should be encouraged and public-private partnership arrangements can apply.
- Introduce modern and scientific production system (especially in agriculture) such as floating vegetable garden for tomatoes, ladies finger, etc.; fish culture using fish pen or net; duck raising; food or fruits preservation and storage; taking preventive and curative measures for natural calamities.
- Redesign existing leasing systems of water-bodies for ensuring free & open access to fishing facilities of the villagers so that they can earn livelihood for food security without artificial interruption.
- Regulate the existing money-lending system to save the borrowers from the exploitation of the system and create parallel credit, particularly micro-credit, facilities through formal financial institutions by controlling un-head payment and easing the hassle of document-related complexity. The overall borrowing system should be easier with enhanced coverage.

- Develop awareness among the haor people about food security, specially, nutritional balance in food intake; hygienic condition, particularly use of sanitary toilet; and education of children.
- Launch a program to repair the existing embankments by attaching the respective villagers so that the height and strength of the embankment might be ensured to protect the crops from untimely heavy downpour. The food for work program can be incorporated to materialize it.

Long-run plan of actions

- Make comprehensive and sustainable arrangements for education, both formal and informal, for the haor people to alleviate poverty and hence to combat food insecurity in the long run.
- Provide health care facilities at the doorsteps of the haor people in a cost-effective way and implement family planning program very effectively to reduce the family size in the haor region.
- Introduce food bank (a non-profit and charitable organization that collects food aid either in-kind or in-cash from different sources and distributes to different food insecure communities through public or private organizations) to support the food insecure households, particularly in the lean season.
- Make proper arrangements for international migration for the interested haor people along with financing to remove the curse of unemployment, the main culprit for food insecurity in this region.
- Conduct further research on multi-crop production system (including short duration rice variety) and integrated farming.
- Construct new embankments to protect crops from natural calamities and to facilitate introducing multi-crop production.

References

Adams, A.M., Cekan, J. and Sauerborn, R. (1998), "Towards a Conceptual Framework of Household Coping: Reflections from Rural West Africa", *Journal of the International African Institute*, Vol. 68, No. 2, pp 263-283.

Agresti, A. (1996), "An Introduction to Categorical Analysis", Wiley Series in Probability and Statistics, John Wiley and Sons Inc.

Alderman, H. and Garcia, M. (1993), "Poverty, Household Food Security and Nutrition in Rural Pakistan", International Food Policy Research Institute, Washington, D.C.

Amin M.R. and Farid, N. (2005), "Food Security and Access to Food: Present Status and Future Perspective", paper presented at the national workshop on Food Security in Bangladesh, organized by GoB and WFP.

Barrow, M. (1998), "Statistics for Economics, Accounting and Business Studies", Longman Group UK**.**

BBS. (1998), "Household Expenditure Survey- 1995-96", Bangladesh Bureau of Statistics, Ministry of Planning, GoB, Dhaka

BBS. (2000), "Rural Poverty Monitoring Survey 1998", Bangladesh Bureau of Statistics, Ministry of Planning, GOB.

BBS. (2001) "Preliminary Report of Household Income and Expenditure Survey-2000", Bangladesh Bureau of Statistics, Ministry of Planning, GOB.

BBS. (2003), "Household Income and Expenditure Survey-2000", Bangladesh Bureau of Statistics, Ministry of Planning, GoB, Dhaka.

BBS. (2004), "Report of the Poverty Monitoring Survey 2004", Bangladesh Bureau of Statistics, Ministry of Planning, GoB, Dhaka.

BBS. (2007), "Household Income and Expenditure Survey-2005", Bangladesh Bureau of Statistics, Ministry of Planning, GoB, Dhaka.

BBS. (2008), "Statistical Pocket Book of Bangladesh 2007", Bangladesh Bureau of Statistics, Ministry of Planning, GoB, Dhaka

Bhuiya, A., Mahmood S.S., Rana A.K.M.M., Wahed, T., Ahmed, S.M., Chowdhury, M. (2007). "A multidimensional approach to measure poverty in rural Bangladesh", *Journal of Health, Population and Nutrition*. Vol.25 (2).

Bickel, G., Nord, M., Price, C., Hamilton, W. and Cook, J. (2000). "Guide to Measuring Household Food Security; Measuring Food Security in the United States", *United States Department of Agriculture (USDA).*

BIDS. (1997), "Methods of Measuring Poverty and Trend", In Rahman, R.I. edited "Poverty and Development: Bangladesh Context", Bangladesh Development Studies, Dhaka.

Campbell, C. (1991), "Food insecurity: A nutritional outcome or a predictor variable?" *Journal of Nutrition* 121: 408-415.

Coates, J., Webb, P. and Houser, R. (2003). Measuring Food Insecurity: Going Beyond Indicators of Income and Anthropometry, FANTA, Academy for Education and Development, Washington, D.C.

Corbett, J.E.M. (1988). "Famine and household coping strategies", *World Development* 16 (9): 1099-1112.

Cramer, J.S. (1971). "Empirical Econometrics", North Holland Publishing Company, Amsterdam.

Dash, B.P. (2005). "Regional Food Security Experience: Lessons Learnt from India and Timor Leste", paper presented at the national workshop on *Food Security in Bangladesh,* organized by GoB and WFP.

Davies, S. (1993). "Are coping strategies a cop out?" *IDS Bulletin* 24 (4): 60-72.

de Garine, I. (1993). "Coping strategies in case of hunger of the most vulnerable groups among the Massa and Mussey of northern Cameroon", *Geojournal* 30 (2): 159- 166.

de Garine, I. and Harrison, G.A. (1988). "Coping with uncertainty in food supply", *Oxford: Clarendon Press.*

de Waal, A. (1989). "Famine that kills", *Oxford: Clarendon Press.*

Devereux, S., and Naeraa, T. (1993). "Drought and entitlement decline in Namibian Agriculture, 1992", *Social Science Division, University of Namibia, Windhoek, Namibia. Mimeo*.

Dore, Anna R., Linda S. Adair and Barry M. Popkin. (2003). "Low Income Russian Families Adopt Effective Behavioral Strategies to Maintain Dietary Stability in Times of Economic Crisis", *Journal of Nutrition*, Vol. 33, pp 3469–3475.

Drèze, J. and Sen, A. (1989). "Hunger and public action", *Oxford: Clarendon Press.*

Eele, G. (1994). "Indicators for food security and nutrition monitoring: A review of experience from southern Africa", *Food Policy* 19 (3): 314-328.

Frankenberger, T. and Goldstein, D.M. (1990). "Food security, coping strategies and environmental degradation", *Arid Lands Newsletter* 30: 21-27.

Frankenberger, T. and Coyle, P.E. (1993). "Integrating household food security into farming systems research/extension", *Journal for Farming Systems Research/Extension* 4 (1): 35-65.

Frongillo, E.A., Chowdhury, N., Ekstro, E.C. and Naved, R.T. (2003). "Understanding the Experience of Household Food Insecurity in Rural Bangladesh Leads to a Measure Different from That Used in Other Countries" *Journal of Nutrition*, Vol. 133, pp 4158–4162.

Haddad, L., Kennedy, E. and Sullivan, J. (1994). "Choice of indicators for food security and nutrition monitoring", *Food Policy* 19 (3): 329-343.

Hosmer D.W. and Lemeshow, S. (2000). "Applied Logistic Regression", John Wiley & Sons, Inc.

Hossain, M. and Bayes, A. (2009). "Rural Economy and Livelihoods Insights from Bangladesh", A H Development Publishing House, Dhaka.

Hossain, M.Z. (2010), "Development of Some Demographic Models and Implementation in Bangladesh", LAP Lambert Academic Publishing Company, Germany. ISBN 978-3-8383-9328-5.

Hossain, M.Z. and Erik H.J. Keus (2004). "Socio-economic Condition and Poverty Situation in Rural Southern Part of Bangladesh: A Household Level Study", *Journal of Population and Social Studies,* Vol. 12, No. 2, pp. 135-163.

Hutchinson, R.A. (1991). "Fighting for Survival: Insecurity, People and the Environment in the Horn of Africa", *International Union for the Conservation of Nature*, Switzerland.

Jaigirder, N. (2008). "An Examination of the Wealth Index using Principal Component Analysis and Scoring Method", An Unpublished MS Thesis, Department of Statistics, Shahjalal University of Science and Technology, Sylhet.

Kazal, M.M.H., Alam, M.J. and Ahmed, T. (2006). Income Distribution and Poverty Level in Sunamgonj Haor Area of Bangladesh: Implication for Poverty Alleviation, *Development Review*, 18: 68-84.

Keller, E.J (1992). "Drought, War and the Politics of Famine in Ethiopia and Eritrea", *Journal of Modern African Studies*, Vol. 30, pp 609-624.

Leonard, W. (1991). "Household-level strategies for protecting children from seasonal food scarcity", *Social Science and Medicine* 33 (10): 1127-1134.

Maxwell, D., Watkins, B., Wheeler, R. and Collins, G. (2003). "The Coping Strategies Index: A tool for rapidly measuring food security and the impact of food aid programs in emergencies", *Field Methods Manual, CARE and World Food Program (WFP) Vulnerability Assessment Mapping*.

Mishra, U. and Hossain, S.A.K.M. (2005). "Current Food Security and Challenges: Achieving 2015 MDG Hunger Milepost", Papers Presented in National Workshop on Food Security

in Bangladesh, Ministry of Food and Disaster Management, GoB & World Food Programme.

Mitra, S.N., Al-Sabir, A., Shaha, T. and Kumar, S. (2001). "Bangladesh Demographic and Health Survey, 1999-2000": National Institute of Population Research and Training (NIPORT), Dhaka, Bangladesh; Mitra and Associates, Dhaka, Bangladesh, and Micro International Inc. Calverton, Maryland.

Molnar, Joseph J. (1999). "Sound Policies for Food Security: The Role of Culture and Social Organization in Review of Agricultural Economics", Vol. 21, No.2, pp. 489-498.

Moris, J. (1989). "Indigenous versus introduced solutions to food stress in Africa in Seasonal variation in Third World agriculture: the consequences for food Security", *ed. D. Sahn. Baltimore, Md., U.S.A.: Johns Hopkins University Press for the International Food Policy Research Institute.*

MWCA (2006). "Impact Survey (Cycle 2003-2004) of FSVGD Project", Department of Women's Affairs, Ministry of Women and Children Affairs, World Food Programme, In Partnership with European Commission (Report written by Dr. M.Z. Hossain).

NIPORT, Mitra & Associates and Macro International (2009). "Bangladesh Demographic and Health Survey – 2007", National Institute of Population Research and Training, Dhaka, Bangladesh.

Oldewage-Theron, Wilna H., Emsie G. Dicks and Carin E. Napier (2006). "Poverty, Household Food Insecurity and Nutrition: Coping Strategies in an Informal Settlement in the Vaal Triangle, South Africa", *Public Health.* Vol. 120, No. 9, pp 795-804.

Poverty Manual (2005). "Introduction to Poverty Analysis", World Bank Institute, August, 2005.

PRSP (2005). "BANGLADESH - Unlocking the Potential" National Strategy for Accelerated Poverty Reduction, General Economics Division, Planning Commission, Government of Bangladesh, 2005.

Radimer, K., Olson, C. and Campbell, C. (1992). "Development of indicators to assess hunger", *Journal of Nutrition* 120: 1544-1548.

Rahman, Pk. M.M. (1994). "Poverty Issues in Rural Bangladesh", University Press Limited, Dhaka, Bangladesh.

Rahman, R.I., Begum, A., Bhuyan, H.R. (2009). "Impact of Paid Employment and Self-Employment on Income and Prospects of Household Food Security", A Research conducted by Bangladesh Institute of Development Studies under NFPCSP of GoB and FAO, Dhaka.

Rahmato, D. (1991). "Famine and survival: A case study from northeast Ethiopia. Uppsala, Sweden", *The Scandinavian Institute of African Studies*.

Rajaretnam, T. and Hallad, J.S. (2000). "Determinants of nutritional status of young children in India: an analysis of 1992-93 NFHS data", *Demography-India*, vol. 29(2): BBS (2004), "Report of the Poverty Monitoring Survey 2004", published by Bangladesh Bureau of Statistics, Dhaka.

Ravallion, M. and Sen, B. (1996)."When Method Matters: Monitoring Poverty in Bangladesh", *Economic Development and Cultural Change*.

Reardon, T., Matlon, P. and Delgado, C. (1988). "Coping with household-level food insecurity in drought-affected areas of Burkina Faso", *World Development* 16 (9): 1065-1074.

Teklu, T. (1992). "Household response to declining food entitlement: The experience in western Sudan", *Quarterly Journal of International Agriculture* 31 (3): 247- 261.

Turner, AG, Magnani, R.J. and Shuaib, M. (1996). A Not Quite as Quick but Much Cleaner Alternative to the Expanded Programme on Immunization (EPI) Cluster Survey Design, International Journal of Epidemiology, Vol. 25, p. 198.

UNDP. (2003). "Human development Report 2003", New York: Oxford University Press.

UNDP. (2005). "Human Development Report 2005", Oxford University Press, New York.

Watts, M. (1983). "Silent violence: Food, famine, and peasantry in northern Nigeria", *Berkeley, Calif., U.S.A.: University of California Press.*

Webb, Patrick and Joachim von Braun. (1994). "*Famine and Food Security in Ethiopia: Lessons for Africa"*, John Wiley and Sons, New York.

Wehler, C. (1994). "The use and refinement of CCHIP survey items for a general population survey", Paper presented to the Food and Consumer Service, United States Department of Agriculture Conference on Food Security Measurement and Research, 21-22 January, Washington, D.C.

WFP. (2005). "Food availability and consumption situation in the country" Bangladesh Food Security Brief, World Food Program.

World Bank. (2004). "Assessment of SSNPs in Bangladesh", The World Bank, 2004

Fishers' access to fisheries resources under different management systems and their livelihood issues

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Abstract: The present study was undertaken during 2009 as a part of policy support to the National Food Policy Capacity Strengthening Programme (NFPCSP) of the Ministry of Food and Disaster Management supported by FAO/USAID/EC to analyze and understand fishers access mechanisms to fisheries resources, fishers' livelihood including coping strategies during the ban and lean fishing periods and to suggest appropriate access mechanisms, fisheries management systems and coping strategies during ban and lean fishing periods. The study revealed that 87% of fishers were poor with monthly income less than Tk.5000/-. They depended on loan from money lender/NGO. About 43% fishers did not have fishing equipment. They worked as labor fishers or on catch share basis in others boat. Revenue oriented fisheries management and fishers' poverty, have been found to affect the fishers access to the resource, their income and livelihoods. Fishers access right to the fisheries have been found ensured in 3 management systems such as (i) the open access system in the flowing river, (ii) fishing right through license, and (iii) community based fisheries management system. During lean and ban fishing period the poor fishers suffered most as they did not have alternate option of work and as such most of them took loan from Mohajon/Aratdar, NGOs and relatives. Some fishers worked as day laborer and rickshaw pullers and reduced number of meals and meal size at the HH level. Fishers affected by 2-3 months fishing ban in 330 km stretches of the lower Meghna for protecting Jatka (Juvenile hilsa) received some compensation from government that was quite insufficient to sustain the livelihood even for a week. The study recommends community based biological management of fisheries including licensing system to poor fishers instead of revenue oriented management, ban of only selective gears instead of banning all fishing gears, sufficient Govt. compensation to the fishers during fishing ban, arranging AIGA during lean and ban fishing period, introducing institutional credit with relatively easy terms and conditions and proper management and conservation of fisheries resources.

Introduction

Total production in inland open water has increased in the recent years due to different management interventions by the government and increasing fishing effort but catch of individual fishers has declined resulting decrease in income. As a result livelihood of inland poor fishers has been affected seriously. Though fishers are the main players in harvesting the fishes with hard labor in the sun and rains, their access right to the fisheries resources has always been intervened due to faulty management system of the government and interference by middlemen (rich and powerful people). The poor fishers cannot pay lease value of the Jalmohal and they rely on rich people/Mohajan who pay the lease value and get control of the Jalmohal where fishers work as labor fishers or on contract/catch sharing. The rich people pay the lease value on behalf of the fishers' association and get the use right of the fisheries. The fishers are usually poor, landless and neglected in the society and are deprived of their right. They live hand to mouth. Fishing is seasonal with peak and lean period. During lean period their catch decreases to minimum or none, when the poor fishers struggle maintain their livelihoods. The fishers' livelihoods are also affected by fishing ban and restriction imposed by the government for protection and conservation of fisheries resources. As the fishers do not have any alternate job opportunity as such they suffer heavily during fishing ban and lean fishing period.

In the backstop, appropriate policy and strategies of the proper implementation are needed to ensure sustainable management of fisheries resource and also to ensure poor fishers access right to the resource and support during lean and ban fishing period for sustainable livelihood and food security. The present study was undertaken for a thorough understanding of the existing access mechanism to the resource under different management systems and their coping strategies during lean and ban fishing period including problems and constraints with a view to provide policy recommendations and guidelines.

The study was undertaken during 2009 as a part of policy support to the National Food Policy Capacity Strengthening Programme (NFPCSP) of the Ministry of Food and Disaster Management supported by FAO/USAID/EC to analyze and understand fishers access mechanisms to fisheries resources, fishers' livelihood including coping strategies during the ban and lean fishing periods and to suggest appropriate access mechanisms, fisheries management systems and coping strategies during ban and lean fishing periods. The objectives of the research/study were -

(1) To analyze the existing access mechanism to fisheries resources by the poor fishers, their livelihood pattern and socio-economic condition, and coping strategies during lean and ban fishing period.
(2) To suggest/recommend policy strategies/measures for enhanced and improved access mechanism to common property fisheries resources by the poor fishers and for better fisheries management options aiming at sustainable fish production, food security and livelihoods of the poor fishing community of Bangladesh including enhanced coping strategies of the poor fishers during lean and ban fishing period.

Methodology

The study involved collection, compilation and analysis of data/information obtained from primary and secondary sources on fisheries resource status, management systems, fisher's access mechanisms and coping strategies during lean and ban fishing period, socio-economic condition of the fishing community. Secondary sources data/information have been gathered from published and un-published reports, books and journal from relevant organizations. Primary data/ information have been collected from seven strategic study sites of the country in different ecological and geographical locations with different types of water bodies/ Jalmohals (river, beels, haor, estuaries etc.) under different management systems (leasing system, free access system, community based fisheries management (CBFM) system, new fisheries management policy (NFMP) system etc. The study sites with name of study areas, related water bodies and fisheries management system are shown in the Table 1.

Table 1. Study sites with selected villages

Location/Sites	Related water bodies	Fisheries management system	Selected villages
Chandpur sadar of Matlab upazila, Chandpur	Lower Meghna river	Lease free and open access, fishing ban for 2 month, March -April	1. Bishnupur / Damodordi 2. Lalpur 3. Sataki, Matlab
Kalapara Upazila, Patuakhali	Andher-manik river	Lease free open access, fishing ban for 3 month, November - January	1. Merau para 2. Paschim Khajura 3. Hossainpur
Chilmari Upazila, Kurigram	Brahmaputra river	Lease free open access	1. Kanchkol 2. Majhipara 3. Patharkhata
Purbadhala, Netrokona	Beels (Hogla Jolmahal & Haor)	New fisheries management policy access through license.	1. Hat dhala 2. Neej Hogla 3. Sadhu para

Location/Sites	Related water bodies	Fisheries management system	Selected villages
Karimgonj Upazila, Kishorgonj	Beels	Under normal leasing system	1. Char Noagaon 2. Kadim Majhihati
Sreemangal, Moulavibazar	Hail haor with many beels	Community based management and leasing system	1. Hazipur 2. Rustampur
Chakoria, Moheshkhali & Sadar Upazila of Cox's Bazar District	Coastal/marine waters	Access through permit / license	1. Purba Boalkhali Jolodashpara 2. Kaur para, 3. Taraj ghata Jaladashpara

For collection of primary information, a considerable number of fishing households in 2-3 villages were selected and required information/data were collected through household survey and FGD with fishers, farmers, fish traders, labourers and other people of the village. Qualitative information/data were gathered through KII (key informant interview) with government officials, UP Chairman, knowledgeable person/local elites etc.

For socioeconomic study, all the households of a selected village have been listed with name of household heads, family size, education, occupation, assets etc. All the households then have been categorized as fishing household and non-fishing household. From each category, sample households have been selected using simple random sampling technique for household socio economic survey. The selected households have been surveyed following a questionnaire.

Minimum 20% but limiting to around 30 households have been studied from each village. For socio-economic survey supported by FGD, this sample size was considered enough. In each site more than 20% of all households and more than 30% of fishing households have been sampled for the study.

One FGD has been conducted in each of the selected villages with 12-15 persons from fishers, farmers, knowledgeable persons etc. of the village following a checklist. KII has been conducted with the concerned district fisheries officer (DFO), upazila fisheries officer (UFO), upazila nirbahi officer (UNO), assistant commissioner (land) and UP chairman in each site following a checklist prepared before-hand.

A total of 19 FGD, 35 key informant interviews (KII) and 640 households (465 fishing households and 183 non fishing households) survey have been conducted in 7 study sites. Data/information has been analyzed and results and findings are furnished in the next chapters.

Results and discussion

Socio-economic condition

Fishers are mostly poor, landless and neglected in the society. They are backward in education and economically depressed. They are exploited by rich and influential people, mohajan and aratdars by their intervention in fisher's access to resource, lending money at higher rate and dadon (Pokrant 1997 and Rahman 2001). The study shows that 87% fishers are poor (40% very poor and 42% poor) while 62% non-fishers are poor (30% very poor and 32% poor) which is much higher than the national poverty level estimated based on calorie intake. According to national poverty level, 40.4% people are poor (energy intake less than 2,122 k.cal per person per day) and 19.5% people are ultra poor (energy intake less than 1,805 k.cal per person per day). This study results on poverty as estimated based on physical assets, income and expenditure, cannot be comparable with the national poverty level figure. However, the study shows that the fishers belong to the generally poorer in the society.

Due to decline of catch and hindrance in fisher's access to the resource in absence of alternate income generation activities, their economic conditions has deteriorated. In most of the study sites, overall income of the fishers has been found to be less than the expenditure while the non-fishers income was higher than their expenditure (Table 2).

Table2. Average monthly income and expenditure per fishers' and non-fishers household in study area

Study Area	Fishers		Non-Fishers	
	Income	Expenditure	Income	Expenditure
Chandpur	4016	5330	6239	5455
Cox's Bazar	6925	6466	8410	7003
Kishorgonj	5043	5201	6323	5863
Kurigram	4260	3930	4311	4175
Moulovibazar	5792	5148	8812	5785
Netrokona	3175	3509	4559	4070
Patuakhali	4521	5497	5414	5588
Average	4815	5612	6118	5442

The monthly income of about 73% of the fishers was less than Tk.5,000. In the higher income group the incidence of fishers household was lower than that of non-fishers (Table 3).

Table 3. Percentage distribution of fishers' and non-fishers households by monthly income level

Monthly Income (Taka)	Fishers	Non-Fishers
Up to 2500	8.6	4.9
2500 -5000	64.0	56.8
5000 – 7500	17.9	17.3
7500 – 10000	6.4	11.1
10000+	3.1	9.9
Total	100.0	100.0

Fishers association: In all the survey, sites existence of fisher's association have been reported. Howvere, these association are not functioning properly except Hail haor of Sreemongal, Hugla beel of Netrokona and Cox's bazar where there are Govt. interventions for community based fisheries resource management and new fisheries management policy under different projects.

Occupational status: The occupation in the study area was found to be diversified. The people depends on different occupations in different seasons except the professional fishers who usually are strict to fishing occupation. Occupational diversification of the household members of the study sites is shown in the following Table 4.

Table 4. Main occupations of fishers and non-fishers household members

Main Occupation	% of Fishers household members	% of Non fishers household members
Full time fishing	30.4	2.3
Part time fishing	2.9	1.0
Fish business	0.1	2.9
Fish Culture	0.1	0.1
Agriculture	0.6	9.9
Housewife	24.8	23.1
Household work	5.0	3.7
Day labor	1.8	10
Business	0.6	6.9
Service	1.9	7.3
Student	30.5	30.3
Rickshaw/Van puller/Boatman	-	1.3
Unemployed	-	0.6
Others	1.3	0.6
	100	100

In fishers' household about 60% members (housewife/house work 29.8% and student 30.5%) and in non-fishers households 57.1% members (housewife/housework 26.8% and student 30.3%) are non-income generating, while about 40% members in fishers' household and 42.9% household members in non-fishers household are engaged in income generating activities/occupations. There are much similarities between fishers and non-fishers household occupational distribution in respect of members engaged in income generating and non-income generating activities, but there is difference in distribution of income generation occupation. In fishing households fishing is the single highest income generating occupation, covering 33.3% in 40% (83% of income generating members) while non-fishers households income generating occupations are much diversified and distributed significantly over agriculture 9.9%, day labor 10%, service 7.3%, business 6.9% and fishing 3.3%. In fishing households about 72% income comes from fishing followed by 12% from day labor and 8.5% from fish and other trading and 3.7% from agriculture (Table 5).

Table 5. Fishers households income by sources

Income source	% of Fishers households income							
	Chandur	Cox's Bazar	Kishorgonj	Kurigram	Moulovi bazar	Netrokona	Patuakhali	All
Fishing	77.0	79.7	74.4	86.9	60.6	59.0	65.6	71.7
Fish trading	7.2	2.3	7.6	8.0	0.6	2.6	-	3.7
Business	3.7	6.9	2.0	2.4	5.3	4.3	7.0	4.8
Fish culture	0.2	-	-	-	0.4	-	1.7	0.3
Net making and selling	-	0.4	8.9	-	0.4	-	-	1.0
Agriculture	1.2	0.8	0.4	0.2	7.3	10.8	3.0	3.7
Day labor	10.7	5.4	5.2	0.7	16.2	22.0	19.1	11.5
Service	-	0.7	-	0.8	1.4	0.8	1.3	0.8
Others	-	3.8	1.5	1.0	7.8	0.5	2.3	2.5
Total	100	100	100	100	100	100	100	100

Education: The study shows that 70% fishers are illiterate with no higher education. The illiteracy rate is higher than the national figure of 51% (National Economic Census, 2009) while about 55% non-fishers are illiterate but they have more access in the higher education than that of the fishers.

Land holding: About 12% fisher's households are landless, 72% households have only homestead land and about 16% have agricultural land. Landless people live on embankment, roadside or in others houses. Landless households in non-fishing and fishing communities are almost the same, but households having both agricultural

and homestead land is much higher in non-fishing households (32.7%) than in fishers households (15.2%).

Fishing equipment: On average, about 44.3% fishers do not have fishing boat and 30% do not have any fishing gears. They catch fish using boat and net owned by Mohajons on catch share basis or as laborer. About 43% fishers households have their own boat and 70% fishers households have own fishing gear. In some areas (Netrakona and Patuakhali) fishers have been found to own fishing boats on share basis through fishers association.

Type of homestead: About 80% of the house holds (both fishers and non-fishers) have tin roofed house and about 15% houses are thatched and the rests are pucca or semi-pucca. No significant difference has been found in respect of house types between fishers and non-fishers in the study sites.

Livestock: On average 53.2% of fishers households and 37.6% of non-fisher households do not own any livestock. Major type of livestock owned by both fisher and non-fisher house holds are cow and poultry (cow-30% HH, poultry- 52% HH).

Health and hygiene: In respect of the access to health and hygiene the fishers are almost in the same status as of the non-fishers. However, there are some discrepancies in some cases. There is higher incidence of using pond and river water as drinking water among fishers than that of the non-fishers. Less percentage of fishers household have been found to use sanitary latrine than the non-fishers while more fishers households (7.3%) use open space against 2.5% in case of non-fishers.

Loan and credits: Fishers are disorganized and do not have any bargaining power and as such they are exploited. Fisher's access to fisheries resources is intervened by middlemen and is often exploited by mohajon/aratdar/middlemen. About 77.6% fishers household take loan from different resources for maintaining their family during lean and ban fishing period as well as for purchasing fishing equipment. Major source of fisher's loan is the NGO covering 70% households followed by 18% from mohajon, aratodar, relatives and neighbors and 8% from bank, and 4% from cooperatives. The fishers do not have access to institutional credit as they cannot pay collateral and as such depend on private money lenders/NGOs.

Fisheries resource management and fishers access mechanisms to the resource

History and background of fisheries resource management and fishers access

Historically fishers used to enjoy customary rights to fish in rivers, beels, haors and baors either free or paying some tolls or handing over some portion of their catch to the people of the state (Ali *et al.* 1996). In 1773 a new system of land rights was introduced by British Govt. known as permanent settlement under which influential people (Zamindar) were granted ownership of large tracts of land including water bodies. The Zamindar or landlords used to lease the Jalmohals (section of rivers, individual/group of beel, baors) to well to do people for harvesting fish. The lease holder used to engage fisher as laborer for fishing or sometimes fishers would get fishing rights on payment of money. The fishers did not have direct access to the fisheries and were exploited by the rich and powerful people and also money lender from whom they would take loan for purchasing fishing equipment and maintaining livelihood in off season. The Zamindar system was abolished in 1950 and the ownership of the Jalmohals in rivers, canals, beel/haors, and oxbow lakes was vested with the Govt. for management of fisheries resource. On behalf of the Govt. the Ministry of Land administration and Land Reforms (now Ministry of Land) used to control and mange the water bodies. Management of Jalmohals by MoL includes leasing out of the Jalmohals for harvesting fish and collection of govt. revenue according to public water bodies (Jalmohals) management policy of MoL (MoL 1987, MoL 2001). However, since 1995 the Jalmohals in the flowing river were declared lease free and open to all for fishing. Though the administrative control of the water bodies is with the Ministry of Land, the MoFL/DoF is responsible for fisheries resource management and conservation to increase fish production on sustainable basis for poverty alleviation and food security according to the National Fishery Policy (MoFL 1998).

The fisheries in the water bodies within Sundarbans forest area is managed by the Department of Forest through issuing permit to the fishers for harvesting fish. Marine fisheries resources in the Bay of Bengal are managed by the Department of Fisheries (DoF) through issuing license in both industrial and artisanal fishing including enforcement of marine fisheries conservation laws and regulations. Bangladesh Navy and coast guard are also responsible for protection and conservation of marine fisheries resources through implementation of the marine fisheries laws and regulations.

Present management practices and fishers access

Inland Fisheries/Jalmohal management system that were found in practice in the country during this study were (1) no leasing system with free and open access to all in the flowing rivers without any control of fishing intensity, (2) leasing system of closed Jalmohals up to 20 acres to the unemployed youth association and Jalmohals above 20 acres to the fishers association through tender system, (3) New Fisheries Management Policy providing fishing right directly to the genuine fishers through licensing by abolishing middlemen, (4) Community based fisheries management, and (5) Govt.-community co-management. However, the MoL has recently declared new jalmohal management policy, 2009 revising some of the previous system.

For management of Jalmohals (Inland), Ministry of Land time to time adopts policy for management/leasing of Jalmohals. Recently Government has declared Public Water Body (Jalmohal) Management Policy 2009, vide, MOL Memo No. Land Ministry/Sec-7/Misc (Jal)/02/2009-1991, dated 23.06.09 superseding all previous policy/orders etc. for the purpose of (i) Giving priority in leasing the Jalmohal to the genuine fishers, (ii) Earning of government revenue, (iii) Protection and conservation of fisheries resources and increase of fish production, and (iv) Conservation of biodiversity (MoL, 2009). Major change in this policy is to introduce licensing system to the genuine fishers only with a token fee instead of free access for all to the flowing river for fishing which was introduced in 1995.

Fishers access to floodplains

Seasonal floodplains are the important sources of fish production in open waters where the poor fishers undertake fishing free of cost for their livelihoods. Recently floodplain aquaculture with embankment/enclosure has been widely in practice by the land owners particularly in Daudkandi area of Comilla district and expanding in other areas of the country (Morshed 2007). Presently about 10,000 ha of seasonal floodplains are under aquaculture (Unpublished report from DoF). This has affected the access of poor fishers to floodplain fisheries (Parvin 2007). The poor fishers do not have access to this aquaculture as they do not have land in the floodplain area. This aquaculture practice is community based by the land owners. However, in some cases, landless/fishers have been included as share holder of this aquaculture practice through intervention of some NGOs.

Problem in fisher's access and fisheries management

Though leasing of the Jalmohals was earmarked preferably for the fisher's cooperative society, the poor fishers could not pay the lease value and hence they depend on the rich man/mohajan for payment of lease value. The rich man/mohajon pay the lease money on behalf of the fisher's society and get full control of the Jalmohals where the fishers undertook fishing on payment of money or as laborer or on catch share/contract basis.

Fishers reported that lease value of jalmohal is fixed at very higher rate without considering the fish resource status which encourages over fishing and affect fishers access to the resource as they can not pay high lease value and ultimately the control of jalmohal goes with the rich people and the fishers work there as laborer or share basis for fishing.

Short-term revenue driven management system of jalmohals through leasing is harmful both for the fishers and fisheries resources. This system encourages over fishing by the lessees. On the other hand, the new fisheries management policy (NFMP) through licensing to the fishers and community based fisheries management system (CBFM) ensure fishers access to fisheries resources, proper management of fishery resources and increase in fishers catch and income.

Manmade interventions and natural causes like over fishing, implementation of FCD/FCDI project, construction of roads and highways, agrochemical and industrial pollution, siltation etc. have reduced and degraded fish habitat/water bodies and affected the aquatic lives and production and thereby fish production has declined and fishers are affected (Ali 1997).

Due to construction of embankment for control of flood under FCD/FCDI project and unplanned, construction of roads and highways, the to and fro migration of fish between river and floodplain have been disrupted and thereby fish stock in inland open water has declined. Flood control structure and drainage program along with siltation of inland water areas have reduced water area affecting fish production. Due to implementation of FCD/FCDI project about 1.00 million ha floodplain water area has been dried up (Ali 1995). Water pollution caused by use of agro chemical and industrial effluent has affected fish stock. Along with the loss and degradation of fish habitat, over fishing/exploitation due to increase of human population has created tremendous pressure on the fish stock leading to depletion of fisheries fish resources in the open waters.

Access right to the fisheries resource by the poor fishers appeared to be ensured under 3 management systems such as: (i) the open access system in the flowing river which is now replaced by licensing system to the genuine fishers, (ii) new fisheries management policy providing fishing right to the fishers directly through license by abolishing the middleman, and (iii) community based fisheries management system under DoF development projects/programme.

Fisheries Laws & Regulations

For protection, conservation and biological management of inland and marine capture fisheries resources there exist some Act/ordinance, laws and regulations such as (1) Protection of Conservation of Fish Act 1050 and (2) the Marine Fisheries Ordinance 183 & Rules. The main features of the fisheries laws and regulations in Bangladesh are to ensure sustainable fish production, social justice and equity through (i) protection of juveniles fishes to attain maturity for the re-production and increase of production; (ii) protection of brood fishes to allow them for breeding;(iii) ensuring migration of fish for growing and breading; (iv) protection of fish habitats and (v) ensuring social justice and equity in access to fishery resources by allocating fishing zone for small scale fishing and industrial fishing by trawler.

Fishing ban and fish sanctuary and their impact on fishers access and fisheries resource

According to fisheries law, catching of juvenile hilsa (Jatka) below 23cm during the period from November to April is prohibited. The major Jatka fishing gear-current jal (gill net made of monofilament synthetic fiber, upto mesh size 4.5 cm) is also prohibited. However, the laws and regulations are not properly implemented. Government has also banned manufacture of current jal. However, the factory owners have lodged case against this ban. The ban is still pending for decision and current jal is being manufactured and easily available in the market. However, Government has taken up a special programme to protect Jatka through banning of all fishing gears in major Jatka fishing ground for 2-3 months.

The fisheries laws and regulations are not usually against interest or benefit of the fishers. However, ban of all kinds of fishing in large area for a long time affect the fishers as has been the case that the govt. has imposed ban of all kinds of fishing for the last 3 years in 330 km long continuous stretches of the large river system of the lower Meghna, Tetulia and Andharmanik for 2-3 months in order to protect Jatka. This ban has been reported to be beneficial for the fisheries resources but the fishers livelihood are affected during fishing ban. Due to this ban production of Hilha has

increased significantly during the recent years. Hilsha production of the country has increased from 1,99,032 MT in pre-ban period (2003-04) to 2,90,000 MT during the ban period in 2007.

Accrding to some stakeholders, banning only the harmful gears like jagatber jal, current jal etc. in jatka catching can protect hilsha instead of banning all fishing gears. They also suggested compensation should be given to the true and affected fishers during fishing ban to intensify the enforcement of laws and regulations. On the other hand some stakeholders particularly DoF officials informed that if the fishers were allowed to use other gears they would take the opportunity and use Jatka fishing gear particularly the Current Jal secretly.. Virtually the laws and regulations are not properly enforced due to institutional weakness of the implementing agency of the Govt. (DoF). Even during the ban period huge quantity of Jatka have been reportedly caught from the areas of fishing ban.

Establishment of fish sanctuary along with other management interventions in Hail haor has been reported to have increased fish production from 151 kg/hectare per year during pre-intervention period to 389 kg/hectare per year due to sanctuary establishment and other management practices (Ali et al, 2006). There are about 120 beels of different size in Hail Haor and 27 beels were managed under USAID funded MACH Project by Community Based Organizations (CBO). The 27 beels were leased to the CBOs for 10 years which was renewable based on satisfactory performance. In most of the beels, CBO established sanctuaries in part of the beel area. One permanent sanctuary was established in 122 acres of a beel named 'Baikka beel' with public support and managed by CBO. The community based management system including establishment of sanctuary created significant impact in increasing the fish production, biodiversity and fishers income. Besides, about 464 fish sanctuaries were established in 291 Jalmohals covering an area of 1745.6 ha under different development project of DoF and other organizations under community based management approach. Sanctuaries were established in part of the Jalmohal and the rest areas were used for harvesting fish by the community.

Coping strategies during lean and ban fishing period

There is lean fishing periods in different months in different area/water bodies when fishers catch becomes extremely low to the tune of less than one forth to half of the peak season catch. In a study conducted by BCAS in 1995, it was found that fisher's daily catch was 4.3 kg in peak fishing season while it was only 1.8 kg in lean season in the river Jamuna (BCAS 1995). In the present study the lean season catch is also almost ¼ of the peak season catch (Table 6) which is supported by the results of the

study conducted by BCAS in Jamuna River. In the present study the overall peak season catch has been 8.54 kg and that of lean season catch 2.09 kg which are much higher than that of BCAS study. This higher might be due to the inclusion of beel and sea catch where catch is usually higher than the riverine catch.

Table 6. Average daily fishers catch in peak and lean seasons

Study Area	Average daily catch of fisher	
	Fisherman	
	Peak season	Lean season
Chandpur	4.9	1.1
Cox's Bazar	14.9	3.6
Kishorgonj	11.1	2.84
Kurigram	4.5	1.3
Moulovibazar	8.5	2.1
Netrokona	5.5	1.3
Patuakhali	12.2	3.0
All	8.54	2.09

About 80% of the fishers are poor and they do not have opportunity for alternate income generation activities so they suffer much during lean fishing period. During lean fishing period the fishers usually take loan/Dadon from mohajan/aratdar on condition that they would sell their catch to them at the rate fixed by them as well as from the NGOs and relatives. They also reduce expenditure by different ways including taking less food etc. Sometimes the fishers go for other works such as day laborer, rickshaw van puller etc (Table 7). Howevere, the Hindu fishers are not used to this type of activities and hence they suffer most. Coping practices of the fishers as assessed under the study are furnished in Table 7.

Table 7. Coping strategies adopted by fishers household during lean fishing period

Coping Strategy	% of households adapting various coping strategies							
	Chandpur	Cox's Bazar	Kishorgonj	Kurigram	Moulovi-bazar	Netrokona	Patuakhali	All
Daily labor, Rickshaw pulling etc.	24.7	9.7	28.4	6.6	39.8	34.4	26.4	22.6
Loan from different sources	27.9	24.5	32.8	19.5	43.0	24.7	41.4	28.5
Taking Dadon	9.7	20.3	22.4	5.3	1.1	1.8	20.7	10.2
Agriculture	-		-	-	-	-	9.1	8.0

work								
Reduce expenditure/ take less food	36.4	26.6	4.5	40.2	7.5	34.3	3.4	26.4
Spending from savings	1.3	18.9	11.9	28.4	8.6	4.8	8.0	12.3
Total	100	100.0	100	100	100	100	100	100

Govt. has imposed ban on all kinds of fishing in 290 km stretches of the lower Meghna and Tetulia rivers for a period of 2 months (March-April) in Chandpur, Laxmipur and Bhola districts; and in the Andharmanik river (40 km) in Patuakhali district (study sites) for 3 months (Nov. – Jan.). About 3-4 lacs fishers are affected by this fishing ban.

During fishing ban period, fishers adopt different coping strategies in addition to the government support in Chandpur and Patuakhali area. Most of the fishers depend on loan from different sources such as mohajan/aratdar/money lender and NGOs. Some fishers go for other activity like day labour, rickshaw pulling etc.

Government provides some compensation during the ban period at the rate of 10 kg of rice to each affected fisher family and Tk.1000 to some of the ultra poor family. This compensation is quite insufficient for them and the distribution of the compensation is not properly done. In Chandpur area, 98.4% fishers received the compensation while in Patuakhali only 32% fishers received the compensation. Fishers in Patuakhali reported that the Govt. compensation was not properly distributed in that area because of the choice of the local UP Chairman who favored his own people and ignored many affected fishers. The fishers asked for increasing the compensation or to provide food/cash works for them during the fishing ban period.

In other study sites there is no such fishing ban by the govt. but under the New Fisheries Management Policy (NFMP) and CBFM system and in other areas where there is fishers association, fishing ban is imposed by the fishers association during fish breeding season. However, there is scope of fishing in floodplains and other water bodies where there is no fishing ban. Coping strategies adopted by the fishers during fishing ban are furnished below (Table 8).

Table 8. Coping strategies adopted by fishers household during ban fishing period

Coping Strategy	% of households adapting various coping strategies							
	Chandpur	Cox's Bazar	Kishorgonj	Kurigram	Moulovi-bazar	Netrokona	Patuakhali	All
Daily labour	21.6	12.9	10.4	-	46.4	46.1	28.3	27.3
Loan from different sources	33.8	61.0	39.6	-	47.8	41.4	34.4	38.5
Govt. support	41.3	-	-	-	-	-	20.2	18.6
Agriculture work	1.3	-	2.1	-	-	6.9	2.0	2.5
Spend money from saving	-	9.7	4.2	-	-	-	1.0	1.4
Reduce expenditure	-	-	6.3	-	-	-	-	0.7
Catch fish in other water bodies	-	3.5	6.3	-	5.8	4.5	3.0	3.3
Others works	2.0	12.9	31.1	-	-	1.1	11.1	7.7
Total	100	100	100	-	100	100	100	100

Key findings

Socio-economic aspects of the fishing community

a) Fishers are mostly poor, landless and neglected in the society and are exploited by the rich people/mohajan/aratdar in different ways. In the riverine and coastal/marine areas many fishers do not have fishing equipments (boat and net) and as such they undertake fishing in Mohajan's boat as laborer or on catch share basis. In spite of fishers priority in getting lease of Jolmohals they do not get direct access right to the fisheries resource (Jalmohal) as they are to rely on the Mohajn/rich people for payment of lease value.
b) Fishers are mostly illiterate, not organized and do not have voice for bargaining to get their right.
c) Fishers are economically depressed, their income is less than the expenditure and as such ineptness is a chronic problem to the fishers and mostly dependant on non-institutional credit from mohajan/aratdar/rich people with high rate of interests. Many of the fishers take dadon (advance money) from the aratdar/mohajan to maintain their family and purchase of fishing equipments on condition that they would have to sell the fish to the aratdar/mohajan at lower price of fish. They do not have access to institutional credit due to lack of collateral and also a lengthy process.

d) Coastal/marine fishers are affected by natural hazards like cyclone; tidal bore etc. due to climate change effects and gradually the fishers are becoming poorer.
e) Fishers do not have opportunities for alternate income generating activities during lean and ban fishing period and they suffer much during those periods.

Fisheries resource, management and fishers access to the fisheries resource

a) Revenue oriented short term leasing/management system by MoL affects fisher's access and encourages over fishing by middleman leading to depletion of fish population.
b) Increasing population is putting heavy pressure on fisheries resource in absence of alternative job opportunity of fishers.
c) In dry season, beels and haors dry up and brood fish and fish production are affected.
d) Free and open access to flowing river ensures fishers access to the resources but it indulged over fishing. However, in recent Jalmohal management policy of MoL, this lease free system has been replaced by licensing system with token fee in order to ensure genuine fishers access and to control over fishing. Though under the new management system the fishers will have to pay token money but it would be beneficial for the fishers as well as to the fisheries resources.
e) The new fisheries management policy (NFMP) and the community based fisheries management (CBFM) system has been found to ensure fishers access to the resources and also beneficial for the fisheries resources.
f) Ban of all kinds of fishing for three months (November-January) in Andharmanik river and two months (March-April) in lower Meghna for protection of Jatka (Juvenile Hilsa) has positive impact on production of Hilsa and other fishes. However, due to ban of all gears fishers livelihood have been affected during this ban period as they do not have any alternate income generating activities. Govt. support to the affected fishers during ban period is quite insufficient and is not properly distributed.
g) Fish sanctuaries along with implementation of fisheries regulations impacted positively on the fish production and fisher's income in Haor and Beel areas and in other water bodies under community based fisheries management.
h) Manmade interventions such as FCD/FCDI project, indiscriminate use of insecticide and pesticide in agriculture, siltation of waterbody affect fish habitat causing decline of fish production and affecting fisher's livelihood.

i) Recently widely introduced floodplain aquaculture practices particularly in Daudkandi area is affecting the access of fishers to the floodplain fisheries and also the open water fisheries, biodiversity and environment.
j) Jalmohals are controlled and leased out for harvesting fish by MoFL for collection of Govt. revenue while MoFL is responsible for sustainable increased production of fish for food security and improving the livelihood of the fishing community through biological management of the fisheries resources. There is lack of co-ordination between MoFL and MoL and other related agencies rather there is policy and power conflict between the agencies which has led to decline the fisheries resources and production and hampered fishers access to the resource.

Coping strategies during lean and ban fishing period

a) During lean and ban fishing period the fishers suffer much and their livelihoods are affected as they do not have opportunities for alternate income generating activities. They take loan from non-intuitional sources like Mohajan, Aratdar, NGOs, relatives, banks etc. for maintaining their livelihood during lean and ban fishing period. However, some of the fishers work as laborer and migrate to other areas for job.
b) During ban of all fishing in lower Meghna and Andharmanik River the fishers get some compensation from the Govt. but it is quite insufficient and mal distributed.

Policy implications and recommendations

Based on the results and findings of the study the following policy implications and recommendations are made to ensure fisher's access to fisheries resource for income generation and improved livelihood including enhancement of their copping strategies during lean and ban fishing period.

i) Revenue oriented short term leasing/management system is responsible for overexploitation and impediment to fisher's access to the resource. This system should be replaced by biological management through community based/co-management of fisheries resources (CBFM) and new fisheries management policy (NFMP)/licensing system to the genuine fishers for longer period in order to ensure fishers access to the resource and sustainable production and for this purpose the fishers be organized and empowered.
ii) Ban of all kind of fishing gears for 2-3 months in 330 km stretches of the lower Meghna and Andharmanik river for conservation of Jatka affects the livelihood of thousands of poor fishers. All gears are not harmful to Jatka. Therefore, only

harmful Jatka fishing gear (Current jal, Jagatber etc) may be banned instead of banning all types of fishing gears with intensifying enforcement of law with provision of sufficient manpower and logistics. To see the effectiveness of banning only the Jatka fishing gears, a study may be undertaken.

iii) During fishing ban Govt. provides some compensations which is quite insufficient and not distributed properly. Govt. support should be increased to the affected fishers during fishing ban and distribution of the government compensation be properly managed and supervised so that each affected fisher gets his share during fishing ban. The govt. support may be in the form of food/cash money for work where possible.

iv) The fishers do not have any alternate job opportunities during lean and ban fishing period. Therefore, arrangement for AIGA should be provided for the fishers during lean and ban fishing period and also for controlling over fishing.

v) Fisheries laws and regulations should be enforced strictly and sufficient number of fish sanctuaries be established in suitable locations as a national programme and enforced properly.

vi) The poor fishers do not have access to the institutional credit as they can not arrange collateral. They also are afraid of the cumbersome and lengthy process of institutional credit. Easy term institutional credit with low interest without collateral should introduced for the poor fishers.

vii) Dual administration in fisheries management by MoL and MoFL with conflicting policy strategies affects fisheries resource and fishe'rs access to resource and their income and livelihood. Better coordination among the ministries is needed to be established or unified management system needs be introduced.

viii) There are sufficient laws and regulations and policies for protection, conservation and management for fisheries resources but these are not properly enforced due to lack of institutional capability of the enforcing agencies, particularly of DoF. Institutional capacity of the DoF responsible for protection, conservation and management of fisheries resource need to be strengthened with more manpower and logistics for proper enforcement of fisheries laws and regulations.

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References

Ali, M.L. and Thompson, P. (2006). MACH Technical Paper 4, Wetland Protection through Sanctuaries in Bangladesh.

Ali, M.Y, (1997). Fish, Water and People, Dhaka, Bangladesh. University Press Ltd. & BCAS.

Ali, M.L, Alam, S.S., Doxon, P.J., Halls, A.S. and Thompson, P. (2003). Understanding Livelihood Dependant on Inland Fisheries in Bangladesh, World Fish Centre/DFID/MRAG.

Ali, M.L, Hossain, M.A.R. and Ahmed, M. (2008). Impact of Fish Sanctuary on Fish Production, Biodiversity and Socio-economic Condition of the Fishing Community in Bangladesh. Research Report, Supported by BFRF, 2007.

BBS, (2007). Report of the House hold Income & Expenditure Survey 2005, Bangladesh Bureau of Statistics, 2007.

BCAS, (1995). Impact of Jamuna Bridge on Fisheries Resources in the River Jamuna.

DoF, (2008). Fisheries Statistical Yearbook, 2007-08. Department of Fisheries.

DoF, (1983, 1993 and 2007). Fish Catch statistics/Fisheries statistical yearbook of Bangladesh, Department of Fisheries.

DoF, (1963). 1973, Unpublished Report of Fish Production of Bangladesh, Department of Fisheries.

DoF, (2009). Souvenir, National Fish Week, 2009. Department of Fisheries.

IMED, (1990). Evaluation of New Fisheries Management Policy in Bangladesh.

MoFDM, (2006). National Food Policy, 2006. Ministry of Food and Disaster Management.

MoFL, (1998). National Fisheries Policy, 1998. Ministry of Fisheries and Livestock.

MoF, (2009). Bangladesh Economic Review, 2009. Ministry of Finanace.

MoL, (2001). National Land Use Policy, 2001. Ministry of Land.

MoL, (2009). Public Water Body (Jalmohal) Management Policy, 2009. Ministry of Land.

Morshed S.M., (2007). Community Floodplain Aquaculture – Daudkandi Model, Souvenir of Fish Fortnight 2007, Department of Fisheries 2007.

Mustafa, M.G. and Brook, A. (2009). A Comparative Study Of Two Seasonal Floodplain Aquaculture System in Bangladesh, Water Policy Supplement.

Pokrant, B., Reaves, P. and McGuire, J. (1997). Riparian Rights, the Organization of Work and Market Relation among the Inland Fishers of Colonial Bengal 1793 to 1950. Open Water Fisheries of Bangladesh, edited by Chu Fa Tsai and M. Yousuf Ali, Published by UPL and BCAS.

Rahman, (2001). Sustainable Development of Poverty Eradication, Fishery Resource Technology and Management, Proshika, 2001.

Siddiqui K, and Naqui S.A. (1989). Licensing Versus Leasing System for Govt. Owned Fisheries (Jalmohal/Inland Fisheries) Management in Bangladesh, edited by M.Aguaro et al, 1989, DoF, BCAS & ICLARM.

Sultana, P., Thompson, P, Alam, S.S. and Ahmad, A. (2003). PRA Report on Livlihoods Dependent on Inland Fisheries in Bangladesh, World Fish Centre/DFID/MRAG.

Sultana, P. (2009). Distributional implications of enclosures of floodplain commons in Bangladesh, Flood Hazards Research Centre, Dhaka.

Rural aquaculture: way to poverty alleviation and livelihood security at Patiya, Bangladesh

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Abstract: Aquaculture has gaining importance in Bangladesh to compensate for the declining fish production from capture sources. Present study was carried out at Patiya Upazilla under Chittagong district and aimed for analyzing the role of community-based aquaculture in livelihood sustainability. Data was collected through the questionnaire survey, focus group discussion, participatory field observation and key informant interview. Data analysis revealed that extensive, improved extensive and semi-intensive aquaculture systems with carp and tilapia polyculture has been practiced in 438 ha, which covers about 6% of the study area. Average carp and tilapia production was recorded 1800 and 1275 kg/ha/yr with local market prices of Tk 130/kg and Tk 110/kg respectively. Total yearly production was recorded about 680 MT with economic value of Tk 82 million (1 US$=Tk 82) from the study area. The respondents reported that about 10% of the production has been consumed by farmers household. It is amazed that 96% fish farmers improved their life style with cash income, intake protein food, bought good cloths, increased school-going children and repaired houses; where disease outbreak in some farms hindered farmer's progress. Shortage of quality fish fry and lack of loan facilities are the main operational barriers for rural aquaculture at Patiya. Extension services with farmers training, disease monitoring and in-time loan can stimulate aquaculture production several folds to contribute in food production, malnutrition control and above all secure rural livelihoods.

Introduction

Bangladesh is considered one of the most suitable countries in the world for small-scale freshwater rural aquaculture, because of its favorable resources and agro-climatic conditions (Ahmed and Hasan 2007). The socio-economic benefits derived

from aquaculture expansion include the provision of nutrients, employment and income generation for the poor, diversification of production and generation of foreign exchange earnings through export of high-valued products (Hossain 2009). It is estimate that about 4.4 million people is directly employed in the sector, while another 12 million people earn their livelihoods from fisheries and related activities. This sector contributes about 58% animal protein intakes of the population of Bangladesh. It is constitutes 3.74% of GDP and 4.04% of export earnings (DoF 2009). Rural aquaculture plays an important role for rural development in Bangladesh because more than 70 percent people of our country live in village (BBS 2008).

Aquaculture activities have been improved significantly in the recent years aiming the increased production target worldwide in a sustainable way. Sustainable aquaculture development can contribute to the prevention and control of aquatic pollution since it relies essentially on a good quality water resources (Das and Hossain 2005). Aquaculture in Patiya is significantly increasing trends due to good transportation facilities, establishment of many hatcheries, presence of suitable aquatic habitats, and involvement of local people with maximum investment. The numbers of cultured pond are 8400 covering 992 ha. In addition, the number of cultivable ponds is 2056 covering an area 243 ha, which indicates probability of aquaculture expansion at Patiya. More than 30,000 people engaged directly or indirectly in this occupation at Patiya (DoF 2008). Present study aims to identify different types of aquaculture system, yearly production, barriers of aquaculture expansion and to assess aquaculture potentiality as a climate change adaptation option.

Study area

Patiya Upazila consists of one municipality, 25 unions and 124 villages. Present study was carried out in 15 villages of Patiya Upazila under Chittagong district that lies between 22°12′ and 22°20′ latitudes and 91°48′ and 92°04′ longitudes covering an area of 7500 ha and consists of 5 unions with population of 130,000 (BBS 2008). The area is blessed with multiple aquatic ecosystems in the forms of canals, small and large ponds which are suitable for expansion of fish farming and support multitudes of fisheries species. Beside these, seasonally waterlogged paddy fields are also suitable for rice cum fish farming and a better option for maintaining ecological balance, utilizing space, generating major source of employment for poor people and also act as a protein source for the rural community. Farming of tilapia, carp, koi pangus and punti as well as establishment of backyard hatchery has gained popularity due to shorter production period (3-4 months) with higher economic returns. Ponds

are filled with rainwater and then maintain weed clearing, eradication of unwanted animals, liming, fertilizing, releasing fry for nursing, supplying adequate feeds and harvesting for marketing. Moreover, water from canals, low laying areas, swamps and steam corridors are also used in the culture pond. Sometimes, torrential rains during the rainy season and hilly flash floods may cause severe damage of culture fisheries at Patiya.

Materials and methods

Fifteen villages from Kharana, Dhalghat, Kolagaon, Juldah, and Kasiais union were selected for the study. A total of 200 fish farmers were randomly selected from the 15 villages. The study was relied on questionnaire survey, participatory observation, focus group discussion (FGD) and key informants interview following the approaches of Pido (1995), Pido *et al.* (1996), Townsley (1996) and Hossain et al. (2004). Questionnaire survey is suitable for eliciting perceptions, motivations and feelings of local stakeholders including baseline data on demography, occupations, economics and social harmony. Participatory observations offer a good opportunity to get a comprehensive and authentic insight in actual situations of the evaluation topic including actions, conversations, and physical descriptions (Gittleson and Mookherji 1997). FGD were conducted to identify the seasonal and daily activities of the community as it has the advantage that a tendency of self-correction mechanism within the group because if one person put across an over-favorable picture of his/her own or group's behavior, a peer would give a more realistic observation (Das and Hossain 2005). The interviewee focused on present status of aquaculture, its contribution on rural livelihoods and operational barrier of aquaculture technology in this area. Collected data from questionnaire survey were feed into the computer software Microsoft Excel and SPSS (Statistical Package for Social Science) version 11.5 for analysis. Correlation analysis was conducted to show the relationship between production and different criteria considered for aquaculture. ArcGIS software (version 9.3) was used for the preparation of digital maps with geo-spatial distribution of farming areas.

Results

Present status of aquaculture at Patiya

Present study revealed 73% farmers used improved extensive system followed by 19% extensive and only 8% semi-intensive in Patiya Upazila. Fish farming area was 438 ha with 2700 farmers in 5 Unions (Table 1). Carp and tilapia production ranged 1570-2090 and 1020-1520 kg/ha/yr respectively. Tilapia and major carps (ruhu, catla

and mrigal) were the most dominant culture species in Patiya. The other species such as kalibous, sada ghaniya and Chinese carp (carpu, bighead, grass carp, mirror carp and silver carp) were also cultured. Data analysis indicated 48% and 38% farmers used commercial feed and homemade feed respectively, where only 14% farmers used and no feed in Patiya.

Table 1. Union wise average production, fish farming area and market price at Patiya Upazila, Chittagong

Union name	HH number	Union area (ha)	Fish farming area (ha)	No. of Fish farmers	Production (kg/ha/yr)			Total prod'n (MT /year)	Farm gate price (kg/Tk)		Price (million Tk)
					Carp	Tilapia	Average			Tilapia	
Kharana	3210	1233	82	440	1570	1020	1295	106	135	110	13
Dhalghat	4450	1730	88	570	1950	1470	1710	150	125	110	17.5
Kasiais	3640	1356	79	480	1740	1150	1445	114	125	105	13
Kolagaon	4230	1370	81	490	1720	1520	1620	131	125	110	15.5
Juldah	3990	1820	108	720	2090	1220	1655	178	140	120	23
Total	19,520	7,509	438	2700				679			82

Contribution of aquaculture to rural livelihoods

Among the 19,520 households (HHs) in 5 unions, 2700 HHs were directly involved with fish farming at Patiya. About 8,000-10,000 additional indirect beneficiary have been involved with backward and forwardly linked sectors of aquaculture (harvesting, packing, trading, transportation, fry supply, feed supply and preparation). As a result, more than 50% HHs are involved in aquaculture sector as their income generating options with secure livelihoods and social harmony. Total annual production was 679 MT with market price 82 million Taka (1 US$ = 82 Taka) from only 438 ha fish farming area (Table 1). The respondents reported that about 10% fish are consumed by the farmer's household, which has substantial contribution in eradicating malnutrition problem in rural area.

The result showed that 96% fish farmer improve their life style through aquaculture, where only 3% fish farmer's lifestyle remained constant and only 1% faced economic loss at Patiya. Data analysis revealed that fish farmer's lifestyle improved with 77% increased food consumption rate, 53% improved house structure, 47% increased savings, 39% expanded aquaculture facilities, 23% bought cattle for homestead dairy and 17% leased land for agriculture (Fig. 1). Other improvement such as buying land (6%), opening shop (9%), sending son abroad (7%) and tube well installation (5%) were also reported by the respondents.

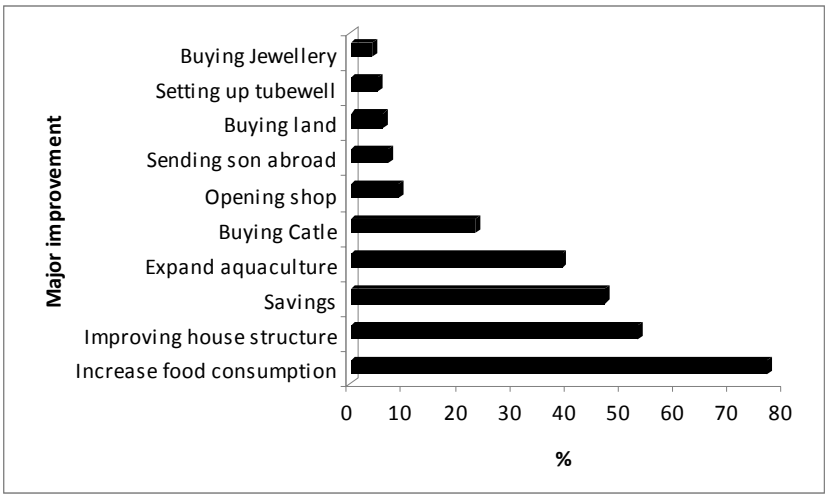


Fig. 1. Major improvement occurred in fish farmer's life style through aquaculture at Patiya (multiple responses).

Fig. 2 shows the correlation between production and different criteria considered for aquaculture. The correlation indicated improve extensive and semi-intensive culture system has significant contribution on aquaculture production (0.259 and 0.245, $p<0.01$), where extensive culture system has no significant contribution on production (-0.266, $p<0.05$) at Patiya. Use of commercial feed has significant contribution on fish production (0.643, $p<0.01$) followed by homemade feed (0.453, $p<0.01$), where natural feed showed no significant contribution on fish production (0.357). The overall increase of fish production significantly enhances (0.247, $p<0.05$) the livelihood of rural fish farmers at Patiya.

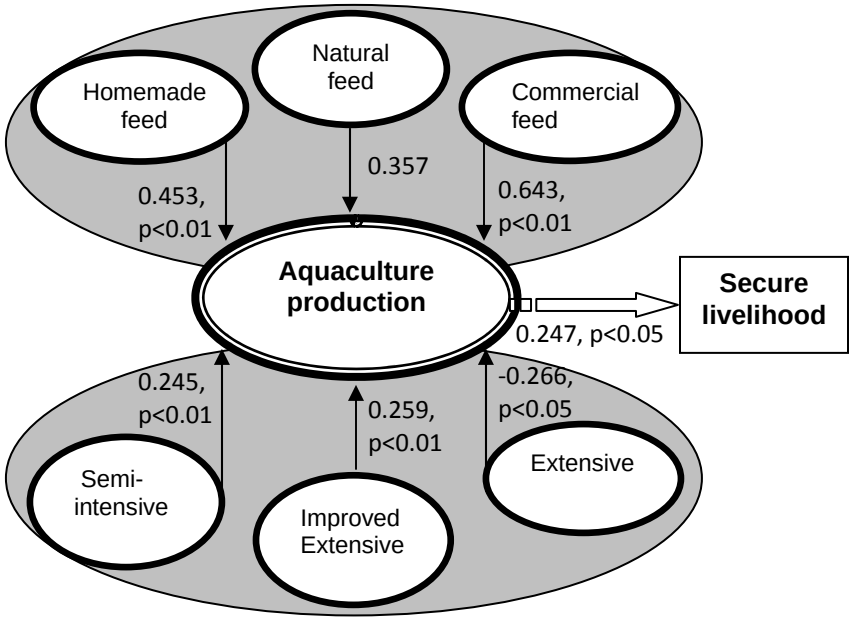
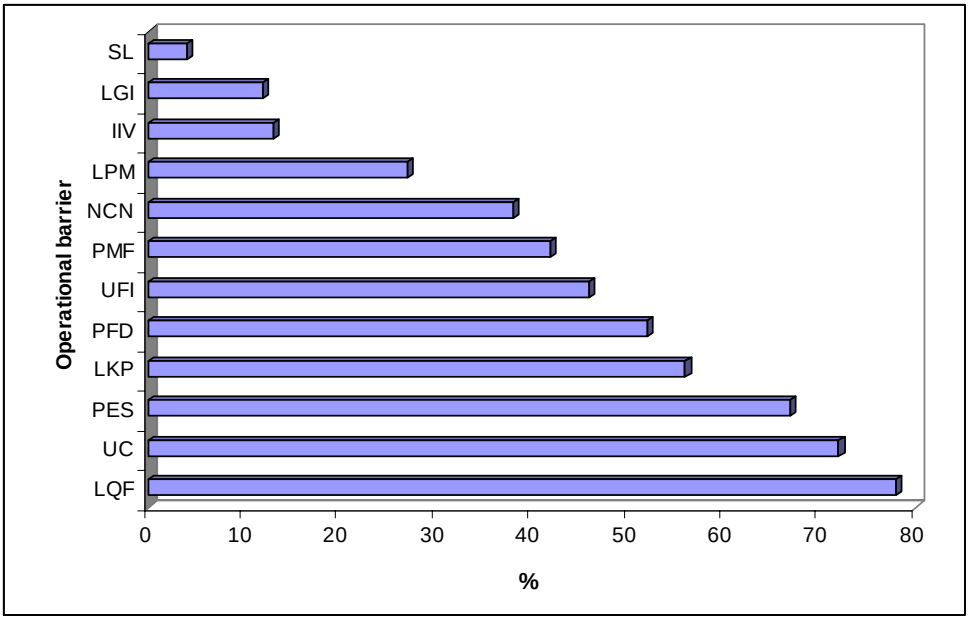


Fig. 2. Role of culture systems and feed sources on aquaculture production for livelihood security at Patiya.

Operational barrier of aquaculture

Present study identified major operational barrier of aquaculture at Patiya. Poor quality of fish fry, unavailability of credit, lacking of extension service with updated information, lack of technical knowledge on pond management and prevalence of fish diseases were reported as major barrier by 78%, 72%, 67%, 56% and 52% farmers respectively (Figure 5). On the other hand, unavailability of feed ingredients, poor market facilities, non-cooperation from neighbors (fish theft and pouring poison in the pond), low prices of fish in local markets, increased inter-professional violence, lack of government initiative for encouraging aquaculture activity and shortage of labor were mentioned by 46%, 42%, 38%, 27%, 13%, 12% and 4% fish farmer respectively.



LQF- Lack of quality fry, UC- Unavailability of credit, PES-Poor extension services and lack of information, LKP-Lack of knowledge on pond management, PFD- Prevalence of fish diseases, UFI- Unavailability of feed ingredients, PMF-Poor market facilities, NCN- Non-cooperation from neighbors, LPM- Low prices of fish in local markets, IIV-Increased inter-professional violence, LGI- Lack of govt. initiative for maintaining favorable entrepreneurship and SL-Shortage of labor.

Fig. 5. Operational barriers of rural aquaculture at Patiya Upazila.

Discussion

Around 400,000 ha of freshwater ponds/ditches and more than 900,000 households are involved in aquaculture in Bangladesh (ADB 2005). The main production systems for freshwater aquaculture in Bangladesh are extensive and semi-intensive pond polyculture of carps which account for 80% of the total freshwater aquaculture production (ADB 2005). The remaining 20% of the production is mainly attributed to pangus, tilapia, small indigenous species (SIS) and rice fish farming (Muir 2003). The Patiya Upazila of Chittagong demonstrates three types of culture systems such as extensive, improved extensive and semi-intensive. Polyculture of carps is a popular option used by many farmers, where pond preparation, water quality management, species selection, stocking density, and fertilizer doses are commonly known through inter-community dissemination and observing behaviour of neighbours and relatives. Ruhu, catla, mrigal and tilapia are the dominant culture species in Patiya. Polyculture of carp with tilapia in paddy field during rainy months is also observed in some area.

Singh and Singh (1975) reported to have achieved a yield of 4500 kg/ha/yr from polyculture of *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala* using chemical fertilizers and cow dung. Shohel (1998) obtained the production of 6000 kg/ha/yr in semi-intensively managed ponds in Noakhali district by supplying inorganic fertilizers compost and supplemental feed. Islam and Dewan (1986) estimated pond fish production 1700-3889 kg/ha/yr through semi-intensive culture of carps. The present study showed average production 1295-1710 kg/ha/yr carp-tilapia polycultre, which is lower compared to these previous findings.

The most important inputs required for more intensified aquaculture are feed. In Patiya, about 40% fish farmers use homemade feed. The feed ingredients that are predominantly used are rice bran, wheat bran and oil cake. Some farmers use commercial feeds from the local markets and very few farmers use no feed in their fish pond. The farmers of Patiya apply feed in direct casting method and suspended perforated sack method using jute bag. The jute bag is tightening with feed and tied with bamboo and placed at the corners of the pond. Sarker (2010) reported three major problems affecting tilapia cage culture in Chandpur are high cost and low quality of feeds, security problems and theft, severe disease problems and high mortality. Non-availability of hatchery produced fish seed is considered a major problem, although at certain times of the year (e.g the end of the cool season, or following the recession of flood waters) the demand may sometimes exceed local supply, particularly for large sized seed (Belton and Little 2011). Dey *et al.* (2010) also note that quality seed is a major problem faced by fish farmer due to the poor selection of broodstock, indiscriminate hybridization and inbreeding which are same to the present study area.

Aquaculture development approaches to uplifting livelihood opportunities for the rural poor remains a challenge. The rural poor face many constraints to entry into aquaculture, particularly impediments to the uptake of technologies and management practices because of such factors as lack of access to capital and resources, vulnerability, and aversion to risks. Aquaculture is the fastest growing segments in Bangladesh. Its success and growing popularity have resulted in inquiries as to its potential as an investment, as a means to diversity production on traditional agricultural farms. Rural aquaculture is economically sustainable system, when it is practiced scientifically and systematically. It not only fulfills our protein demand but also creates job opportunities for large number of poor people and sustain rural livelihood.

References

ADB. (2005). An Evaluation of Small scale Freshwater Rural Aquaculture Development for Poverty Reduction. Operation Evaluation Department, Asian Development Bank, Manila, Philippines.

Ahmed. N. and Hasan, M.R. (2007). Sustainable livelihoods of pangus farming in rural Bangladesh. Aquaculture Asia. XII (4): 5-11

BBS, (2008). Statistical Yearbook of Bangladesh. Statistics Division, Ministry of Planning, Govt. of the Peoples Republic of Bangladesh.

Belton, B. and Little, D.C. (2011). Contemporary visions for small-scale aquaculture. In: Chuenpagdee, R. (ed.) Contemporary Visions for World Small-Scale Fisheries. Eburon, Delft.

Das, N.G and Hossain, M.S. (2005). Livelihood and resource assessment for aquaculture development in waterlogged paddy land-remote sensing, GIS and participatory approach. GNAEP, DANIDA and University of Chittagong, Bangladesh.

Dey, M.M., Bose, M.L., Alam, M.F. (2010). Demand for aquaculture development: perspectives from Bangladesh for improved planning. Reviews in Aquaculture. 2:16-32.

DoF (Department of Fisheries). (2008). Fishery Statistical Yearbook of Bangladesh 2008-2008. Fisheries Resources Survey System, Department of Fisheries, Dhaka.

DoF (Department of Fisheries). (2009). Fishery Statistical Yearbook of Bangladesh 2008-2009. Fisheries Resources Survey System, Department of Fisheries (DOF), Dhaka, Bangladesh

FAO, (2007). The State of World Fisheries and Aquaculture 2006. Rome, FAO.

Gittleson, F. and Mookherji ,S.N. (1997). Comparing household survey-based measures of food insecurity across countries: case studies in India, Uganda and Bangladesh.

Hossain, M.S, Alam, S.M.N, Lin, C.K, Demaine H, Khan, Y.S.A, Das, N.G and Rouf, M.A., (2004). Integrated Management Approach for Shrimp Culture Development in the Coastal Environment of Bangladesh. *World Aquaculture*. Vol. 35, No. 1: 35-45.

Hossain, M.S., (2009). Floodplain Aquaculture in Begumgonj: New Horizon for Rural Livelihoods in Bangladesh. *Aquaculture Asia*, XIV(3): 7-10.

Islam and Dewan, S. (1986). Rice-fish system in Bangladesh: past, present and future In; Delt Cruz, C.R, Light Foot, C., Costa-pierce, B.A Cartangal,V.R and Bimbao,M.P (eds) rice fish research and development in Asia. ICLARM conference proceedings 24:11-16.

Muir, J.F. (2003). The Future for Fisheries: Economic Performance. Fisheries Sector Review and Future Development Study, Commissioned with the association of the WORLD BANK, DANIDA, USAID, FAO, DFID with the cooperation of the Bangladesh Ministry of Fisheries and Livestock and the Department of Fisheries, Dhaka.

Pido, M. D. (1995). The application of Rapid Rural Appraisal Techniques in Coastal Resources Planning: Experience in Malampaya Sound, Philippines. Ocean & Coastal Management 26(1), 57-72.

Pido, M.D., Pomeroy R.S., Carlos, M.B. and Garces, L.R. (1996). A handbook for rapid appraisal of fisheries management systems (version 1). Manila, Philippines: ICLARM.

Sarker, A.K.M.R.A. (2010). Development of Cage-based Tilapia Farming in Dakatia River in Chandpur, Bangladesh: Study on Socio-economic and Technical Perspectives. A

dissertation submitted in partial fulfillment of a Maters Degree in Aquatic Resource Development University of Stirling Scotland, UK, 94 pp.

Shohel, N.U. (1998). A socio-economic study of pond fish production in some selected areas of Noakhali district. An M. S. thesis submitted to the Department of Agriculture Economics, Bangladesh Agricultural University, Mymensingh. 91 pp.

Singh CS, Singh, K.P. (1975). Feeding experiments on Indian major carps in Terai ponds. J. Inland Fish Soc. India, 7: 212-215.

Townsley, P., (1996). Rapid Rural Appraisal, Participatory Rural Appraisal and Aquaculture. FAO Fisheries Technical Paper No. 358. Rome, Italy, pp 109.

Mud crab (*Scylla serrata*) fattening in Bangladesh: present status and future prospects

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Abstract: In Bangladesh, as an exportable fishery, mud crab has been playing an important role in national and international market. It can generate employment directly and indirectly in terms of people employed in the farming, marketing and other associated activities. Two mud crab fattening seasons in Bangladesh were identified; one is dry season from October to May and another one is the wet season from June to September. Fattening of crab is mainly done by stocking wild stock in small coastal ponds. There is obvious need for hatchery produced PL for crab farming. No one, however, is ready to take the challenge. Most of the mud crabs are exported particularly to East and Southeast Asian countries. Considering the total export earnings from the mud crab, the fishery showed immense potentiality. During1997-2007, Bangladesh earned US$21,064,000 (excluding local sales) by exporting crabs to twenty three countries around the world. More than 96% of the total export earnings came from Asian countries mainly from East and Southeast Asia. Development, supports from government and different nongovernmental organizations need to be more involved to improve more for sustainable mud crab farming and marketing in Bangladesh.

Introduction

Among all the highly valued and nutitious foods, crustaceans play an important role both economically and environmentally. Mud crab (*Scylla* sp.) is one of them and is commonly known as **'**serrated swimming crab, giant mud crab, edible mud crab, red crab or mangrove crab' occurs throughout the Indo-West Pacific Ocean, Australia, Japan, Philippines, Indonesia, East and South Africa and the Red Sea (Eldredge and Smith 2001). Now a days many countries are intentionally in attempt to establish

populations of this commercially important species. Keenan et al., (1998) identified four distinct species; *S. serrata, S. tranquebarica*, *S. olivacea* and *S. paramamosain*. Among the four, *S. serrata* is more abundant in high saline water (Heasman and Fielder 1983). Because of their large size *S. serrata* fetch the highest market price of the four species in Eastern markets (Agbayani 2001).

Using the experience of shrimp culture, some professional crab catchers have become interested in crab culture. Though crab culture is in its initial stage and there is considerable potential for further expansion. About 228,111 hectares of land which situated near the riverbanks in the tidal zone in the southwest part of Bangladesh are suitable for brackish water crab farming (Salam et al., 2003). It can be a new source of income in the south western area of Bangladesh as a brackish water aquaculture. Though Bangladesh started mud crab export since 1977-78, the Bangladeshi exporters started to send high quantity of crab to overseas markets particularly to Hong Kong, China, Thailand only after 1982. Since then the annual export has gradually been increasing. The country earned USD 3,668,000, 4,649,000 and 7,670,00 respectively in 2005-06, 2006-07 and 2007-08 fiscal years. Crab is now only second to shrimp in terms of earnings in country's fisheries products export line-up.

Due to its importance, to date, most studies dealt with crab biology, distribution, brood stock development, taxonomy, biochemical and industrial analysis done (Islam 1976, Obayed 1998), but little have been known of the present farming system of crabs in Bangladesh with future prospects. The purpose of this study is to broadly understand the current mud crab farming system in Bangladesh and its impacts on total export earnings. The study also explored the problems and risks in crab farming and marketing system.

Methodology

The paper is based on the review of published reports, papers, official documents and reviews on the different aspects of mud crab farming and marketing system in southwest region of Bangladesh. In addition, a survey was conducted using a semi-structured questionnaire through interview among the cross section of people including the mud crab fattening farmers, crab collectors, depot owners, and exporters in the southwest part (Khulna, Bagerhat, and Satkhira region) of Bangladesh. The paper also tried to identify problems in the sector and provided suggestions and recommendations for the overall development for this resource.

Though the official figures were unavailable about the total number of intermediaries involved in the sector, the individual were selected for questionnaire interviews

through cross checked information gathered from the key informants (school teachers, relevant NGOs, Department of Fisheries staffs in the field level). Before interviews, questionnaire was pre-tested in field level during the first phase of the research works. The interviews were focused on current fattening practice and on the market information, price, policy involved and problems faced by the intermediaries.

FGDs (Focus Group Discussions) were applied to get the overview of fattening and marketing of crab in Bangladesh. During each focus group discussion, respondents were asked about the crab farming and marketing in Bangladesh covering different issues such as price, problems, demand and future potential. The FGD consisted of a minimum of seven people and the duration was approximately 2 hours. Cross-check interviews were conducted with the help of the Upazila Fisheries Officers, relevant local NGOs, school teachers and local leaders throughout the study period.

Result and discussion

Source of mud crab in Bangladesh

Mud crab is a mangrove dwelling crustacean, inhabits muddy bottoms, mangrove marshes, and river mouths in estuarine environments (Motoh 1979). It occurs abundantly in the coastal rivers of Cox's Bazaar, Chittagong, inshore island of Moheskhali, kutubdia, Sandip and Hatia and Dubla except St. Martin Island (Khan and Alam 1992). Comparative higher population density of mud crab was appeared in the Cox's Bazaar, Chittagong, Khulna, Satkhira and Bagerhat than that of Noakhali. Bhola, Potuakhali and Bonsal (Khan and Alam 1992).

Supply of mud crab for fattening, export and for domestic consumption mainly depend on wild source – like Sundarban Reserved Forest (SRF), tidal rivers and cannels and tide fed traditional shrimp ghers. The rainy season (April-July) is the major fishing period for almost all areas particularly in mangrove and shrimp ponds. Crabs caught in the rainy season are larger in size than those caught in winter (September-January). During this time, the catch is relatively high, 3 - 4 times higher by weight than in winter (Khan and Alam 1992). Usually the maximum catching is achieved during spring tide and neap tide. The dry season (October to March) is the peak season from the SRF while June to October is the peak harvesting season from shrimp gher. However, the fishing in Sundarban East and West Sanctuaries along the sea coast during December to February and May to June is strictly prohibited by the government of Bangladesh to protect the mud crab broodstock.

Table 1 is shows the availability of crabs according to the season. The peak harvesting season for female crabs is January to May and October to December; male mud crabs are abundant in the rest of the months.

Table 1. Availability of crab according to the season

Season	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
PSM												
PSF												
LSM												
LSF												

PSM= Peak season for Male, PSF=Peak season for Female, LSM=Lean Season for Male, LSF=Lean Season for Female

Present farming practice in Bangladesh

Among four available mud crab species in the Indo-pacific region only the *Scylla olivacea* is being fattened in the southwest part of Bangladesh. Farmers continue crab fattening in traditional way throughout the year. Usually mud crab larvae enter into the ponds along with the tidal waters through different channels. Besides this, some farmers/fatteners collect the crabs from the wild catchers and from different depots which are rejected for exporting and fatten them in their ponds for future selling. Most of the farmers generally continue fattening crabs for a short time usually 21 days to 30 days. Table 2 is showing the stocking grade of crabs for fattening.

Table2. Grade of mud crab used for fattening

	Grade	Weight (g)	Carapace
Male	PD-XXL	>500	Soft
	PD-XL	>400	Soft
	PD-L	>300	Soft
	PD-M	>250	Soft
	PD-SM	<250	Soft
			Hepatopancreas
Female	KS1	>180	Partially developed
	KS2	>150	Poor
	KS3	<120	Poor

Comparatively higher stocking density was found in dry season than wet season. The cause might be the availability of the crab and high market price. The high price during the Chinese New Year and the availability of the crabs encourage farmers to stock more during dry season than wet season. Farmers stock less during wet season due to the unfavorable weather condition in the southwest part of Bangladesh. Most of the fattening ponds are rectangular in shape with a common inlet and outlet made of PVC pipes for the water exchange facility during the culture period. Water level is important factor for crab fattening because fattening is mainly dependant on the application of trash raw feed during production period. To keep the water quality in a suitable range, most of the farmers exchange water during the fattening time. Generally farmers exchange the water during the neap tide and spring tide. Some farmers were also found to change water from ponds when they thought the water was polluted. Post-stocking management mainly involved feeding and daily monitoring of their stocked crabs. Commonly available small fishes, small tilapia, shrimp head and eel used as crab feed. Farmers mostly apply feeds as raw during the fattening period at every alternative day or daily basis at the rate of 5% to 10% of the body weight of stocked crabs. Before feeding farmers check if their crabs are ready for marketing and separate the diseased and dead one.

Post harvest handling

Though mud crab can survive out of water for about 4 to 5 days in good quality packages, the post harvest handlings have significant contribution towards higher profit. Due to their cannibalistic nature, harvested crabs are tied with coarse twine to avoid the injury to human and physical damage to each others, as well as reduce the mortality during transportation.

Crab selling by the fatteners

Mutual understanding is the major factor upon which the mode of payment depends in case of purchasing and selling of mud crab in the southwest region. The payment was found to be 50% immediate or advance (Dadon) and 50% within 1 to 7 days of selling. It is similar for all marketing operators in mud crab trading, from fattener to local agent.

Grading for marketing

After reaching the depot, at first all the collected crabs from different sources are weighed and examined using a torch light. Different grading systems are observed in marketing of crabs in Bangladesh. It is varied among the sex and also for the domestic and international marketing. Tables 3 and 4 are showing the different

grading generally used for marketing of crabs in domestic and international market. Only female more than 120 gm and male more than 200 gm are considered for exporting overseas. Generally the soft shell male crab (locally called PD) and the eggless female (locally called KS) are rejected for exporting. The crabs having physical damage such as, broken legs or other physical damage are rejected for exporting outside. All of those rejected crabs come to the local market for domestic consumption or go to the fattening ponds for future selling after fattening.

Grading system of crabs for international market varies with the grading system in domestic market. Generally male with hard carapace and full of meat is considered for exporting; while for female, hard carapace with eggs is considered. Although some exporters were found to export small size female with partial gonad development.

Table 3. Grade of mud crab in domestic market

Male	Grade	Weight (gm)	Claw condition	Shell condition
	XL	>400	Full of meat	Hard
	L	>300	Full of meat	Hard
	WXL	>400	Partial development	Soft
	WL	>300	Partial development	Soft
	M	>250	Full of meat	Hard
	SM	>200	Full of meat	Hard
Female	Grade	Weight (gm)	Gonad condition	Shell condition
	F1	>180	Full gonad	Hard
	KS1	>180	Partial gonad	Hard
	F2	>150	Partial gonad	Hard
	F3	>120	Immature gonad	Hard

Table 4. Grade of mud crab in international market

Male	Grade	Weight (gm)	Claw condition	Shell condition
	XXL	>500	Full of meat	Hard
	XL	>400	Full of meat	Hard
	L	>300	Full of meat	Hard
	M	>250	Full of meat	Hard
	SM	>200	Full of meat	Hard
	Grade	Weight (gm)	Gonad condition	Shell condition
Female	FF1	>200	Full gonad	Hard
	F1	>180	Full gonad	Hard
	KS1	>180	Partial gonad	Hard
	F2	>150	Full gonad	Hard
	F3	>120	Full gonad	Hard
	KS3	>120	Immature gonad	Hard

Crab price: The market price varies significantly due to the wide variation in the landing. This is also influenced by the seasonality and events like Chinese New Year. Generally price was found to be higher during this time. Similar price fluctuation was also found in Philippine (Balio et al., 1999) and Queensland (Lee 1992). Table 5 is showing the average market price of mud crab for exporting during the study.

Table 5. Price of different grade of mud crab during the survey period

	Grade	Price during dry season (US$/Kg)	Price during wet season (US$/Kg)
Male	XXL	9.42	5.51
	XL	7.97	4.06
	WXL	6.52	2.90
	L	5.07	2.61
	WL	3.62	2.17
	M	2.46	2.61
	SM	1.50	1.01
Female	FF1	11.59	6.81
	F1	10.14	5.80
	F2	4.35	3.62

Domestic market: In comparison to other fishes and fishery products, the demand for mud crabs in Bangladesh for domestic consumption is less. Generally rejected underweight crabs with broken legs come to the local rural and urban market for domestic consumption. Two types of domestic market so far have been reported by Ahmed (1992). One is local market, in the vicinity of the fishing village and another one is the consumer market away from fishing area. The non-Muslim and tribal people are the main consumer of crabs in Bangladesh. The market price varied with the grade and with the season. The crabs are generally sold in a price fixed by bargaining between the retailers and consumers.

1nternational market: From 1977, Bangladesh started to export crab. Beside live crab, many East Asian and Southeast Asian countries export different form of crabs and crab's products throughout the world. Table 6 is showing different form of crab and crab products found to be exported by different countries.

Table 6. Different country mud crab product type

Country	Product type
Bangladesh	Live crab
India	Live crab, frozen crab meat,
Pakistan	Live crab
Japan	Frozen and live crab
China	Live and frozen crab, soft shell crab, sausage, crab juice, crab sticks
Indonesia	Live crab, steamed frozen crab, black/red crabs. eggs or without eggs, frozen soft shell crab, crab meat, dried crab shell
Philippine	Live crab, soft shell crab, dried crab shell
Singapore	Live crab , canned crab meat
Thailand	Soft shell crab, sausage,
Vietnam	Live crab, frozen crab meat, soft shell crab
Hong Kong	Live crab, steam frozen mud crab
Malaysia	Live crab, crab claw
Australia	Live crab, frozen raw meat

Export value and quantity: Figs. 1 and 2 are showing the total export quantity and value of mud crab. By comparing with 2002-2003, the total export quantity increased more than six folds during 2007-2008 (4283.27 mt), while during 2008-2009 the export quantity decreased from 4283.27 mt to 3264.62 mt (EPB). It might be due to less production and damage caused by cyclone Aila which hit the south-western coast of Bangladesh on 25 May 2009.

From 1997-1998 to 2006-2007, Bangladesh fetched US$ 21,064,000 (excluding the local sale) by exporting crabs to 23 countries around the world (EPB). More than 96% of total export earning came from Asian countries. Among them, the East Asian and Southeast Asian countries are playing significant role in the foreign export earnings for Bangladesh. Figure 5 shows the percent of export value from Southeast Asian and East Asian countries from 1997-98 to 2006-2007. Taiwan and Malaysia are two biggest buyers of mud crab from Bangladesh. Bangladesh fetched about US$ 6,280,000 and US$6,286,000, respectively, from Taiwan and Malaysia which together constituted more than 60% of the total export value earned from Asian countries during 1997-98 to 2006-07 (Fig. 3). (Source: EPB).

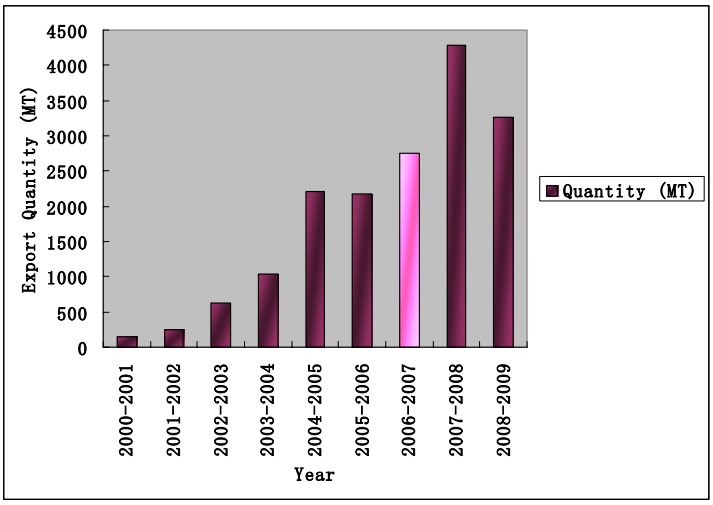

Fig. 1. Export quantity of mud crab during 2000-01 to 2008-2009. (Source: EPB)

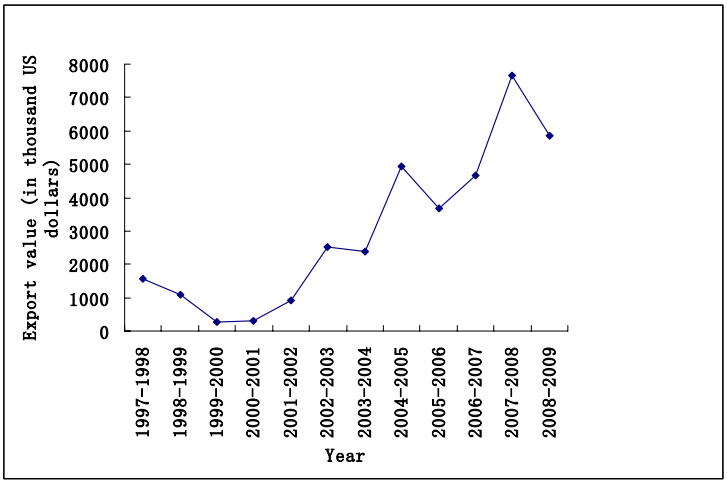

Fig. 2. Export value of mud crab during 1997-98 to 2008-2009. (Source: EPB)

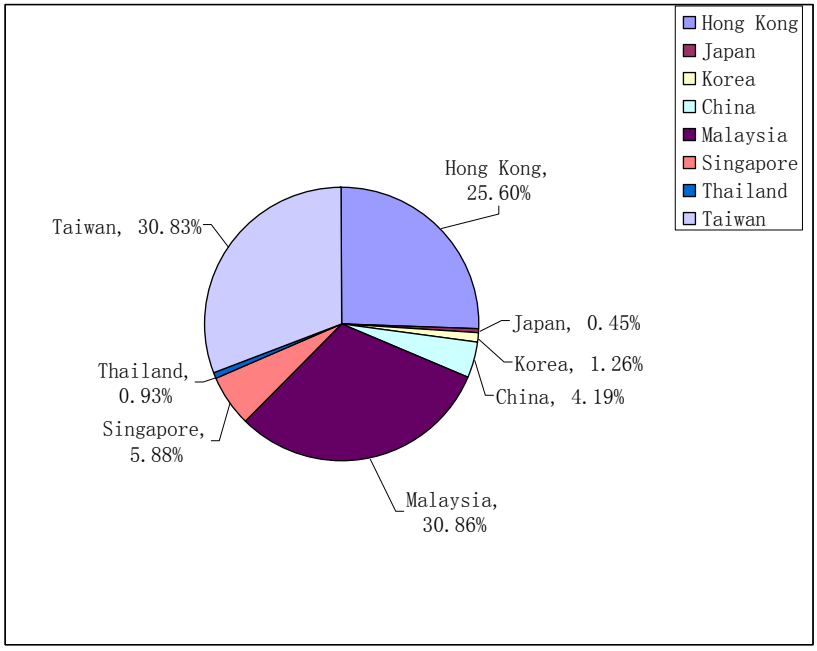

Fig. 3. Percent of total export earnings from East Asian and Southeast Asian countries through exporting mud crab during 1997-98 to 2006-07. (Source: EPB)

Main factor promoting farming and marketing in Bangladesh

There is a growing interest among the farmers towards crab fattening all over the coast. Main factor promoting the farming and the business is the increasing demand for crabs in the international markets. According to fatteners reports fattening of crabs give higher profit within very short time with small investment compared to shrimp. On the other hand, Bangladesh Fisheries Research Institute in Paikgachha is playing a significant role by providing different training programs among the farmers and establishing model farms for disseminating modern crab farming and fattening technologies to the field. Different non-government organizations in the southwest part of Bangladesh (Caritas, Shushilan etc.) are also encouraging the crab fattening farmers and training them with sustainable farming technology through different developmental programs.

Factor hindering the mud crab trade in Bangladesh

As found in the focus group discussion with farmers and traders, several factors reported are hindering the crab fattening and trade in Bangladesh. Factors hindering

the trade also varied among the marketing operators. Table 7 is shows the problems faced by the marketing operators in mud crab business in Bangladesh.

Besides the lower profit, catchers reported the overexploitation of juveniles and the environmental degradation as major problems for gradually reduced crab catch from the wild. In addition, the farmers and the catcher also reported the illegal export of underweight crab to the international market. This is also a major reason for the over-fishing of juvenile crab from the natural source leading the species into an endangered status. Another common issue is the lack of capital or credit support from the government or nongovernment institutes for crab farming or trading. Though there is sufficient credit facility for shrimp, loan for the crab farmers, fishers and traders neither easily available nor institutionalized like shrimp/prawn farming.
Less demand in the domestic market was also reported by the marketing operators. In Bangladesh, the social and religious believes on consumption of crabs hinder the business and prevent the farmers to get the good price of crab in the domestic market.

Due to frequent occurrences of disease in prawn and shrimp and fall of price in international markets, farmers are looking for alternative species for sustainable aquaculture practice both in economically and environmentally. Farming of mud crab can provide the most suitable alternate source of income for the rural people especially the coastal people in Bangladesh. However, well developed farming and trading mode and infrastructures and cooperation and partnership between farmers, fishermen, traders and other stakeholders in can substantially improve the sector that can assist significantly in coastal poverty alleviation, employment generation and foreign exchange earnings.

Reference

Agabayani, R.F. (2001). Production economics and marketing of Mud crabs in the Philippines. *Asian Fisheries Science* 14 (2):201-120.

Ahmed, K. (1992). Mud crab: a potential aqua-resource of Bangladesh. *In: C.A. Angell (ed), Report of the seminar on the Mud Crab Culture and Trade.* Surat Thani, Thailand, November 5-8, 1991. BOBP/REP/51. Madras, India: Bay of Bengal Programme, pp. 95:102.

Baliao, D.D., Santos, M.de los and Franco, N.M. (1999). Penculture of mud crab in mangroves. Aquaculture Extension Manual No. 25. SEAFDEC Aquaculture Department Tigbauan, Iloilo, Philippines, 10 pp.

Eldredge, L.G. and Smith, C. (2001). Guidebook to the Introduced Marine Species in Hawaiian Waters. Bishop Museum Technical Report 21. Bishop Museum, Honolulu.

Heasman, M.P. and Fielder, D.R. (1983). Laboratory spawning and mass larval rearing of the mangrove crab *Scylla serrata*, from t zoea to crab stage. *Aquaculture.* 34: 303-326.

Islam, M.J. (1976). Brachyura of the Karnafully estuary and northeast part of the Bay of Bengal with special reference to the biology of *Scylla serrata* (Forskål, 1975). M.Sc. Thesis. Department of Marine Biology, Chittagong University. Bangladesh 150 pp.

Keenan, C.P., Davie, P.J.F. and Mann, D.L. (1998). A revision of the genus Scylla De Haan, 1833 (Crustacea: Decapoda: Brachura: Portnidae). *Raffles Bull. Zoology,* 46, 217-245.

Khan, M.G. and Alam, M.A., (1992). The mud crab (*Scylla serrata*) fishery and its bio-economics in Bangladesh. *In: Angell, C. A. ed. Report of the seminar on the Mud Crab Culture and Trade. Surat Thani, Thailand, November 5-8, 1991.* BOBP/REP/51. Madras, India: Bay of Bengal Programme pp.29-40.

Khan, Md. Giasuddin. (2005). Development and Management of the Marine Fishery resources for Economic Priority in Bangladesh. Workshop on the Management for Economic Growth of Bangladesh-19th August 2005 organized by DOF and Marine Fishers Association, Bangladesh.

Lee, C., (1992). A brief overview of the ecology and fisheries of the mud crab, *Scylla serrata* in Queensland. *In: Angell, C. A. ed. Report of the seminar on the Mud Crab Culture and Trade.* Surat Thani, Thailand, November 5-8, 1991. BOBP/REP/51. Madras, India: Bay of Bengal Programme, pp.65-70.

Motoh, H. (1979). Edible crustaceans in the Philippines, 11th in a series. *Asian Aquaculture* 2:5.

Obayed, S. (1998). Study on the culture and fattening of the mud crab *Scylla serrata* (Forskal) in the great Khulna region. M.Sc. Thesis. Institute of Marine Science University of Chittagong. Bangladesh, 93 pp.

Salam, M.A., Ross, L.G., and Malcolm Beveridge C.M., (2003). A comparison of development opportunities for crab and shrimp aquaculture in southwestern Bangladesh, *Aquaculture* 220: 477–494.

Sarker, M.N. (1993). Marine Fishery Resources of Bangladesh (in Bangla). *In: Bangla Academy Science Newsletter*. Baisaak - Assnin (1400 B.Y.). pp. 113-157.

Shafi, M. and Quddus, M.M.A. (1982). Fisheries Resources in Bangladesh. (Bangladesher Matshaya Sampad, in Bengali), Bangla Academy, Dhaka, pp. 369-396.

Microbial quality assessment of Indian white shrimp, *Penaeus indicus* from southwest Bangladesh

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Abstract: The microbial quality of Indian white shrimp (*Peneaus indicus*) collected from Bagerhat, Khulna and Satkhira of Southwest Bangladesh was assessed. The parameters varied with different sources and the quality was found to be poor for Satkhira shrimp samples. Total bacterial count of all the samples was beyond the acceptable limit 10^5 cfu/g recommended by ICMSF. In case of total coliform and *E. coli* density, no substantial difference ($p<0.5$) was found among the different shrimp samples from different districts and high quantity of TC exceeding the limit ($>10^2$ cfu/g) proves the poor quality of shrimp. The FC abundance found in shrimps of Bagerhat and Satkhira was similar and significantly higher ($p<0.5$) than that of Khulna samples. No significant difference ($p<0.5$) was found among the high density of *Salmonella-Shigella*, *Vibrio* spp. and *Staphylococcus* spp. of the shrimp samples from different sources. In case of antibiotic sensitivity pattern of the indicator and pathogenic isolates, all of them were resistant to ampicillin and penicillin, and sensitive to kanamycin. Most of the isolates were frequently sensitive to ciprofloxacin and streptomycin in the sensitivity test. In case of nutritional composition, no significant difference (t-test, $p<0.05$) was found among protein, lipid, moisture and ash contents of shrimp samples. The findings prove that shrimp under this study was more or less contaminated and samples from Satkhira were contaminated with food borne pathogens which confirmed the unhygienic condition of the shrimp farms as well as the presence of antibiotic resistance bacteria in shrimp supposed to be a threat to food safety and deteriorates the export quality.

Introduction

Shrimps, as highly priced seafood delicacy, are cash crop grown mainly for the affluent export and urban markets. The microbial load and the presence of the bacterial pathogens in seafood are a good indication of the food quality and the potential health risk they pose to consumers (Rosmini *et al.* 2002). Pathogenic microbes usually are anaerobic forms harbored within the intestinal tract of fish, along with a complex microbial community, known as intestinal micro flora (Tannock 1995) which has a close connection with micro-flora present in the environment. These are considered to be the major organisms contributing to the rapid deterioration of shrimp quality. Often, shrimp products are rejected for the export markets due to small size, bacterial load, or chemical residue levels and are shunted to local markets (Primavera 1994).

There has been an increase in awareness about nutritional value and health benefits of fish consumption over the last two decades. Seafood is also known to have been responsible for a significant percentage of food borne diseases (Wallace *et al*. 1999). Consumption of raw or uncooked seafood is the factor most commonly associated with infection (Butt *et al*. 2004). Though viruses are most common cause of seafood related infections, most of hospitalization and deaths are due to microbial agents (Butt *et al*. 2004). Thus, microbial criteria are laid down when there is a need to protect public health (Prakash *et al*. 2011). As a consequence, food safety and quality aspects in trade became important, since fresh food is more prone to certain microbiological contamination (Sawhney 2005).

Microbial hazards causing infections and poor health are closely related to food safety concerning with animal proteins derived from fish, fishery products, meat and meat products. This creates a burning question for all consumers with a high risk commodity with regard to pathogenic bacterial contaminations alarming to food safety challenge (Nilla *et al*. 2012c,d). Food borne diseases result from ingestion of bacteria and toxins produced by microorganisms present in the sea-food and the intensity of the signs and symptoms may vary with the amount of contaminated food ingested and susceptibility of the individuals to the toxin (Clarence *et al.* 2009).

Moreover, the control of infectious diseases is seriously threatened by the steady increase in the number of microorganisms that are resistant to antimicrobial agents. Multiple studies have indicated that resistance may be increasing in developing countries and diarrheal disease is one of the most important causes of illness and death in young children (Okeke *et al*. 2005). Antibiotic resistance is a significant human health issue and in recent years, a link between antibiotic use in food

producing animals and the transfer of these resistant organisms to humans via food chain has been established (Akinbowale *et al*. 2006). Therefore, it is possible that similar problems may exist in connection with the use of antibiotics in shrimp farming (Holmstrom *et al*. 2003).

Shrimp export market of Bangladesh is threatened for low quality of processed shrimp products which might be deteriorated due to improper handling and responsible for food borne diseases (Nilla *et al*. 2012a,b). Due to the presence of different types of bacteria in frozen shrimps, they may lose their exportability. This study was objected to determine the microbiological abundance in the muscle of Indian white shrimp, *Peneaus indicus* collected from shrimp farms of southwest Bangladesh where the major share of exported shrimp is produced.

Materials and methods

Sample collection: Indian white shrimp (*Peneaus indicus*) samples in fresh (raw) condition were collected from Bagerhat, Khulna and Satkhira districts of southwest Bangladesh during April 2010 - December 2010. Total 4-5 shrimps in each sample were taken to perform microbial assessment. Identification was done according to Shafi and Quddus (2004). The shrimp samples were collected by special sterile Zip lock bags to avoid further contamination and transported in an insulated box with ice to maintain the temperature (4 to 6 ^{o}C) and stored at –20^{o}C at the laboratory until use (ICMSF 1998). The samples were processed and used within 24 hours of collection.

Processing of the samples: The samples were thawed at room temperature for 5-6 h to allow the ice to melt. The whole shrimps were taken following the method of APHA (1998). The collected samples were separately homogenized with normal saline solution using a homogenizer. Pour plate or spread plate were prepared using 1 ml - 0.1 ml of the treated samples.

Microbiological analysis: The microbiological analysis was performed as per the standard methods adopted from Online Bacteriological Analytical Manual, USFDA for detection, enumeration and identification of individual organisms (BAM 2005).

Total bacterial count (TBC): Total bacterial count was obtained on nutrient agar (Becton Dickinson, France). The colonies were incubated for 24 h at 35-37 ^{o}C and calculated as cfu/g.

Total coliform (TC): Diluted samples were pour-plated on MacConkey agar (Oxoid Ltd., Hampshire, England); typical pink colonies for TC were counted after 24 h of incubation at 35-37 ^{o}C.

Fecal coliform (FC) and E. coli (EC): Dilutions made for TBC were pour-plated on MacConkey agar (Oxoid Ltd., Hampshire, England). Typical colonies were counted after 24 h of incubation at 35-37^{o}C. The suspected isolates were streaked on modified fecal coliform (mFC) agar plates and incubated at 44.5^{o}C for 24 h. Typical blue colonies were counted and was further confirmed by growing in eosin methylene blue (EMB) agar plates (Oxoid Ltd., Hampshire, England).

Salmonella-Shigella (SS): The sample (25 g) was homogenized in saline water. After the enrichment of samples, a loopful of growth from the broth was streaked on Salmonella-Shigella agar (SSA; Oxoid), typical black colonies from plates were isolated and identified by biochemical tests.

Xylose Lysine Deoxycholate (XLD) (Oxoid Ltd., Hampshire, England) agar also used for the selective isolation of *Shigella* and *Salmonella* spp. The incubation period for *Shigella* and *Salmonella* spp. were 48 h at 35-37^{o}C.

Vibrio spp.: The sample (25 g) was homogenized in 225 ml of alkaline peptone water (APW) and incubated at 35^{o}C for 24 h. Diluted homogenates were pour-plated on TCBS agar (Oxoid Ltd., Hampshire, England).

Staphylococci spp.: Diluted sample for TBC were spread-plated on Mannitol Salt Agar (MSA) (Oxoid Ltd., Hampshire, England). Typical yellow colonies were counted after 48 h of incubation at 35^{o}C.

Biochemical tests: Biochemical tests were done according to the manual for general bacteriology of the American Society of Microbiology (ASM 1981). Oxidase test, catalase test, carbohydrate fermentation/ utilization test, Kligler's iron agar (KIA) test, indole production test, methyl red (MR) test, Voges-Proskauer (VP) test, citrate utilization test, nitrate reduction test, motility indole urea (MIU) tests, and salt tolerance (3%, 5%, 10% and 15% NaCl) test were done to identify the bacteria (Cappuccino and Sherman 1990).

Determination of antibiotic susceptibility of the isolated bacteria from shrimp samples: Susceptibility of *E. coli*, *Salmonella-Shigella* and *Staphylococcus* isolates to different antimicrobial agents was measured *in vitro* according to the Kirby-Bauer disk diffusion method (Bauer *et al.* 1966). Commercially available 12 antimicrobial

discs [amoxicillin (AML), ampicillin (AMP), bacitracin (B), chloramphenicol (C), ciprofloxacin (CIP), erythromycin (E), gentamycin (GN), kanamycin (K), penicillin (P), polymyxinB (PB), streptomycin (S) and tetracycline (TE)] were used for the test.

Proximate composition analysis: Proximate analysis such as moisture, protein, lipid and ash were carried out following the methods of AOAC (1984).

Statistical analysis: Statistical analysis was performed with the SPSS software package **(**verson11.5, SAS Institute Inc, Cary, USA) to present the data as mean ± SEM was considered. Tukey's HSD post hoc for the multiple comparisons with the level of significance ($p < 0.05$) was followed.

Results and discussion

The results of microbial quality assessment conducted on *P. indicus* samples directly collected from shrimp farms of Bagerhat, Khulna and Satkhira districts in southwest Bangladesh are shown in Table 1. The results reveal that bacterial count detected in shrimp samples from Satkhira was significantly higher than that of other samples (Table 1, t-test, $p < 0.5$).

The bacterial density in shrimp apparently gives an idea about the quality of the samples. A significant difference ($p<0.5$) was found between the TBC of the shrimp samples from different sources. The TBC of shrimp was varied between 10^5 and 10^7 cfu/g and beyond the acceptable limit ($>10^5$ cfu/g) recommended by International Commission on Microbiological Specifications for Foods (ICMSF 1986). There is evidence to support the fact that surface water carries less bacteria compared to bottom mud (Williams 1952). As the shrimps are bottom dwelling animals, the likelihood of their becoming contaminated with bacteria from the muddy substance is always a possibility. Besides, the contaminated source of water, poor hygiene and sanitation condition of the landing centers might be the causes for such contagion (Hatha *et al.* 2003) and high microbial abundance (Nilla *et al.* 2012c). Shewan (1961) reported that the bacterial flora on newly caught fish depends on the environment in which it is caught rather than on the fish species. Another source of contamination of harmful microorganisms could be catching vessels (Wahab *et al.* 2003). Besides, icing only can limit the growth of microbes for a little period and when favorable condition comes back, most of the microbes can multiply within short time (Leita˜O and Rios 2000). Therefore, the result of the study proved that quality of fresh shrimp from southwest Bangladesh in respect of bacterial load was not in consumable condition.

Table 1. Density (mean ± SEM) of total bacterial count (TBC), total coliform (TC), *Vibrio* spp., *Staphylococcus* spp., *Salmonella-Shigella* (SS), faecal coliform (FC) and *E. coli* (EC) of Indian white shrimp from southwest Bangladesh. Different superscript letters within row are significantly different ($p < 0.05$)

	Sources		
Bacterial count (cfu/g)	Bagerhat	Khulna	Satkhira
TBC	$6.37\pm0.38 \times 10^{5bc}$	$1.88\pm 0.02\times 10^{6b}$	$5.83 \pm 0.12\times 10^{7a}$
TC	$2.83\pm0.44 \times 10^{3}$	$4.80\pm0.81 \times 10^{3}$	$3.00\pm0.95 \times 10^{3}$
Vibrio spp.	$7.47\pm0.39 \times 10^{3a}$	$1.70\pm0.05 \times 10^{4a}$	$1.59\pm0.04 \times 10^{5a}$
Staphylococcus spp.	$3.00\pm0.36 \times 10^{4a}$	$3.07\pm0.32 \times 10^{4a}$	$4.77\pm0.58 \times 10^{4a}$
SS	$2.40\pm0.23 \times 10^{4a}$	$2.70\pm0.10 \times 10^{4a}$	$1.19\pm0.10 \times 10^{4a}$
FC	$1.50\pm0.15 \times 10^{4a}$	$2.17\pm0.38 \times 10^{3b}$	$2.03\pm0.43 \times 10^{4a}$
EC	$3.10\pm0.30 \times 10^{3}$	$3.95\pm0.46 \times 10^{3}$	$2.05\pm0.27 \times 10^{3}$

In case of total coliform and *E. coli* density, no substantial difference ($p<0.5$) was found among the different shrimp samples from different districts (Table 1). All the samples were observed having high quantity of TC exceeding the limit ($> 10^2$ cfu/g) suggested by ICMSF (1986) and proves the poor quality of shrimp. The presence of TC in raw shrimps confirms the sewage contagion. It also indicates the contamination during handling and selling processes in the markets or the landing centers including holding temperature (Nilla *et al.* 2012c,d). In this case the main source of contamination might also be water. Besides, *E. coli* is usually considered as an indicator of fecal contamination. There is no indication that seafood is an important source of *E. coli* infection (Ahmed 1991). Most infections appear to be related to contamination of water or handling under unhygienic conditions (Huss 1994). Moreover, the contamination may also come from the water used for washing or icing (Boyd 1990). The presence of EC in higher range suggests the contamination of the samples before or during handling and processing. This result indicates that the water or processing units were somehow contaminated with human or animal waste. Although the water cannot be linked directly to the contamination by human sewage, since the bacteria is found in high concentration within the sewage (Yousuf *et al.* 2008). However, Japan, USA and other European countries do not allow the presence of *E. coli* in the shrimp or shrimp food (FAO 1997).

Fecal coliform are considered as a more accurate indication of animal or human waste than the total coliform because the origins of FC are more specific than the origins of TC group of bacteria (CDCP 2010). The FC bloom found in shrimps of

Bagerhat and Satkhira was similar and significantly higher (t-test, $p<0.5$) than that of Khulna samples (Table 1). The lower contamination in shrimps of Khulna reveals the better quality than that of other samples. The higher load of FC indicates that the water or processing vessels were somehow contaminated fecally. But external contamination may also be the source of the occurrence of these bacteria in fish (Huss 1994). Furthermore, the FC present highly in diarrheal stools of infected persons. The unwashed hands of infected shrimp or fish handlers forgetting to wash hands with soap after using the bathroom, may also contaminate sea food (CDCP 2010). The FC contents in shrimp also refer the poor sanitary and hygienic conditions of the landing centers or the market premises (Nilla *et al*. 2012c,d).

Salmonella spp. are of great concern in public health and are explained as a key example of shellfish transmitted pathogen. The concentrations of *Salmonella-Shigella* observed in different shrimp samples of Satkhira, Bagerhat and Khulna were similar. No significant difference (t-test, $p<0.5$) was found among the shrimp samples from the source places (Table 1). Incidence of *Salmonella* in shrimp, fish or similar foods of aquatic habitats is due to external contamination (Reilly *et al*. 1992). This evidence presents that farmed tropical shrimps frequently contain *Salmonella*. It has also been demonstrated that *Salmonella* in farmed shrimp products is originated from the environment rather than as a result of poor standards of hygiene, sanitation, and poultry manure as feed (Nilla *et al.* 2012c,d). *Salmonella* associated with food borne gastroenteritis's has been isolated from fresh, frozen, canned and sun dried sea food products (Natarajan *et al.* 1985). Besides, the relatively long storage period with low ice quality until sold and improper storage condition due to handling disruption might be the reasons for the SS infection in shrimp. Moreover, as the shrimp either fresh or iced directly came from different sources of southwest Bangladesh, so the fish might contain SS isolates (Reilly *et al.* 1992).

The presence of *Vibrio* spp. in shrimp is of public health issues as they may cause of infection to the consumers. In the present study, there was no significant difference found in *Staphylococcus* spp. and *Vibrio* spp. (Table 1, t-test, $p<0.5$). As all the samples containing *Vibrio* spp. were found above the limit ($> 10^2$ cfu/g) according to ICMSF (ICMSF 1986), this study reveals that microbial quality of shrimp collected from southwest Bangladesh was not good due to presence of *Vibrio* spp. in most samples. It was very remarkable to find out *Vibrio* spp. in the samples because *Vibrio* normally cannot survive in the frozen condition due to the absence of moisture (Jay 1996). Here, the cross contamination with other white fish, inadequate ice during transportation and the presence of moisture during icing might be probable reasons for survival of *Vibrio* spp. in shrimp samples. As the shrimp already contained the *Vibrio* spp., they revived themselves easily during the study and developed (Rahman

et al. 2009). Besides, *Vibrio* spp. is mainly present in the intestine, so the density was found high because the whole fish was considered for microbial analysis (Nilla *et al.* 2012c,d). There were considerable numbers of *Staphylococcus* spp. found in all examined samples (Table 1) and were observed cross the recommended limit (> 10^3 cfu/g) by ICMSF (ICMSF 1986). This result confirms the contagion of the samples with *Staphylococcus* via infected food handlers or from the environment. The infected individual with an infection on hands or with a cold or sore throat more often acts as the contamination source in shrimp. In contrast, rapid growth and toxin production can take place in shrimp if re-contamination with *Staphylococcus* is taken place (Hatha *et al.* 2003).

The present study revealed the incidence of antibiotic resistance in the bacterial strains isolated from cultured shrimp. Table 2 summarizes the antibiotic sensitivity pattern of four *E. coli*, four *Salmonella-Shigella* and two *Staphylococcus* isolates to 12 antimicrobial agents tested in this study. The results show that all of the 10 isolates were resistant against AMP and P, and sensitive to K; and frequently sensitive to CIP and S in the sensitivity test. Among the four isolates of EC, three were resistant to B but all were sensitive to S. Three SS isolates were also sensitive to S and three were resistant to C, whereas both *Staphylococcus* isolates were resistant to E and two were sensitive to S (Table 2). This result clearly confirms that the abusive use of antibiotics as bactericidal, fungicidal etc. might threat potential risk to health (Rahman *et al*. 2009).

Table 2. Antibiotic sensitivity of *E. coli* (EC), *Salmonella-Shigella* (SS) and *Staphylococcus* isolates of shrimp samples from southwest Bangladesh.

Isolated strains	Resistant	Intermediate	Sensitive
EC-1	AMP, AML, B, P, TE	C, GN, PB	E, K, S, CIP
EC-2	PB, P, AMP, B	AML, GN, TE	S, E, K, CIP, C
EC-3	P, AMP, PB, TE	C, GN, B	CIP, E, K,S, AML
EC-4	AMP, C, P, B, E	CIP, TE, PB	GN, S, AML, K
SS-1	P, AMP, B, C, E	AML, PB, TE	GN, S, K, CIP
SS-2	P, E, AMP, AML, C	K, S, TE	PB, K, GN, B
SS-3	AMP, TE, P, C, CIP	GN, B, E	S, K, AML
SS-4	P, AMP, TE, GN	B, AML, C, PB	K, S, E, CIP
Staph-1	P, CIP, PB, AMP, E	GN, C	B, S, K
Staph-2	AML, P, AMP, C, E	B, GN, PB	S, CIP, K, TE

AMP = ampicillin, AML = amoxicillin, B = bacitracin, C = chloramphenicol, CIP = ciprofloxacin, E = erythromycin, GN = gentamycin, K = kanamycin, P = penicillin, PB = polymyxinB, S = streptomycin and TE = tetracycline

Multiple antibiotic resistance (MAR) have been reported in shrimp pathogen and bacteria from aquaculture environment with a variety of drug or an uncertain antibiotic usage history (Ghosh and Mandal 2010). The high level of water contagion with the industrial effluents and agricultural pollutants may magnify the exchange possibilities of drugs. Besides, widespread use of antibiotics in the aquaculture systems and agricultural sectors in Bangladesh may act as the source of antibiotics diffusion into the sediment. The uncontrolled antibiotics will remain in the sediment and an alternation of micro flora composition of the sediment and antibiotic-resistant bacteria (ARB) may occur with exerting of selective pressure (Sorum 2006). So this result indicates that the uncontrolled and irregular use of antibacterial agents in aquaculture systems and agricultural sectors is responsible for the occurrence of the MAR traits among the fish pathogens and the majority of the ARB carry drug resistant (R) factor (Keys *et al.* 1986). This result also suggests that commercial shrimp may act as the reservoir for MAR and facilitate the dissemination of the ARB (Ryu *et al*. 2012).

Table 3. Mean (± SEM) proximate composition of *Peneaus indicus* collected from different shrimp farms of southwest Bangladesh.

	Sources		
	Bagerhat	Khulna	Satkhira
Moisture	79.76 ± 0.13	79.99 ± 0.01	79.29 ± 0.31
Protein	15.77 ± 0.41	16.17 ± 0.08	16.15 ± 0.13
Lipid	3.05 ± 0.12	3.30 ± 0.36	3.67 ± 0.27
Ash	1.45 ± 0.11	1.89 ± 0.10	1.81 ± 0.14

Table 3 shows the proximate composition of *P. indicus* collected from southwest regions of Bangladesh. No significant difference (t-test, $p < 0.05$) was found among the nutritional contents of shrimp. The quantity of protein in shrimp is largely influenced by the extent of fat and water content (Geiger and Bergstrom 1962). Ravichandran *et al.* (2009) estimated moisture, crude protein, crude lipid and total ash in flesh of *P. indicus* as dry weight basis (%) 14.7 ± 0.7, 41.3 ± 0.3, 7.6 ± 0.7 and 18.5 ± 0.6, respectively. Begum and Hoque (1986) studied on the effects of temperature on the composition, color, texture and reconstitution of dehydrated shrimps and found moisture 74.20%, protein 17.35%, fat 1.68% and ash 2.60% in raw shrimp. The composition varies with season, size, stages of maturity, temperature (Dinakaran *et al*. 2009) and deviation may occur due to natural feeding habits and

availability of feed, fasting duration during spawning and migration (Viswanathan and Mathew 2000).

This study revealed the presence of high pathogenic microbial abundance in *P. indicus* samples of shrimp farms from southwest Bangladesh that supposed to be threat to food safety and deteriorate the export quality. It also reveals that the shrimp samples from Bagerhat were comparatively less contaminated with bacteria than those of other sources. The higher total bacteria and coliform count in shrimp samples indicate the unhygienic condition of the vessels and landing centers. The main reasons for infecting the shrimp might be rough handling and sorting or lack of sanitation. Cross contamination with other white fish might also be another reason for bacterial contagion in shrimp. Moreover, antibiotic resistance bacteria is a major public health problem. The result suggests that microbial load and presence of antibiotic resistance bacteria into shrimp may create ecological and public health implications as well as are of special concern. The handlers should take proper training on the aspect to avoid the health risks and cross contamination. This study also accentuates the necessity of increasing awareness about the use of antibiotics in shrimp farms to ensure the absence of drug-resistant pathogenic microorganisms in shrimp for achieving the food safety and the foreign earnings.

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References

Ahmed F.E. (1991). *Seafood Safety*. National Academy Press, Washington D. C. USA. 3-20 pp. http://books.nap.edu/openbook.php?record_id=1612&page=R1.html. Accessed on April 12, 2010.

Akinbowale OL, HH Peng and MD Barton. (2006). Antimicrobial resistance in bacteria isolated from aquaculture sources in Australia. *J. Appl. Microbiol*. **100(5)**: 1103-1113.

AOAC (Association of Official Analytical Chemists) (1984). Official Methods of Analysis. Association of Official Analytical Chemists. 13th edition, Washington DC.

ASM (American Society of Microbiology). (1981). Manual for General Bacteriology. Website: http://ourfood.com/General bacteriology.html. Accessed on April 15, 2010.

APHA (American Public Health Association). (1998). *Standard Methods for the Examination of Water and Wastewater*. ed. Clesceri LS, LS Greenboug and AD Eaton. Washington DC: American Public Health Association/ American Water Works Association/ Water Environment Federation.

BAM (Bacteriological Analytical Manual). (2005). USFDA for Detection, Enumeration and Identification of Individual Organisms. Website: http://www.foodinfonet.com/publication/fdaBAM.html. Accessed on April 17, 2010.

Baudart J, J Grabulos, JP Barusseau and P Lebaron (2000). *Salmonella* spp. and faecal coliform loads in coastal waters from a point vs non-point source of pollution. *J. Environ. Qual*. **29**: 241-250

Bauer AW, WMM Kirby, JC Sherris and M Turck. (1966). Antibiotic susceptibility testing by a standardized single disk method. *Amer. J. Clin. Pathol.* **45**: 493-496.

Begum JA and MS Hoque. (1986). Effects of temperature on the composition, color, texture and reconstitution of dehydrated shrimps. *Bangladesh J. Agril. Sci*. **13(1)**: 1-4.

Boyd CE. (1990). *Water Quality in Ponds for Aquaculture*. Birmingham Publishing Co., Alabama, USA. 480 pp.

Butt AA, KE Aldridge and CV Sanders. (2004). Infections related to the ingestion of seafood Part I: viral and bacterial infections. *Lancet Infect. Dis*. **4**: 201-212.

Cappuccino JG and N Sherman (1990). *Microbiology : A Laboratory Manual*. 4th Edition. 137-183 pp.

CDCP (Center for Disease Control and Prevention). (2010). FAQ. *Escherichia coli*. Website: http://www.cdc.gov/ncidod/dbmd/diseaseinfo/escherichiacoli_g.html. Accessed on May 10, 2010.

Clarence SY, CN Obinna and NC Shalom. (2009). Assessment of bacteriological quality of ready to eat food in Benin city metropolis, Nigeria. *Afr. J. Microb. Res.* **3(6)**: 390-395.

Dinakaran GK, P Soundarapandian and SK Chandra 2009. Proximate composition of edible palaemonid prawn *Macrobrachium idae* (Heller, 1862). Current Res. J. Biol. Sci. **1**(3): 78-82.

FAO. (1997). *Review of the State of World Aquaculture*. FAO Fisheries Circular No. 886 FIRI/ C 886 (Rev. 1). Website: http://www.fao.org/fi/. Accessed on June 8, 2011.

Geiger E and G Bergstrom (1962). *Fish as Food* II. 30-35 pp.

Ghosh K and S Mandal. (2010). Antibiotic resistant bacteria in consumable fishes from Digha coast, West Bengal, India. *Proc. zool. Soc.* **63(1)**: 13-20.

Hatha MAA, TK Maqbool and S Kumar. (2003). Microbial quality of shrimp products of export trade produced from aquacultured shrimp. *Int. J. Food Microbiol.* **5(2)**: 82, 213-221.

Holmstrom K, S Graslund, A Wahlstrom, S Poungshompoo, BE Bengtsson and N Kantsky. (2003). Antibiotic use in shrimp farming and implications for environmental impacts and human health. *J. Food Sci*. **38**: 255-266.

Huss HH. 1994. *Assurance of Seafood Quality*. FAO Fisheries Technical Paper 334. Food and Agriculture Organization, Rome.

ICMSF (International Commission on the Microbiological Specification of Foods Microorganisms in food) (1998). *Sampling for Microbiological Analysis: Principles and Specific Applications.* Vol. *2*. University of Toronto Press, Toronto, Canada. 142p.

ICMSF. (1986). Microorganisms in Foods. In: *Application of the Hazard Analysis Critical Control Point (HACCP) System to Ensure Microbiological Safety and Quality*. 2nd edition. Blackwell Scientific Publications. 42, 181-195 pp.

Keys A, JT Aderson and F Grande. (1986). Serum cholesterol response to changes in the diet. *Metabolism*. **14(7)**: 776-787.

Leita˜O MFF and DPA Rios. (2000). Microbiological and chemical changes in freshwater prawn stored under refrigeration. *Braz. J. Microbiol*. **13(3)**: 31, 3-7.

Natarajan R, T Ramamurthy and S Ramesh. (1985). Salmonella in Marine Food Products- A Review. *In Harvest and Post-Harvest Technology of Fish.* Eds. Ravindran K and others. Society of Fisheries Technologists (India). pp. 658.

Nilla SS, MG Mustafa, MMR Khan and MAR Khan. (2012a). Bacterial Profusion in Indian White Shrimp *Penaeus indicus* of two Different Market Conditions from Dhaka City, Bangladesh. In: *Abstracts book of 5th Fisheries Conferences and Research Fair 2012* (eds. MA Wahab, MJ Alam, ME Hoq, AKMN Alam, BK Barman, SMS Rahman and MAR Hossain). Bangladesh Fisheries Research Forum (BFRF), 18-19 January 2012. p 178.

Nilla SS, MG Mustafa, MMR Khan and MAR Khan. (2012b). Microbial Quality Assessment of Indian White Shrimp *Penaeus indicus* from Southwest Bangladesh. In: *Abstracts book of 5th Fisheries Conferences and Research Fair 2012* (eds. MA Wahab, MJ Alam, ME Hoq, AKMN Alam, BK Barman, SMS Rahman and MAR Hossain). Bangladesh Fisheries Research Forum (BFRF), 18-19 January 2012. p 179.

Nilla SS, MG Mustafa, DA Ahsan, MMR Khan and MAR Khan. (2012c). Bacterial abundance in Indian white shrimp, *Penaeus indicus* collected from two different market conditions of Dhaka city. *Dhaka Univ. J. Biol. Sci*. **21(1)**: 29-38.

Nilla SS, MAR Khan, MMR Khan, DA Ahsan and MG Mustafa. (2012d). Bacteriological quality of marketed mola fish, *Amblypharyngodon mola* from Dhaka metropolis. *Bangladesh J. Zool*. **40(1)**: 77-88.

Okeke IN, R Laxmaninarayan, ZA Bhutta, AG Duse, P Jenkins, TF O'Brien, A Pablos-Mendez and KP Klugman. (2005). Antimicrobial resistance in developing countries. Part 1: recent trends and current status. *Lancet Infect. Dis*. **5**: 481-493.

Prakash S, I Jeyasanta, R Carol and J Patterson. (2011). Microbial quality of salted and sun dried sea foods of Tuticorin dry fish market, southeast coast of India. *Int. J. Microbiol. Res*. **2(2)**: 188-195.

Primavera JH. (1994). Shrimp Farming in the Asia-Pacific: Environmental and Trade Issues and Regional Cooperation. *In: Trade and Environment in Asia- Pacific: Prospects for Regional Cooperation. Workshop held in East-West Center, honolulu*, 23-25th September 1994. Tigbauan, Iloilo, Philippines: Aquaculture Department Southeast Asian Fisheries Development Center.

Rahman M, MZ Rahman, H Akhter, A Begum and SI Khan. (2009). Occurrence and characterization of *Vibrio* spp. in raw and frozen shrimps. *Bang. J. Zool*. **37(2)**: 247-255.

Ravichandran S, G Rameshkumar and AR Prince (2009). Biochemical composition of shell and flesh of the Indian white shrimp *Penaeus indicus* (H. Milne Edwards 1837). *American–Eurasian J. Sci Res*. **4(3)**: 191-194.

Reilly PJA, DR Twiddy and RS Fuchs. (1992). *Review of the Occurrence of Salmonella in Cultured Tropical Shrimp*. FAO Fish. Circ. No. 851. FAO, Rome, Italy.

Rosmini MR, ML Signorini, R Schneider and JC Bonazza. (2004). Evaluation of two alternative technique for counting mesophilic aerobic bacteria in raw milk. *Food Control*. **15(1)**: 39-44.

Ryu SH, SG Park, SM Choi, YO Hwang, HJ Ham, SU Kim, YK Lee, MS Kim, GY Park, KS Kim and YZ Chae. (2012). Antimicrobial resistance and resistance genes in *Escherichia coli* strains from commercial fish and seafood. *Int. J. Food Microbiol.* **15(2)**: 14-18.

Shafi M and MMA Quddus (2004). *Bangladesh Matsho Shampad (Fisheries of Bangladesh)*. 2nd edition. Kabir Publications, Dhaka. 354-356 pp.

Sawhney A. (2005). Quality measures in food trade: the Indian experience. *The World Econ*. **28(3)**: 329-348.

Shewan JM. (1961). The Microbiology of Seawater Fish. In: *Fish as Food Vol. I* (ed. Brogstrom, G.). Academic press, New York. 487 p.

Sorum H. (2006). Antimicrobial resistance in bacteria of animal origin. In: *Antimicrobial Drug Resistance in Fish Pathogens*. Chapter 13 (ed. Aarestrup, FM). American Society for Microbiology Press: Washington, DC, USA. 213–238 pp.

Tannock GW. (1995). Normal microflora- An introduction to microbes inhabiting the human body. Chapman & Hall, London, 115 p.

Viswanathan PGN and S Mathew (2000). *Biochemical composition of fish and shellfish*. Central Institute of Fisheries Technology, Cochin. CIFT Technology Advisory Series. 4-7 pp.

Wahab MA, A Bergheim and B Braaten. (2003). Water quality and partial mass budget in extensive shrimp ponds in Bangladesh. *Science Direct (Internet ed).* **218**: 413-423.

Wallace BJ, JJ Guzewich, M Cambridge, S Altekruse and DL Morse. (1999). Seafood-Associated Disease outbreaks in New York, 1980-1994. *Americ. J. Preven. Med*. **17(1)**: 48-54.

Williams OB, HB Ress and LL Campbell. (1952). The bacteriology of Gulf coast shrimp I and II. Experimental procedures and quantitative results. *Texas J. Sci*. **4**: 49-52.

Yousuf AHM, MK Ahmed, S Yeasmin, N Ahsan, MM Rahman and MM Islam (2008). Prevalence of microbial load in shrimp, *Penaeus monodon* and prawn, *Macrobrachium rosenbergii* from Bangladesh. *World J Agri. Sci*. **4**(S): 852-855.

Nutrients (NO_3, PO_4, NH_4, SO_4) concentration under different tidal and weather conditions in Kholpetua-Arpangasia river system of the Sundarbans

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Abstract: A comprehensive study was conducted to evaluate spatial and seasonal variations in concentrations and fluxes of major nutrients- nitrogen (NH_4^+, NO_3^-) and phosphorus (soluble reactive phosphorus, PO_4^{-3}) in a riverine mangrove forest during the post-monsoon (October–December, 2010), Dry (January–February, 2011) and monsoon (July–September, 2011) seasons in the Kholpetua- Arpangasia river system of the Sundarban mangrove forest. During the study, ammonia (NH_3–N) was found to vary from 0.008 to 0.436 mg/L with an average concentration of 0.138 mg/L, while nitrate (NO_3–N) was recorded to be 0.024 to 1.246 mg/L with an average of 0.154 mg/L. Phosphate (PO_4–P) and sulphate (SO_4) values were 0.025 to 1.156 mg/L and 32.439 and 141.044 mg/L, respectively. Field measurement showed that on an average of 0.124 mg/L phosphate (PO_4–P) was carried by this intertidal river system and the value was recorded as 95.694 mg/L for sulphate (SO_4). Different physic-chemical parameters of the water such as dissolved oxygen (DO), temperature and pH were measured as 5.00 mg/L, 27.17 ^oC and 7.6 respectively. During the study period, average electric conductivity (EC) and total dissolved solid (TDS) were found to be 26.15 mS and 1733 ppm, respectively. Present study shows that the concentration of major nutrients in the Sundarbans water was still within suitable range for aquatic lives and within environmental quality standard (EQS) limit.

Introduction

The Sundarbans in Bangladesh covers an area of nearly 6,017 km^2 along its South-western part sharing land area of 4,143 km^2 (including exposed sandbars – 42 km^2) and the remaining water area of 1,874 km^2 encompasses rivers, small stream sand canals. River mouths in the Sundarbans are meeting places of salt water and freshwater. Thus, it is a region of transition between the freshwater of the rivers originating from the Ganges and the saline water of the Bay of Bengal. The coast of the Sundarban is crisscrossed by a network of complex estuarine system created by river Rupsa, Passur, Shibsa, Arpangasia and others rivers which flows into the Bay of Bengal and carry large amounts of nutrients that varies with tides and seasons which makes the area nutrient-rich and highly productive. Due to the existence of numerous cross connected rivers, the physical and chemical composition of this area varies with location, tide, depth and season. Soil of this delta is unripened, slightly calcareous, alkaline, clayey mud with low organic matter content. These regions also play an important role in processing nutrients exchanged between land and sea (Eyre and Twigg 1997). The high nutrient and productivity of estuaries make them, important breeding grounds, rich nurseries and important feeding grounds for juvenile fish. Globally, estuarine nutrient loads have steadily increased over recent decades coincident with rise in the human population and industry. Such increases generally boost primary production and provide either an additional sink and/or source for carbon, and phosphorus, nitrate and sulphate in coastal waters.

Water column nutrients play an important role for the living and sustenance of aquatic organisms including fish. The nutrients nitrogen (N) and phosphorus (P) are essential building blocks for plant and animal growth. Nitrogen exists in water both as inorganic and organic and in dissolved and particulate forms. Inorganic nitrogen is found both as oxidized {*e.g.* nitrate (NO_3^-) and nitrite (NO_2^-)} and reduced {*e.g.* ammonia (NH_4^++NH_3) and as nitrogen gas (N_2)}. The occurrence of different forms of ammonia depends on pH. Phosphorus is found in waterbodies in dissolved and particulate forms. Dissolved phosphorus is readily available for plants, and consists of inorganic orthophosphate (*e.g* $H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}) and organic phosphorus-containing compounds (DOP). The particulate phosphorus pool consists of plants and animals, and their remains, phosphorus in minerals (*e.g.* fluorapatite) and phosphate adsorbed onto iron oxyhydroxides on mineral surfaces. All aquatic organisms including fish depend directly on nutrients for their living, growth and reproduction. Again some nutrients are related with the chlorophyll availability of water body i.e., availability of phytoplankton in the water. Thus nutrient availability is directly related to the productivity of water body. Again excess of it causes eutrophication by algal bloom and makes the water toxic. Therefore, nutrient concentration must be within the acceptable limit for good aquatic environment and better production of

aquatic organisms including fish. In general most mangroves grow well in between the mean high water spring tide and mean sea level. Combined, this dynamic amalgam of hydrological factors influences the distribution of plants and animals and leads to development of fascinating physiological adaptations which must be given much more attention in research. Thus, the present study has been undertaken to quantify some major nutrients at different depths and locations and to evaluate tidal and seasonal fluctuations of nutrient concentration from upstream to downstream in the Kholpetua-Arpangasia river system of the Sundarbans mangrove forest.

Materials and methods

Study area and time

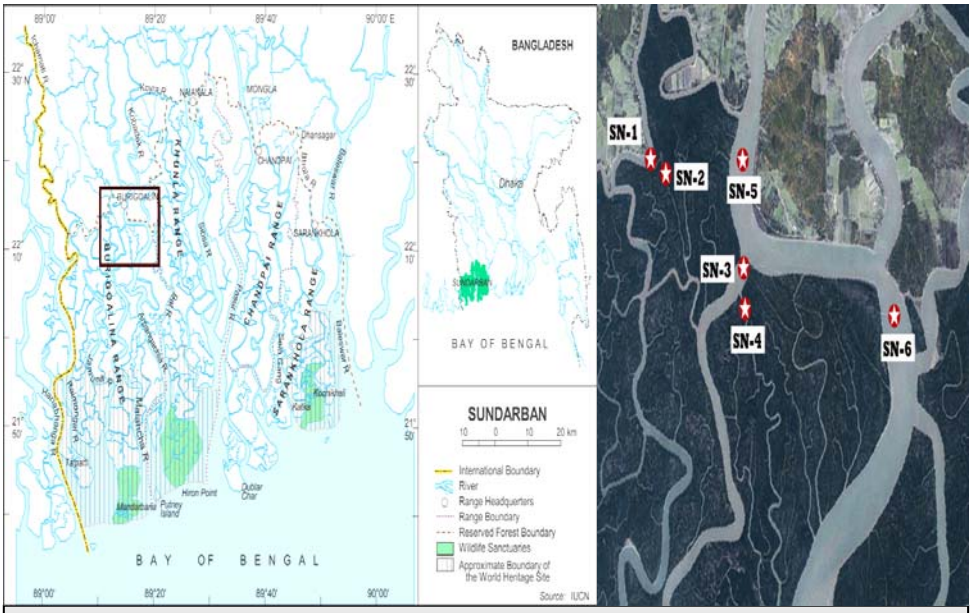
The present study was conducted in the Kholpetua-Arpangasia river system of Burigoalini range, the western part of Sundarbans mangrove forest (polyhaline zone) of Bangladesh (Fig.1). The river Kolpetua is connected with Arpangasia and Bal river. Six stations were selected in different locations of the river system to conduct the study (Table 1). Comprehensive field measurements were made under different climatic - dry season (January-May), monsoon season (June-September) and post monsoon (October-December) and tidal conditions. *In-situ* measurement and laboratory analysis were conducted for the study during October, 2010 to September, 2011.

Table 1. Geographical location of the study points and water depth at different tides

Sampling station	Longitude	Latitude	Water depth (m)	
			High tide	Low tide
Pasurtala	89º 11' 934" E	22º 14' 038" N	15.85	12.50
Pasurtala Canal	89º 12' 043" E	22º 14'077" N	3.66	1.63
Kolagachhi	89º 14' 541" E	22°20'51.35" N	11.43	6.55
Kolagachhi Canal	89º 14' 638" E	22º 12' 392" N	5.15	3.20
Nildumur	89º 14' 708" E	22º 14'828" N	10.92	10.06
Arpangasia	89º 18' 581" E	22º 12'406" N	11.58	9.75

In situ data collection and analyses

Seasonal monitoring of hydrological and water quality parameters were made at suitable frequency. Field measurements of tidal level, flow pattern, temperature, salinity, pH and water sample collections for water quality analysis were included in the sampling program. Water depth and tidal fluctuation of rivers were measured by a marked rope which was attached with a heavy weight. Water samples were collected from discrete layers- surface, middle and bottom through deploying Ruttner water sampler. Temperature, pH, DO, TDS and conductivity were determined in the field by multi parameter water test kit and DO meter. Salinity was estimated by a refractometer. The flow pattern of tidal current was detected by a current meter. Transparency of the water was measured by a secchi disk.



SN-1: Pasurtala, **SN-2:** Pasurtala Canal, **SN-3:** Kolagachi, **SN-4:** Kolagachi Canal
SN-5: Nildumur, and **SN-6:** Arpangasia

Fig. 1. Map of the Sundarbans and location of the study points.

Ex situ data collection and analysis

The samples were analyzed in the Water Chemistry Laboratory of Fisheries and Marine Resource Technology Discipline, Khulna University for the nutrient analysis.

During laboratory analysis, phosphate and sulphate were determined by the ascorbic acid method, while ammonia and nitrate were measured by Nesslerization and phenol disulphonic acid method, respectively.

Results and discussion

Nitrate

NO_3–N concentrations were found to vary between 0.024 and 1.246 mg/L with an average of 0.154 mg/L. The highest and lowest values were found in the Kolagachi station of Kholpetua river in the monsoon and dry season, respectively. No distinct seasonal variation of NO_3–N was observed during the study (Figs. 2, 3 &4). Concentration of NO_3-N at different tides was found to be inconsistent. The maximum and minimum concentrations were recorded in Pasurtala and Kolagachi stations, respectively when the tidal level was rising. Combined tidal and seasonal effects of NO_3–N concentrations were found to vary in an independent manner. Maximum concentration was measured in the combined effect of high tide during monsoon and minimum concentration was recorded in case of rising tide during dry season. The average NO_3–N concentration of 0.154 mg/L is indicative of low human intervention in the river system. The reason behind irregular fluctuation of NO_3–N throughout the year and irrespective of tide could be the presence of greater N_2 concentration in the air and continuous absorption of N_2 from air to water. The present value is comparatively lower than the value of Wahid et al. (2007) who recorded an average value of 0.461 mg/L.

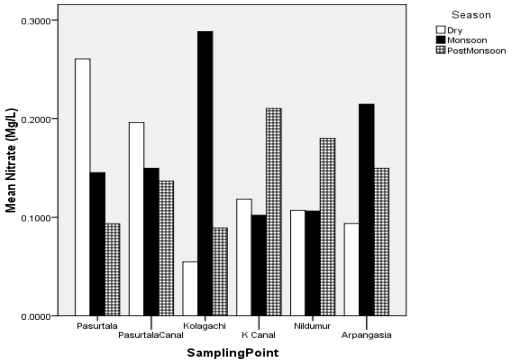


Fig. 2. Concentrations of NO_3-N at different sampling stations under varying seasons.

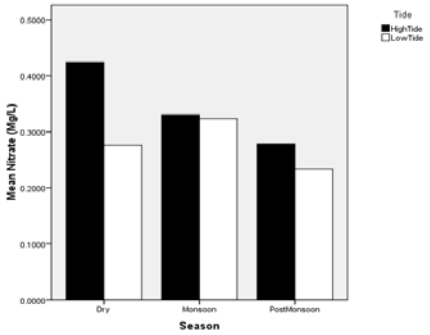


Fig.3. Status of NO_3-N level at different sampling points under tidal conditions.

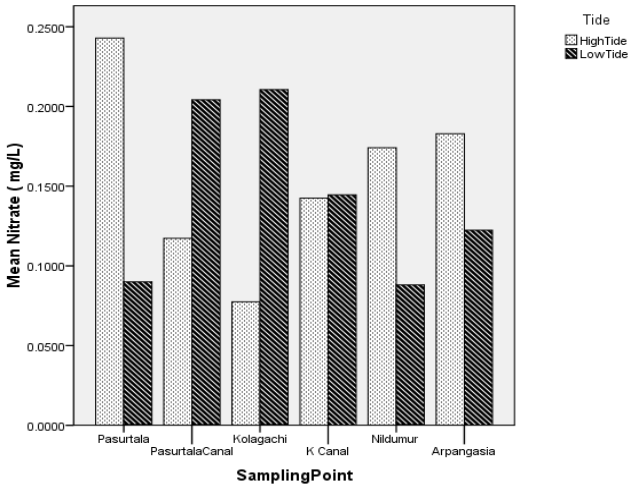


Fig. 4. Seasonal and tidal variation of NO_3-N in the study area.

Phosphate

Phosphate concentrations as PO_4–P were generally low in such a mangrove estuarine ecosystem that varied from 0.025 to 1.156 mg/L with average being 0.124 mg/L. The maximum concentration was recorded during dry season at Nildumur point and the minimum one also measured at Pasurtala station in the dry season. As for the NO_3–N, no distinct seasonal concentration pattern was noticed for PO_4–P with the available data (Figs. 5, 6 &7).

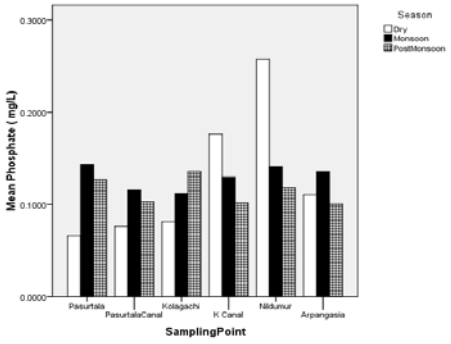


Fig. 5. Seasonal distributions of PO_4–P.

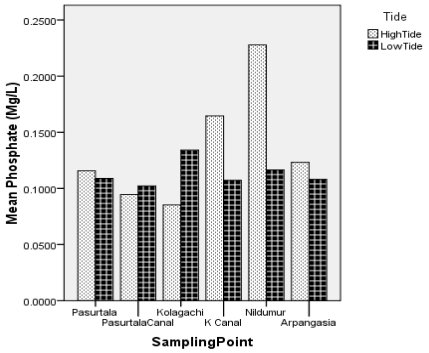


Fig. 6. Tidal variations of PO_4–P.

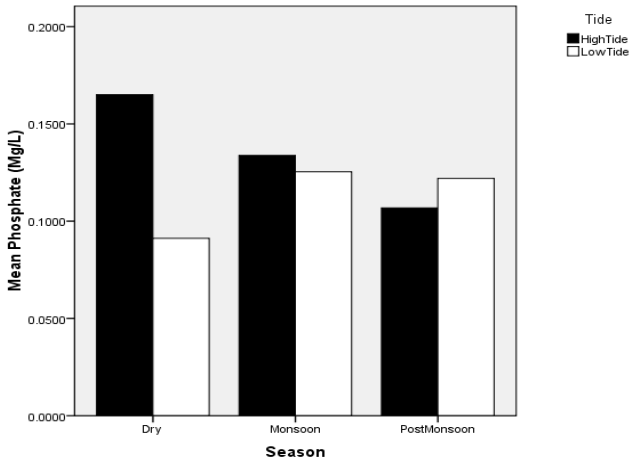


Fig. 7. Seasonal and Tidal variation of PO_4–P in different seasons.

PO_4–P showed more or less a distinct variation with tide. In most cases, it was observed in its maximum limit during high tide while in minimum range during dropping tide condition. During high tide, concentration of PO_4–P reached maximum limit at Nildumur station and minimum level at Pasurtala point while during dropping tide PO_4–P level was found to be maximum at Kolagachi station and minimum at Kolagachi canal. The average value of PO_4 was recorded as 0.124 mg/L which is lower than the acceptable limit of PO_4–P set by the EQS of Bangladesh. Department of Environment (DOE), Bangladesh defines the EQS of PO_4 by the limiting range 6–10 mg/L (DOE, 1991). This range is converted to PO_4–P– 0.2–0.3 mg/L for comparison purpose. Recorded values are more or less similar with the findings of Wahid et al. (2007) where average value was mentioned as 0.115 mg/L and IWM (2003) recorded relatively low concentration as 0.009-0.582 mg/L, where average value was recorded as 0.115 mg/L. It is assumed that limited freshwater flow from the western part of our country and a cut of from the Ganges, the largest source of freshwater flow in the country may contribute to the lower concentration of phosphate in the river system.

Sulphate

SO_4 concentrations were found to vary between 32.44 and 141.04 mg/L with an average of 95.69 mg/L. It showed a distinct seasonal variation. The maximum concentration of SO_4 was detected in the monsoon and minimum was observed

during the post-monsoon season and its concentration was found to be raised from upstream to downstream (Figs. 8, 9 &10).

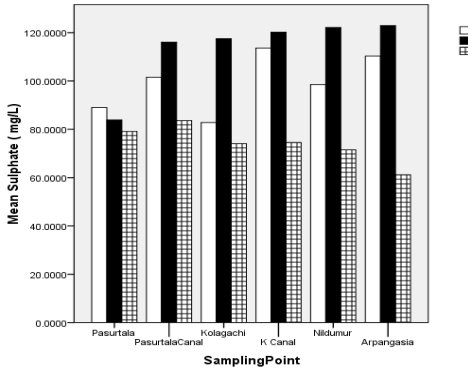


Fig. 8. Seasonal variation of SO_4 at different sampling stations

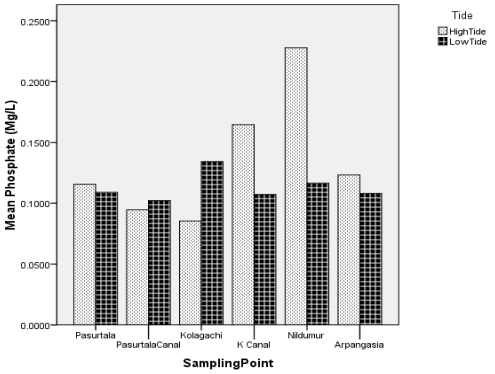


Fig. 9. Tidal variation of SO_4 at different sampling stations

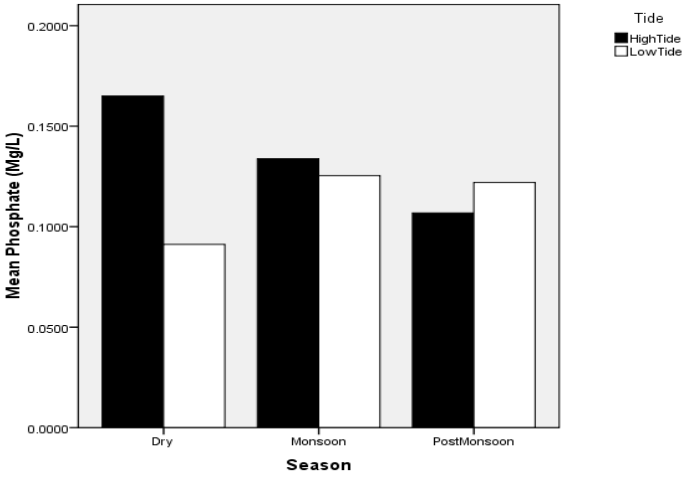


Fig. 10. Seasonal and tidal variation of SO_4 in the study area.

The concentration of SO_4 was found to be raised mostly in low tides than in high tides and the concentration was higher in the canals than in the rivers. The average SO_4 value (95.69 mg/L) indicates sufficient SO_4 concentration in the mangrove

water. The reason behind maximum concentration of SO_4 during monsoon can be the huge river run off and runoff from agricultural lands (*e.g.* fertilizers), urban drainage water and wastewater (including sewage), eroded soils and aquaculture activities.

The relatively lower concentration of sulphate in the upper estuarine stretch may be due to consumption of the anion by paddy fields along the upstream stations, whereas removal is compensated in the lower part of the estuary by the contribution of seawater and decay of organic matter from mangroves. According to Ramanathan et al. (1993) seawater input along with resuspension mixing (turbidity and mixing) of decayed organic matter and oxidation of buried biogenic materials result in enhanced sulphate levels in mangrove waters. The sulphate value is generally higher during high tide in monsoon due to the intrusion of river runoff from upstream land.

Ammonia

It was found that NH_3–N varied between 0.008 and 0.436 mg/L in the river system with an average concentration of 0.138 mg/L. The NH_3–N level was found higher in the monsoon and lower range was recorded mostly in dry season and in few cases in post monsoon period also (Figs. 11, 12 &13).

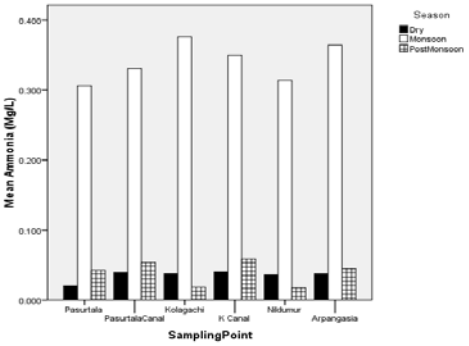


Fig. 11. Seasonal variations of NH_3–N.

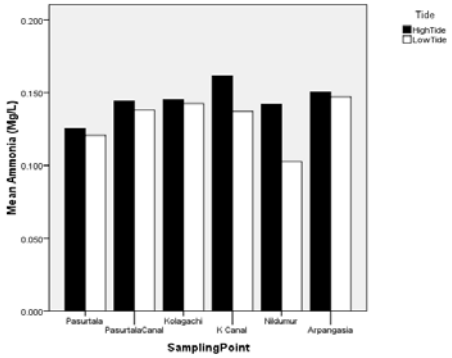


Fig.12. Tidal variations of NH_3–N.

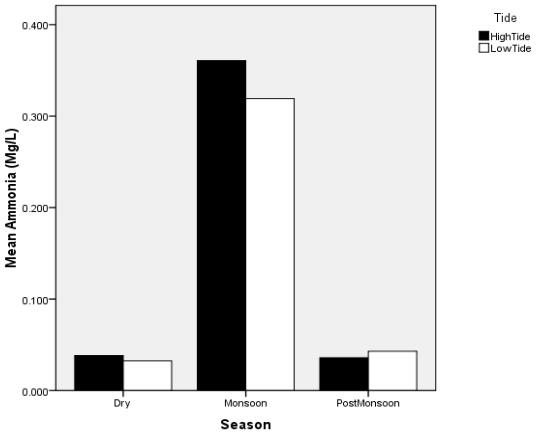


Fig. 13. Seasonal and tidal fluctuations of NH_3–N in the study area.

During field measurement, NH_3-N showed distinct tidal fluctuation with maximum range during rising tide and minimum limit in low tide irrespective of climatic conditions. However, in case of post monsoon period it showed maximum limit in dropping tide condition and minimum in high tide time. Presence of non-ionized ammonia (NH_3–N) in very low proportion (an average of 0.138218 mg/L) is an indication of good quality of river water with respect to ammoniacal nitrogen inside the Sundarbans. Because of higher concentration it causes toxicity in river water. The reason of maximum concentration in monsoon can again be the huge run off and runoff from agricultural areas (*e.g.* fertilizers), urban water and wastewater (including sewage), eroded soils and aquaculture. The observed values are slightly lower than the findings of Wahid et al. (2007) who observed an average concentration of 0.054 mg/L. IWM (2003) found ammonia in the range of 0.001 to 0.33 mg/L while the average value is figured out as 0.043 mg/L.

Physical parameters

Temperature

The temperature of water ranges from 21.1 to 31.1 ^oC having an average of 27.17 ^oC (Fig. 14). The estuarine stretch did not exhibit significant tidal variation of surface water temperature; neither the spatial variation was prominent. The uniformity in water temperature values is due to high specific heat of the aquatic phase, which enables water to resist much fluctuation of temperature than the adjacent landmasses. The water temperature has considerable effect on phytoplankton population density

by influencing the process of cyst germination (Ishikawa and Taniguchi 1994; Blanco 1995). The present spatial and tidal uniformity in surface water temperature, however, has the least probability to affect the plankton community of the estuary.

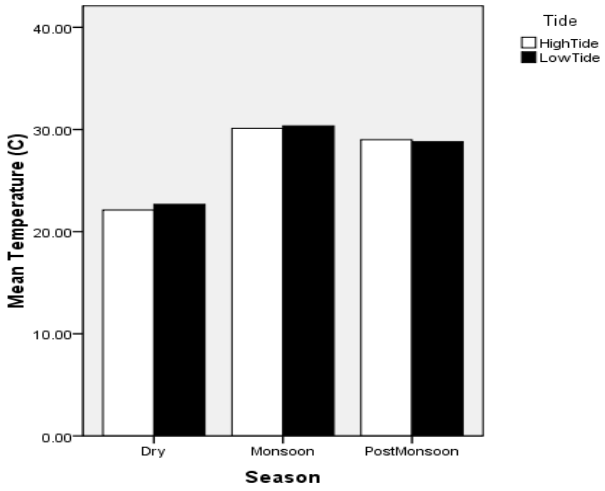


Fig. 14. Seasonal and tidal fluctuations of water temperature.

pH

The pH of water ranged between 6.89 and 7.9 having an average value of 7.6. The tidal and seasonal variations of pH are almost negligible. Maximum temperature was found in dry season but lowest one in monsoon period (Fig.15). Generally, fluctuations in pH values can be attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of seawater by freshwater influx, reduction of salinity and temperature and decomposition of organic matter.

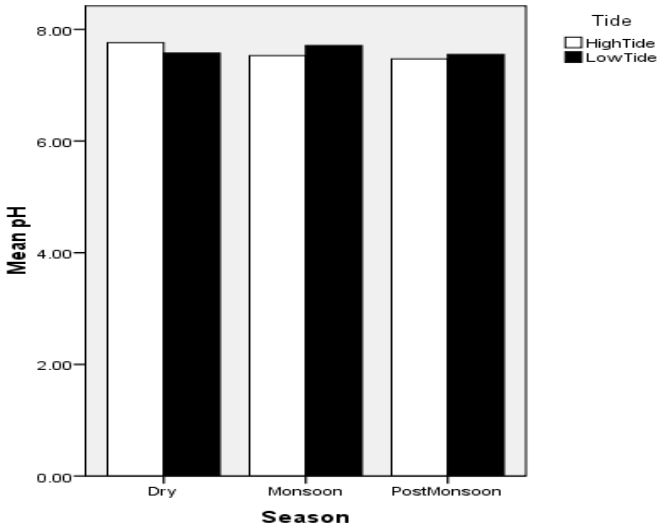


Fig. 15. Seasonal and tidal variations of water pH in the experimental region.

Salinity level and its effect to nutrients

Salinity at Kholpetua-Arpangasia river system (western boundary areas) did not reduce below 5 ppt even during monsoon which experiences significant precipitation and it increased at a steady rate during dry season up to 23-25 ppt (Fig.16). At the end of monsoon, salinity started decreasing slowly which is thought to be dependent on freshwater inflow from upstream rivers of the western part. Nutrient concentrations in river water were found inversely proportional to salinity. Salinity level in the Sundarbans river system is highly dependent on the volume of freshwater coming from the upstream and the nature of tide. Salinity near the coast and inside the forest varies over a number of different timescales. Daily peak salinity at the coast generally coincides with the arrival of high water, whereas the daily range of salinity level varies with season.

The salinity values increased from the upstream to the downstream zone. During high tide water from Bay of Bengal enter the present estuarine zone that contributes to the rising of salinity. However, during low tide the effect of fresh water discharge from the upstream rivers lower the salinity of the study area. Such variation of salinity with tide was also documented by several earlier workers (NEERI 1976, Mitra 2011 and Mukhopadhyay *et al.* 2006).

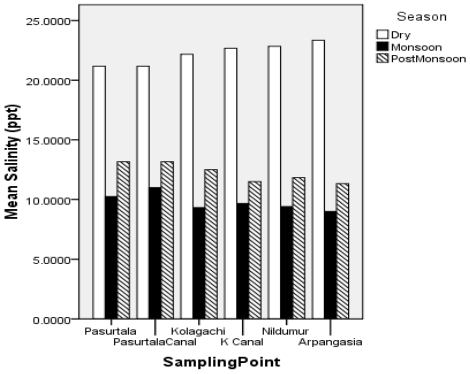


Fig.16. Seasonal variation of Salinity in the sampling area.

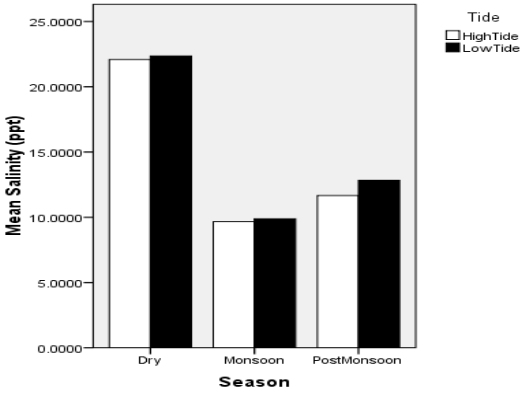


Fig.17. Tidal variation of salinity in the sampling area.

Electrical Conductivity and TDS

Electrical conductivity (EC) estimates the amount of total dissolved salts or the total amount of dissolved ions in the water that was recorded to vary from 16 to 34.1 mS with an average of 26.149 mS and Total Dissolve Solid (TDS) ranged between 1060 and 2270 ppm with an average of 1733.519 ppm. EC and TDS both showed maximum concentration in monsoon while minimum in post monsoon which indicated more or less positive relation with nutrient load.

Dissolved Oxygen (DO)

Dissolved oxygen varied from 3.8 to 7.2 mg/L with an average of 5.00 mg/L (Fig. 20). Concentration of DO decreased with increasing depth and its maximum concentration was found in post monsoon and minimum in monsoon. The concentration of dissolved oxygen falls in the monsoon. On the other hand, most nutrient constituents were found to become increased in the monsoon. Thus DO and nutrient showed almost inverse relationship. For example- water column phosphorus concentrations have also been shown to increase under anoxic conditions. This is because anaerobic some of the iron oxyhydroxides that bind phosphate are converted to iron sulfides during sulfate reduction and the iron sulfides cannot bind phosphorus. The average DO level was found to be 5.00 mg/L which is more or less similar with the findings of IWM (2003) who mentioned DO level in the range of 4.90 to 6.90 mg/L with an average value of 5.99 mg/L.

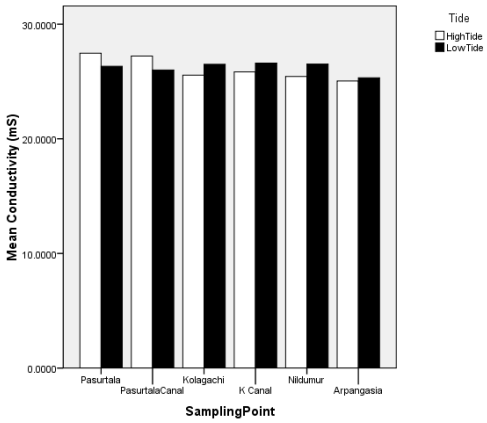


Fig. 18. Seasonal variation of EC (mS) at study locations.

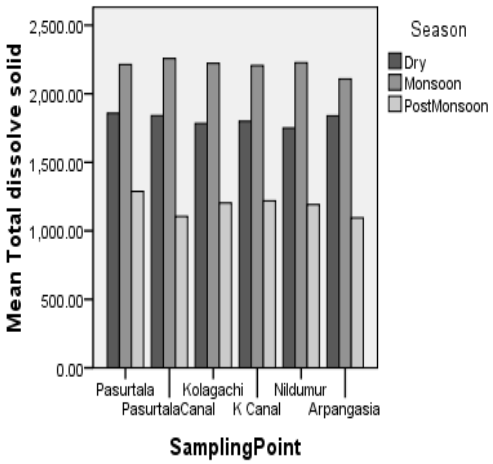


Fig. 19. Seasonal variation of TDS (ppm) at study locations.

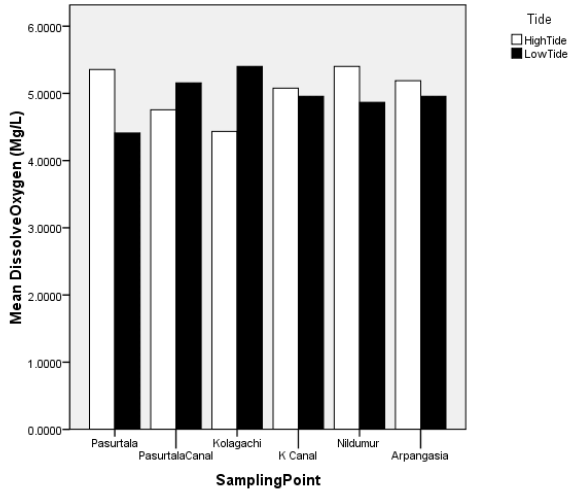


Fig. 20. Tidal variation of DO at different study points.

The Sundarban mangrove forest serves as a link between terrestrial and marine ecosystems. The study provides comprehensive seasonal, tidal and spatial characterization of hydrological regime of the Sundarban ecosystem of Bangladesh.

The major nutrients show significant seasonal and tidal variations. Concentrations of NO_3–N were found to vary between 0.024 and 1.246 mg/L with an average of 0.154 mg/L with no distinct seasonal variation. Phosphate concentrations as PO_4–P were generally low and varied from 0.025 to 1.156 mg/L, average being 0.124 mg/L. SO_4 concentrations were found to vary between 32.439 and 141.044 mg/L while the average value was recorded to be 95.694 mg/L. NH_3–N varied between 0.008 and 0.436 mg/L and average concentration indicated to be around 0.138 mg/L. Electric Conductivity (EC) ranged from 16 to 34.1 mS with an average value of 26.150 mS. Total Dissolve Solids (TDS) was depicted as 1060 to 2270 ppm while the average was counted for 1733.52 ppm with distinct seasonal fluctuation pattern. EC and TDS showed maximum limit during monsoon and minimum level in post monsoon period. Thus the highly productive mangrove water body provides a suitable nursery ground for aquatic organisms including fish.

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References

Blanco, J. (1995) Cyst production in four species of neritic dinoflagellates. Jour Plank Res 17:165-182.

Coonley LS, Baker EB, Holland HD (1971) Iron in the Mullica River and the Great Bay, New Jersey. Chem Geo 7:51- 63.

Eyre BD, Twigg C (1997) Nutrient behaviour during post-flood recovery of the Richmond River Estuary northern NSW, Australia. Estu Coas and Shelf Sci 44:311-326.

Gobeil C, Sundby B, Silverberg N (1981) Factors influencing particulate matter geochemistry in the St. Lawrence turbidity maximum. Mari Chem 10: 123- 140.

IWM (Institute of Water Management) (2003) Sundarbans Biodiversity Conservation Project –Surface water modelling TA No. 3158-BAN. Final report.Volume 1. IWM, Dhaka. Bangladesh.

Ishikawa A, Taniguchi A (1994) The role of cysts on the population dynamics of *Scrippsiella* spp. (Dinophyceae) in Onagawa Bay, Northeast Japan. J Mar Biol 114: 39-44.

Mitra, A, Mondal K, Banerjee K (2011) Spatial and Tidal Variations of Physico Chemical Parameters in the Lower Gangetic Delta Region, West Bengal, India. J Spat Hydro 11: 52-69.

Mukhopadhyay SK, Biswas HDeTK, Jana TK (2006) Fluxes of nutrients from the tropical River Hooghly at the land–ocean boundary of Sundarbans, NE Coast of Bay of Bengal, India. J Mari Sys 62: 9-21.

NEERI (1976) Baseline water quality studies in the Hooghly Estuary. National Environmental Engineering Research Institute, Nagpur, India.

Ramanathan AL, Subramanian V, Ramesh R, Chidambaram S, James A (1993) Environmental geochemistry of the Pichavaram mangrove ecosystem (tropical), southeast coast of India, Envi Geo 37 (3): 223-233.

Sholkovitz ER (1976) Flocculation of dissolved organic and inorganic matter during the mixing of river water and seawater, Geochimica et Cosmochimica Acta, 37: 851-880.

Wahid SM, Mukand SB, Bhuiyan AR (2007) Hydrologic monitoring and analysis in the Sundarbans mangrove ecosystem, Bangladesh. Journal of Hydrology, 332(3–4): 381–395.

Yeats PA, Bewers JM (1982) Discharge of metals from St. Lawrence River, Cana J Earth Sci 19: 982-992.

Shark fisheries status and management approach in the Bay of Bengal, Bangladesh

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Abstract: Shark fishery is not a target fishery in Bangladesh water rather regarded as by-catch. A total of 36 species of sharks, five species of skates and 30 species of rays were so far recorded from Bangladesh waters but no chimaerids. Fish Act has no restriction on harvesting of sharks, while Forestry Act restricts it in and around the Sundarbans. Catch records reflect that catches are declining and bulk of the catches are composed of small sized individulas. Study on the biology of Elasmobranch fishes of Bangladesh is very scanty and this is probably because of the difficulty in getting adequate statistics and samples. Review of stock assessments and present stock status of sharks is essential with a National Plan of Action (NPOA) for a regional fishery management plan which would help in introducing and promoting collaborative fisheries management approaches in the BoB region. Fishery Act should be updated with strong rules and proper monitoring, and control and surveillance (MCS) should be implemented for restricting indiscriminate exploitation of the Elasmobranchs.

Introduction

Sharks are predominantly marine, oceanic and are widely distributed in the tropical, subtropical and temperate waters of the seas around the world. A few species, however, enter in the brackish water and even in the freshwater rivers beyond the tidal range, like the Ganges, the Tigris and the Zambezi (Migdalsky *et al.* 1989). Sharks, skates and rays of the oceans are subject to high and often unrestricted levels of mortality from by-catch and targeted fisheries for their meat and valuable fins. They are especially vulnerable to overfishing because they mature and reproduce slowly. Fishing spans all over oceans and the impact on these top predators is largely

unknown. Lack of data and complicated transboundary jurisdictional issues pose challenges for assessing and conserving high seas biodiversity (Dulvy *et al.* 2008). As top predators, their depletion also has risks for the health of the entire ocean ecosystems. CITES (2010) reports that illegal, unregulated and unreported trade is contributing to unsustainable fishing of a number of shark species.

Sharks skin, meat, fin, teeth, bones etc. are processed and sold as shark products. Iced and slated dry flesh, sun-dried hide, bones, fins, tails, teeth and shark liver oil are traded in Bangladesh. Sharks and rays skin is used for rasping and polishing. A special feature of sharks and rays is the surface of the skin known as 'shagreen' which is a kind of rough leather with dermal denticles embedded in the skin, used for rasping and polishing. A rare and expensive product known as 'boroso leather' can be obtained by polishing the denticles to a high gloss. The hide can also be converted into fancy leather by removing the dermal denticles. This leather can be used for shoes and other value-added products such as wallets, dress belts, handbags and purses. Sharks and rays dried fins and fin rays are used for making soups. High-value, squalene-rich shark liver oil is used in the tanning and textile industries, as a lubricant and also as a rich source of vitamin-A having a high medicinal value. The livers weigh 10-25% of the shark's body weight and contain 60-70% oil. The species much sought after for extraction of medicinal oil enriched with high vitamin-A content (Bykov 1983, Bal and Rao 1990) in terms of International units (IUs) per gram weight of oil, such as *Glyphis gangeticus* (97,000 units), *Carcharhinus. melanopterus* (45,450 units), *Sphyrna zygaena* (22,752 units), *Rhizoprionodon acutus* (up to 8,853 units), and *Pristis microdon* (6,618 units).

Up to 73 million of these animals are killed each year to support the global fin trade, while 30% of all sharks are threatened or near threatened with extinction. Some populations, such as the scalloped hammerhead, have declined by up to 98%. Many governments, however, are recognizing that sharks are more valuable alive and can be a key economic driver as a tourist attraction. Most of the oceanic sharks have slow growth rate, delayed maturation, low fecundity and long life span. These factors determine the low reproductive potential of many shark species, which makes them more vulnerable to overfishing than other fish (Castro *et al.* 1999). According to the FAO Code of Conduct for Responsible Fisheries, States are required to minimize waste discards by adopting suitable measures. In Bangladesh, Fish Act has no restriction on harvesting of sharks, while Forestry Act restricts it in and around the Sundarbans coast. The present paper describes the status of shark fisheries in Bangladesh with management options targeted to prepare a National Plan of Action on shark.

Materials and methods

Like many other countries species-wise catch is not recorded in Bangladesh, rather recorded only by groups of sharks and rays. Catch record, gear-wise catch, percentage of different groups, etc. data were collected during July 2011 - June 2012 from Cox's Bazar, Chittagong and Barisal region as part of the landing data of shark recorded by Department of Fisheries and shark trading associations. Besides, secondary data on export trends and gear-wise catch were taken from the various sources and known management options being implemented by some other countries were sourced from the published literature with proper citation of references.

Results and discussion

Trends in shark catch and abundance

In Bangladesh, sharks are mainly caught by artisanal fishery with drift gill nets (used for catching hilsa and Indian salmon), set bag nets, long lines and trammel nets within 10-80 m depth ranges. Mostly small sized sharks and rays are caught because of gear limitations. In Cox's Bazar-Chittagong area sharks are caught at greater depths than the rest of the areas and bulk of the catch comes from Cox's Bazar area (Table 1). This is mainly due to their habitat preference as most elasmobrnchs prefer marine habitat.

Table 1. Location-wise harvesting depth, catch percentages of sharks, skates and rays

Location	Depth (m)	Catch %	Gears used
Cox's Bazar	10-50	35.0	Estuarine and marine set bag nets, gill nets, shark net, hooks and lines and trammel net.
Chittagong	10-50	21	Estuarine and marine set bag nets, gill nets, shark net, hooks and lines and trammel net.
Patharghata, Kuakata	5-30	15.0	Mostly caught with hilsa net
Barisal, Pirojpur, Bhola	5-30	12.0	Mostly caught with hilsa net
Dublar char, Bagerhat	10-30	16.0	Mostly caught with hilsa net

National catch statistics show that total yearly landing since 2000-01 up to 2009-10 varied around 4,000-6,000 t (Fig. 1), while the present study could record only 1/4th of the yearly landing and bulk (792.0 t) of the catch were the rays (Table 2).

Table 2. Total landings from July 2011 to June 2012 in the study areas.

Group	Landing (t)	Contribution (%)
Shark	179.38	17.2
Skates	71.47	6.85
Rays	792.31	76.0
Total	1,043.16	100

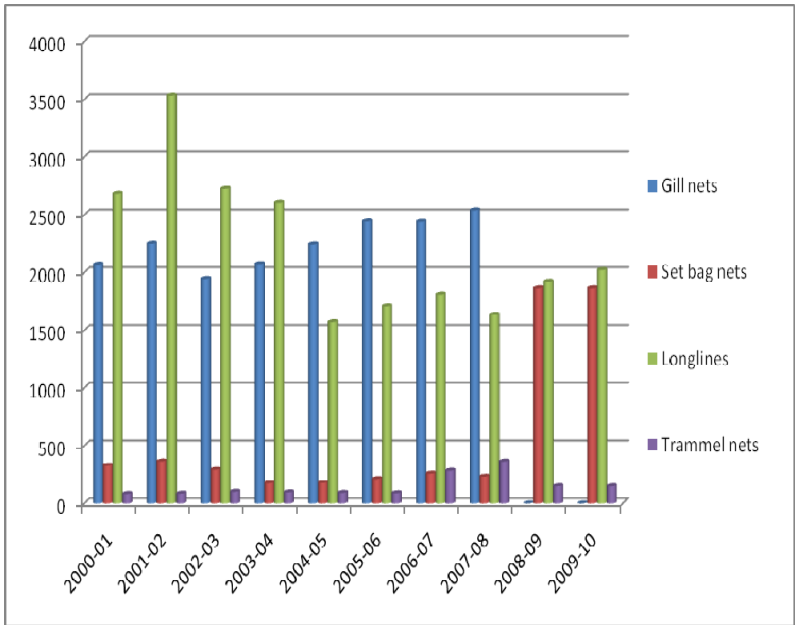

Fig. 1. Gear-wise exploitation (%) of sharks and rays.

Seasonal abundance reveals that shark harvesting gains momentum in October-December and reaches peak during January-March, catch gradually falls after that (April-June) with lowest catches during July-September (Table 3).

Table 3. Seasonal abundance of sharks, skates and rays during July 2011 through June 2012

Group	July-September (%)	October-December (%)	January-March (%)	April-June (%)
Sharks	10.4	26.5	37.2	25.9
Skates	12.8	24.3	34.8	28.1
Rays	14.3	23.6	36.7	25.4

In Cox's Bazar-Chittagong, most catch came from long lines and hooks, estuarine set bag nets (ESBN) and marine set bag nets (MSBN), shark nets and gill nets. In Barisal region most catch came from the gill nets and ESBN/MSBN. Trammel net catches were recorded from all stations but in small percentages (Table 4). Gear-wise time series data of the Fisheries Resources Survey System, Department of Fisheries revealed that bulk of the national shark catch comes from gill nets and long lines. Since 2008-09 there is no catch of sharks by gill nets (Fig. 1), reason, however, is not clear at the moment but future data may throw some light on this aspect.

Table 4. Gear-wise catch (%) of sharks, skates and rays in study areas

Area	Long lines+ hooks	ESBN+MSBN	Gill net/ Lakkha jal	Shark net	Trammel net
Cox's Bazar	42.3	18.8	12.4	20.6	5.7
Chittagong	39.5	22.6	13.4	18.7	5.8
Barisal	12.8	20.5	53.4	-	13.3
Pirojpur	24.4	30.8	26.6	8.7	9.5
Bhola	25.4	25.6	36.7	7.8	4.5
Barguna	20.5	29.7	32.8	14.6	2.4
Patharghata	26.7	22.6	33.4	12.8	4.5
Kuakata	20.8	25.4	26.5	14.7	2.6
Dublarchar	46.4	33.8	12.2	12.6	5.0

ESBN = Estuarine set bag net, MSBN = Marine set bag net

Identified species along with their length-weight size and catch percentages were shown in Table 5. This revealed that dogfish shark was the dominant one followed by hammerhead and milk sharks.. Whale shark, bull shark and saw-shark were caught in bigger sizes (Table 5).

Table 5. Species-wise catch, catch percentages along with their mean length and weight

Group	English name	Total catch (t)	%	Mean length (cm)	Mean weight (kg)
Shark	Dog shark	72.13	6.91	41.5	0.65
	Milk sfishhark	26.31	2.52	47.6	1.75
	Spear tooth shark	4.30	0.41	46.0	1.50
	Black shark	19.50	1.87	63.0	1.51
	Bull shark	0.375	0.036	128.0	21.0
	Hammerhead sharks	44.72	4.27	43.80	1.46
	Zebra shark	0.226	0.022	68.00	7.34
	Whale-shark	0.63	0.06	170.00	157.50
	Saw shark	0.743	0.071	83.00	17.20
	Silky shark	7.47	0.72	78.00	5.50
	Tiger shark	2.98	0.286	51.00	4.42
Skates	Sharp nose guitar fish	48.29	4.63	96.40	8.50
	White spotted guitar fish	23.18	2.22	112.00	5.50
Rays	Sharp snout stingray	24.58	2.36	63.50	7.30
	Kite ray	0.824	0.08	47.60	3.50
	Cow tail sting ray	66.346	6.36	86.50	7.95
	Gangetic sting ray	131.27	12.58	91.40	7.76
	Dwarf sting ray	205.71	19.72	89.30	9.45
	Leopard whip ray	197.56	18.93	95.20	8.23
	Bleeker’s whip ray	112.16	10.75	114.00	19.10
	Long tail butterfly ray	3.45	0.33	36.60	1.02
	Short tail butterfly ray	6.61	0.63	39.20	1.86
	White spotted whip ray	31.43	3.01	87.50	14.90
	Brown electric ray	7.21	0.69	67.50	8.04
	Black spotted electric ray	4.31	0.41	71.60	9.50
	Devil ray/Bat ray	0.853	0.08	38.20	1.46
	Total =	1,043.16	100		

Percentage of size abundance revealed that sharks were mostly caught at small sizes (>30 cm) while skates and rays were caught at bigger (>50 cm) sizes (Table 6).

Table 6. Percentage of size abundance of sharks, skates and rays

Group	>30 cm (%)	30-50 cm (%)	>50 cm (%)
Sharks	57.2	31.5	11.3
Skates	18.6	28.4	52.8
Rays	10.4	21.8	66.5

A total of 30 species of sharks, two species of skates and 37 species of rays were so far recorded from Bangladesh waters but no chimaerids (Haroon 2011). In the early 2000s catches were around 5,000-6,000 t/yr (about 1-1.5% of the total marine catch, in mid-2000s catches were little over 4,000 t/yr -0.8-0.9% of the total marine catch) and it declined to 3,900-4,200 t/yr during 2009-11 (only 0.77% of the total marine catch) (Table 7 and Fig. 2). Catch records clearly reflects declining trend and bulk of the catch is small sized ones. This indicates that excess removal of non-target species can alter the biodiversity by removing the top predators and prey species at unsustainable level. Ecosystem models and some field studies suggest that the removal of these top predators has the potential to negatively impact marine ecosystems (Myers *et al.* 2007; Polovina *et al.* 2009). Removal of sharks may drive an increase in prey abundance, which can cause a cascade of indirect effects, including changes to the abundance of other organisms (Myers *et al.* 2007). By-catch raises ecological concern, as some by-catch species are sensitive to increased mortality above natural level because of their life history traits.

Table 7. Year-wise catch records of sharks and rays in Bangladesh.

Year	Catch* (t) of sharks and rays
2010-11	4,205 (0.77)
2009-10	4,033(0.78)
2008-09	3,933 (0.76)
2007-08	4,767 (0.96)
2006-07	4,790 (0.98)
2005-06	4,448 (0.93)
2004-05	4,085 (0.86)
2003-04	4,946 (1.09)
2002-03	5,063 (1.17)
2001-02	6,234 (1.50)
2000-01	5,162 (1.36)

* Figures in the parentheses are % of total marine catch
Source: Fisheries Statistical Year Book of Bangladesh, DoF.

The Bay of Bengal (BoB) region is one of the most heavily fished regions in the world's ocean for sharks. Indonesia and India rank highest in FAO statistics for shark landings bordering the BoB. Five of the top 14 sharks fishing nations are the Bay of Bengal Large Marine Ecosystem (BOBLME) project members (India, Bangladesh,

Sri Lanka, Myanmar, Maldives, Thailand, Indonesia and Malaysia) (Sattar and Anderson 2011). Top shark fishing countries are Indonesia, India, Taiwan, China, Spain, and Mexico together, they account for 42% of the global landings in 2007 (Camhi *et al.* 2009). Indonesia has the highest reported country of annual landings of sharks and rays worldwide, with an estimated annual catch of over 109,000 t during 2000 to 2008 (13% of the world total), and their export value of shark was US$13 million. In 2004, Indonesia alone caught 15% of the world's total shark catch (Sattar and Anderson 2011). During 1985-2010, the annual average shark landings in India were 33,280 t.

The contribution of sharks to the total annual marine fish landings in Bangladesh declined from 2.2% in 1985 to 0.77% in 2011 (Table 7). Like Bangladesh, Malaysia's shark landing is not more than 1% of the total of marine fish landings. A study in 1992 demonstrated that a live reef shark was worth much more than a dead shark in Maldives, with shark watching by tourist divers generating US$ 2.3 million in 1992, versus the US$ 0.7 million generated from shark product exports in the same year. The ban on all shark fishing within Maldivian waters was implemented on 15 March 2010. Sri Lanka contributed 3.1% of the global catch of sharks during 1990-2004, being 10th in shark fishery world rankings. In 2004 the contribution reduced to 2.4% of global catch. In Thailand sharks catch from 1985 to 2007 showed an increase compared to 2003, when it reached a peak of approximately 14,400 t. After this there was a steep decline, with shark catches in 2008 reported to be approximately only 4,000 t.

Shark products and trade

Shark meat contains up to 2.5% urea and has high nitrogen content in the form of volatile bases, ammonia and tri-methyl amine. It, therefore, has an unpleasant specific odor and pungent-acid taste. The utilization of elasmobranch fishes for food is mostly by the tribal people in Bangladesh, and poor people in Myanmar, India, Sri Lanka and the Maldives as the flesh is considered not quite wholesome. Small species of sharks are used for preparing shark meat. The fish is not filleted and the preparation is limited to removal of guts, fins, skin and head. The shark meat is packed either fresh or frozen or salted dry according to the requirements of the customer. Present market price of raw shark meat varies between Tk. 70 and 100/kg [Tk. 82 = 1 US$] in Bangladesh (Haroon 2011).

Shark product exports from Bangladesh shows irregular ups and downs since 1992-93 (Table 8). It reveals that there is a big volume of export for consecutive 4-5 years and then a drop for 1-2 years since 1992-93. This figure excludes all undocumented exports of shark products (hide, fins, crude oil, meat, etc.) to the neighboring Myanmar, India, Singapore and Thailand. Significant amount of shark products are straddled through the transboundary movement from Bangladesh to neighboring countries (Haldar 2010). Not only shark fins, oil and meat but also shark skins are exported from Bangladesh and this plays an important role in the economy. Shark fin, fin rays and dorsal skin of sharks and rays are exported in Singapore, Hong Kong, China and USA (Roy *et al*. 2011).

Table 8. Time series data of shark exports from in Bangladesh

Year	Export (metric tons)*	Value (million Taka)
2009-10	955.0	126.6
2008-09	276.0	17.70
2007-08	266.0	18.20
2006-07	244.0	41.10
2005-06	78.0	8.00
2004-05	1.0	3.90
2003-04	4.0	15.30
2002-03	172.0	223.50
2001-02	263.0	270.70
2000-01	181.0	206.30
1999-2000	262.0	311.70
1998-99	154.0	174.00
1997-98	155.0	107.90
1996-97	113.0	85.5
1995-96	56.0	42.10
1994-95	212.0	166.00
1993-94	45.0	27.90
1992-93	238.4	142.50

* also includes some amount of air bladder of fin fishes

Shark conservation and National Plan of Action

The International Union for Conservation of Nature (IUCN) Red List designates 17% of assessed shark and ray species (of a total 1,045 assessed) to be threatened (11% vulnerable, 4% endangered and 2% critically endangered), 13% near threatened, 23%

least concerned and 47% data deficient (Merry *et al.* 2007, Camhi *et al.* 2009). Current Red List of global assessments for species of relevance to the BOBLME shark species are as follows:

Silvertip shark	*Carcharhinus albimarginatus*	Near Threatened
Bignose shark	*Carcharhinus altimus*	Data deficient
Spinner shark	*Carcharhinus brevipinna*	Near threatened
Silky shark*	*Carcharhinus falciformis*	Near threatened
Galapagos shark	*Carcharhinus galapagensis*	Near threatened
Blacktip shark*	*Carcharhinus limbatus*	Near threatened
Oceanic white tip shark	*Carcharhinus longimanus*	Vulnerable
Australian black tip shark	*Carcharhinus tilstoni*	Least concern
Tiger shark*	*Galeocerdo cuvier*	Near threatened
Blue shark	*Prionace glauca*	Near threatened
Whale shark*	*Rhincodon typus*	Vulnerable
Pelagic thresher shark	*Alopias pelagicus*	Vulnerable
Big eye thresher shark *	*Alopias superciliosus*	Vulnerable
Common thresher shark	*Alopias vulpinus*	Vulnerable
Crocodile shark	*Pseudocarcharias kamoharai*	Near threatened
Scalloped hammerhead shark*	*Sphyrna lewini*	Endangered
Great hammerhead shark *	*Sphyrna mokarran*	Endangered
Smooth hammerhead shark *	*Sphyrna zygaena*	Vulnerable
Spotted eagle ray*	*Aetobatus narinari*	Near threatened
Ornate eagle ray	*Aetomylaeus vespertilio*	Endangered
Manta ray	*Manta birostris*	Near threatened
Mobula ray	*Mobula tarapacana*	Data deficient
Smooth tail mobula	*Mobula thurstoni*	Near threatened

Source: Sattar and Anderson (2011); * also recorded from Bangladesh waters.

Among those listed above the whale shark (*Rhincodon typus*) is very important which traverse geographic and political boundaries during their life history and interbreed with animals from distant populations and show only low levels of genetic differentiation between geographically distinct whale shark populations. Existing satellite tracking data have revealed both regional and long-range migration of whale sharks throughout their range, which supports the finding of gene flow between populations (Schmidt *et al.* 2009). Hence conservation efforts must therefore target international protection for this species (Irvine and Keesing 2005).

In the Maldives, a 'Shark watch' programme was started in June 2009 and has been very useful for monitoring shark sightings and shark population numbers. Thailand has marine parks for whale shark watching in the Similan Islands. Myanmar had already designated a Marine Protected Area, where shark fishing cannot be conducted, between Ross Island (12°13'N, 98°05'E) and Lampi Island (10°48'N, 98°16'E).

Study on the biology of elasmobranch fishes of Bangladesh is very insignificant and this is probably because of the difficulty in getting adequate statistics and samples. Review of stock assessments and present stock status of sharks is essential with a National Plan of Action (NPOA-shark) for a regional fishery management plan which would help in introducing and promoting collaborative fisheries management approaches in the BOBLME region. Fishery Act should be updated with strong rules and proper monitoring, control and surveillance (MCS) should be implemented for restricting indiscriminate exploitation of elasmobranch fishes. The survey of the BoB by the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC), the Department of Fisheries and Southeast Asian Fisheries Development Centre (SEAFDEC), Thailand during 25 October through 21 December 2007 reported harvesting of *Iago garricki*, *Carcharhinus falciformis* and *Pteroplatytrygon violacea* by pelagic longline and drift gill net in the Bangladesh part of the BoB (Krajangdara *et al.* 2008).

Many exploited shark species are transboundary, and are being exploited by several BOBLME countries. Hence, the need for appropriate management of the shark fishery resources in the BOBLME is urgent. In 1999, FAO adopted the International Plan of Action for the Conservation and Management of Sharks (IPOA-sharks) and has mandated for all the states that catch sharks and their relatives voluntarily prepare National Plan of Actions (NPOA-sharks) and Shark Assessment Report (SAR) for the conservation and management of sharks. Although the deadline for submission of NPOA-sharks was in 2001, as of June 2010 only 12 of some 37 shark-fishing countries had submitted NPOA-sharks (FAO 2009, 2012). Through the Committee on Fisheries (COFI) of the FAO, all BOBLME countries agreed to better manage shark populations in their EEZs by endorsing the IPOA-sharks.

The regional BOBLME project supported by the Global Environment Facility (GEF) and other 8 donors have a plan to conserve sharks (biodiversity and stocks) in the BoB and also develop and exert efforts for the implementation of NPOA-shark in the

BOBLME region. BOBLME is committed to assist its member countries to develop and implement NPOA-sharks. Bangladesh Fisheries Research Institute as a partner of BOBLME in Bangladesh has advanced a step ahead through first round of consultation in November 2010 and identified the status, potentialities, available data, statistics and data gaps (Hoq *et al*. 2011) and hopes to make a draft NOPA-shark in near future for submission to the Govt. for implementation. Of the eight member countries, two (Indonesia and Malaysia) have already adopted (but not fully implemented) their NPOA-sharks, three (Maldives, Myanmar and Thailand) have draft NPOA-sharks which require updating and adoption, and three (Bangladesh, India and Sri Lanka) did not have an NPOA-sharks as yet (Sattar and Anderson 2011). The Whale Shark (*R. typus*) is already protected in four of the eight BOBLME countries (Maldives, India, Thailand and Malaysia) and needs to be declared as to be protected by Bangladesh, Sri Lanka, Myanmar and Indonesia.

Through the BOBLME project assistance, Bangladesh is progressing to formulate a NPOA-shark and devise a regional fishery management plan for sharks for input to Transboundary Diagnostic Analysis (TDA) which would help in introducing and promoting collaborative fisheries management approaches in the BOBLME. Prior to this, Bangladesh would need to: review present stock and status of sharks; proper recording of species-wise catch data; identify and compile harvesting grounds of sharks, skates and rays in Bangladesh; fishing gears and crafts used; initiate ecosystem-based research to understand the **i.** migratory patterns of sharks, skates and rays as those are mostly transboundary species; **ii.** trophic interaction, **iii.** predator-prey relationship, **iv.** shark-turtle and shark-tuna relationships, **v.** impacts of shark on other predators and preys and **vi.** biodiversity and genetics, and economics of shark fisheries in Bangladesh. Further studies, research and management strategies and regional efforts that would be essential for sustainable harvesting and conservation-management of sharks were framed out.

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References

Bal, D.V. and Rao, K.V. (1990). Marine fisheries of India. First revised edition. Tata McGraw-Hill Publishing Company Ltd., New Delhi, 472 p.

Bykov, V.P. (ed.). (1983). Marine fishes. Chemical composition and processing properties. Amerind Publishing Co. Pvt. Ltd., New Delhi, India. 322 pp.

Camhi, M.D., Valenti, S.V., Fordham, S.V., Fowler, S.I. and Gibson, C. (2009). *The Conservation Status of Pelagic Sharks and Rays: Report of the IUCN Shark Specialist Group Pelagic Shark Red List Workshop*. IUCN Species Survival Commission Shark Specialist Group, Newbury, UK, 78 p.

Castro, J.J., Woodley, C.M. and Brudek, R.L. (1999). A preliminary evaluation of the status of shark species. *FAO Fisheries Technical Paper* 380:72 p.

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). (2010). Fifteenth meeting of the Conference of the Parties. Doha (Qatar), 13-25 March 2010. CoP15 Doc. 53, 14 p.

Dulvy, N.K., Baum, J.K., Clarke, S., Compagno, L.J.V., Corte's, E., Domingo, A., Fordham, S., Fowler, S., Francis, M.P., Gibson, C., Martine'z, J., Musick, J.A., Soldo, A., Stevens, J.D. and Valenti, S. (2008). You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. *Aquatic Conserv: Mar. Freshw. Ecosyst.* 18: 459-482.

FAO (Food and Agriculture Organization of the United Nations). (2012). *Report of the FAO/CITES Workshop to Review the Application and Effectiveness of International Regulatory Measures for the Conservation and Sustainable Use of Elasmobranchs*. Genazzano, Italy; 19–23 July 2010. FAO Fisheries and Aquaculture Report. RIRF / R984. Rome, FAO. 2012. 31 pp.

FAO (Food and Agriculture Organization of the United Nations). (2009). Report of the Technical workshop on the status, limitations and opportunities for improving the monitoring of shark and fisheries trade. Rome, 3–6 November 2008. *FAO Fisheries and Aquaculture Report No. 897*. FIMF/R897 (En). 161 pp.

Haldar, G.C. (2010). National plan of action for shark fisheries in Bangladesh. pp. 75-89. *In:* M.G. Hussain and M.E. Hoq (eds.). *Sustainable management of fisheries resources of the Bay of Bengal*. SBOBLME Pub./Rep. 2. Support to Sustainable Management of the BOBLME Project, Bangladesh Fisheries Research Institute, Bangladesh. 122 p.

Haroon, A.K. Yousuf. (2011). Shark fishery in the Bay of Bengal, Bangladesh. pp. 11-32. *In*: M. E. Hoq, A. K. Yousuf Haroon and M. G. Hussain (eds.) 2011. Shark fisheries in the Bay of Bengal, Bangladesh: Status and potentialities. *SBOBLME Pub./Rep. 4.* Support to Sustainable Management of the Bay of Bengal Large Marine Ecosystem Project, Bangladesh Fisheries Research Institute, Bangladesh. 76 p.

Hoq, M. E., Haroon, A.K.Y. and Hussain, M.G. (eds.). (2011). Shark fisheries in the Bay of Bengal, Bangladesh: Status and potentialities. Support to Sustainable Management of the BOBLME Project. SBOBLME Pub./Rep. 4. Bangladesh Fisheries Research Institute. 76 p.

Irvine, T. R. and Keesing, J.K. (2005). The first international whale shark conference. 9-12 May 2005. CSIRO Marine and Atmospheric Research, Western Australia. 116 p.

Krajangdara, T., Sujittosakul, R. and Rahman, M.J. (2008). Elasmobranches found in the Bay of Bengal from pelagic long line and drift gill net fishing. pp. 190-194. *In:* The ecosystem-based fishery management in the Bay of Bengal. Published by BIMSTEC, the Department of Fisheries and Southeast Asian Fisheries Development Centre, Thailand. 250 p.

Merry D.C., Sarah, V.V., Fordham, S.V., Fowler, L.A. and Gibson, G. (eds.). (2007). Report of the IUCN Shark Specialist Group. Pelagic Shark Red List Workshop. Tubney House, University of Oxford, UK, 19-23 February 2007.

Migdalski, E.C., Fichter, G.S. and Weaver, N. (1989). The fresh and salt water fishes of the world. Greenwich House, New York, USA, 316 p.

Myers, R.A., Baum, J.K., Shepherd, T.D., Powers, S.P. and Peterson, C.H. (2007). Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science* 315:1846-1850.

Polovina, J.J., Abecassis, M., Howell, E.A. and Woodworth, P. (2009). Increases in the relative abundance of mid-trophic level fishes concurrent with declines in apex predators in the subtropical North Pacific, 1996-2006. *Fisheries Bulletin* 107: 523-531.

Roy, B.J. (2011). Catch monitoring and assessment of shark and allied fisheries in the Bay of Bengal. pp. 33-42. *In:* M.E. Hoq, A.K. Yousuf Haroon and M.G. Hussain (eds.). 2011. Shark fisheries in the Bay of Bengal, Bangladesh: Status and potentialities. SBOBLME Pub./Rep. 4. Support to Sustainable Management of the BOBLME Project, Bangladesah Fisheries Research Institute. 76 p.

Sattar, S. A. and Anderson, R.C. (2011). Report of the BOBLME Sharks Working Group. 5-7 July 2011, Male', Maldives. BOBLME (Bay of Bengal Large Marine Ecosystem) Project. BOBLME-Ecology-2011-15. 50 p.

Schmidt J. V., Schmidt, C.L., Ozer, F., Ernst, R.E., Feldheim *et al.* (2009). Low genetic differentiation across three major ocean populations of the whale Shark, *Rhincodon typus*. PLoS ONE 4(4): e4988. doi:10.1371/journal.pone.0004988

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