COASTAL AQUACULTURE DEVELOPMENT IN BANGLADESH: UN-SUSTAINABLE AND SUSTAINABLE EXPERIENCES

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ABSTRACT

Coastal aquaculture in Bangladesh mainly consists of two shrimp species (*Penaeus monodon* and *Macrobrachium rosenbergii*). Currently, there are about 16,237 marine shrimp (*P. monodon*) farms covering 148,093 ha and 36,109 fresh water shrimp (*M. rosenbergii*) farms covering 17,638 ha coastal area. More than 0.70 million people are employed throughout the farmed shrimp sector in Bangladesh. In 2005-2006 the foreign currency earning were 403.5 million USD through exporting the frozen shrimp. Although coastal aquaculture contributes significantly in rural employment and economy its importance is overshadowed by negative social and ecological impacts. This paper reviews the key issues, constraints and opportunities of sustainable shrimp farming. In addition we present the results of two case studies from southwestern coastal areas where the shrimp farming originated and central coastal areas where shrimp especially *M. rosenbergii* farming sparked in recent years. Lessons learned from the review and case studies are considered in the context of recommendations to encompass a socially equitable and ecologically sound coastal aquaculture.

Keywords: Coastal aquaculture, shrimp, socio-economic, sustainability**,** Bangladesh

INTRODUCTION

The coastal area lies in the alluvial plains of Bangladesh between 89.0^{o}E and 92.20^{o}E in the northern and northeastern part of the Bay of Bengal**.** The 710 km long coastline can be broadly divided into three regions; the southwestern, the central and the southeastern regions. The alluvium in the southwestern and central flood plains is derived from the *Ganges-Brahmaputra-Megna* river systems, and that in the southeastern *Chakaria sundarban* (mangroves) area is derived from *Matamuhuri* river systems [1]. The coastal zone is characterized by an almost level, clay landscape criss-crossed by interconnecting tidal rivers and creeks. The land on the coast is flooding at high tide twice daily through out the year. In the 1960s when the FAO declared Green Revolution program to promote cereal crops the then Government had taken various steps to recover the coastal agricultural land through poldering [2]. Government also took necessary actions to raise the coastal river embankments (locally called *bheri badh*) to control flood and saline water intrusion. These steps made the people confident to live in the coastal area and many people migrated for permanent settlement in the coastal zone. Although the coastal areas are only 25000 km^2 but it supports a huge population (743/km^2) and a variety of livelihood activities [3]. Aquaculture is one of the important activities in terms of foreign currency earnings and rural employment. More than 0.70 million people are involved directly or indirectly, in shrimp aquaculture and its associated activities [4]. The main cultivated species is marine tiger shrimp (*Penaeus monodon*) locally called *bagda chingri*. Apart from *P. monodon* giant fresh water shrimp (*Macrobrachium rosenbergii*) referred *golda chingri* also a prominent species culture practiced in coastal fresh and brackish water environment. The ecological and climatic conditions of coastal areas are extremely suitable for shrimp culture with very low production cost [5]. In 2005-2006 Bangladesh produced 42000mt of shrimp and the

export earnings were 403.5 million USD. Sea food, mainly shrimp, is the second largest export earner after ready-made garments in Bangladesh. The share of fisheries in the national total export earning is about 6.0% out of which approximately 85% are contributed by shrimp alone [6]. Although coastal aquaculture is an impressive contributor in the employment and export earning its importance is overshadowed by negative ecological and social impacts. This paper explores the key issues of environmental and social aspects, constraints and opportunities of sustainable coastal aquaculture. It then describes the results of two case studies, which presents glimpses of unsustainable and sustainable experiences of coastal aquaculture in Bangladesh.

BACKGROUND OF COASTAL AQUACULTURE

In Bangladesh, shrimp culture started to expand after 1971, but at a slow pace. The export oriented shrimp industry took off in the 1980s, when large scale shrimp aquaculture in higher income East-Asian countries such as Thailand, Indonesia, China, the Philippines and Taiwan began to suffer from environmental and social damage [7]. Increased fishing pressure on natural shrimp stocks in the sea and maximum harvesting in all possible areas had generated the idea of large-scale shrimp farming in coastal areas.

Table1. The number and areas of shrimp farms in different districts.

District	Number of Farms		Total area (ha)	
	P. monodon	*M. rosenbergii*	*P. monodon*	*M. rosenbergii*
Khulna	4050	11,700	40,180	4513
Shatkhira	5010	110	30,271	75
Bagerhat	4907	17,463	48,728	10,526
Jessore	-	480	-	518
Narail	-	210	-	452
Barishal	-	170	-	66
Patuakhali	88	1920	449	271
Barguna	70	635	446	378
Greater Noakhali	112	2936	519	585
Gopalgonj	-	215	-	122
Madaripur	-	270	-	132
Cox’s Bazar	2000	-	27500	-
Grand total	16,237	36,109	148,093	17,638

The southwestern coastal low-lying area and the mangrove area of the southeastern region including *Chakaria sundarban*, had appeared as a gold mine in regards to economically important species of shrimp. It made the venture attractive to national policy makers, international agencies and private entrepreneurs. From the early 1980, the government of Bangladesh has been endeavoring to improve the shrimp farming [5]. Shrimp farming rapidly expanded in the coastal districts including Shatkhira, Khulna, Bhagerhat, Cox’s Bazar. Bangladesh has become one of the major exporting countries of shrimp (*P. monodon* and *M. rosenbergii*) in the world [8]. Currently, there are about 16237 brackish water shrimp (*P. monodon*) farms covering about 148,093 ha and 36,109 fresh water shrimp (*M. rosenbergii*) farms covering about 17,638 ha (Table 1).

CULTURE PRACTICES

The primitive shrimp (*P. monodon*) culture involving stocking of wild seed in ponds is probably centuries old in Bangladesh. It is believed that traditional shrimp farming had started during 1829 in the *Sundarban* (mangrove) area [9]. '*Bheri*' culture was the main system for shrimp farming that time. '*Bheri*' culture involves the trapping and grow-out of shrimp in tidal and low-lying areas by dikes. In *bheri* culture it is difficult to predict the number of post-larvae (PL). Moreover unwanted species and predators are also being trapped. On the other hand the abundance of wild PL cannot keep pace with the rapid expansion of shrimp farms. Hence many farmers have changed the culture technique to keep unwanted species and predators out of their farms. They stock their farm entirely with collected wild fry and exchange the tidal water in the farms through screens. More and more shrimp farmers are collecting and stocking PL, besides trapping the post larvae of tidal waters by closing the dikes. This culture system is locally called *gher chash* [10]. Shrimp (*P. monodon*) farming in the southeastern area rotates with salt production and some rice farming though in the more saline areas only shrimp are farmed. This contrasts with the southwestern area, where a rotation between rice farming and shrimp farming is most common [11]. In recent years commercial poly culture with marine and brackish water species including mullet (*Liza spp*.) and mud crab (*Scylla serrata*) is carried out on a small scale. Various authors have described the details of production systems and economic return of shrimp farming activities [5,12].

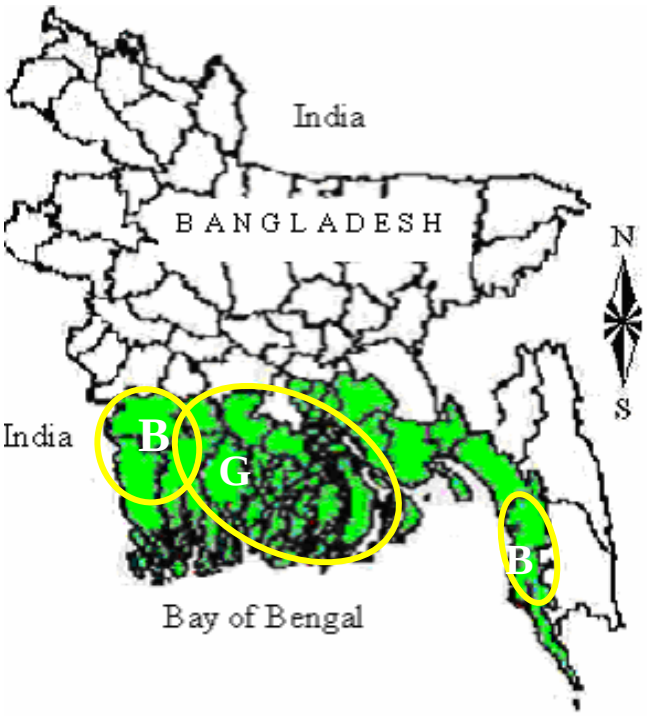

Figure1. Colored areas indicated the coastal zone of Bangladesh. Area B covers *bagda* (*P. monodon*) and area G covers *golda* (*M. rosenbergii*) *ghers*

On the other hand a few pioneers, some time between the late 1970s and the mid 1980s, developed the first freshwater shrimp (*M. rosenbergii*) cultivation in low-lying agricultural land and paddy fields**.** In the late 1980s, the farming practice began to be adopted widely in the original location in Bagerhat district, in which freshwater shrimp *(M. rosenbergii*) have been cultivated along with carp, rice and other crops. The expansion of freshwater shrimp cultivation has been dramatic, and since 1990 adoption has accelerated, spreading to other southern districts including Khulna, Satkhira, and Jessore

[13]. In recent years *M. rosenbergii* farming sparked in the central coastal zone including Patuakhali, Barguna and greater Noakhali districts (Fig.1). The government of Bangladesh under the auspices of Danish International Development Agency (DANIDA) supported the poor and marginal farmers to adopt integrated farming systems where *M. rosenbergii* was cultivated along with filter feeder carps (*Hypopthalmichthys molitrix* / *Catla catla*), rice and vegetables on dikes. The details of different fresh water shrimp farming systems were discussed by Williams and Khan; Azad et al. and Giap et al. [14-16].

UN-SUSTAINIBILITY ISSUES

The environmental and social impacts of shrimp farming include large-scale degradation of mangroves, alteration of wetlands, land subsidence, salinization of ground and surface water, pollution of agricultural lands and coastal waters by pond effluents and sludge, introduction of exotic species or pathogens into coastal environment, loss of wild larvae and subsequent loss of goods and services generated by natural common property resources. In the followings we briefly describe key issues of unsustainable shrimp aquaculture.

Mangroves and Wetlands destruction

Globally, more than a third of mangrove forests have disappeared in the recent decades, and shrimp culture is the major human activity accounting for 35% of such decline [17]. Most of the shrimp farms in Southeast Asian countries including Thailand, the Philippines and Vietnam are derived from mangroves and coastal wetlands [18-20]. In Bangladesh relatively small mangrove area has been converted to shrimp farms. Approximately 9734 ha of mangrove loss in the southeastern part have been directly attributed to shrimp culture [21]. But at the southwestern coast a considerable area of both tidally influenced and freshwater wetlands converted to shrimp farms [22]. The ecological and economic importance of mangroves and wetlands has been widely documented [23,24].

Soil acidity

In ponds, developed in mangrove areas, highly pyretic soils are formed resulting in high acid sulfate soil and aluminum concentrations in and around the farms. Potential acidity causes severe stress for the cultured animals which makes them susceptible to diseases or parasites and even death. In Bangladesh several shrimp disease and production losses were linked to acid sulfate soils [25].Many shrimp farms of coastal zones in Southeast Asia including Taiwan, Thailand and Indonesia have been abandoned due to acid sulfate soils and other associated problems [26,27].

Salinization of soil and water

In the 1980s to mid 1990s a large volume of underground water was used to achieve brackish water which led to the lowering of groundwater levels, emptying of aquifers, land subsidence and salinization of adjacent land and waterways in Taiwan and other Southeast Asian shrimp farming countries [28]. The discharge of saltwater from shrimp farms also causes salinization in adjoining rice and other agricultural lands. In the southwestern part of Bangladesh, the saltwater intrusion has caused freshwater crisis and related gastrointestinal disease, loss of diversified crops, poultry and fodders [29].

Loss of fry and wild stock

Although hatchery produced post larvae (PL) are now available in many countries in Asia and Latin America, wild fry still provides a significant source of seed in many locations [27]. Wild PL harvesting has assumed a notorious image for being ecologically destructive [30,31]. In Bangladesh approximately 2,000 million shrimp fry is collected annually from wild sources. With respect to fresh water shrimp (*M. rosenbergii*) more than 90% of the total for the PL is derived from natural sources and in the case of black tiger shrimp (*P. monodon*), more than 50% is derived from wild sources [4]. Approximately 40% of the collected seeds died before stocking in culture facilities due to poor handling and transportation [1]. It was reported that about 99 fin fish and other shrimp species fry are discarded for

collecting a single shrimp post larvae [32]. In many countries shrimp hatchery operation depends on wild-caught brood stock rather than farmed ones. The hatchery operation is often hampered by a lack of berried female [33]. By catch during the capture of wild brood stock is a critical point of shrimp farming. It has been observed that adult shrimp (*Penaeus spp*) comprise only 0.06-0.14% of the total catch from trawls in the Arafura Sea, Indonesia [34].

Demand for fish meal, fish oil and trash fish for aquaculture

Although poultry and swine industries are the largest consumer of fish meal, aquaculture has the fastest growing demand for fish meal, fish oil and trash fish. Small and so called less valued species including anchovy and sardinella are used as feed for the higher valued farmed species including shrimp. The proportion of fish meal supplies used for aquaculture farming rose from 10% in 1988 to 17% in 1994 and 33% in 1997 [35]. In Bangladesh shrimp farmers traditionally use apple snail (*Pila globosa*) meat to fed farmed shrimp. The estimated harvest of snails from various wetlands, canals and paddy fields in 1999 was 365,849mt. The demand for snails intensified with the expansion of *ghers*. As a results *P. globosa* disappeared from many wetlands of southwestern region [36].

Socio-economic implications

The major cause of the social problems resulting from shrimp aquaculture is lack of planning of coastal land use. All across southeast and south Asia, forest, agricultural lands, pastures, burial ground and other common property wetlands are being converted into shrimp farms [37]. In Bangladesh government owned (*khash jamin*-a common property resource) coastal lands leased out to so called shrimp farmers who are mostly urban residents. According to the land reform act of 1989, the government owned suitable agricultural lands should be allocated for the landless people but most of those went to 'sufficiently powerful' shrimp farmers including political leaders, relatives of bureaucrats, bankers and businessmen [25]. Beside this, a huge areas of public lands in the coastal zone have been illegally occupied by the so called political leaders and local power holders. In the southwest region most of the farms have been constructed in the *beel* (natural depressed lands) area, which has contributed to reduction of spawning and nursery grounds of small indigenous species (SIS). The dikes construction has reduced the water flows of connecting channels and blocked the migration routes of fishes [22]. Many authors have documented the impacts of SIS in nutrition and employment of rural poor [38,39].

COMPARATIVE ANALYSIS OF CASE STUDIES

The results of the case studies are based on a series of fieldwork visits since 2002. During the field visits 40-45 farmers from southwestern coastal areas, where the shrimp farming originated and 40-45 farmers from central coastal areas, where the shrimp farming especially *M. rosenbergii* sparked in recent years, were interviewed. In addition the agro-ecological and management aspects were precisely observed during the study period. The study assessed the current social and ecological issues that are primary concerns related to sustainable shrimp farming. The issues including land ownership, labor involved and farm management practices of two areas are presented in table 2.

The land holding and labor involved in shrimp farming in both regions are common with traditional rice production systems. It was observed that female family members, in particularly in the central coastal area are involved with *ghers* farming activities especially vegetables cultivation on *gher* dikes. In Bangladesh women are traditionally more interested in doing homestead vegetable gardening. There was a belief that the coastal area is not suitable for vegetable farming due to higher soil salinity. But due to low rate of inundation by tidal water the soil salinity level has been reduced significantly and more and more farmers become interested in growing vegetables. So, the household members have a strong incentive to operate their own integrated farms [15,40]. Land lease among the local farmers of the southwestern region has become more popular because an annual leasing fee for a small piece of land often fetches a sufficient amount of cash for one to seven years rental agreements. Even small and landless neighbors can afford to lease a low productive (agricultural crops) or fallow land which is

suitable for shrimp farming if they have access to credit [40]. It contrasts with the bigger size farms especially for *P. monodon* that are confined to narrow bands of land along the shoreline of the Bay of Bengal where lands and resource access conflicts have been inevitable.

Table2. The land use and management practices in two shrimp farming regions

Key issues	Southwestern region		Central region	
	Frequency	%	Frequency	%
Land ownership				
-private	34	85.0	37	92.5
-lease/rent	06	15.0	03	7.5
Land use prior to shrimp farm				
-paddy culture	36	90.0	37	92.5
-fallow	04	10.0	01	2.5
-fodder weed	-	-	02	5.0
Labor sources				
-family	03	7.5	15	37.5
-wages	03	7.5	02	5.0
-family + wages	34	85.0	23	57.5
Cultured species				
-*P. monodon*	07	17.5	-	-
-*M. rosenbergii*	30	75.0	39	97.5
- both	03	7.5	01	2.5
Sources of water				
-rain	32	80.0	26	65.0
-canals	08	20.0	14	35.0
Present rice cultivation				
-one crop	27	67.5	30	75.0
-two crops	02	5.0	07	17.5
-none	11	27.5	03	7.5
PL sources				
-wild sources	19	47.5	02	5.0
-hatchery sources	16	30.0	30	75.0
-hatchery + wild	05	12.5	08	20.0
Stocked carp species				
-filter feeders	06	15.0	36	90.0
-grass carp	15	37.5	-	-
Feed use*				
-snail meats	39	97.5	02	5.0
-home made feed	33	82.5	38	95.0
-commercial pellets	07	17.5	01	2.5
Vegetables on dike	09	22.5	34	85.0
Adoption of IPM	37	92.5	33	82.5
Partial shrimp harvest	35	87.5	04	10.0
Chemicals use				
-lime	38	95.0	27	67.5
-symbush	01	2.5	02	5.0

*Total respondents 40 (respondents have given more than one answer)

The *P. monodon* farming needs a specific level of saline water. Many farmers of the southwestern areas have attempted *P. monodon* farming but they failed because rivers and canals through which saline water was to flow were frequently silted up or had reduced water flow. The conditions were aggravated by the reduced volume of water influx from upstream through the Farakka dam across the Ganges River in the north east of India. So they gradually changed the culture practices leading to *M. rosenbergii* farming [7]. This is also resulted in saltwater intrusion in the inland area at high tide damaging the

Sundarban Reserved Forest (SRF) and agricultural lands. The reduced levels of flooding hamper the dispersal of mangrove seedlings for further expansion of the forest [41]. Furthermore, the *ghers* of southwestern area construct in an unplanned manner. To save labor cost, the neighbor farmers did not build their own dikes. They just shared the dikes of surrounded *ghers*. This resulted in lack of drainage and irrigation systems as well as blocked the interconnecting canals. It made the farming heavily dependent on rainwater. The farmers of the central coast are in a convenient position as the *ghers* are developed in a scattered way. The interconnecting tidal rivers and creeks are still alive and farmers can easily draw water as needed.

Although most of the shrimp farms land had previously been used as paddy field, a significant number (27.5%) of farmers in the southwestern region were reluctant to cultivate rice. If brackish water was available in nearby canals or rivers, *P. monodon* and winter rice (January-July) were farmed simultaneously in the *ghers*. After this they farmed only *M. rosenbergii* in the *ghers* during July-December when the rainwater available. If a *gher* was in a sufficiently low-lying area the farmer would farm only the fresh water shrimp (*M. rosenbergii*). For transplanting of rice seedlings it is necessary to plough the *ghers*. This makes the water turbid which is harmful for the shrimp. Some of the farmers have experienced shrimp mortality due to turbidity, which had made them reluctant to cultivate rice in the *ghers*. At present most of the farmers considered shrimp as their main crop instead of rice. This contrasts with central coastal region where the farmers cultivated only the winter crops (eg. rice, vegetables, water melon) in *ghers* or kept it fallow during winter (January-May). After that (June-December) they farmed rice and shrimp (*M. rosenbergii*) simultaneously in the *ghers*.

It was observed that 60% of the farmers in the southwestern region depended on wild source PL. They believed that wild PL had a lower mortality, were disease resistant and had good growth rates. Also a strong marketing and distribution network has been developed for wild source PL which made it timely available for the farmers [42]. At present more than 53 *P. monodon* hatcheries are in operation but all of them are in the southeastern part of Bangladesh. Some of the hatchery operators are using cargo planes to supply *P. monodon* PL but the distribution network is still in its infancy. On the other hand the majority of the farmers (85%) in central coastal area have stocked hatchery- produced PL. In the central coastal area five *M. rosenbergii* hatcheries have been developed in recent years. They produced approximately 17.0 million PL annually and supplied to the local farmers. Some of the farmers received PL on credit from the hatchery operators. A total of 25% of the farmers of the central region stocked wild source PL. Some of the farmers of the central region stocked over-wintered wild juveniles in the *ghers*. The over-wintered wild juveniles are sometimes available in nearby swamps and rivers. These juveniles are popular as farmers traditionally stock them into carp ponds.

The nutrient rich water of *ghers* sustains a dense biota of plankton and many other organisms, which may not be consumed directly by the shrimp. A combination of filter feeders and herbivorous species may provide opportunities to control phytoplankton bloom and nutrient recycling. Very few farmers (15%) of the southwestern region stocked filter feeder carps (*Hypopthalmichthys molitrix* / *Catla catla*) in the *ghers*. Although grass carp (*Ctenopharyngodon idella*) is not an ideal species (it lives on grass including rice plants) to cultivate with rice but a significant number (37.5%) of farmers stocked this species in the *ghers*. Either these *ghers* are not suitable for rice cultivation or the farmers are not interested in cultivating rice where they stocked the grass craps. On the other hand most of the farmers (90%) of the central coast stocked filter feeder carps (*H. molitrix* / *C. catla*) in the *ghers*. The inclusion of filter feeder species with shrimp is advocated by many authors [43,44].

Most of the interviewed farmers could not afford to buy a good quality starter or grower feed for the stocked PL. The PL in both regions was regularly fed with rice bran or wheat flour spread over the water surface. Although some of the farmers of the southwestern region applied locally available commercial feeds, the quality of these feed was not up to the mark. The use of snail meat for juveniles and adult shrimp is very popular in southwestern region. The farmers believed that 'meat brings meat' and all of the farmers applied snail meat at least one time into *ghers*. The snail meat has become costly as it gradually has disappeared from the wetlands of the southwestern region due to over exploitation. Home made feed (a mixture of fish meal, rice bran, and oil cake) is popular in the central coastal region. The by-

catch *chewa* (*Trypauchen vagina*) and fiddler crab (*Uca spp*.) fishery are important sources of fish meal in the central region. It was observed that farmers from both regions applied feed irregularly since they could not buy the large quantities of feed ingredients.

Figure2. An integrated *gher*. Farmer used scrap nets as trellises over trench.

Many farmers grow vegetables on the dikes of their *ghers*. Wider dikes offer an option for more varieties of vegetables but trellises could also be built above the trench in order to enhance yields (Fig.2). Farmers of the central coast mostly grow pumpkins (*Cucurbita moschata*), bitter gourds (*Momordica charantia*), long beans (*Vigna unguiculata*) and okras (*Abelmoschus esculentus*) on *gher* dikes. Very few farmers in the southwester region practiced dike cropping. Some of the farmers grow banana plants on *gher* dikes and banana leaves are used as feed for grass carps. Most of the farmers adopted integrated pest management (IPM) systems during the farming period. Farmers are very much conscious about the shrimp in their *ghers* and shrimp is viewed as a tool for IPM adoption. Integrated pest management refers to the agricultural practice of limiting crop damage by simultaneously using multiple methods of pest control (natural enemies, crop rotation, rational use of selective pesticides etc) in a coordinated manner. The IPM systems are popular methods of sustainable and eco-friendly crop production in many countries [45].

The harvest of shrimp starts after 4-5 months from October ending in December, with a big harvest or a final harvest. The farmers of the southwestern area practiced partial harvesting. They would leave the small non-graded shrimp for over-wintering and allow them to grow the following year. This way they have the opportunity to partially harvest the graded shrimp during the culture period. Most of the farmers of the central region harvested all the shrimp during the final harvest. They sold the graded size shrimp to the traders and non-graded juveniles to the local ponds owners. Local rich farmers traditionally grow fresh water shrimp (*M. rosenbergii*) in carp ponds.

The most common chemical used in shrimp farms is liming materials. Both limestone and agricultural lime (dolomite) are used by the farmers of both regions. The farmers of the coastal area traditionally use lime in paddy fields to increase the soil pH. A good number of farmers used rotenone to remove predators and unwanted fish species from the farms. Most of the farmers reported that they harvested a significant amount of SIS fish during the final harvest. The SIS recruited into *ghers* naturally due to poor dike construction and/or through holes made by crabs. The practice of Symbush (an

agricultural pesticide) to eradicate unwanted species raised concern among the farming groups. The Symbush pesticide is now being used to poach the shrimp from *ghers*, ponds and natural swamps.

DISCUSSION

Many authors have documented the problems and prospects of *P. monodon* farms that are relatively bigger in terms of size and ownership. The adoption of shrimp farming especially *M. rosenbergii* by small and marginal farmers has received relatively little attention in the literature although Ito [7, 40] investigated its evolving history and socioeconomic perspectives. Fresh water shrimp *M. rosenbergii* farming has been expanding at a much faster rate than marine shrimp *P. monodon* in Bangladesh. At present the number of small size farms especially for *M. rosenbergii* is more than double that of bigger size *P. monodon* farms (Table 1). The management and production for the two systems also differ. Small-scale integrated *gher* farming has become a low-risk venture and the profit margin is also encouraging [12,15].The integrated *gher* farming has provided regular and additional employment to rural people both for men and women. Traditional rice monoculture generally provides an average of two months' employment whereas in integrated *gher* farming it was continuous almost all the year. *Gher* farming also generates employment opportunities for the landless peasants that include part time wage labor, wild PL harvesting and collecting, and de-shelling of snails. Although the rapid growth of *M. rosenbergii* farming is a relatively recent phenomenon, the technique appeared relatively early in the establishment of *P. monodon* culture. The adoption of *M. rosenbergii* farming came about through the efforts of innovative small scale farmers who were endeavoring to deal with practical problems. The southwestern area where the *ghers* originated was particularly prone to flooding and water logging causing regular failure of rice crops [40]. This factor may encourage farmers to switch from rice to shrimp farming. Some of the earlier projects have attempted to promote a conventional approach for environmentally friendly *gher* farming among the southwestern region farmers. This involves dike cropping, inclusion of carp species and introduction of home made feed instead of snail meat. Recent expansion in the central coastal areas is the results of extension and motivational work of Danida funded projects. The target groups of the projects are the small and marginal farmers although the selected hatchery operators are from the rich business entrepreneurs. The projects have encouraged stocking hatchery-produced PL, dike cropping, inclusion of filter feeder species and adoption of integrated pest management (IPM) systems. Many farmers recognized that the wild PL is not an infinite resource and they are changing their preference towards hatchery-produced PL. The availability of wild PL at the farm gates is perhaps the main stimulating factor for the preference of wild PL. Farmers in both regions could not supply the optimum amount of feed in their farms. The scarcity of quality feed and the financial constraints were the major causes for low levels of supplied feed. As a result yields of *ghers* mostly depend on natural productivity. Farmer preferences for filter feeders and herbivorous species indicate some differences between the southwestern and central regions but polyculture helped to recycle the nutrients and increase the yields. Polyculture has also begun to be practiced in the *P. monodon* farms with mullet (*Liza spp*) and mud crab (*Scylla serrata*) in brackish and saline water environment [5,46].

CONCLUSION AND RECOMMENDATIONS

In integrated *gher* systems, as a cash crop shrimp farming reduced the economic risks and created employment opportunities for small and marginal farmers. On the other hand rice, vegetables and low price carp species have significantly contributed to food security and family nutrition. Both integration and rotation of rice and shrimp helped to combat the environmental pollution. The bottom of *ghers* act as a nutrients sink and these nutrients are utilized by the rice plants. Therefore self pollution or ecological foot print [47] is not a concern in the case of small-scale integrated *gher* farming. The environmental lobbyists and research agencies should be less concerned with technical optima of integrated *gher* systems. Focus should be given on PL/juveniles production and affordable quality feed development. As the integrated *gher* farming is more capital intensive than rice monoculture, the local commercial banks

and NGOs should come forward with micro-credit financing programs for the small and marginal farmers. It is necessary to split up the coastal big size *P. monodon* farms into small size *ghers* for better management and increasing the yields [12]. The leased out and illegal occupied government owned lands should be recovered, split up and allocated among the landless coastal communities in accordance with the land reform act of 1989. Although this may be a challenging job for the involved agencies, it is also a critical issue to promote a socially equitable and ecologically sound coastal aquaculture in Bangladesh.

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