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Environmental and socio-economic impacts of shrimp culture in south-western Bangladesh

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ABSTRACT

Shrimp culture in the coastal belt of Bangladesh is pre dominantly dependent on the collection of *Penaeus monodon* fry from the wild. Horizontal expansion of shrimp farming has resulted in a decline of this resource alarmingly in the coastal rivers. About 26-119 other shrimps, 9-13 finfish larvae and 64-922 macro-zooplankton are being destroyed during the collection of a single *P. monodon* fry, causing loss of aquatic biodiversity in the coastal environment. It is evident that shrimp culture does not significantly influence the short-term rice cultivation. Grave socio-economic impacts, including conversion of agricultural land, salinization of water and soil, marginalization of coastal communities and social conflicts have been observed in the wake of shrimp culture development in Bangladesh.

Key words : Environmental impact, shrimp culture, socio-economics

INTRODUCTION

In Bangladesh, shrimp is the third largest foreign exchange earning commodity, after garment and jute, contributing 9% to national export earnings. MAlthough intensive brackish water shrimp culture is practiced in south-eastern Bangladesh, there are extensive to semi-intensive culture practices in south-western region. The farmers traditionally culture shrimp and fish, by trapping them in low lying coastal areas with construction of embankments (polder). In recent years, shrimp culture has been extended even to non-poldered areas and to some extent to areas where mangrove forests have been cleared. There have been several studies on the relationship between shrimp culture and the environment, which recognize that shrimp culture has direct environmental impacts (Primavera 1989; Macintosh and Phillips 1994, Beveridge *et al.* 1997). However, the significance of environmental and social impacts of shrimp culture are poorly understood in Bangladesh.

The expansion of shrimp culture in coastal areas of Bangladesh in recent years has been accompanied by growing debate on its compatibility with other land-use patterns (Rahman *et al.* 1995). It is claimed that not only the quality of land has been affected by this intrusion, but people related to the land have also been variedly affected. Aside from the environmental consequences, modern shrimp farming has socio-economic costs (Chowdhury 1988, Primavera 1993, Baird and Quarto 1994). This presentation is the outcome of a detailed study on the environmental and socio-economic impacts of shrimp farming industry in south-western region of Bangladesh.

MATERIALS AND METHODS

A survey was carried out in 13 *thanas* of Satkhira, Khulna and Bagerhat districts in the south-west region of Bangladesh, where shrimp farms (extensive, improved extensive and semi-intensive) are concentrated. The information for the study was collected primarily by participatory observation method. Information gathered from the respondents were recorded in the pre-tested questionnaires. For better understanding, sampling sites were categorized into unplanned, planned and non-shrimp farming zones. In particular, the study was benefited greatly from the data bases created by the Shrimp Culture Project (IDA) under Department of Fisheries and Brackishwater Station in Khunla under Fisheries Research Institute.

A small rectangular drag net of nylon netting (mesh size 1mm) and bamboo split structure (1.6x0.6m) was used to assess the quantum of damage caused to shellfish and finfish larvae while collecting *P. monodon* larvae in coastal rivers. Samples of water and soil were collected for laboratory examination systematically. Statistical analysis of collected data was performed using STATGRAPHIC (7.0) statistical package.

RESULTS

Shrimp culture in Bangladesh entirely relies on the supply of wild fry. Although hatchery operations producing post-larvae (PL) exist, they are limited in number with very short supply. As farmers realized the economic benefits of shrimp farming, the wild fry collection and marketing have emerged as profitable trade during early 1980's. *P. monodon* fry collection trends between 1992 to 1996 are presented in Table 1. A notable seasonal variation was observed in the abundance of *P. monodon*, other shrimps, finfishes and macro-zooplankton in the coastal rivers. *P. monodon* fry were found available round the year but peak period was in between February and April with a link to the breeding cycle and high salinity in river water. Relative abundance of *P. monodon* PL was significantly ($P<0.05$) reduced in years 1994 and 1996 compared to 1992. Besides the fry of other shrimp species and fish, a number of other species are also caught with *P. monodon* (locally known as *bagda*) fry in collectors' net. The catchers, however, pick up the fry of *bagda* discarding the other species caught in the net. It was estimated that to catch a single *bagda* shrimp fry, 26-119 post-larvae of other shrimps, 9-31 finfish post-larvae and 64-922 other zooplankton are wasted in coastal rivers of south-western region (Table 2). This rate of "wastage" is very high compared to the *P. monodon* fry collection.

Table 1. Yearly catch composition (per cent individuals/unit effort)* of *P. monodon*, other shrimps, fin fishes and macro-zooplankton in different rivers of south-western Bangladesh.

Coastal rivers of	*P. monodon*			Other shrimps[1]			Finfishes[2]			Macro-zooplankton[3]		
	1992	1994	1996	1992	1994	1996	1992	1994	1996	1992	1994	1996
Satkhira	0.97^a	0.28^b	0.17^b	37.34^a	7.6^b	23.28^a	6.46^a	2.11^b	5.20^a	55.23^c	90.01^a	71.35^b
Khulna	0.64^a	0.44^b	0.28^c	16.04^a	11.23^a	16.00^a	9.97^a	5.74^b	4.92^b	73.35^a	82.59^a	78.80^a
Bagerhat	2.38^a	1.07^b	0.28^c	33.70^a	40.46^a	44.51^a	13.26^a	12.07^a	11.35^a	50.66^a	46.40^a	43.86^a

*Operating a drag net ($1.6 \times 0.6\ m^2$) for about 10 minutes as a unit effort.
[1]Other shrimps : *Penaeus indicus, Metapenaeus monoceros, M. Brevicornis, Palaemon styliferus, Macrobrachium rosenbergii, M. Villosimanus, M. dyanus, M. dolichodactylus, M. rude.*
[2]Fin fishes : *Liza parsia, Lates calcarifer, Glosogobius giuris, Hilisha ilisha, Pangasius pangasius.*
[3]Macro-zooplanktons : *Acetes* spp., mysids, alima larvae, copepod larvae, isopod and megalopa (crab larvae).
Figures in the same raw having the same superscript are not significantly different ($p>0.05$).

Shrimp farming activity is thriving in the south-western region of Bangladesh because of the availability of land and saline water with suitable environmental conditions and low-cost labour. At present, about 0.14 million ha coastal land are under shrimp cultivation. The trends in land-use pattern of the shrimp farming areas are shown in Table 3. The average annual rate of increase of shrimp farming areas in the study area was 5.6 per cent during 1975 - 1983 and 22.6 per cent during the period 1983 - 1990. Correspondingly, the annual rate of decrease of agricultural land, however, was 1.1 per cent during 1975 - 1983 and 12.9 per cent during 1983 - 1990. The settlement and water areas have remained almost the same. Thus, it has been found that the rate of increase of shrimp farming areas was high during the period from 1983 to 1990 and very low during the period from 1975 to 1983.

Table 4 shows the different cropping patterns in shrimp farming areas. On comparing these cropping patterns and yields before shrimp farming, 84 per cent of land (two seasons per year) was cultivated to paddy, with an average yield of 2,078 kg ha^{-1}. After shrimp farming, paddy cultivation areas declined to 74 per cent, but average yield increased to 2,177 kg ha^{-1}. Combining crop intensity with yield, the net increase in paddy production was about 8 per cent.

Table 2. Number of other species wasted for each *P. monodon* PL during wild seed collection in coastal rivers.

Years	Other shrimps	Finfishes	Macrozoo-plankton
1992	26	9	64
1994	42	12	312
1996	119	31	922

Average values from 12 rivers of Satkhira, Khulna, and Bagerhat coastal districts.

Table 3. Average rate of increase/decrease of shrimp/agriculture land in selected thana under Khulna district (after Shahid *et al.* 1992).

Period	Annual average rate of increase (%) of shrimp farms	Annual average rate of decrease (%) of agricultural land
1975 to 1983	5.6	1.1
1983 to 1990	22.6	12.9
1975 to 1990	13.6	6.6

Table 4. Comparison of cropping patterns and yields before and after shrimp farming in the south-western region of Bangladesh.

Districts	After				Before	
	Shrimp		Paddy		Paddy	
	% area	Yield, kg ha^{-1}	% area	Yield, kg ha^{-1}	% area	Yield, kg ha^{-1}
Satkhira	100	168	65	2,627	83	1,853
Khulna	100	153	78	1,992	93	2,330
Bagerhat	100	165	80	1,913	76	2,051
Average		162	74	2,177	84	2,078

Source : Ahmed *et al.* (1990).

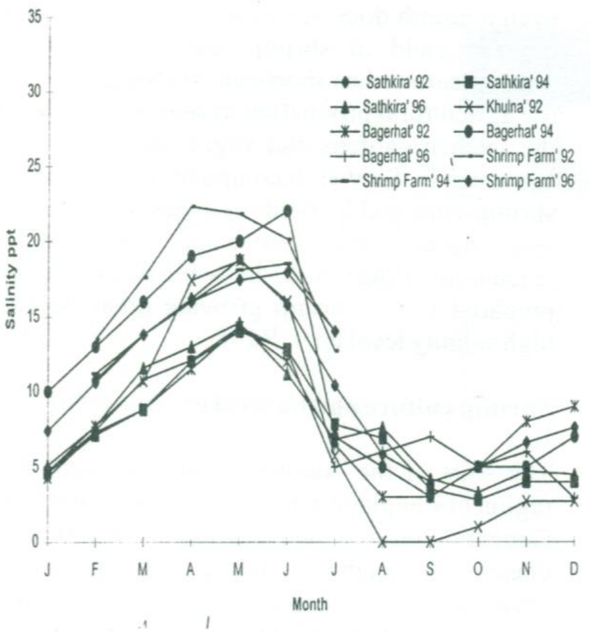

Fig. 1. Annual variations of water salinity in shrimp farms and different rivers of south-western Bangladesh.

Figure 1 represents monthly salinity variations in coastal rivers and the level of water salinity in the shrimp farms during 1992-96. Gradual decrease in river water salinity was observed from 1992 onwards. Water salinity also had a decreasing trend in shrimp farms. Generally, salinity was higher in farm water ranging from 11 to 22 ppt during the shrimp culture period of February to July.

A comparison between optimum and prevailing farm conditions in studied areas are presented in Table 5. Water quality was within the optimum range, although soil conditions differed slightly. The nitrogen (N) content of soils in shrimp land in study areas was low (30-50 μ g ml^{-1}) to medium (80-150 μg ml^{-1}). In non-shrimp area, it ranged around 40-60 μ g ml^{-1}. The available phosphorus (P) status of soils in shrimp and non-shrimp areas was mostly low (2-9 μg ml^{-1}). The organic matter content in soils in shrimp farming areas varied within a broad range. Out of ten, in six sampling sites, the amount of organic matter in top soil ranged from 2.21 per cent to 3.30 per cent indicating medium status of soil organic matter. The soils in other four areas contained high to very high organic matter (3.59 to 8.10 per cent). However, in non-shrimp areas, the organic matter content in soils was less than in shrimp areas ranging from 1.90 to 4.10 per cent (Table 5).

Table 5. Comparison between optimum conditions and prevailing shrimp farming in study areas.

Parameters	Optimum Conditions*	Study areas		
		Unplanned	Planned	Non-shrimp farming
Water sanility (ppt)	10-30	9.0-22.0	10.8-22.2	3.0-16.0
Water pH	7.5-8.5	7.4	8.4	8.0
Soil salinity (ppt)	<7.5	7.9	9.06	7.0
Soil pH	5-7	6.0	6.4	5.8
Nutrients (μg/ml)- N	-	30-150	30-80	40-50
P	-	5-20	7-15	2.14
K	-	0.55-0.99	0.55-1.00	0.76-0.84
Soil texture	Clay loam	Clay	Clay	Silt
Organic matter (%)	-	3.4	4.0	2.9

* According to C.P. Group (1993).

Table 6. Matrix showing the social impact of shrimp farming in south-west region of Bangladesh.

Parameters	Impacts				
	Rice cultivation	Fish culture	Shrimp farming		
			Extensive	Semi-intensive	
Impacts					
Land use conflicts	-	-	+	+	
Employment	+/-	-	+	+	
Wage and income	-	-	+	+/-	
Food supply	+	+	-	-	
Infrastructure development	-	-	+	+	
Gender issues		-	-	+	+
Problems					
Water and soil salinization	+	+	+	+	
Embankment destruction	-	-	+	+/-	
Drinking water	-	-	+	+	
Reduction in vegetable fodders, food supply	-	-	+	+	
Law and order	-	-	+	+	

+ denotes presence, - denotes absence

From the stand point of economic development, shrimp culture has been a self-generating industry in Bangladesh. Shrimp culture may be profitable in a financial analysis, but the cost which the society has to pay, along with a number of inputs of qualitative nature, results in making a small number of people benefited. Matrix showing socio-economic impacts and problems of shrimp culture in south-western Bangladesh is presented in Table 6.

DISCUSSION

Loss of biodiversity

Many forms of aquaculture still depend on wild fish and shellfish seed. It is well established that many wild resources are in decline, but it is difficult to quantify the relative impacts of overfishing, habitat loss, coastal pollution, and even natural cycles of abundance on this problem. It was estimated that 10 kg of fish and shrimp larvae were destroyed during the collection of every 1 kg of tiger shrimp post-larvae in the Sundarban region of West Bengal (Silas 1987). In Bangladesh, up to 5000 shrimp fry may be wasted for every 100 marketable shrimp fry captured by collectors (BOBP ·1990). Similar wastage of fishery resources, because of the shrimp fry trade, has been noted in Ecuador (Fast and Lester

1992). Present findings indicate a marked decline in *P. monodon* seed population in coastal rivers which ultimately reduces fry supply in shrimp farms. As a result, a large quantity of PL are imported from neighbouring countries, causing disease out-break in shrimp farms.

It is necessary to understand the cause of natural mortality of *P. monodon* larvae, so that we can understand the reasons for decreases in PL numbers in the wild resources. As marine shrimp is highly fecund and the natural mortality of fertilized eggs and larvae is also very high, collection of seed by the fry collectors can not be considered as the principal cause of gradual decrease in PL of *P. monodon* in the coastal rivers. Many Asian countries now use hatchery produced shrimp fry, most notably is Thailand having more than 2000 hatcheries. Nevertheless the production methods are still dependent on wild broodstock. Already fishing pressure on shrimp spawners in Thailand has resulted in much smaller females being used by hatcheries with a resultant decrease in fecundity per spawner. Although tiger shrimp are still abundant in many parts of its range, the long-term sustainability of this supply is in doubt (Asian Shrimp Council 1994).

The present study revealed that a wide variety of fish *Ophocephus punctatus, O. striatus, O. marulius, Mastacembelus armatus, Anabus testudineus, Heteropneustes fossilis, Pangasius pangasius, Liza tade, Eel* sp., *Macrobrachium malcolmsonii* etc. were abundant before shrimp farming. At present this rich diversity has been narrowed to such an extent that only a few species like *Lates calcarifer, Glossogobius giuris, Mystus golio, Mugil* sp., *Palaemon styliferus, P. olichodactylus* are available in shrimp culture areas.

Land resources and shrimp farming

Shrimp culture has added a new dimension to the land-use pattern in the coastal areas of Bangladesh. When the product turned out to be financially profitable in consideration of repayment period and volume of returns on investment, the entrepreneurs were attracted to this area. As a result, coastal lands are increasingly leased out to shrimp farmers. Juville and Serene (1990) estimated that average annual rate of increase of shrimp farming areas in Paikgacha *thana* under Khulna *district* was 26.6 per cent from 1987 to 1989.

There is apparently a seasonal conflict between shrimp and paddy production cycles. Paddy farmers complain that the shrimp farmers do not harvest their products in time to make land available for subsequent paddy production. The shrimp farmers argue that a delay in harvest of shrimps by 15 days or even a month does not affect the paddy production but the yield of shrimp increases significantly. Shrimp culture has short-run and long-run costs for the agricultural production system *per se,* including the kitchen gardens and vegetable patches around homesteads. Slower decomposition of rice roots in shrimp-cum-paddy fields reduces soil quality and may increase the chance of "stem rot" virus (Siemelink 1982). Seed-beds for paddy can not be prepared in the shrimp growing areas because of high salinity levels (DDP 1983).

Shrimp culture and natural environment

The soils of the coastal belt in the south-western region of Bangladesh are developed mainly from the Gengetic alluvium and the tidal alluvium deposits. Ganges floodplains including tidal floodplain have been producing fair to good crops for many decades with little or no use of manure or fertilizer. However, none of these soils are naturally fertile enough to maintain sustained high yields. Saline soils and acid sulphate soils are the major problem in the study area. It can therefore be argued that continued shrimp cultivation could lead to deep soil leaching. An argument put forward by supporters of unplanned shrimp farming, that heavy monsoon rains can flush out the salinity from the soil was disproved by the results of the present study. Increased salinity up to 30 cm depth indicates that percolation of saline water occurs, especially as the area remains water-logged for a considerable period of time, which is not flushed out by the monsoon rains. During the last six years, salinity increased up to 46% in Khulna region as reported by Bangladesh Water Development Board. Soils of relatively low areas are silty clay to clay. Within poldered areas soils are slightly to moderately saline in dry season whereas in non-poldered areas soils are moderately to strongly saline (Halcrow 1992). The highest salinity, both in terms of intensity and extent (Ecds m^4> 16), falls within Satkhira, Khulna and Bagerhat *districts* of the south-west region of Bangladesh. Salinity conditions prevent cultivation of *rabi* crops and even considerably reduce paddy yield, specially during low rainfall years.

Generally, extensive/semi-intensive shrimp farming systems driven by inorganic nutrients tend to be autotrophic, while intensive systems driven by organic nutrients (artificial feed) tend to be heterotrophic (Fast and Lester 1992). Extensive and semi-intensive farms represent relatively complicated ecological systems where the running dynamic processes influence the water quality throughout the grow-out period. Traditional extensive systems for shrimp farming are not expected to provide any significant loading of organic matter and nutrients to the surrounding coastal environment (Phillips *et al.* 1993), and is considered to be a potentially sustainable aquaculture system. Little information is available on the effluent loading from extensive systems. Undoubtedly, the ecological significance of the discharges from these systems grows as the input rate and the productivity increase. The progression from traditional to improved extensive systems is marked by increasing input of organic-inorganic fertilizers and consequently an increasing potential loading of nutrients and organic matter per unit farm area or per unit weight of shrimp production (Phillips *et al.* 1993). There are no current reports describing monitoring of the effluent loading from extensive culture systems neither in Bangladesh nor in other parts of the world.

With manure as the only input to shrimp ponds, Lee *et al.* (1986) did not find any increased nutrient levels in pond discharge water. In Bangladesh, the shrimp production, within the typical range of extensive and improved extensive production systems ranged from 226 kg ha^{-1} to 514 kg ha^{-1} per cycle, used 1.5-2.5 tons of manure per ha in fortnightly doses (Hoq *et al.* 1994 & 1997), which adds about 40-60 kg of nitrogen and 15-35 kg of phosphorus per hectare. Therefore, cattle manure is efficiently digested in shrimp ponds and such systems are unlikely to pollute the environment with high concentrations of dissolved nutrients. In extensive and semi-intensive systems with low water exchange rate, a major part of nitrogen and phosphorus is accumulated in the sediments (Edwards 1993).

Soil tests have indicated that an important part of the clay soil in the south-western delta originates from the microbiological activity of algae and other soil organisms, taking free nitrogen from the air and fixing it in organic form. Water inundation stops this type of activity very efficiently, and the organic material decomposes into mineral components, making available for subsequent crop growth. If inundation is maintained year round, this may reduce free nitrogen fixation, halt mineralization and ultimately reduce the soil fertility within 2 years (Shahid *et al.* 1992). In extensive systems with controlled water exchange (low rate) the main discharge of organic matter and nutrients are expected to be connected to the pond drainage at harvest and to the farm land preparation between the cycles. Undoubtedly, the effluent loading is strongly affected by the water exchange rate throughout the growth cycle: low or no water exchange rate from stocking to harvest reduces the potential for environmental impact (Hopkins *et al.* 1993). Frequent water exchange for shrimp culture increases the rate of siltation in the fields. This will, in the long run, reduce the possibilities for deepwater rice farming and also for paddy-cum-fish culture (Siemelink 1982). Long-term problems of water management are likely to result because of siltation in shrimp fields (Guimaraes 1989).

It is revealed from the present study that eutrophication process is significant in some waterbodies under shrimp farming. The eutrophication phenomenon refers to the effects of adding nutrients to a waterbody, as represented by the rapid growth of organisms such as zooplankton, phytoplankton or algae. When they are present in sufficient numbers, some species of algae can cause "water bloom", resulting in bad odours and produce toxic substances during their metabolic process. Under certain conditions, the population of algae may die, and the subsequent decomposition depletes the dissolved oxygen in the entire waterbody and produces a foul smell and taste. Molting process of shrimp as well as its wastage in the water, which includes phosphate rich bio-chemical products are some of the major sources of water pollution in shrimp farms. The discarded portion of a shrimp accounts for about 37 per cent of the total body weight. The total quantity of discards of heads and other wastage amounted to around 10,000 tons $year^{-1}$. These discards are mostly thrown into the rivers and canals by beheading centres located at different market places. Moreover, shrimp feed as well as chemical fertilizers applied in agricultural lands are major sources of the phosphorus and nitrogen in waterbodies.

Socio-economic effects

More than 0.15 million people are involved in shrimp fry collection in the coastal belt extending from Cox's Bazar to Satkhira (BOBP 1990). It was found that during the peak season of the availability of *bagda* fry, about 70-75% of the family members residing along the rivers of Sundarban mangrove forest areas are engaged in collection of shrimp fry (Chowdhury 1990). About 30% of the fry collectors from coastal regions are female, either adult or children. The persons associated with post-harvest activities of shrimp are mostly women who are forced to work at a lower wage. Women fry collectors are more independent than those involved in post-harvest handling.

Shrimp farming uses less labour than paddy cultivation (Chowdhury 1988), so if more of high saline land is brought under shrimp farming it is obvious that many agricultural labourers, sharecroppers will be deprived of their livelihood opportunities. Sometimes, lands of small and poor farmers adjacent to the shrimp farms become unsuitable for paddy cultivation due to the flow of saline water. The affected people, finding no other alternatives, have to lease out their land to shrimp producers despite their unwillingness to do so. The water drainage canals are blocked due to extra embankments built by the shrimp farmers, resulting in water logging in the surrounding areas. Before shrimp culture, local farmers allowed livestock to graze upon the paddy stubble left in the field. The post-harvest fallow period has now been substituted by shrimp culture posing a grave problem to the supply of cattle feed. Cattle are of crucial importance as a source of draught power in agriculture. Due to the shrinkage of rice acreage with the expansion of shrimp acreage, there has arisen an acute shortage of paddy straw causing great sufferings to the poor farmer families in respect of cattle rearing, cooking etc.

CONCLUSIONS AND RECOMMENDATIONS

Shrimp culture in coastal areas of Bangladesh needs to be further analyzed as an extension of a particular social economy. Under the present conditions, it is beneficial only for a section of people, but it is a matter of grave concern for the great majority of people. Shrimp farmers should be encouraged to adopt semi-intensive mode of shrimp farming rather than horizontal expansion, as this farming pattern may lead to the destruction of other agricultural lands and to some extent mangrove forest. It is therefore suggested to minimize the unplanned horizontal expansion of shrimp farming areas and formulate criteria for selecting the areas that are most suitable for shrimp and shrimp-paddy culture on a rotation basis. Keeping all these in view, the following recommendations are made:

1 The shrimp farms are scattered in a wide area, even at the homestead areas causing problems of varied nature to the inhabitants. Therefore delineation of shrimp farming areas using remote sensing and GIS applications should be undertaken.
2 Timely availability of adequate number of good quality shrimp fry should be ensured by establishing sufficient hatcheries.
3 For better management, the mean area of shrimp farms should be maintained around 1 ha.

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