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Review

Impacts of shrimp farming in Bangladesh: Challenges and alternatives

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ABSTRACT

Shrimp farming is growing in Bangladesh due to suitable agro-climatic conditions, adequate water resources, cheap labour force, international donor agencies and the involvement of multinational corporations. Although it provides immediate economic benefits, contributes to poverty reduction and food security, as well as generates employment from seed collectors to exporters, it has also been facing a host of challenges. They hinder the sustainable development of this otherwise thriving sector. This paper aims to expound the hindrances and challenges for sustainable shrimp farming in Bangladesh by means of reviewing the available scientific literature. It finds that socioeconomic impacts such as traditional livelihood displacement, social unrests and market fluctuations are hindering the sustainable development of shrimp farming in Bangladesh. Similarly, environmental impacts such as mangrove degradation, salt water intrusion, sedimentation, pollution and disease outbreaks are found to be obstacles for the development of sustainable shrimp farming. Inappropriate management practices and inadequate plans regarding water quality, seed supply, irrigation facilities and fishery resources, added to institutional weaknesses, jeopardize the future growth of shrimp farming. Therefore, this paper shall provide substantial input to set the directions that research for alternatives can take and that can contribute to the sustainability of shrimp farming.

1. Introduction

Shrimp farming is growing in almost all regions of the globe and it has a long history also in Bangladesh. Between 2002 and 2008, global shrimp production has increased by 34 percent (FAO, 2008) as a result of industrial transformation and intensification of production patterns (Lebel et al., 2002) as well as the global decline in fish catch from marine sources (Bailey, 1988; Naylor et al., 2000; Erondu and Anyanwu, 2005). It has become an important part of the economic sector in many tropical and subtropical countries. Aquaculture currently accounts for nearly half of the world's food fish (FAO, 2006; Hishamunda et al., 2009). Annual global aquaculture production has almost tripled since 1990 (Sapkota et al., 2008). In Bangladesh, the export of frozen shrimp was 15,023 tonnes in 1988, which tripled to about 49,907 tonnes two decades later, i.e. in 2008 (DoF, 2009a). The contribution of frozen seafood towards the GDP amounted to about 4 percent in the financial year 2008–09 (BBS, 2009). Frozen seafood is Bangladesh's second largest export commodity after ready-made garments (EPB, 2009). However, environmental and socioeconomic impacts have increasingly become a matter of concern for both government and public. Objections are often associated with ecological consequences (mangrove destruction, salt water intrusion, disease outbreak and pollution), social conflicts, and negative impact on the economy. Several authors have already expressed doubts about the sustainability of shrimp aquaculture (Dewalt et al., 1996; Dierberg and Kiattisimkul, 1996; Primavera, 1997; Deb, 1998; Flaherty et al., 1999; Hein, 2002; Paez-Osuna et al., 2003; Hall, 2004; Chowdhury et al., 2006; Azad et al., 2009).

The negative impacts of shrimp farming have arisen from poor planning and management practices, as well as a weak application of the existing regulations. As a response to criticism, donors and shrimp experts have been trying to develop good aquaculture practices (GAP) and better management practices (BMP); these aim at reducing ecological losses and social disruption, which would provide good quality and safe food products (FAO/NACA/UNFP/WB/WWF, 2006). The management practices of GAP have addressed the issues of site selection, farm management, fish health management, feeds and feeding, record keeping, as well as the application of drugs and chemicals to ensure uncontaminated, safe food (Yamprayoon and Sukhumparnich, 2010). The BMP have additionally raised the issues of farm sustainability and environmental

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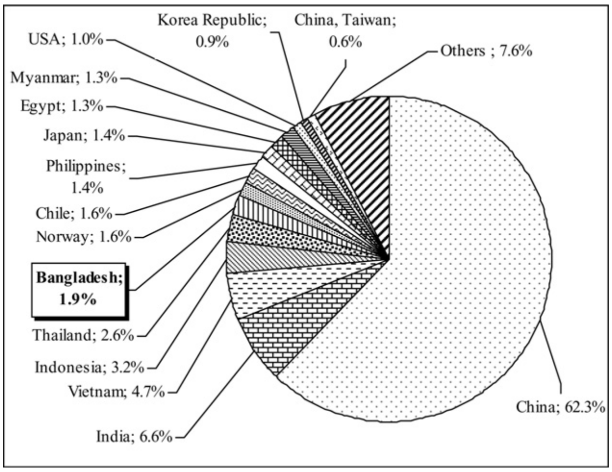

Fig. 1. Percentage distribution of aquaculture production by the top fifteen countries of the world (FAO, 2010).

degradation, and they are solving mostly technical problems (Bene, 2005). Both management guidelines can provide an important stimulus for government, public and private sectors to take over responsibility. Still, GAP and BMPs continue to be criticised for not considering social, political and health issues in many countries (Bene, 2005; Rahman et al., 2006). Shrimp farming expansion in Bangladesh is often unregulated, uncontrolled and uncoordinated (Deb, 1998; Metcalfe, 2003; Samarakoon, 2004; Alam et al., 2005). The shrimp sector is facing problems essentially due to the increasing occurrence of diseases and the lack of government stimulus: quality feed, available seed, good quality water and soil, and improved management practices are needed in order to establish sustainable farming and well-managed farms.

As a reaction to the negative socioeconomic and ecological impact of conventional farming methods, organic shrimp aquaculture has been introduced to the southwest region of Bangladesh as an alternative culture. In 2005, the Organic Shrimp Project (OSP) was initiated in Bangladesh by the Swiss Import Promotion Program (SIPPO). Recently, the OSP has been implemented by the Germany-based importing organization WAB-Trading International together with Gemini Sea Food Ltd. The organic farms of the OSP are certified by Naturland, a German private organic farmers association. The compliance of the farmers with this Naturland scheme gets inspected by the Institute of Market Ecology. The concept of organic shrimp aquaculture is relatively new to Bangladesh. WAB cooperates with 160 farmers' groups (consisting of 15–40 farmers each) and 3379 individual farmers. Worldwide, the growth rate of organic shrimp aquaculture is unknown but estimates for organic aquaculture ranged from 20% to 30% annually (Ruangpan, 2007). This is due to high market prices, growing consumer awareness regarding safe food, because it protects environment and biodiversity, and also for the further social and economic benefits it offers to farmers and society (Boehmer et al., 2005; Biao, 2008).

This paper reviews the global trends in aquaculture development as well as the role and culture patterns of shrimp farming in Bangladesh. The main aim of the review is to provide a firm foundation for advancing knowledge on the environmental and socioeconomic impacts of shrimp farming. It also investigates the links between shrimp production and economic growth, as well as the impact of institutional weaknesses. Finally, this review will lead to an empirical viability study of organic shrimp production in Bangladesh.

2. Trends in global aquaculture and its status in Bangladesh

The aquaculture sector is being fostered all around the globe because it is assumed to substantially contribute to food security, nutritional supply, poverty reduction and economic development (Bondad-Reantaso and Subasinghe, 2008). Between 1999 and 2008, annual global production of aquaculture increased from 31 to 53 million tonnes and earned 45 to 98 billion US dollars (FAO, 2010). Aquaculture in the developing countries contributes about 90% of global production in weight and 80% in value (Beveridge et al., 1997; Hishamunda et al., 2009). Recent statistics for global aquaculture show that eleven of the top fifteen producer countries are in Asia, accounting for 86.9% of the total global production (Fig. 1) (FAO, 2010). China is the leading producer in the world, accounting for almost 62.3% of the total production. The position of Bangladesh is sixth, contributing approximately 1.9% to the total aquaculture production (Fig. 1).

Capture fisheries account for 64% of the total fishery production in worldwide, while the remaining 36% of the food fish supply comes from the aquaculture sector (FAO, 2007). Globally, annual

Table 1
Relative importance of aquaculture production by the top fifteen countries of the World, 1999–2008.

Country	Total fishery production (tonnes)		Total aquaculture production (tonnes)		Share of aquaculture in total food fish production (%)	
	1999	2008	1999	2008	1999	2008
China	35,162,719	47,527,107	20,141,602	32,735,944	57.3	68.9
India	5,606,963	7583,567	2,134,814	3478,690	38.1	45.9
Vietnam	1,784,768	4549,200	398,468	2,461,700	22.3	54.1
Indonesia	4,736,188	6647,219	749,269	1,690,121	15.8	25.4
Thailand	3,646,070	3831,208	693,762	1,374,024	19.0	35.9
Bangladesh	**1,552,417**	**2,563,296**	**593,202**	**1,005,542**	**38.2**	**39.2**
Norway	3,103,466	3274,572	475,932	843,730	15.3	25.8
Chile	5,325,835	4397,956	274,216	843,142	5.1	19.2
Philippines	2,223,364	3302,334	352,567	741,142	15.9	22.4
Japan	5,944,302	4981,071	759,262	732,374	12.8	14.7
Egypt	648,941	1,067,630	226,276	693,815	34.9	65.0
Myanmar	1,011,124	3168,526	91,114	674,776	9.0	21.3
USA	5,228,325	4849,967	478,679	500,114	9.2	10.3
Korea Republic	2,422,561	2417,664	304,036	473,794	12.6	19.6
China, Taiwan	1,347,447	1340,372	247,732	323,982	18.4	24.2
Total (15)	79,744,490	101,501,689	27,920,931	48,572,890	21.6	32.8

Sources: (FAO, 2010).
Bangladesh highlighted to show the importance of aquaculture production compared to the top fifteen countries.

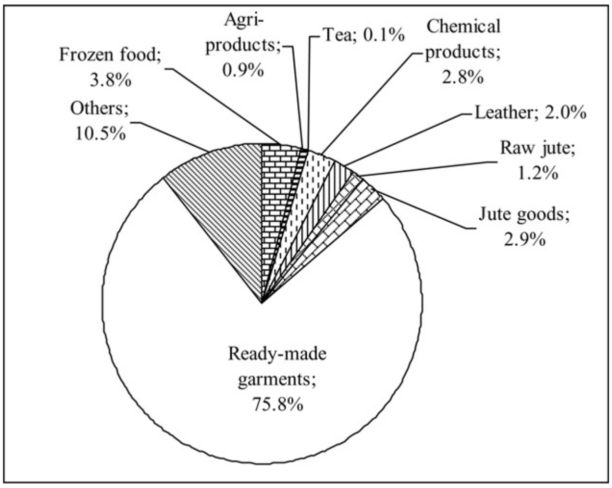

Fig. 2. Relative position of frozen seafood in Bangladesh from principal exported commodities (EPB, 2009).

capture fishery production decreased from 93 to 89 million tonnes between 2000 and 2008 (FAO, 2010). However, the top fifteen countries' total fishery production increased significantly, from 80 million tonnes in 1999 to 102 million tonnes in 2008 due to an increase in aquaculture production (Table 1). In the same period, the annual aquaculture production of the fifteen leading countries has increased from 28 to 49 million tonnes (Table 1). These countries together contribute almost 92% to the world's aquaculture production, but there are significant differences in their relative shares (Table 1). Bangladesh's production, in the same period, has grown at an annual average rate of 0.593 million tonnes to 1.005 million tonnes. The total share of aquaculture has increased from 21.6% in 1999 to 32.8% in 2008 in the top fifteen countries, but when individual countries are taken into account, the growth may be lower, as in the case of Bangladesh, where it was only 1% (Table 1). This proportionally low increment may be attributed to a commensurate increase in capture fisheries, as well as disease outbreaks and inadequate management practices.

3. Role and pattern of shrimp aquaculture in Bangladesh

The export-oriented production of frozen seafood plays a significant role in the national economy of Bangladesh and accounts for 3.8% of the country's export earnings (Fig. 2) (EPB, 2009). Frozen seafood earned US$ 550.53 million of foreign exchange from export in the financial year 2007–08, to which shrimp contributes with approximately 81% (BSFF, 2008). Thereof, shrimp aquaculture accounts for 42.2% of total production. The remainder comes from marine and coastal sources by means of capture fishery (Table 2). Shrimp farming activities alone both directly and indirectly employ more than 0.6 million people in the country (Islam et al., 2005).

Shrimp aquaculture has expanded from the south-eastern to the south-western parts of the coastal areas of Bangladesh. Initially, the pond area under shrimp aquaculture comprised 20,000 ha (ha) in 1980, growing rapidly to approximately 217,877 ha in 2007/08 (Metcalfe, 2003; DoF, 2009a). This expansion of shrimp aquaculture in the country is ascribed to its suitable climatic conditions and the availability of resources such as feed, seed, water and a cheap labour force (Islam, 2003). The swift increase after the 1980s is mainly due to the high profits obtained, high demand for shrimps on the international markets, employment generation, and earning of foreign currency (Deb, 1998). The private sector initiatives include the involvement of multinational corporations, which attracted both national governmental and international development agencies to expand shrimp aquaculture in the country (Deb, 1998). This same notion has been articulated by scholars of several Asian countries (Bailey, 1988; Bailey and Skladany, 1991; Stonich and Bailey, 2000).

In the 1970s, shrimp aquaculture in Bangladesh was started in *ghers*, which are traditional earthen ponds or fields situated by riversides and impounded by dykes (Islam et al., 2005; Ahmed et al., 2008b). Generally, a *gher* is used to grow rice between the months of August and December/January, and shrimp culture is practiced during the months of February to July/August (Deb, 1998; Ahmed, 2003; Islam et al., 2005). Tidal water exchange is important in the *gher* system for trapping wild seeds and natural food as well as for maintaining water quality (Primavera, 1991; Islam et al., 2005; Ahmed et al., 2008a).

However, this system has evolved over time and today, Bangladeshi shrimp aquaculture is classified into four categories: traditional, extensive, semi-intensive and intensive (Table 3) (Deb, 1998; Islam et al., 2005); similar classification systems have been reported for Southeast Asia, however, the categories can vary from country to country (Primavera, 1993, 1998; Dierberg and Kiattisimkul, 1996; Rönnbäck, 2002). The Bangladeshi classification is fully based on the intensity of the culture pattern such as stocking density, inputs (feed, fertilizer) and water quality management (Table 2). The stocking rate is low and any kind of sophisticated management is almost absent in traditional culture practices (Islam et al., 2005). Therefore, smaller size *ghers* and improved management practices are encouraged to obtain sustainable production and profits (Wahab, 2003). Intensive culture achieves 50 times more production than traditional culture if water management and supplementary feed are adequately employed together with a high stocking density (Primavera, 1993). In Bangladesh, 70% of the shrimp farms use traditional and/or

Table 2
Annual shrimp production (tonnes) and percentage contribution of shrimp aquaculture in Bangladesh (1998–99 to 2007–08). Source: DoF (2009a,b).

Financial year	Year-wise shrimp production (tonnes): Inland Fisheries: Capture	Inland Fisheries: Culture	Inland Fisheries: Total	Marine Fisheries: Trawl	Marine Fisheries: Artisanal	Marine Fisheries: Total	Grand total	Percentage of cultured shrimp
1998–99	49,296	63,164	112,460	3765	27,977	31,742	144,202	43.8
1999–00	43,167	64,647	107,814	2915	28,480	31,395	139,209	46.4
2000–01	44,343	64,970	109,313	3172	27,865	31,037	140,350	46.3
2001–02	54,965	65,579	120,544	3168	28,808	31,976	152,520	43.0
2002–03	60,876	66,703	127,579	2486	29,445	31,931	159,510	41.8
2003–04	63,103	75,167	138,270	3075	33,413	36,488	174,758	43.0
2004–05	68,768	82,661	151,429	3311	40,950	44,261	195,690	42.2
2005–06	77,381	85,510	162,891	3444	44,675	48,119	211,010	40.5
2006–07	82,422	86,840	169,262	2175	49,694	51,869	221,131	39.3
2007–08	75,678	94,211	169,889	2620	50,586	53,206	223,095	42.2

Table 3
Four different types of shrimp aquaculture practices. Source: Primavera (1993, 1998), Dierberg and Kiattisimkul (1996), Deb (1998), Rönnbäck (2002), Islam et al. (2005).

	Intensity of farming systems			
Criteria	Traditional	Extensive	Semi-intensive	Intensive
1) Pond (*gher*) size (ha)	5–10 or >	5–10 or >	1–10	< 1
2) Stocking	Natural	Natural + artificial	Artificial	Artificial
3) Stocking density (seed/m^2)	1–1.5	2–10	20–40	40–60
4) Seed source	Wild	Wild	Wild + hatchery	hatchery
5) Survival rate (%)	50–60	60–80	70–80	70–90
6) Feed used	Natural	Natural, little low cost feed	Natural and pelleted feed	Formulated complete feed
7) Water exchange	Tidal	Tidal, minimal pumping	Tidal, pumping	Pumping, reservoir, filter
8) Aeration	No	Little or no	Yes	Yes
9) Yield (t/ha/yr)	0.1–0.5	0.6–1.5	2–6	7–15
10) Production cost (US $/kg)	No data	1–3	2–6	4–8
11) No. of crops/year	1–2	1–2	2–3	2–3
12) Diversity of species	Polyculture	Polyculture	Monoculture	Monoculture
13) Lime used (kg/ha/yr)	Little or no	< 100	250–400	500+
14) Fertilizers used (kg/ha/yr)	Little or no	Cowdung-500, little or no urea/TSP	Cowdung-2000+, Urea-300+, TSP-100+	Cowdung-4000+, Urea-500+ TSP-200+
15) Chemicals used	No	No or little	Used	Widely used
16) Employment (Persons/ha)	No data	< 7	1–3	1
17) Disease problems	Rare	Rare	Moderate to frequent	Frequent
18) Operational costs	Little or no	Low	Moderate to high	Extremely high
19) Development costs	Little or no	Low	Moderate to high	Extremely high
20) Environmental impact	Little or no	Relatively little	Moderate to high	Extremely high
21) Social implications	Little or no	Relatively little	Moderate to high	Extremely high
22) Economic proliferation	Subsistence	Subsistence	Commercial	Entrepreneurial
23) Sustainability concerns	High	Moderate to high	Moderate to low	Relatively low

extensive, 25% semi-intensive, and 5% intensive culture techniques (Hussain, 1994).

4. Environmental impact

The rapid growth of shrimp farming has led to both short and long-term negative environmental impacts, involving ecological imbalance, environmental pollution and disease outbreaks. Thus, shrimp farming is facing management-related difficulties which lead to greater concerns about water quality, feed and seed supply.

4.1. Destruction of the mangrove ecosystem

The transformation of the naturally multifunctional mangrove ecosystem into privately-owned, single-purpose shrimp aquaculture systems is destroying the ecology of the coastal zone (Folke and Kautsky, 1992; Primavera, 1997). Roots and stems of intact mangrove forests provide free multiple services such as shelter, habitat for fry and brood stock, feeding ground, buffers against storm surges and shoreline erosion (Primavera, 1991, 1997; Dierberg and Kiattisimkul, 1996; Ahmed, 2003; Iftekhar, 2006; Giri et al., 2008). A lot of literature points to the fact that the biodiversity in both fauna and flora has degraded due to the unabated destruction of the diverse mangrove ecosystem (Iftekhar, 2006; Hoq, 2007; Iftekhar and Takama, 2008). Mangrove destruction in the world is caused by two main factors: aquaculture and agricultural expansion, as well as industrial and settlement development (Primavera, 1997; Giri et al., 2008). Destruction of mangroves due to shrimp aquaculture has been reported by several scholars in different parts of the world (Primavera, 1991, 1997; Dierberg and Kiattisimkul, 1996; Hein, 2002). Around the world, between 30% and 70% of the mangrove area has been lost due to shrimp farming (Barbier and Cox, 2004). Mangrove clearing gets further escalated by the low price of shrimp, minimum wage, distance from market, price of feed, population growth and the density of shrimp farms (Barbier and Cox, 2004).

In the Bengali Sundarbans, most of the mangrove destruction occurred before the rise of shrimp farming and is associated with agricultural expansion (Richards and Flint, 1990). However, in Bangladesh, mangrove wetlands are still being converted to ponds/*gher* for shrimp aquaculture (Deb, 1998; Chowdhury et al., 2006). The exact rate of mangrove destruction due to the construction of ponds in the south-western parts of Bangladesh is not yet known. However, the rates as well as the causes for the reduction of mangrove forests vary, both spatially and temporally (Giri et al., 2008). Nevertheless, in the south-eastern parts of Bangladesh an area of 18,200 ha of mangrove (Chakaria Sundarbans) has almost completely been destroyed to make place for shrimp aquaculture (Akhtaruzzaman, 2000). The government-led development projects for shrimp aquaculture, patronized by the Asian Development Bank (ADB) and the World Bank, might have caused massive destruction of the forests (Deb, 1998). However, shrimp aquaculture is not the only reason for mangrove degradation; other land uses such as rice production and salt production have also played a substantial role in the destruction of mangrove forests in Bangladesh (Deb, 1998). The remaining mangrove forests are under pressure by continuous cutting, encroachment, storms and climate change (Iftekhar and Saenger, 2008).

4.2. Land degradation

Shrimp aquaculture in Bangladesh is competing with farmers' cultivable plain land, state-owned mangrove swamp, and coastal land. Worldwide, most shrimp ponds in coastal areas have been converted from rice-producing fields and the remainder by manipulating coastal salt flats, marshes and mangroves (Bailey, 1988; Paez-Osuna, 2001). However, large areas of natural mangrove and other land uses such as low-lying floodplains, marshes, etc. have been used for the construction of *gher* in southwest Bangladesh (Chowdhury et al., 2006; Ahmed et al., 2008b). This construction of ponds/*gher* and associated dykes and polders for shrimp cultivation as well as access roads has changed the current land use pattern (Islam, 2003). Unplanned construction of canals and dykes causes flooding and waterlogging for several months every year in some coastal areas of Bangladesh (Islam, 2009). The conversion of natural wetland ecosystems may reduce fish migration routes and avert natural water flows. Newly constructed ponds may accumulate salt water for shrimp aquaculture and the salt water slowly alters the chemical properties of the pond water and soil. This alteration renders the land unsuitable for crop production in the future (Chowdhury et al., 2006). The land may previously have been used for rice production during the wet season, but shrimp aquaculture affects the rice ecosystem and does not allow this any longer. In other cases, rice land converted to shrimp ponds is of poor quality for agriculture because it is salt affected; thus, conversion in some cases can be a quite sensible land use if there is no potential for the ponds to leach salts into surrounding fields (Flaherty and Karnjanakesorn, 1995; Dierberg and Kiattisimkul, 1996; Flaherty et al., 1999). Still, the transformation of rice fields into shrimp ponds has significantly reduced the rice yield in Bangladesh (Ali, 2006), which may create food insecurity in rural areas. Like elsewhere in the country, rice fields are often used as pastures as well as for cultivating other crops and vegetables in the dry season. The decline in grazing land has substantially reduced livestock resources (Ali, 2006). The degradation of land has altered the coastal land use pattern, which increases the threat of an unsustainable use of natural resources.

4.3. Loss of capture fishery stock

Shrimp aquaculture farms in Bangladesh stock wild-caught juveniles rather than hatchery-reared post-larvae. Owners of shrimp farms encourage the local people to collect wild spawn from estuaries and coasts. However, trawl fishermen collect mother shrimps as brood stock from the deep sea. This collection of brood stock and spawn plays a major role in the loss of capture fisheries as the by catch increases (Primavera, 2006). The rate of depletion from rivers and estuaries in Bangladesh has been 10% during the past 10 years (DoF, 2009a). In Mexico, the stock of capture fisheries has gone down at the rate of 28–30% between 1980 and 1990 due to overexploitation (Paez-Osuna et al., 2003). Capture fisheries are used to supply trash fish to make fish meal. When the shrimp industry uses pelagic fish as trash fish to make fish meal, and ultimately to produce pellet feed, it diminishes the wild fishery resources (Naylor et al., 2000). In intensive farming, pellet feed is applied as a supplement for rapid growth. Compared to poultry and livestock feeds, high quantities of fish meal are required to produce pellet feed for the shrimp aquaculture industry; the production of 1 kg of carnivorous fish requires up to 5 kg of wild fish (Naylor et al., 2000). The high proportion of fish meal in the shrimp aquaculture industry has induced a loss of wild capture fish stock (Primavera, 2006). In most cases, fishermen collect very small fish for making fish meal, which directly reduces the chance of getting table fish. Shrimp farms and the growing number of people dependent on fishing have had a significant role in the decline of fish stocks. Catches of wild shrimp in both open sea and coastal ecosystems have declined because of the overexploitation and contamination of the coastal zone (Paez-Osuna et al., 2003).

4.4. Seed supply

Natural sources for shrimp collection are threatened by environmental pollution and overexploitation, causing a severe scarcity of wild seed supply (Islam et al., 2004; Hoq, 2007). Shrimp seeds are harvested exclusively by women and children in estuaries and coasts, using a variety of fine-mesh hand-handle push nets. Men do not usually harvest seed, except by boat.

The rate of mortality in post-larvae (PL) is high, and biodiversity is reduced for every single PL collected (Dewalt et al., 1996; Primavera, 1998; Naylor et al., 2000; Hoq et al., 2001). In Bangladesh, 12 to 551 PL of other shrimps, 5 to 152 PL of finfish, and 26 to 1636 PL of other macro-zooplankton are wasted during the collection of a single *P. monodon* PL (Hoq et al., 2001). Collection of shrimp seeds from natural sources for aquaculture operations directly influences wild fisheries (Naylor et al., 2000; Primavera, 2006). More than fifty hatcheries have been built in Bangladesh in the last seven years to meet the demand for shrimp farms (DoF, 2009b). While precise data do not exist, an estimated 60–75% of the post-larvae used by shrimp farms get produced in these hatcheries (Islam et al., 2004). This has reduced the dependency on wild sources and avoided risks of disease, as hatcheries provide pathogen-free shrimp seeds that grow better and survive better than wild post-larvae (Islam et al., 2004). Still the big concern is better quality: what mechanism should hatchery operators apply to reduce the mortality of shrimp and free them of pathogens, so to ensure their rapid growth?

4.5. Sedimentation

Water runoff during the rainy season carries sediments from upstream through river tributaries to coastal areas (Dewalt et al., 1996). When water from estuaries or river channels is stored in shrimp *ghers* or ponds, the sediments quickly settle on the bottom as water velocity slows down (Dewalt et al., 1996). In intensive shrimp farming, however, sediments originate also from the pond bottom and surrounding walls as well as from the sludge that accumulates on the pond bottom during each production cycle (Briggs and Funge-Smith, 1994). Furthermore, the pond management activities worsen the sedimentation problem, as a daily exchange of water is required (Barraclough and Finger-Stich, 1996; Funge-Smith and Briggs, 1998). Management practices, including high stocking density, feed application, aerator use, liming and fertilizers, etc., also contribute to suspension and sediment accumulation (Funge-Smith and Briggs, 1998). Intensive farming accumulates high amounts of sediment, such as 185–199 tonne dry wt./ha or 139–150 m^3/ha (Briggs and Funge-Smith, 1994). Extensive culture systems in Bangladesh produce less than 1 tonne/ha/year, which does not pollute the surrounding water and rather acts as a sink for nutrients and solids (Wahab et al., 2003).

The sediment is often discharged into waterways leading into the sea, or is sometimes used to build new dykes or maintain existing dykes (Barraclough and Finger-Stich, 1996; Dierberg and Kiattisimkul, 1996; Paez-Osuna, 2001). Maintenance of dykes deteriorates the quality of water during the next production cycle and discards sludge into the open sea, creating a waste disposal problem (Dierberg and Kiattisimkul, 1996). The pond bottom accumulates excessive organic materials such as nutrients (nitrogen, phosphorus and ammonia) and hydrogen sulphide, which creates foul odours, hypernutrification and eutrophication (Barraclough and Finger-Stich, 1996; Funge-Smith and Briggs, 1998). The action of suspended solids or colloids produces turbidity, which reduces sunlight penetration into the water column, which, in turn, ruins primary productivity and the trophic structure of the ecosystem (Dewalt et al., 1996). Turbidity is reported at 23% for extensive farms and at 39% for semi-intensive farms in Bangladesh (Wahab et al., 2003). Furthermore, the sediment loads have a detrimental impact on other water users as well as the local fauna and flora (Barraclough and Finger-Stich, 1996; Dewalt et al., 1996).

4.6. Pollution

Intensive shrimp farming requires a daily change of water, approximately 5–10% of the total pond volume per day during earlier, and 30–40% during later stages of growth period (Flaherty and Karnjanakesorn, 1995). In extensive shrimp farming, water gets changed for four or six days at full and new moon in every fortnight at a rate of 0–10% of the total pond volume (Wahab et al., 2003).

Sluice gates are constructed to maintain water flow and to control salinity levels via water exchange. They are also used as effluents to remove waste, dissolved metabolites and particulate matters, which are formed by the collective action of various chemicals, fertilizers, excreta, unused feed, unwanted organisms, detritus, etc. (Flaherty and Karnjanakesorn, 1995; Flaherty et al., 2000; Hall, 2004). Such directly discharged effluents can easily pollute the surrounding water and soil quality (Deb, 1998; Neiland et al., 2001). Effluents from shrimp ponds are typically enriched in suspended solids; nutrients such as ammonia, nitrate, nitrite; Chlorophyll *a* and biochemical oxygen demand (BOD) (Barraclough and Finger-Stich, 1996; Paez-Osuna, 2001). The discharging effluents can reduce the dissolved oxygen, create hypernutrification and eutrification, increase sedimentation load, and cause changes in the benthic communities (Flaherty and Karnjanakesorn, 1995; Dewalt et al., 1996; Stonich et al., 1997; Flaherty et al., 2000).

The major sources of marine pollution in the Bay of Bengal are industrial, municipal and agrochemical waste and oil spill (Islam, 2003). The negative impact of pollutants on human beings, fish and other organisms has already been reported (Matin, 1995; Gräslund and Bengtsson, 2001). Agrochemicals and pesticides contaminate the water environment through agricultural runoff (Paez-Osuna et al., 2003). About 9000 tonnes of different pesticides and more than 2 million tonnes of fertilizers are used annually in Bangladesh (Matin, 1995). The unplanned use of agrochemicals and the discharge of industrial and municipal waste without treatment through river channels to the sea cause a decline in capture fisheries (Islam, 2003; Hall, 2004). In the same way, polluted water from the sea contaminates the aquaculture ponds. Sources of quality water are becoming scarce because effluents are impaired by the combined effects of shrimp pond, industrial, municipal and agricultural waste. Similarly, the water quality in shrimp ponds declines when weather and tidal conditions affect it through a combination of factors such as cloudy days, low winds and neap tides (Paez-Osuna, 2001).

4.7. Saltwater intrusion

Shrimp aquaculture has raised serious concern about the impact of saltwater intrusion into the surrounding agricultural lands (Flaherty and Vandergeest, 1998; Flaherty et al., 2000). The impact of saltwater intrusion into different coastal areas is reported by the following authors (Primavera, 1991, 1997; Flaherty et al., 1999). Ponds are being constructed for shrimp aquaculture behind mangrove forests where freshwater wetlands and rice-growing areas still exist (Flaherty and Karnjanakesorn, 1995; Dierberg and Kiattisimkul, 1996). Inundation of land by saline water for long periods leads to its percolation into the surrounding soils, resulting in an altered soil chemistry (Islam, 2003). Prolonged inundation inhibits the fixation of free nitrogen and halts mineralization, thus impairing soil fertility within a few years (Islam, 2003). Nevertheless, shrimp farms need additional fresh and salt water supplies throughout the growing phase of the cultures, as water is lost by seepage and evaporation (Flaherty et al., 1999; Paez-Osuna, 2001). The demand for salt water is fulfilled by digging narrow canals from near the shore or river channel for each shrimp-growing season, which disperse salt water along the coast of Bangladesh. Fresh water demand is fulfilled by setting up deep tubewells, which directly affects groundwater aquifers (Islam, 2003; Chowdhury et al., 2006). In the south-western parts of Bangladesh, salt water intrusion has not only changed the productivity of *ghers* and the land use pattern, but also affected freshwater supplies for irrigation (Deb, 1998). The withdrawal of groundwater through pumping has lowered the groundwater table and consequently fresh groundwater is contaminated by salt water (Barraclough and Finger-Stich, 1996; Flaherty et al., 2000).

4.8. Danger of imported fry and genetic alteration

The scarcity of wild shrimp seeds has inspired traders to import them from different countries. This importing of shrimp seeds without quarantine has spread several viral and fungal diseases throughout Bangladesh (Deb, 1998). Additionally, various infectious diseases have been widely disseminated through the introduction of fishes to the natural environment, as shrimp cultivators draw on the tidal water. Several research articles about gene pool alteration through mismanagement, accident or storm surges from farm to natural environment, discuss corresponding precautionary measures (Deb, 1998; Neiland et al., 2001). Gene pool interactions between wild animals and farm livestock may negatively affect the surrounding ecosystem through interbreeding (Naylor et al., 2005). The native biodiversity of both wild and farm stocks are confronting environmental hazards due to the introduction of invasive species and modified genotypes (Naylor et al., 2000; Diana, 2009).

4.9. Diseases

Intensive farming makes the shrimps highly susceptible to diseases (Primavera, 1991). Bangladesh has experienced disease outbreak in both semi-intensive and extensive farms in 1996 (Alam et al., 2007). When physico-chemical factors such as pH, temperature, dissolved oxygen, etc. fluctuate frequently, shrimps become susceptible to stress, leading to diseases (Paez-Osuna et al., 2003) such as red colour, soft shell, tail rot and black gill (Primavera, 1991; Alam et al., 2007). Disease outbreak has been recognized as the biggest obstacle to the development of shrimp aquaculture in Bangladesh. High stocking density and excessive use of feed lowers water quality, which contributes to stress and diseases among shrimp in intensive farming systems (Flaherty and Vandergeest, 1998; Paez-Osuna et al., 2003). It is dangerous when redundant feed and waste are discharged directly into the environment, which renders it extremely susceptible to carrying diseases. The intake of polluted water from neighbouring farms often spreads water-borne diseases from farm to farm (Paez-Osuna, 2001). Poor water quality, associated with unplanned and uncontrolled farming, has increased the incidence of diseases and reduced production (Deb, 1998). Viral diseases such as the White Spot Syndrome Virus (WSSV) and Yellowhead virus have infected shrimps in a catastrophic manner, causing huge economic losses across Asia (Primavera, 2006). In 1996, Bangladesh lost 44.4% of its total shrimp production due to an outbreak of disease caused by WSSV (Mazid and Banu, 2002).

4.10. Use of biological and chemical products in shrimp aquaculture

Shrimp aquaculture in Bangladesh relies heavily on the input of artificially formulated feed and the application of agrochemicals, antibiotics and disinfectants. The impact of these chemicals and biological products on shrimp farming as well as other aquaculture industries is well recognized by several authors (Alderman and Hastings, 1998; Gräslund and Bengtsson, 2001; Holmström et al., 2003; Cabello, 2006; Uddin and Kader, 2006; Sapkota et al., 2008). These products are often used in shrimp ponds to treat water and sediment as well as to prevent disease outbreaks. Some chemicals are used even in hatcheries to disinfect equipment. Information on the names and quantities of chemicals is not available for want of documentation. The quantities of these products usually vary, depending on the type of management system followed (Gräslund and Bengtsson, 2001; Uddin and Kader, 2006). The most common products used in shrimp aquaculture are fertilizers for the enhancement of natural feed and liming material for water and soil control. Disinfectants, antibiotics, algaecides, herbicides and probiotics are also used to increase production (Boyd and Massaut, 1999). When diseases spread out extensively, shrimp farmers tend to make heavy use of antibiotics as a prophylactic measure. The use of certain antibiotics in aquaculture may cause the development of antibiotic-resistance among pathogens, which compromises both human and the cultivated animals' health (Holmström et al., 2003). Chloramphenicol, Erythromycin, Oxytetracycline, Furazolidone and Prefuran, which are effective against Gram-positive and Gram-negative bacteria, are the synthetic agents commonly used as antibiotics in hatcheries (Uddin and Kader, 2006). However, these antibiotics are used in different concentrations and spectrums in most Asian countries (Baticados et al., 1990; Primavera et al., 1993). Nitrofuran is suspected to be infected with carcinogens and, therefore, prohibited for use on food animals in the European Union (GESAMP, 1997). Chloramphenicol may cause severe adverse effects, such as aplastic anaemia, in the human body and increase drug resistance (GESAMP, 1997). Some chemicals used in shrimp farming, such as organotin compounds, copper compounds and toxic residues, are likely to have a negative impact on the environment (Gräslund and Bengtsson, 2001). The commonly used disinfectant chlorine is applied to kill bacteria and viruses. Further pesticides are applied in shrimp ponds to kill unwanted organisms such as fish, crustaceans, snails, fungi and algae (Gräslund and Bengtsson, 2001).

5. Social impact

In addition to the environmental and economic impacts, the social impact of shrimp aquaculture has been widely discussed by several scholars (Primavera, 1991; Barraclough and Finger-Stich, 1996; Primavera, 1997; Stonich and Bailey, 2000; Neiland et al., 2001; Alam et al., 2005; Primavera, 2006; Costa-Pierce, 2008). In Bangladesh, most of the coastal land is operated by national and multinational investors (Deb, 1998; Ito, 2002). These investors are highly influential persons or institutions such as political leaders, army officers, bureaucrats, bankers, businessmen, journalists and NGOs (Deb, 1998). In India, powerful landlords and elected state representatives violate laws and acquire large areas for shrimp aquaculture (Primavera, 1997). These investors offer money to small landowners to lease out or sell their rice fields to them for shrimp aquaculture (Ito, 2002). If landowners refuse, then investors sometimes forcibly submerge their fields in salt water (Ito, 2002). In such cases, the small landowners have no choice but to either migrate out of the area or accept the investors' humiliating proposals (Deb, 1998). There are protests against illegal or forced occupation of land, but in fact, they often lead to violence and killing. In Bangladesh, about 85% of the investors are from outside the local area (Gain, 1995). However, in West Bengal (India), small-scale farmers and traditional (paddy-cum-prawn) cultivators have recently been actively participating in shrimp aquaculture (Philcox et al., 2010). Conflicts have arisen between investors and local farmers over land grabbing and denial of access to natural resources (Shiva, 1995; Dewalt et al., 1996; Stonich and Bailey, 2000; Neiland et al., 2001). In the Indian Sundarbans, a comparatively low level of conflict has arisen, which is probably due to the farmers being locals, low-intensity cultivation practice, and the small area of land under operation (Knowler et al., 2009). This situation might change if investors got access to pursue large scale commercial cultivation.

When investors get access to an area for shrimp aquaculture either by purchasing land or by forcibly taking it, land prices skyrocket (Barraclough and Finger-Stich, 1996; Ito, 2002). In Bangladesh, land prices have risen eighteen fold between 1994 and 2000 (Ito, 2002). In India and Thailand, too, land prices have multiplied following the initiation of shrimp farming in coastal areas, and, as a result, local farmers could no longer afford to purchase land (Barraclough and Finger-Stich, 1996). Thus, local farmers are losing access to common property resources such as mangroves, marshes, etc. Mangrove areas are directly important for coastal fishermen, mainly for aquatic food items such fish, crustaceans, molluscs, but also for other economic activities (Primavera, 1997). It is assumed that the catch per unit effort (CPUE) for widely caught fish has declined substantially because of reduced fishing stock and, therefore, fishermen's livelihoods have been rendered vulnerable (Dewalt et al., 1996). Traditional fishermen from the open sea and coastal lagoons are facing unemployment risk due to the damaging of the coastal ecosystem and the resulting decrease in fishery yields (Paez-Osuna et al., 2003). Loss of fisheries has forced fishermen to switch to other employment avenues such as cutting mangroves for firewood and other economic activities inside mangrove forests in order to survive (Dewalt et al., 1996). These changes in employment pattern have greatly contributed to the destruction of mangrove forests.

Destruction of mangroves causes loss of wildlife, increases flood risk and leads to damages on property through typhoons and tsunamis every year (Primavera, 1997; Iftekhar and Takama, 2008). In the recent past, the cyclones SIDR and AILA have destroyed huge numbers of shrimp farms in the south-western parts of Bangladesh, jeopardizing farmers' futures.

The earnings from *gher* construction through conversion of rice fields are temporary (Ito, 2002). As soon as the construction of a *gher* is completed, this employment opportunity as a labourer is gone. Rice farming is more labour-intensive than shrimp farming (Barraclough and Finger-Stich, 1996). In India, rice cultivation on 40 ha of land requires 50 labourers, but shrimp farming in the same area needs only five workers (Shiva, 1995). Also, the conversion of rice fields into shrimp ponds has reduced the opportunities for other traditional dry season activities, such as grazing cattle and homestead gardening (Alam et al., 2005).

The expansion of shrimp ponds causes massive waterlogging in the south-western parts of Bangladesh (Ito, 2002). The main cause is unplanned *gher* construction, which has extended from coastal agricultural land to residential areas. In consequence, a large number of people are forced to flee their homes and take shelter in unoccupied school or government buildings. Long-term water logging by saline water reduces soil fertility for agricultural production, diminishes opportunities for freshwater irrigation and creates scarcity of fresh drinking water in the community (Primavera, 1997; Flaherty et al., 2000; Islam, 2003; Ito, 2004; Ali, 2006). Fresh water is used in shrimp ponds both to minimize salinity and in hatchery operations. The contribution of shrimp aquaculture to poor people's nutrition can be neglected because most of the farmers cannot afford to eat the high-value shrimp. Poor farmers are forced to sell their high-value shrimp and buy low-value fish from the local markets for domestic consumption. Even the low-value fish is scarce in the local markets because it is used as a raw material for fish feed that in turn is to be administered in shrimp aquaculture. Accordingly, when fish supplies decline and prices go up in the local market, poor consumers are forced to shift to inferior food and fish tends to disappear from dinner plates (Kent, 1997). Therefore, international and national environmental organizations, human rights groups and academics are raising their voices against the social and environmental problems caused by shrimp aquaculture (Stonich and Bailey, 2000).

6. Economic impact

Shrimp aquaculture has expanded in many countries without considering the total economic value (TEV) of intact mangrove forests (Balmford et al., 2002; Gunawardena and Rowan, 2005). The cost-benefit analysis of a 42-ha farm in Sri Lanka shows that the internal benefits of shrimp farming are higher than the internal costs in the ratio of 1.5:1 (Gunawardena and Rowan, 2005). When the wider environmental impact is comprehensively evaluated, however, the external benefits are much lower than the external costs in a ratio which ranges from 1:6 to 1:11 (Gunawardena and Rowan, 2005). The economic benefits of shrimp aquaculture may perhaps be manifold, but considering its environmental costs, shrimp aquaculture needs to be treated as economically more harmful than good (Khor, 1995). The economic performance of shrimp farming is also affected by fluctuations in the local and international markets. The market price of cultured shrimp fluctuates, especially in the beginning and at the end of the production cycles. The prices for inputs increase meteorically, but the price of shrimp declines during the harvest season, which also has directly impeded the growth of shrimp cultivation. Therefore, shrimp farmers are facing various challenges because of the hike in the prices of inputs during the culture period, and unanticipated market fluctuations during the harvesting season (Neiland et al., 2001).

In Bangladesh, the shrimp price decreases when importing countries put restrictions on the import volume because there is no local market for shrimps. Furthermore, shrimp farmers incur losses when importing countries impose import bans due to harmful components in the processed shrimp. Farmers that are on the edge of surviving with the income from their farms face difficulties when the prices for inputs (seed, feed, fuel) increase tremendously, which may even force them out of business (Shang et al., 1998). Due to the scarcity of shrimp seed from natural sources, also the price of the shrimp seed rises, and small operators face problems in maintaining their costs. Shrimp seeds are still not sufficiently available from hatchery sources and, in addition, their prices are controlled by hatchery operators. The market for the pellet feed used in shrimp farming is highly competitive, with many private companies from Bangladesh and outside in the fray. Nevertheless, the price of pellet feed for shrimp farming has gone up and remains high, which has had severe impacts on production costs and returns. Shrimp farming is hindered by this steep hike in the price of feed, which can undermine the long-term viability of shrimp aquaculture. The price of fuel also influences the costs for inputs, and the inflation in Bangladesh has further increased the farmers' production costs. The scale of operation depends on the farmers' financial capacity, which in turn influences the intensity of the culture system.

The financial risk is always associated with the intensity of the culture pattern and is influenced by planning, design, management capacity and market fluctuations. However, the financial risk varies substantially, depending on farm size, management capacity and knowledge, and the operators' financial conditions. Recently, the economics of shrimp aquaculture in Bangladesh have changed: a twin-driven commodity chain has developed, in which buyers govern the supply network, while third party certifiers and environmental NGOs define the regulatory aspects of the industry (Islam, 2008). This governance of the chain offers opportunities for sustainable aquaculture and has the potential to identify the key market players and roles in the supply chain (Islam, 2008).

7. Institutional impact

Sustainable shrimp farming is possible, but it takes numerous technological improvements, adequate knowledge transfer through institutional changes, and sufficient monitoring of compliance with environmental and social requirements (Dierberg and Kiattisimkul, 1996; Primavera, 1997; Stonich and Bailey, 2000; Hein, 2002; Alam et al., 2005). Improved governance is an essential precondition to reduce social discrimination and safeguard the natural ecosystem (Samarakoon, 2004; Costa-Pierce, 2008). The shrimp sector of Bangladesh is characterized by a multitude of institutions, including 17 ministries and divisions, and 28 departments and agencies (Maniruzzaman, 2006). In addition, there are several institutions and organizations that play a role in the shrimp sector, such as NGOs, donor agencies, cooperatives of shrimp farming groups and the local union *parishad* (council) (Pokrant and Bhuiyan, 2001). Seventeen major policies, laws, acts, rules and ordinances have been enacted in Bangladesh to develop the shrimp sector (DoF, 2006; Maniruzzaman, 2006; DoF, 2010) (Table 4). The Department of Fisheries is the main implementing agency in the fisheries and aquaculture sector under the administrative control of the Ministry of Fisheries and Livestock. The other policies relevant to the shrimp sector include the FAO Code of Conduct for Responsible Fisheries, the National Water Policy, National Agricultural Policy, National Rural Development Policy, National Land Use Policy, National Environmental Policy and Coastal Zone Policy (DoF, 2006). These legal issues promote the conservation of natural resources and protect the rights of the local people and those of various stakeholders of the shrimp sector (Ahmed et al., 2002). The Government of Bangladesh has amended several acts such as an act permitting farmers to take up saline water into new

Table 4
Relevant fishery policies, laws, rules, acts and ordinances in Bangladesh. Source: Maniruzzaman (2006), DoF (2006, 2010).

Title of policy/law/rule/act/ordinance	Aspects covered
The Protection and Conservation of Fish Act, 1950	Conservation of fisheries resources as a whole
Embankment and Drainage Act, 1952	Protecting crops, not allowing cuts in embankments (to produce shrimp)
Bangladesh Water and Power Development Board Ordinance, 1972	Develop water management infrastructure for shrimp farming
Territorial Water and Maritime Zone Act, 1974	Conservation of marine fisheries
Marine fisheries ordinance, 1983	Conservation of marine fisheries
Fish and fish product (Inspection and quality control) ordinance, 1983	Quality control of fish and shrimp, mainly targeting export
Fisheries Rules, 1985	Framing rules for enforcement of various provisions of Fish Act 1950
Manual for Land Management, 1990	Allocate unused state (*Khas*) land to the landless on a permanent or temporary basis
Shrimp Estate (*mohal*) Management Ordinance, 1992	Allocate suitable state (*khas*) land for shrimp culture
Shrimp farm taxation law, 1992	Imposing higher tax on shrimp land to cover cost of polder infrastructure
Bangladesh environment conservation act, 1995	Conservation of natural resources and ensure eco-friendly development
Bangladesh environment conservation rules, 1997	Conservation of natural resources and ensure eco-friendly development
Fish and fish product (quality control) rules, 1997	Quality control of fish and shrimp, mainly targeting export
National Fisheries Policy, 1998	Conservation, management, exploitation, marketing, quality control and institutional development
Fish and Animal Food Act, 2010	Safe fish and animal feed production, processing, quality control, import, export, marketing and transportation
Hatchery Act, 2010	Sustainable hatchery development to ensure quality fish and shrimp seed

farms with the approval of the Bangladesh Water Development Board. Collection of shrimp fry from natural sources has been banned and import of shrimp seeds has been stopped (Alam et al., 2005). The use of chemicals and drugs has been regulated, and farmers are encouraged to apply sustainable pond management techniques (Alam et al., 2005). As for the existing provisions, each shrimp farm has to register and get a licence from the Department of Fisheries, but still a substantial number of farms have not been registered (Alam et al., 2005). The implementation of these policies and regulations by the institutions concerned as well as institutional assertiveness is weak, so huge gaps exist in enforcement (Hein, 2002; Alam et al., 2005). Furthermore, it is essential that a policy on waste treatment be formulated and pollution abatement from near shore tidal zones be emphasized. Strict enforcement of the FAO code of conduct, and the amendment of rules and regulations, including a multisectoral approach, interdepartmental cooperation and resource diversification, is indispensable for sustainable shrimp aquaculture (Paez-Osuna, 2001; Alam et al., 2005). A clear legal and institutional position about land use change by shrimp aquaculture is still missing in the national policy of Bangladesh (Alam et al., 2005; Chowdhury et al., 2006).

8. Conclusion/discussion

In Bangladesh, shrimp aquaculture has not progressed as much as in China or Thailand, owing to inadequate planning and inappropriate regulations. The economic benefits of shrimp aquaculture are well recognized. However, when its environmental and social problems are considered, shrimp farming has not improved the farmers' living standard. Although it has created temporary employment opportunities, the cost of destruction is much higher than these benefits. The major environmental impacts include the conversion of mangroves and agricultural lands into shrimp ponds/*ghers*, loss of capture fisheries and biodiversity, pollution and disease outbreak. Salinizations of groundwater and consequent problems with potable water and agriculture have been recognized as the main environmental and social impacts. Displacement and marginalization of fishermen, water logging and loss of livestock resources are other social problems that have affected the local communities. Resources such as feed, seed and water supply affect the sustainability of shrimp aquaculture.

Nevertheless, the existing type of aquaculture has enabled farmers to meet their immediate needs at the cost of environmental degradation; however, it is not a sustainable type of aquaculture. A sustainability concept for an eco-friendly and socially acceptable farming and management system must be developed around the world to ensure the future. The increasing negative environmental and social impacts have generated huge research efforts aimed at improving shrimp aquaculture's long-term sustainability.

According to the World Commission on Environment and Development through the Brundtland report, 'sustainability is the process of sustainable development and it is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). Shrimp aquaculture does have the potential to be carried out in such a way as to meet the needs of the present and at the same time not exceed the capacity of the resources. Pertinent management practices need to be renewed and adjusted continuously for future generations, so as not to pose an environmental hazard.

The definition provided by the FAO reads that 'sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs to present and future generations' (FAO, 1988). Such sustainable development is environmentally non-degrading, technically appropriate, economically viable, socially acceptable and includes different sectors such as agriculture, forestry and fisheries, conserving land, water, plant and animal genetic resources (Barg, 1992).

In a further definition provided by Goodland and Daly, 'sustainable development is development without growth in throughout of matter and energy beyond regenerative and absorptive capacities' (Goodland and Daly, 1996). The sustainable development of aquaculture requires adequate consideration of environmental, social and economic factors (Goodland and Daly, 1996; Caffey et al., 2000). Therefore, sustainable aquaculture development is interlinked with better management and institutional considerations, implementing regulations which have to be based on the principles of economic viability, social equity, and environmental acceptability. Although GAPs and BMPs are widely used at international and national levels as standardized methods, both are in many ways ignoring the environmental and socioeconomic factors in Bangladesh. Sustainability can only be acquired when environmental conditions are appropriate, and maintained, which expressly includes the ecological, socio-anthropological, and economic aspects of the environment (Frankic and Hershner, 2003).

The adoption of an ecosystem approach to aquaculture depends on governance and social issues, which requires combined action of science, policy and management (Costa-Pierce, 2008). The sustainability of shrimp farming relies on many factors, e.g., comprehensive policies and regulations, good ecology, excellent breed, appropriate technology and adequate support from the government (Biao and Kaijin, 2007) as well as mutual respect between farmers and exporters. Therefore, alternative and innovative culture systems must be identified as they form pathways to make aquaculture production sustainable; this can be attained by organic shrimp aquaculture. According to the definition given by the IFOAM, organic agriculture is a holistic approach which includes all agricultural systems (the farming of animals and plants) that promote the environmentally, socially and economically sound production of food and fibers. These production systems sustain the health of soils, ecosystems and people. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved (IFOAM, 2008). Organic production dramatically reduces external inputs by prohibiting the use of chemosynthetic fertilizers, pesticides, pharmaceuticals and feed additives, while encouraging natural ecological processes, biodiversity and using locally available resources (IFOAM, 2008). Therefore, this review study has inspired the author to undertake research for a future development of organic shrimp production, to assess its potentials, and to understand its impacts.

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