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REVIEWS

Impacts of shrimp farming on the coastal environment of Bangladesh and approach for management

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Abstract The frozen food export sector, next to readymade garments sector, is the second largest export earner of Bangladesh. Shrimp, main item of frozen food, is a major contributor in the national economy of Bangladesh since mid 1980s. Although it provides millions of employment and earns more than US$ 445 million annually, it has been facing a host of challenges. Shrimp farming has been associated with a number of negative environmental and social impacts which hinder the sustainable development of this blooming sector. This paper aim to focus on how the shrimp culture in Bangladesh is affecting the adjacent environment as well as society and management approach for it's sustain ability by means of reviewing the available scientific literatures. It finds the grave socioeconomic impacts including traditional livelihood displacement, loss of land security, food insecurity, marginalization, rural unemployment, social unrest and conflicts in the wake of shrimp culture development in Bangladesh. Similarly, environmental impacts such as mangrove degradation, loss of biodiversity, sedimentation, saltwater intrusion, and pollution and disease outbreaks are found to be the main obstacles for the development of sustainable shrimp farming. Inappropriate management practices and inadequate plans regarding water quality, seed supply, irrigation facilities and fishery resources are the main reasons for these impacts of shrimp farming. The effective management measures to mitigate the adverse environmental impact of shrimp farming development have now become urgent requirement.

Keywords Environmental impact · Frozen food · Socio-economic impact · Sustainable shrimp culture · Management approach · Bangladesh

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1 Introduction

Shrimp/ prawn production is one of the fastest growing fisheries industries in Bangladesh because of its advantages in terms of land use and improvements in the protein production and export earnings. Shrimps are one of the most important commodities of the global fishery trade (Bhaskar et al. 1995). They command a leading position in the world market by virtue of their increasing demand and competitive international price. Because it offered a huge immediate economic return, shrimp farming showed a booming expansion and soon became a multi-million dollar industry (Islam et al. 2004a, b).

Due to the favorable climate and availability of space, shrimp aquaculture has developed mainly in tropical and subtropical coastal lowlands. In 1998, the world's shrimp farmers produced approximately

850,000 metric tons of whole shrimp; the Asian region produced the largest amount (72 %), followed by Latin America (FAO 1999). Between 2002 and 2008, global shrimp production has increased by 34 % (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 catches from marine sources (Naylor et al. 2000; Erondu and Anyanwu 2005). 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 2009).

In Bangladesh, shrimp aquaculture has significant benefits in socioeconomic terms, and its high profitability and generation of foreign exchange have provided major driving forces in the expansion of the industry. Due to poor planning and management and a lack of appropriate regulations, many environmental impacts and social conflicts have occurred in the Southwestern part of the country. Objections are often associated with environmental consequences (mangrove destruction, saltwater intrusion, disease outbreak and pollution), social conflicts, and negative impact on the economy due to decline land for crop production. Several authors have already expressed doubts about the adverse environmental impacts and the sustainability of shrimp aquaculture (Hein 2002; Paez-Osuna et al. 2003; Chowdhury et al. 2006; Azad et al. 2009).

This paper reviews the production trends, role and culture patterns of shrimp farming in Bangladesh. The aim of the review is to provide a firm foundation for advancing knowledge on the environmental and socioeconomic impacts of shrimp farming in Bangladesh. Finally, this review will lead to an empirical viability study of management approach for sustainable shrimp farming in Bangladesh.

2 Shrimp production trend of Bangladesh

The shrimp sector has experienced dramatic changes in terms of area, production, and improvement of quality and marketing. Annual shrimp production in tonnes and percentage contribution of shrimp aquaculture in Bangladesh (1998–1999 to 2007–2008) are shown in Table 1. The area under shrimp production was 108,280 ha in 1990–1991 which increased to almost double, 217,877 ha in 2007–2008 (DoF 2009). On the other hand, the yield of shrimp for the same period increased from 263 kg to 675 kg/ha, showing a 2.57 fold increase. Two areas in the south, the Chittagong–Cox's Bazar belt and Khulna, Satkhira–Bagerhat belt, account for 95 % of the total area of shrimp culture in the country (Bhattacharya et al. 1999). Total shrimp production takes place from three sources, namely, inland capture, inland culture, and marine fisheries. In 1990–1991, total shrimp production in the country was 80,384 tonnes in which cultured shrimp contributed 24 %. In 2007–2008, the total shrimp production increased to 223,095 tonnes of which cultured shrimp contributed 42.23 %. That means the shrimp production share from the culture sources increased by 18 % as compared to 1990–1991. There were a total of 30.80 million fish and shrimp/prawn farmers in 2007–2008 comprised of 11.50 million shrimp farmers and 19.30 million fish farmers in the country. Figure 1 shows the shrimp production by major shrimp producing nations over last couple of years.

3 Role and pattern of shrimp aquaculture in Bangladesh

The export-oriented production of frozen seafood plays an important role in the national economy of Bangladesh. In 2009, number of licensed fish processing plants of Bangladesh was 130,117 and fish processing plants approved by the EU was 67 (BFFEA 2009). The number of shrimp hatcheries was 57 in 2007–2008 (BFFEA 2009). Frozen seafood earned US$ 550.53 million of foreign exchange from export in the financial year 2007–2008, to which shrimp contributes with approximately 81 % (BSFF 2008). There of shrimp aquaculture accounts for 42.2 % of total production. The remainder comes from marine and coastal sources by means of capture fishery (Table 1). Shrimp farming activities alone both directly and indirectly employ more than 0.6 million people in the country (Islam et al. 2005). The major markets for the Bangladesh shrimp have been the USA, UK, Belgium, Germany and Japan. Percentage of shrimp exported to different countries of the world is presented in Fig. 2. From 2002–2003 to 2007–2008 the quantity exported to the USA was on the increase. The quantity of shrimp exported to the USA was 26 % of the total exported in 2002–2003 which increased to 46 % in 2007–2008 (DoF 2009).

Table 1 Annual shrimp production (tonnes) and percentage contribution of shrimp aquaculture in Bangladesh (1990–1991 to 2007–2008)

Years	Shrimp catch (tonnes)				% of cultured shrimp
	Inland fisheries		Marine fisheries	Total	
	Capture	Culture			
1990–1991	43,262	19,489	17,633	80,384	24.24
1991–1992	61,042	20,335	20,042	101,419	20.05
1992–1993	78,226	23,530	23,975	125,731	18.71
1993–1994	50,721	28,302	21,519	100,542	28.15
1994–1995	58,973	34,030	20,363	113,366	30.02
1995–1996	44,079	46,223	26,353	116,655	39.62
1996–1997	41,868	52,272	24,818	118,958	43.98
1997–1998	46,635	62,167	24,790	133,592	46.53
1998–1999	49,296	63,164	31,742	144,202	43.80
1999–2000	43,167	64,647	31,395	139,209	46.44
2000–2001	44,343	64,970	31,037	140,350	46.29
2001–2002	54,965	65,579	31,976	152,520	43.00
2002–2003	60,876	66,703	31,931	159,510	41.82
2003–2004	63,103	75,167	36,488	174,758	43.01
2004–2005	68,768	82,661	44,261	195,690	42.24
2005–2006	77,381	85,510	48,119	211,010	40.52
2006–2007	82,422	86,840	51,869	221,131	39.27
2007–2008	75,678	94,211	53,206	223,095	42.23

Source DoF (2009)

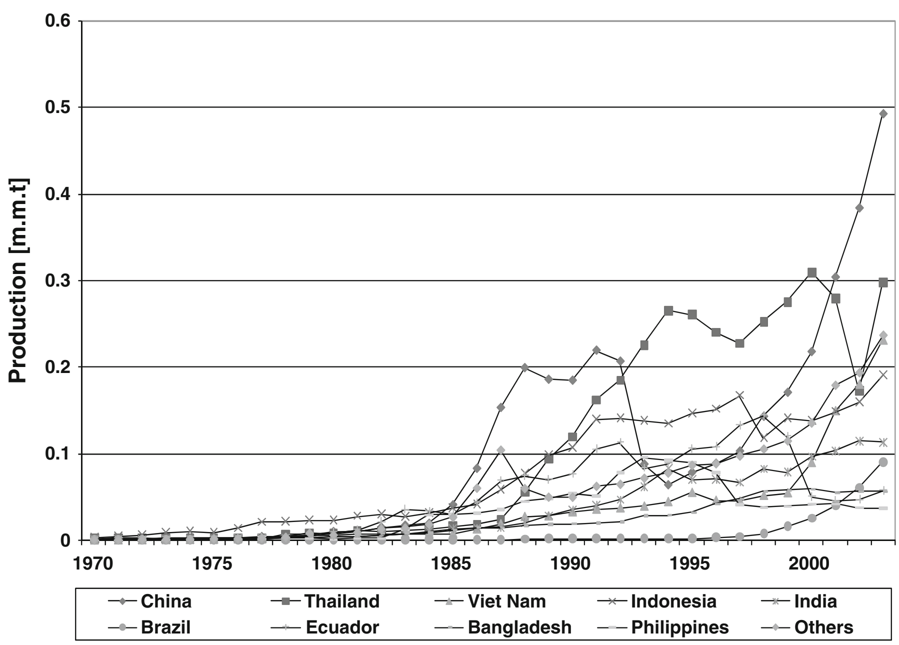

Fig. 1 Shrimp production by major shrimp producing nations since 1970 (FAO 2008)

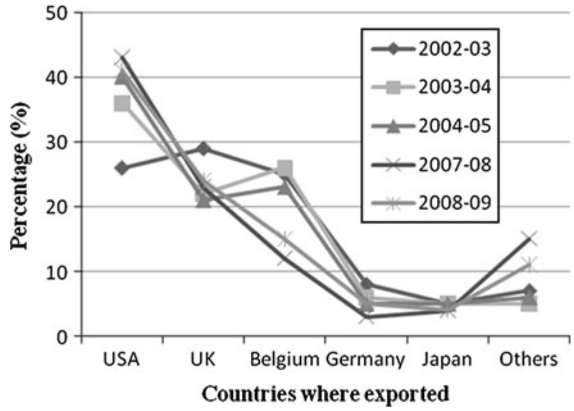

Fig. 2 Percentage of shrimp exported from Bangladesh to different countries from 2002 to 2008

Shrimp aquaculture has expanded from the south-eastern to the south-western parts of the coastal areas of Bangladesh because of its suitable climatic conditions and the availability of resources such as feed, seed, water and cheap labour (Islam 2003). The smooth 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). 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. 2008). Bangladeshi shrimp aquaculture can be classified into four categories: traditional, extensive, semi-intensive and intensive as shown in Table 2 (Deb 1998; Islam et al. 2005; Paul and Vogl 2011); 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 totally based on the intensity of the culture pattern such as stocking density, inputs (feed, fertilizer), seed source, diversity of species, production cost and water quality management. 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 extensive, 25 % semi-intensive, and 5 % intensive culture techniques (Hussain 1994).

4 Environmental impacts of shrimp farming

The impacts of shrimp farming on the environment, ecology and society of Bangladesh are shown in Table 3. Rapid development of shrimp farming brings a series of negative environmental impacts, like ecological imbalance, environmental pollution and disease outbreaks etc. Thus, shrimp farming is facing management-related difficulties which lead to greater concerns about its sustainability.

4.1 Destruction of the mangrove ecosystem

A number of shrimp ponds have been developed along the periphery of Sundarbans mangrove reserve forest area due to the most notable ecosystems that have fallen prey to shrimp pond construction, with the massive destruction of mangrove forest. The exact rate of mangrove destruction due to the construction of ponds in the south-western parts of Bangladesh is not yet known. The process of mangrove destruction in South-Western districts of Bangladesh started two decades ago, which harm the natural environment, ecosystem and social systems (Deb 1997). A lot of literature points to the fact that the biodiversity of mangrove forest 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 major 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 investigators in different parts of the world (Primavera 1997; Dierberg and Kiattisimkul 1996; Hein 2002). Primavera (1998) have reported that 6,500 ha mangrove forest were destroyed due to shrimp farming in Bangladesh. Mangrove destruction due to shrimp farming in Bangladesh is shown in Table 4. The study of Shahid and Islam (2003) revealed that approximately 9,734 ha of mangrove were lost in the southeastern part could be directly attributed to shrimp culture. In Indonesia, Philippines, Thailand, Vietnam and Mexico mangrove forest were damaged due to shrimp cultivation 55, 67, 84, 37 and 30 %, respectively (WRI 2000). However, shrimp aquaculture is not the only reason for mangrove degradation; other land uses such as rice production

Table 2 Comparison of four different types of shrimp aquaculture practices

Criteria	Intensity of farming systems			
	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. Yield (t/ha/year)	0.1–0.5	0.6–1.5	2–6	7–15
6. Production cost (US $/kg)	No data	1–3	2–6	4–8
7. No. of crops/year	1–2	1–2	2–3	2–3
8. Diversity of species	Polyculture	Polyculture	Monoculture	Monoculture
9. Lime used (kg/ha/year)	Little or no	<100	250–400	500+
10. Fertilizers used (kg/ha/year)	Little or no	Cowdung-500, little or no urea/TSP	Cowdung-2,000+, Urea-300+, TSP-100+	Cowdung-4,000+, Urea-500+, TSP-200+
11. Chemicals used	No	No or little	Used	Widely used
12. Survival rate (%)	50–60	60–80	70–80	70–90
13. Feed used	Natural	Natural or low cost feed	Natural and pelleted feed	Formulated complete feed
14. Water exchange	Tidal	Tidal, pumping	Tidal, pumping	Pumping, reservoir
15. Aeration	No	No or little	Yes	Yes
16. Employment (Persons/ha)	No data	<7	1–3	1
17. Disease problems	Rare	Rare	Moderate	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	Little	Moderate to high	Extremely high
21. Social implications	Little or no	Little	Moderate to high	Extremely high
22. Economic proliferation	Subsistence	Subsistence	Commercial	Entrepreneurial
23. Sustainability concerns	High	Moderate to high	Moderate to low	Low

Source Primavera (1993, 1998), Dierberg and Kiattisimkul (1996), Deb (1998), Rönnbäck (2002), Islam et al. (2005), Paul and Vogl (2011)

and salt production have also caused to the destruction of mangrove forests in Bangladesh (Deb 1998).

4.2 Pollution

Poor quality feed is the main pollution source of the farming and its adjacent waters, although the soluble organic matter is the important element of water quality of the environment (Yang et al. 1999). Feed reacts with many elements (pH, temperature, osmotic pressure, wave strike and chemical reaction) by resolving, swelling, breaking, pulverization and desquamation etc. Feed additives dissolve 12.4–13.2 % in 5 min and 17.0–23.9 % in 120 min and soluble matter dissolves rapidly and completely (Chen et al. 1995). 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 6 days at full and new moon in every fortnight at a rate of 0–10 % of the total pond volume (Wahab et al. 2003). Directly discharged effluents can easily pollute the surrounding water and soil quality (Deb 1998). Effluents from shrimp ponds are typically enriched in suspended solids; nutrients such as ammonia, nitrate, nitrite; Chlorophyll a and biochemical oxygen demand (BOD) (Table 5) (Barraclough and Finger-Stich 1996; Paez-Osuna 2001). The discharging effluents can reduce the dissolved oxygen,

Table 3 Some concerns caused by the activities of shrimp culture in the coastal areas Bangladesh

Impact/issue	Fry catching	Fry import	Pond construction	Feed waste	Water exchange	Antibiotics	Lime and Fertilizer	Disease	Overall aquaculture
Water quality	–	–	++	++	++	++	+	++	+
Salt intrusion	–	–	++	–	–	–	–	–	++
Mangrove destruction	+	–	+++	–	–	–	–	–	++
Biodiversity	++	+	++	++	++	+	+	++	++
Artisanal fishery	+++	–/+	–/+	–/+	–/+	+	–/+	–/+	++
Erosion	–	–	++	–	+	–	–	–	+
Calamity	–	–	–/+	–	–	–	–	–	+
Soil acidity	–	–	++	–	++	–	–	–	+
Hydrology	–	–	++	–	–	–	–	–	+
Eutrophication	–	–	–/+	++	++	–	++	–	+
Public health	–	–	–	–/+	+	++	+	+++	++
Rice production	–	–	++	–	++	–	–	–	++
Rural unemployment	–	–	–/+	–	–	–	–	–	+
Land use conflict	–	–	+	–	–/+	–	–	–	+
New disease	–	++	–	+	+	+	–	–/+	+
Social structure	–	–	–	–	–	–	–	–	++

–: No impact, +: Low impact, ++: Moderate impact, +++: Strong impact; *Source* Primavera (1997), Deb (1998), Ahmed (2003), Wahab (2003), Paul and Vogl (2011)

Table 4 Mangrove destruction due to shrimp farming (Shahid and Islam 2002; Hoq 2007)

Area	Mangrove area (ha)		Denuded area (ha)	Cause	Present use	Impact	Remark
	1975	1998					
Gorikhali	36	–	108	Shrimp farming	Shrimp farming	Loss of habitat for wildlife	Denudation started before 1975
Jangalkanda	Non-forest area	Non-forest area	No denudation of forest	–	Shrimp farming	Increasing salinity in buffer zone	Outside the Sundarbans
Kalabogi	Non-forest area	Non-forest area	No denudation of forest	–	Rice and shrimp culture alternatively	Increasing salinity in buffer zone	Outside the Sundarbans
Kailasganj	Non-forest area	Non-forest area	No denudation of forest	–	Shrimp farming	Increasing salinity in buffer zone	Outside the Sundarbans
Khajuria	Non-forest area	Non-forest area	No denudation of forest	–	Rice and shrimp culture alternatively	Increasing salinity in buffer zone	Outside the Sundarbans
Dhangmari	Non-forest area	Non-forest area	No denudation of forest	–	Agriculture	–	Outside the Sundarbans

create hypernutrification and eutrification, increase sedimentation load, and cause changes in the benthic communities (Flaherty and Karnjanakesorn 1995; Flaherty et al. 2000).

4.3 Sedimentation

Water runoff during the rainy season carries sediments from upstream through river tributaries to coastal

Table 5 Pollution load and recommended water quality parameter values for shrimp culture

Parameters	Pollution load from shrimp culture			Recommended water quality parameter values for shrimp culture		
	Sebastian (2009)	Islam et al. (2004a, b)	Kumar et al. (2012)	Nunes et al. (2005)	Alves and Mello (2007)	Chávez (2008)
Temperature (°C)		31.81	29.8	22–32	26–32	18–33
DO (mg/l)		7.07	7.1	>3.0	≥5.0	2.5–10
pH	8.5	8.27		6–9	7–9	7–10
Ammonia Nitrogen (mg/l N–$NH_{3,4}$)	0.1	0.017 (NH_3)		<0.1[a]	<0.3[a]	<0.20[b]
Nitrate (mg/l N–$N0_3$)	0.2	1.80	0.00087	<60	0.2–20	0.4–0.7
Nitrite (mg/l N–NO_2)		0.009		<1.0	<0.3	0.001–0.2
Orthophosphate (mg/l)		0.633	0.0084	<0.5	<0.4	0.01–0.20
Silica (mg/l)				>1.0	≥2.0	5–20
Chlorophyll-*a* (mg/l)				35–50	–	–
Salinity (ppt)		15	31		15–25	–
Transparency (cm)		26.66		35–50	40–60	–
Total Alkalinity (mg/l CaCO3)	90	180.34		>100	–	50–150
Total Hardness (mg/l CaCO3)	1,580			>150	–	5,700–6,600
Calcium (mg/l)				>100	–	350–450
Magnesium (mg/l)				>50	–	1,200–1,350
Potassium (mg/l)			778	–	–	375–400
Marine (UFC/ml)				<10,000	–	–
TCBS (UFC/ml)				<1,000	–	–
Turbidity (FTU)		274				
Total suspended solids (mg/l)	74	420	75			
TDS (mg/l)		570.7				
COD (mg/l)	21.7	8.00				
BOD (mg/l)	9.4					
Primary productivity (gC/m^3/h)		0.352	0.392			

Source Ferreira et al. (2011)

[a] NH_3 (not-ionized ammonia): toxic form

[b] $NH_{3,4}$ (total ammonia)

areas. 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). 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). Shrimp farming increases suspended solids or colloids that produce turbidity (Table 5), 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).

4.4 Use of antibiotics and other drugs

Shrimp culture in Bangladesh relies highly on the input of artificially formulated feed and the application of agrochemicals, antibiotics and disinfectants. The most common antibiotics are used in shrimp hatcheries of Bangladesh were given in Table 6. Overuse of these antibiotics results in too much antibiotics residues in the aquaculture products, which leads to not only the decrease in the immunity of the aquaculture products, but also the decrease in the disease resistance of consumers and the increase in the possibility of infecting the disease (Gräslund and Bengtsson 2001; Holmström et al. 2003; Cabello 2006; Uddin and Kader 2006; Sapkota et al. 2008). These chemicals may be classified as therapeutants, disinfectants, water and soil treatment compounds, algicides and pesticides, plankton growth inducers (fertilisers and minerals) and feed additives. Excessive and unwanted use of such chemicals results in problems related to toxicity to non-target species (cultured species, human consumers and wild biota), development of antibiotic resistance and accumulation of residues (Primavera 1998). The most common products used in shrimp aquaculture are fertilizers for the enhancement of natural feed and liming material for water and soil control. Overuse of lime results in the growing and over abundance of cyanophytes and the restraining of propagation of diatom. 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). The quantities of these products usually vary, depending on the type of management system followed (Gräslund and Bengtsson 2001; Uddin and Kader 2006).

4.5 Diseases

Some of the diseases that trouble the shrimp farming industry are directly caused by environmental problems, while a number of other diseases are triggered or spread more effectively by the stress induced by environmental problems. None of the shrimp diseases are known to be pathogenic to humans. In recent years, shrimp farming has been afflicted with outbreaks of bacterial diseases that have greatly undermined profitability and sustainability of operations (Table 6). 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). 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). Typical values of key water parameters for healthy shrimp cultivation are given in Table 5. Disease outbreak has been recognized as the biggest obstacle to the development of shrimp aquaculture in Bangladesh.

4.6 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 (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 altered soil chemistry. Prolonged inundation inhibits the fixation of free nitrogen and halts mineralization, thus impairing soil fertility within a few years (Islam 2003). Pumping large volumes of underground water to achieve brackish water salinity led to the lowering of groundwater levels, emptying of aquifers, and

Table 6 Common antibiotic usage in the shrimp hatcheries of Bangladesh

Antibiotics	Half life	Persistance	Disease names	Pathogens
Prefuran	–	–	Vibrio infaction	*Vibrio parahaemolyticus*
Furazolidone	18 h	9 days[a]		*Vibrio anguillarium*
Oxytetracycline	125 days	>185 days[b]		
Chloramphenicol	1.6–4.6 h[c]	–	Luminiscent bacteria	*Vibrio harvey*
Erythromycin	2–3 h[d]	–		*Vibrio aplendious*
Furazolidone				
Malachite green	2.1 h	80 days[e]		
Neomycin sulphate	–	–		
Chloramphenicol			Filamentous bacteria	*Leucothrix mucor*
Neomycin sulphate				
$KmnO_4$	–	–		
Formalin + malachite green				
Malachite green			Shell disease	Bacteria belonging to *Vibrio*, *Aeromonas* and *Pseudomonas* group
Formalin (37–40 % formaldehyde)	2–3 days[f]	–		
Oxytetracycline				
Treflan	2–3 days[g]	–	Larval mycosis	*Legenidium* spp.
Malachite green				
Malachite green			Protozoan infection	*Zoothamnium* spp.
Formalin				*Vorticella* spp.
Methelene blue	–	–	Blac Gill disease	Chemical contamination
Prefuran	–	–		
Malachite green				
Flumequine	155 days	>185 days[b]	–	–
Ormetoprim	–	<30 days[h]	–	–
Oxolinic acid	165 days	>185 days[b]	–	–
Sulfadiazine	–	>180 days[h]	–	–
Sulfadimethoxine	–	>180 days[h]	–	–
Trimethoprim	–	>30–<60 days[h]	–	–

Source Primavera et al. (1993), Alderman and Hastings (1998), Gräslund and Bengtsson (2001), Uddin and Kader (2006)

[a] Samuelsen et al. (1991)

[b] Hansen et al. (1992)

[c] HSDB (1995)

[d] Jerry and Zuckerman (2004)

[e] Sudova et al. (2007)

[f] Jung et al. (2001)

[g] Sanders and Seiber (1983)

[h] Samuelson et al. (1994)

salinization of adjacent land and waterways (Flaherty et al. 2000). Even when fresh water is no longer pumped from aquifers, the discharge of salt water from shrimp farms located behind mangroves still causes salinization in adjoining rice and other agricultural lands (Primavera 1993; Dierberg and Kiattisimkul 1996). In the southwestern parts of Bangladesh, salinization reduces water supplies not only for agriculture but also for drinking, domestic needs and irrigation (Deb 1998; Patil and Krishnan 1998). Islam (1999) reported that the mean values of salinity of water were 1.2 and 1.64, 4.25 and 5.14 in the low and medium zones while these were 9.75 and 9.17 in the high saline zones in southwestern Bangladesh. The discharge of saltwater from shrimp ponds also causes salinization in adjoining rice and other agricultural lands. Ali (2006) reported that, saltwater intrusion has caused problems in terms of severely decreased supplies of potable freshwater, which again has led to increase of gastrointestinal infections as well as loss of diversified crops, poultry and fodders in southwestern Bangladesh.

4.7 Introduction of exotic species

The scarcity of wild shrimp seeds has inspired traders to import them from different countries. The practice of transporting shrimp seeds between facilities and/or different geographic regions has resulted in the introduction of five of the six known penaeid shrimp viruses to regions where they may not have previously existed. 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.

In addition to pathogens and diseases, introductions of aquatic species can lead to habitat changes, disruptions of host communities by competition and predation, and genetic interactions with native populations. 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).

4.8 Wild fry catch and decline in biodiversity

Shrimp aquaculture farms in Bangladesh stock wild-caught juveniles rather than hatchery-reared post-larvae that causes loss of biodiversity. Although hatchery post-larvae are now available in many countries in Asia and Latin America, wild fry still provide the major source of seed in others. 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 2009). Capture fisheries are used to supply trash fish to make fishmeal. 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). The high proportion of fish meal in the shrimp aquaculture industry has induced a loss of wild capture fish stock (Primavera 2006). Over exploitation of the adults and larvae of both target and incidental shrimp species could be the cause of declining wild shrimp stocks in some locations. In West Bengal, India, where shrimp seed collection constitutes a significant fishery, the contribution of adult shrimp to fisheries landings decreased from 14.4 % in 1970–1971 to 8.1 % in 1989–1990 (Banarjee and Singh 1993). 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).

5 Social and economic impacts of shrimp cultivation

Shrimp farming is one of very few options for economic development in poor coastal areas with saline soils, and has the potential to enormously enhance small holder income, or to provide relatively well-paid employment at larger operations. Despite claims to the contrary, it appears that shrimp farming can create relatively high levels of employment per unit area of land when compared with most feasible alternatives. However, in addition to the environmental impacts, the social and economic impact of shrimp aquaculture has been widely discussed by several scholars (Barraclough and Finger-Stich 1996; Stonich and Bailey 2000; Alam et al. 2005; Primavera 2006). The key social issues are the marginalization of the rural poor, their increasing landlessness, breakdown of traditional livelihood support systems, increasing poverty, diminishing food security, and the transfer of land and wealth to local and national elites.

5.1 Loss of land security

The shrimp farming system has significant impacts on land holding patterns and land tendril system in southwest Bangladesh. The politically and financially strong large farmers exploit marginal and small farmers. Marginal and small farmers have to sell their small agricultural farmland very cheaply. Sometimes the strong farmers capture nearby farmer's small plots without any payments or sometimes they pay a very small amount of money as land rent. When investors either get access to an area for shrimp aquaculture by purchasing land or by forcibly taking it, land prices skyrocket (Barraclough and Finger-Stich 1996; Ito 2002). In Bangladesh, land prices have raised 18-fold between 1994 and 2000 (Ito 2002). In India and Thailand, in addition, 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. As a result, small and marginal farmers are deprived of conventional farming. Therefore, the small and marginal farmers are diminishing from the agricultural sectors mainly due to the introduction of shrimp farming and the involvement of large numbers of so-called politicians and large farmers. A large number of small and marginal farmers have already migrated to other places for employment and better living.

5.2 Changes in agricultural pattern

Many shrimp ponds have been constructed on ex-agricultural land, especially rice paddy. Here, although land is often privately held, a transfer of land-use (if not ownership) has occurred from the former small-scale farmers to larger private shrimp farming concerns. The means of transfer reported have covered legal sale of deed, forced sale through harassment, sale following degradation of the land by shrimp farm pollution, sale after inundating and degrading the land with salt water, and evictions of tenants. The effects are much the same as for mangroves—an established livelihood support system is broken down as land with multiple agricultural uses is turned over to mono-crop production. 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). These types of land conversion are the following results: rural peasants become detached from reliance on the land and are effectively made available to the wage labor market; food production (and other products) for own-consumption and local markets declines; food security worsens as livelihoods more dependent on both the market for shrimps and the market for foodstuffs;changes in land use and ownership lead to conflict sometimes violent between dispossessed groups and new capitalist owners (Neiland et al. 2001). In addition, 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).

5.3 Food insecurity

Global food security needs are used to justify the heavy promotion and subsidy of aquaculture development by national and international lending agencies. This is a paradox, because most cultured shrimp is destined for luxury export markets. The development of shrimp culture is driven by economic realities, not the goal of improved domestic nutrition. Shrimp culture has adversely affected food security through (a) loss of rice lands by pond conversion or salinization, (b) shifting of culture ponds from milkfish and other domestic food crops to shrimp, and (c) declining near shore fish, crustacean and mollusc catches associated with mangrove deforestation. Decreasing rice production in south-western part of Bangladesh can be traced to salinization and loss of soil fertility as saltwater canals from shrimp ponds cut across paddy fields (Shiva 1995). Moreover, shrimp monoculture has led to the decline of traditional pokily fields in Bangladesh, where alternating rice and shrimp harvests have been sustainable (Baird and Quarto 1994). Consumer demand in rich nations drives the development of the industry. Perhaps the demand would decrease if consumers became aware of the devastating effects caused by their consumption of cultured shrimp.

5.4 Marginalization, rural unemployment and migration

Instead of improving living standards and village welfare, shrimp farming brought about social displacement and marginalization of farmers. The introduction of shrimp farming to the Chokoria Sunderbans in Bangladesh did not improve the socio-economic status of poor people -fishers became daily labourers, peasants lost their grazing lands and others became jobless (Choudhury et al. 1994). Among other factors, the conversion and salinization of rice and other agricultural lands also leads to the marginalization of coastal rural communities. Dispossessed farmers are forced to seek work elsewhere. Migrating to the cities and swelling the ranks of the urban unemployed (Alauddin and Hamid 1996) and leaving women and children alone for long periods (Barraclough and Finger-Stich 1996). The development of shrimp farming in the Satkhira region of Bangladesh has displaced nearly 120,000 people from their farmlands (Baird and Quarto 1994). Modern shrimp farms are capital- rather than labour-intensive. A 40-hactre shrimp farm in India employs only 5 laborers while an equivalent rice farm would need 50 (Shiva 1995). In Indonesia, a rice crop requires an average of 76 workdays ha^{-1} compared with 45 for an extensive shrimp farm (Barraclough and Finger-Stich 1996). Employment of local people in shrimp farms is often limited to low-paying, unskilled jobs such as laborers and guards, while technical and managerial positions are reserved for outsiders. Moreover, funds invested in these farms are mostly generated from the outside. Therefore, profits also leave the community. Three-quarters of the shrimp farmers-investors in the coastal areas of Khulna and Satkhira in Bangladesh in the early 1990s were businessmen from outside the local community (Barraclough and Finger-Stich 1996). One reason was that the lease fee was beyond the reach of local people.

5.5 Social unrest and conflicts

Disruption to local livelihoods and communities has sometimes been sufficient to reveal social disquiet, and in some cases serious social disturbances, e.g., in Bangladesh, India (Murthy 1997). The reasons behind these disquiets and conflicts are the entry of multinational corporate investors or the national elite into local shrimp culture industry. They can provide the necessary capital, have easier access to permits, credits, subsidies, and can absorb financial risks. In this context, local communities in coastal areas and small farmers are disadvantaged. 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. Powerful property owners maintain a linkage with political leaders and the local administration to lease wide areas of land for shrimp culture (Gain 1995). It is clear that there have been social conflicts, and in some cases, more widespread social disturbances associated with shrimp farming.

6 Management approach

Shrimp cultivation has ecological impact in terms of salinity increase, mangrove destruction, pollution, sedimentation, diseases, land degradation, destroying marine species and loss of biodiversity. In spite of the negative impact on ecology, the economic importance of shrimp cannot be overlooked for a developing country like Bangladesh. Proper management can ensure a sustainable growth and benefit of shrimp cultivation. Protection and restoration of aquatic environment from pollution of shrimp cultivation is the most essential theme of environmental management.

For the reduction of nutrient release from shrimp farming, essentially two different promising strategies are ecological or organic approach and latest developments in biotechnology for the highest possible productivity and economic profit. Biao and Kaijin (2007) reported that the reduction of nutrients inputs was an effective strategy for lowering the load of nitrogen and phosphorus released into the adjacent environment from the shrimp aquaculture which has especially focused on improving the manufacture of a feed and fertilizer as low in nutrient content as possible without hampering the growth of cultivated shrimp. A fundamental principle in ecological aquaculture production is to reduce environmental impact as much as possible while developing a valuable and sustainable aquatic ecosystem. The ecological approach emphasizes that the cultivation is done at lower intensity and that efforts to farm shrimp are more in tune with ecosystem processes and functions, e.g., by creating large buffer zones that reserve the discharged wastewater for treatment and provide ecological services, and adapt the farming to the

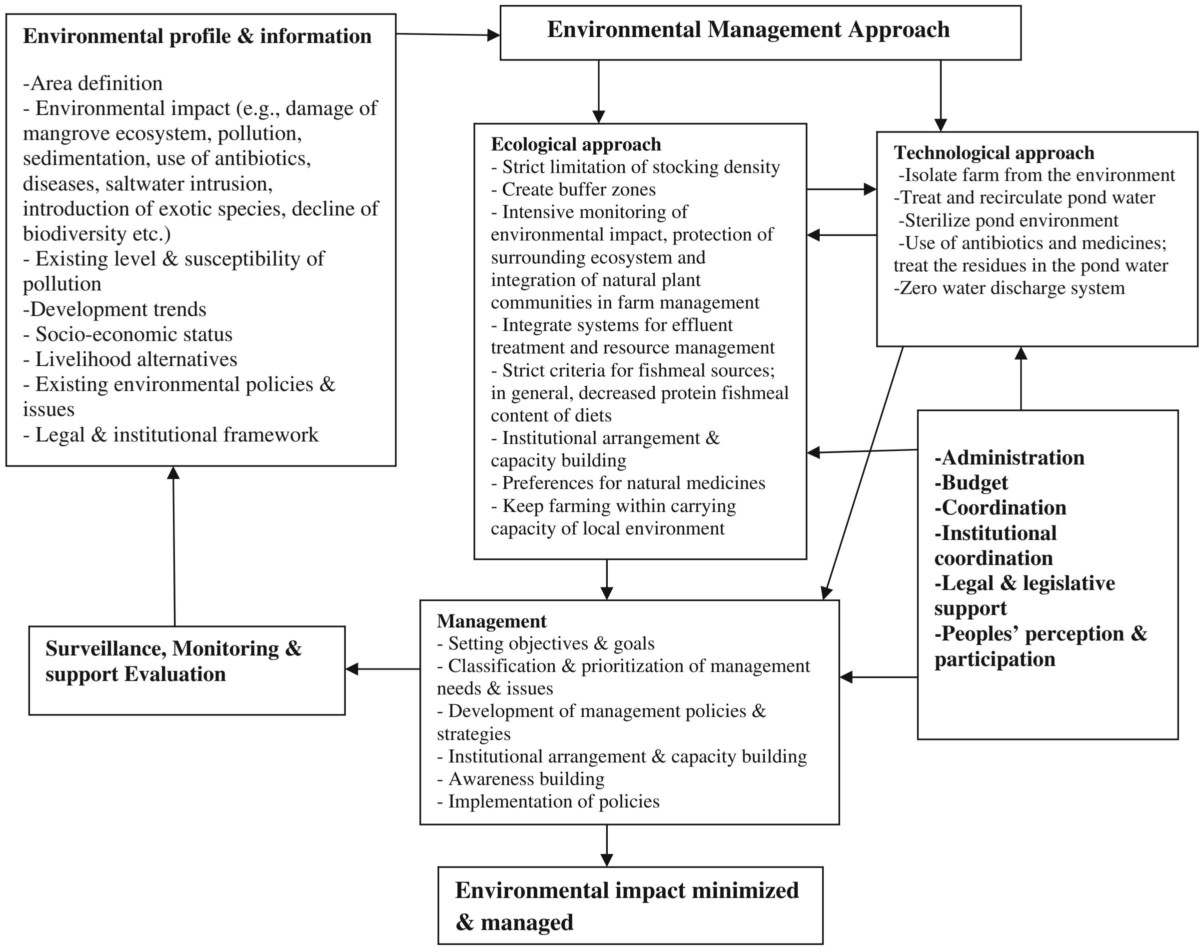

Fig. 3 Conceptual model for environmental impact management of shrimp cultivation. *Source* Deb (1998), Rönnbäck (2002), Islam and Tanaka (2004), Biao and Kaijin (2007), Hoq (2007), Paul and Vogl (2011)

local carrying capacity (Biao and Kaijin 2007). Problems in dealing with environmental pollution were identified as poor communication between scientists and managers, weak institutional structures and manpower capabilities, lack of sectoral integration and approach to environmental management, lack of cooperation between public and private sectors etc. (Williams 1996). The management approach may be highly variable depending upon the ecosystem and the degree of deterioration and management problems and goals. The conceptual model (Fig. 3) should, therefore, have four essential components; the main component, the management body, supported by ecological and technological solution approaches, and monitoring and evaluation. Information on the environmental features is the primary to formulate subsequent ecological and technological solutions and management needs. Suggestions concerning the key point for managements as well the management strategies come from an extensive and effective research and baseline information on ecological and technological approaches. The management component must have the capacity to effectively identify objectives, classify the issues, prioritize management needs and formulate management plans.

In Bangladesh, shrimp is cultivated in approximately 20, 3071 ha of land (Gammage et al. 2006). Since, these shrimp aquaculture requires the frequent exchange of water to maintain the salinity and water quality, discharged wastewater from shrimp ponds pollute the nearby rivers, estuaries or coastal waters and produce heavy loads of wastes which are a mixture of organic and inorganic nutrients, different types of chemicals, fertilizers, bacteria, viruses and other micro flora. For the treatment of effluent water, a sediment trap pond and a constructed wetland can be set up which will improve the water quality as well as reduce the sediment, nutrient and pollutant load. The integration of constructed wetland with phytotechnologies has the potential to convert nutrients and pollutants into plant biomass (Sohel and Ullah 2012). It is observed that plant composition also plays major role in getting improved performance of constructed wetland (Kadlec and Wallace 2009). Some factors determine the suitability of plant species used to construct wetland for treating saline wastewater such as, tolerance to saline condition and flooding, capability against high loads of wastewater, biomass production, rooting depth, and gas transport mechanisms (Brix 1994). Here, plant species are first to be considered growing in salt marsh bed (Gaag et al. 2010). Adopting this approach for shrimp aquaculture will cause an increase in the nutrient uptake, sediment trapping and enhancing the self-purification processes. Sediment accumulated from the bottom of a sediment trap pond can be used as fertilizer, which contains variety of nutrients. A constructed wetland also plays an important role in the uptake of nitrogen and phosphorus; enhancing the denitriphication processes, decomposition of biodegradable organic matter, removal of pathogens and decomposition of toxic organic compounds (Zalewski et al. 2004). A number of authors suggest that constructed wetland might be applied in reduction of nutrient loads and in the water quality improvement (Sun et al. 2005), and this has been already implemented successfully in USA, Australia, Finland, Italy, New Zealand, Belgium and Poland (Kern and Idler 1999; Newman et al. 1999; Knight et al. 2000; Koskiaho et al. 2003; Poach et al. 2003; Rousseau et al. 2004). Moreover, the effectiveness of a sedimentation pond, fish-bivalves pond and constructed wetland is highly influence by the water retention time of the system (Schwartz and Boyd 1995; Verhoven and Meuleman 1999; Lin et al. 2002, 2005; Imfeld et al. 2009). It is necessary to integrate intensive and semi-intensive culture systems to implement this technology for wastewater treatment (Varadi 2003; Varadi and Bekefi 2003) which include a combination of fish-bivalves pond, sedimentation pond and constructed wetland.

For a successful management, effective coordination with related departments/sectors and institutions (e.g., department of industry, fisheries, agriculture, forest, social affairs, law etc.) is necessary to overcome management related problems and obstacles such as land use conflicts and to have legal and legislative supports (Islam and Tanaka 2004). The ecological and technological approaches and management components should be closely related, i.e., the information obtained through ecological and technological solutions will be used by the managers to formulate management plans and directions. Monitoring and evaluation is very much needed for continual improvement of environmental management approach of shrimp cultivation.

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 important precondition to minimize social discrimination, conflict 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 an essential 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). Twenty three major policies, laws, acts, rules and ordinances have been enacted in Bangladesh to develop the shrimp sector (DoF 2006; Maniruzzaman 2006; DoF 2010; Paul and Vogl 2011) (Table 7). The Department of Fisheries is the main agency for the development, implementation and management of 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

Table 7 Relevant fishery policies, laws, rules, acts and ordinances in Bangladesh

Title of policy/law/rule/act/ordinance	Aspects covered
The Canal Act, 1864	Develop and manage water body and infrastructure for shrimp farming
The Bangladesh Forest Act, 1927	Protect and preserve forest from destruction by shrimp farming
The Protection and Conservation of Fish Act, 1950	Conservation of fisheries resources
Embankment and Drainage Act, 1952	Protecting crops, not allowing cuts in embankments for shrimp cultivation
The Government Fisheries Protection Ordinance, 1959	Protection of government owned water bodies against unauthorized fishing
Bangladesh Water and Power Development Board Ordinance, 1972	Develop and manage water body and 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
The Protection and Conservation of Fisheries Rules, 1985	Framing rules for enforcement of various provisions of Fish Act 1950
The Protection and Conservation of Fish Rule, 1985	Conservation and management of fisheries resources
Manual for Land Management, 1990	Allocate unused state (Khas) land to the landless on a permanent or temporary basis
Shrimp Estate Management Ordinance, 1992	Allocate suitable state (Khas) land for shrimp culture
Water Resources Planning Act, 1992	Plan & manage water resources
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
National Land Use Policy, 2002	Plan & manage land use pattern and reduce land use conflict
Integrated Coastal zone Management policy, 2005	Reduce coastal vulnerabilities, improve the livelihood of the coastal people, ensure optimum use of coastal resources
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

Source Maniruzzaman (2006), DoF (2006), Paul and Vogl (2011)

permitting farmers to take up saline water into new 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. The use of chemicals and drugs has been regulated, and farmers are encouraged to apply sustainable pond management techniques. As for the existing provisions, each shrimp farm has to register and get a license 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, laws, rules, acts and ordinances by the institutions concerned as well as institutional assertiveness is weak, so huge gaps exist in enforcement (Hein 2002; Alam et al. 2005). 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).

Some initiatives, which have been taken by the Bangladesh Government for sustainable shrimp farming, are:

- Government has declared the zoning of shrimp areas for providing effective support and growth control in a planned manner.
- The collection of shrimp fry from nature is banned officially by the government, and fries transport from the hatchery located in Cox's Bazar and other places regulated by government, because the shrimp farmers are not fully aware of the quality of the fry.
- Government has initiated preparation of a comprehensive plan encompassing the relevant resources under the Coastal Zone Management project, which focused on production of shrimp with little regard to socioeconomic and environmental consequences.
- Emphasized has given highly on infrastructure development of shrimp farming areas, socioeconomic development of the coastal fisheries, and structural development associated with modern technology to improve quality control for shrimp and fisheries products.
- Initiatives for the construction of water management infrastructures (sluice gates, canals, dikes) on public and private land, hatcheries for shrimp seed production, establishments of demonstration farms and training centres for technology demonstration and farmer training, and landing and service centres to provide post-harvest facilities.
- Government has taken necessary steps for conducting farmers training programs to increase technical knowledge of farmers, disease prevention, and improvement of management and prepared a good numbers of printed extension and training materials about shrimp culture. Sometimes, the Department of Fisheries (DoF), the Department of Fisheries, to a moderate extent, arranged trainings at their local level.
- Government of Bangladesh together with FAO and NACA made a regional network to address fish health and disease information systems in the package of culture practices, a training module, to the farmers for sustainable shrimp cultivation.

7 Conclusions and remarks

Shrimp is the second largest export industry in Bangladesh and has significant impacts on the national economy of Bangladesh. 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, loss of land security, food insecurity, rural unemployment, loss of livestock resources, social unrest and conflicts 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. The increasing negative environmental and social impacts have generated huge research efforts aimed at improving shrimp aquaculture's long-term sustainability. Therefore, proper management and planning can give a sustainable growth and benefit of shrimp cultivation. Keeping all these in view, the following recommendation may be taken to protect and manage the environmental impact of shrimp cultivation:

1. Establish procedures for EIA (environmental Impact Assessment) and monitoring to minimize the adverse ecological change and related social and economic impact resulting from water extraction, land use, effluent discharge, use of drug or chemical and other activities.
2. Coastal zoning should include improve land use planning, minimize conflicts over land tenure and identify appropriate areas for shrimp cultivation and areas that need to be protected. Saline water shrimp cultivation may be restricted only where the soil salinity level is high.
3. Need to engage all the different stakeholders in regular dialogue on issues affecting the industry to ensure sustainability and social equity of shrimp sector.

4. Need to improve extension mechanisms and improve linkage between farmers, extensionists and researchers to develop and select appropriate technology and make it more accessible to shrimp farmers.
5. Need for better cooperation and sharing and dissemination of information about disease prevention and control methods; improved disposal methods for diseased fry; guidelines on handling diseased fry; and training facilities for the farmers.
6. Fry catching should be monitored regularly and catching should be banned in areas where there are adequate hatcheries and in certain ecologically sensitive areas such as Sunderbans and migration routes.
7. Shrimp fry catching by currently used fine meshed nets should be prohibited or at least regulated through a licensing system. Mesh sizes for other nets should also be monitored.
8. Research should be conducted to find out the way for reclamation of salt affected soil for future use for agriculture purpose.
9. Research should be conducted to find out appropriate solution for post drainage management for the salt affected or waste water to be drained from a shrimp pond.
10. 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 areas using remote sensing and GIS applications should be undertaken.
11. An appropriate policy regarding shrimp cultivation should be formulated and implemented for proper management of shrimp farming.

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