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Assessment of aquatic health index for coastal aquaculture activity in and around South-east coast of Bangladesh

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ABSTRACT

Bangladesh's shrimp industry has been rapidly expanding since the early 1980s and is now a major source of export earnings. The coastal aquaculture is a century old practice in Bangladesh. The shrimp activities in the coastal zone of Bangladesh upgrade the lifestyle and increase the income level of many poor coastal people with increasing environmental degradation. The present paper is an attempt to evaluate the economically viable shrimp culture zone through enumeration of Aquatic Health Index (AHI) in and around south-east coast of Bangladesh that formerly known as Chakaria sundarban region. In the present programme, 10 important sites for coastal aquaculture activity area of in and around south east coast of Bangladesh were selected and and the aquatic health index value of these stations varied as per the order Ilishia (Stn. 9)> Badarkhali (Stn. 6) > Maghnama (Stn. 10)> Saharbill (Stn. 5)> Ciringa (Stn. 4)> Dulhajara (Stn. 3) > Khutakhali (Stn. 2)> Paschim Bara Veola (Stn. 7)> Fansiakhali (Stn. 8)> B.M. Char (Stn. 1). The lower value of the index reflects deteriorated condition of the coastal water due to excessive industrial, agricultural and domestic run-off. The high values of the index are the indicators of congenial coastal environment.

KEY WORDS: Aquatic Health Index (AHI), Chakaria sundarban, coastal aquaculture, shrimp industry

INTRODUCTION

Shrimp is one of the most valuable seafood commodities, accounting for approximately 20% of the value of internationally traded fishery products. The rapid growth of shrimp farming and trawling has had serious negative environmental impacts, with direct human consequences. Worldwide, shrimp farming has been associated with environmental degradation, increased social and economic disparities, and, in some countries, serious human rights abuses. Shrimp aquaculture has been responsible for destruction of large areas of ecologically and economically important mangrove and wetland habitats and the degradation of adjacent coastal and marine ecosystems, with implications for biodiversity conservation and ecosystem integrity. These same factors also undermine the very basis of shrimp production.

Shrimp culture is expected to continue to play an important role in ensuring food security and poverty alleviation, particularly for the rural poor. The urban population will be benefited from the improvement in processing, value adding, and marketing of the shrimp industry as a whole. Incidence like "EU ban on Bangladeshi shrimp" should not happen again and most importantly, this industry is operating under capacity and can increase the productivity up to five times than the current capacity. A majority of workers in the processing industries are women. The shrimp industry benefits three to four million "mostly poor" Bangladeshis while providing livelihood directly numbering some 11, 50,000 people. In 2007-2008, a total of 2, 23,095 Metric ton shrimp produced in Bangladesh that contributes 19,567.90 core taka in the GNP. There is ample demand in the international markets for shrimp and Bangladesh is blessed with an environment friendly for shrimp production. Technological innovation has been creating a greater impact on domestic economy. A primary study was undertaken to detect the problems plaguing the different levels of the value chain of shrimp in the country. The increasing demand and steadily rising prices of shrimp encouraged its cultivation in the coastal belt of the country (DoF, 2010).

. Bangladesh has placed a high priority on coastal aquaculture. Coastal aquaculture, particularly in shrimp aquaculture is presently an important coastal industry in Bangladesh (Thia-Eng *et al.*1989). However, this industry has come at a huge environmental cost to coastal communities and ecosystems (Salequzzaman, 2001: Yeh, 2002) because it is accompanied by mangrove destruction, loss of fishery communities and biodiversity, pollution of land and water, loss of employment activity, and even violation of human rights (Salequzzaman, 2001).

Coastal shrimp aquaculture in Bangladesh is mainly confined to two regions, namely: Khulna and Chittagong. At present 80% of the shrimp farms are located at the southwest (Khulna) region while the rest are located in the southeast (Cox's Bazar and Chittagong coastal area) and other coastal areas. Total area of shrimp culture area in south-east coastal region is now 33500 ha and average production of the targeted species is 401.5 kg/ha under the 2620 no of shrimp ponds (Table. 1) . In 2009-2010, total coastal aquaculture production in Bangladesh was 155866 MT which is 2 times higher than production of 90076 MT in 1986-1987 (Fig 1).

Due to difference in water salinity in the southwest and southeast region, the culture practices and production period of shrimp in the two areas are different (DOF, 2003). The Chakoria Sundarban areas located along with the south-east coast of Bangladesh on the location of Chakaria Upazilla in Cox's Bazar District. This coastal zone has a great importance since historical abundance of natural resources. The local communities of this area have been haphazardly utilizing these resources and as a result some of them are completely destruction as an example Chakaria Sundarban mangrove forest, where some resources are being over-utilized like coastal shrimp farming, salt production and natural fish stock.

Regular monitoring of the entire process is of utmost importance in this context to keep an eagle eye on the quality of aquatic phase in and around the shrimp culture activity zone. One important step towards this is scaling the water quality of the marine and estuarine compartment through consideration of relevant parameters, which are functions of space and time. The primary objective of scaling is to develop an index through which a single value can be assigned to the aquatic phase for the purpose of its scoring in terms of status, use and management. Thus water quality indices aim at giving a single value to a particular aquatic system on the basis of list of constituents (parameters/variables) and their concentrations in the said aquatic system. One can then compare different samples for quality on the basis of the index value of each sample. The present article is an approach to compare the water quality of 10 shrimp ponds distributed in 10 different zones in and around South East Coast of Bangladesh, with the aim to prepare a score card for rating these waterbodies in connection to the culture of tiger prawn (*Penaeus monodon*). But the present cuture system of shrimp culture is fully dependent on tidal water of Matamuhuri river and reuse water of shrimp ponds directly back to Matamuhuri river that deteriorates the water quality of the culture pond to a great extent. This leads towards poor growth, disease susceptibility and low flesh quality of the cultured species. It is at this point the importance of evaluating the culture condition arises, which has been highlighted in this article through Aquatic health Index (AHI). The index is basically a modified form of Brown's or the National Sanitation Foundation's water quality index (1970), with incorporation of aquatic salinity and pond bottom organic carbon, which are parameters of high priority for shrimp culture pond. The most important parameters selected by Brown (1970) for the NSFWQI were dissolved oxygen (DO), biochemical oxygen demand (BOD), turbidity, total solids, nitrate, phosphate, pH, temperature, pesticides and toxic elements. Significant ratings and weights were assigned to each parameter (Table 2), but absence of aquatic salinity is one major bar from using this index in the brackish water, coastal, estuarine and marine environment. The present programme was therefore undertaken with incorporation of aquatic salinity in the calculation as this variable not only controls the physiological state of marine and estuarine biodiversity, but also determines the nature of chemical species in the system. The rating of the parameters was done on a scale of 1 to 10 and were converted into final weight for evaluating the water quality of coastal, estuarine and brackishwater system.

MATERIALS AND METHODS

Site Selection

Chakaria Sundarban area was a mangrove forest of the Matamuhuri delta at Chakoria in Cox's Bazar district. The initial area of the Chakoria Sundarban area was about 18,200 ha and 7,490 ha of land were declared as Reserved Forest and rest of the area was Protected Forest (BBS, 2007). The area is the most extended plain landmass located between 21°35¢N to 21°48¢N latitude and 91°57 'E to 90 °5¢ E latitude. The total area between the Matamuhuri-Harbang Khals is the north; the confluence made Khal at the south, the Cox's Bazar-Chittagong highway in the east and the Maheskhali Channels in the west, covers about 260 Km2 and has been considered for the present Study. Chakaria is one of the moderately populated areas in the contest of Bangladesh (Hossain *et al.* 2003). The entire Chakoria Sundarban is now a barren area all the mangrove forest area is vanished only about 200 healthy trees are left. A number of reasons involve to destruction of this forest such as; (i) fuel-wood; (ii) overgrazing of cattle; (iii) spread of human settlements; (iv) fishing and (v) shrimp culture (Musa, 2008). Samplings have been carried out at ten different stations in and around the South East coast of Bangladesh namely B. M. Char

(Stn.1), Khutakhali (Stn. 2), Dulahajara Stn. 3), Ciringa (Stn. 4), Saharbill (Stn. 5), Badarkhali (Stn. 6), Paschim Bara Veola (Stn. 7), Fansiakhali (Stn. 8), Ilishia (Stn-9) and Maghnama (Stn. 10).

Analysis of hydrological parameters of pond water

The entire network of the present programme consist of the evaluation of the health of shrimp ponds with respect to selective physico-chemical variables like surface water salinity, pH, temperature, transparency, dissolved oxygen (DO), BOD (3-day at 27^{o}C), nitrate, phosphate, silicate and sediment organic carbon during 2009 culture period (February to September).

The relevant hydrological parameters in connection to shrimp culture are surface water salinity, pH, transparency, temperature, dissolved oxygen (DO), BOD (3-day at 27^{o}C), nitrate, phosphate, silicate and sediment organic carbon (for the present site). Surface water salinity was measured in the field by refractometer and cross-checked by argentometric method. pH of the pond water was measured by a portable pH meter (sensitivity = ± 0.02). Surface water temperature was measured by a Celsius thermometer and transparency was measured inn the field by using a Secchi disc of 30cm in diameter. D.O., B.O.D., nitrate, phosphate, silicate and sediment organic carbon were measured as per the procedure stated in Strickland & Parson (1968) and APHA (1995).

Aquatic Health Index evaluation

Of all natural resources, water is unarguably the most essential and precious. Life began in water, and life is nurtured with water. There are organisms, such as anaerobes, which can survive without oxygen. But no organism can survive for any length of time without water. Water quality indices aim at giving a single value to the water quality of a source on the basis of one or the other system which translates the list of constituents and their concentrations present in a sample into a single value. One can then compare different samples for quality on the basis of the index value of each sample.

This is an approach to understand the health of the aquatic system by considering all the parameters of water quality relevant for coastal aquaculture. Depending on the importance of the parameter they are allotted a ranking value of 1 (highest) to 10 (lowest) . To convert ratings into weights, a temporary weight of 1.0 was assigned to the parameter, which received the highest significance ratings (here dissolved oxygen received the topmost score). All other temporary weights were obtained by dividing the highest rating by each individual mean rating. Each temporary weight was then divided by the sum of all the temporary weights to arrive at the final weight of each parameter (Table 2). The sum of the product of the individual final weight (Wi) and individual quality rating (qi) were used for evaluating the water quality of coastal, estuarine and brackish water system through AHI as per the following expression:

where, Wi = weight of ith parameter, qi = quality of the ith parameter (a number between 0 and 100).

RESULTS AND DISCUSSION

Successful coastal aquaculture practice is a direct function of the optimum values of hydrological parameters, which are prescribed by statutory bodies like pollution control authority or aquaculture authority. Individual quality rating (of parameters) is done on the basis of deviation from the respective optimum figure, which has been refereed to as the measured value in the present manuscript (Table 3). This rating reflects the congenial environment in almost all the shrimp ponds of the study area with respect to dissolved oxygen, aquatic pH, temperature, nitrate and sediment organic carbon. However, certain parameters like BOD, phosphate and silicate level have deviated from the optimum values to such an extent, that their individual quality rating has reduced (Table 3), which is ultimately reflected in the AHI values (Table 4).

Dissolved oxygen is the most critical water quality variable in aquaculture (Boyd, 1989) and it can be a limiting factor in shrimp culture (Wyban *et. al*., 1987). Bafru (1996) reported that D.O range should be 5-7 mg/l and DoF (2003) stated that D.O level 4.0-6.0 mg/l is the ideal value for *P monodon* culture in Bangladesh. Range of dissolved oxygen varied from 3.96 mg/ l to 5.97 mg / l in all the experiemental stations. So, the present study for D.O range in shrimp ponds clearly ensured for suitable range of coastal aquaculture.

The pH of normal brackish water usually is between 7 and 9 (Boyd, 1989). Chen (1985) stated the optimum pH for *Penaeus monodon* growth is between 8-8.5. Again Boyd (1982) described the effect of pH on aquaculture species was generalized as when p^H is below 4 and above 11, the manifestations acid and alkaline death points respectively. And for 4-6 and 9-11 there is slow growth, where as 6-9 is most suitable for growth. Low water p^H can stress on the shrimp body and cause soft shell and poor survival (Law, 1988). Chanratchakol *et al.,* (1995) and Wyk and Scarpa (2004) stated that pH ranged from 7.0-8.2 is suitable for shrimp culture which were more similar during the present study. Low pH can also reduce natural pond productivity presumably by reducing the availability of nutrients (Alabaster and Lord, 1980). The pH of brackish water is usually not a direct threat to the health of the shrimp. Since brackish water is well buffered against pH change, pH will mostly remain with in the range of 6.5 to 9.0 (Chien, 1992) and pH of pond water coincides the limit of the afforested author in the present study. According to Bafru (1996) p^H ranged 7 to 9 is standard range of shrimp culture in Bangladesh. In the present study, p^H ranged varied from 7.9 to 8.28 which is close similar to the recommended p^H condition of shrimp culture in south-east cost for Bangladesh.

Temperature has a pronounced effect on the biochemical and metabolic process of shrimp (Barua and Zamal, 2010). Water temperatures of the experimental ponds were varied from 34.5^{o}C to 34.8^{o}C, which considered being ideal for the culture of *Penaeus monodon* as Pakrasi (1978) considered 20^{o}C -35^{o}C as optimum for shrimp growths. Temperature range in the present investigation agrees close similar with view of Ling (1974), who stated that 25^{o}C -35^{o}C was optimum for shrimp growth and survival. Larkins found 24^{0}C-35^{0}C for the suitability of shrimp farming which was absolutely similar to the present study. The finding of the temperature range in the coastal shrimp culture ponds of Bangladesh resembles with the finding of many authors namely Mahmood (1985), Alam (1989), and Hassan (1990).

During the investigation, the concentration of PO_4 found 0.98 to 2.90 ppm in experimental ponds. It is recommended that for the sustainable coastal aquaculture, PO_4 ranged from 0.01- 3.0 ppm is the acceptable range for coastal aquaculture

(Precilla and Myrana, 1991). Boyd and Gautier (2000) reported that phosphate-phosphorus ranged 0.5 mg/l or less is the initial standard and target standard 3 mg/l or less is ideal water quality standard for shrimp farming. So, the present study indicated that phosphate-phosphorus range is close similar of Precilla and Myrana, 1991) but within initial standard according to the report of Boyd and Gautier (2000).

The range of NO_3 and SiO_3 concentration in the study area ranges from 9.62- 18.56 ppm and 42.06- 67.51 ppm respectively and these ranges are indicated suitable range of coastal aquaculture in Chakaria sundarban region by compared the optimum range of shrimp farming in Bangladesh by Bafru (1996).

Pond soil plays an important role in the balance of aquaculture system and consequently on the growth and survival at aquatic organism. The soil can functions as a buffer. It provides the water with nutrients serve as a biological filitered through the absorption of the organic residues of food, fish excretions and algal metabolites (Boyd, 1992). For the successful aquaculture it is recommended that organic carbon 1.0- 4.0 % is the best range for coastal aquaculture (Boyd and Clay, 2002). Boyd (1992) also reported that organic carbon value 0.60-1.50% is highly suitable for aquaculture. Ahmed (2005) reported that organic carbon range 0.95 to 1.50% is the suitable range for coastal aquaculture of Bangladesh. Organic carbon in present study was 1.6 % to 3.9% which is the best range for shrimp farming (Boyd and Clay, 2002). But the range of organic carbon in the experimental ponds was higher than report of Ahmed (2005). This variation was found due to using supplementary feeds in the ponds which remain unused and deposited on the soil bottom.

While conversion to commercial monoculture shrimp farming can impact agricultural productivity, in some cases conversion to integrated shrimp or polyculture farming systems can bring benefits for small-scale farmers and may represent more ecologically sustainable approaches to shrimp farming. Polyculture incorporates several species occupying different ecological niches into a single farming system. This can improve resource-use efficiency, and, on a farm level, can help to insure against risks of disease or changes in market conditions. Such systems can be closed and relatively self sufficient and integrated farming technologies where resources and wastes are re-circulated within the farm may be one way of reducing the ecological footprint of shrimp farming. Improved traditional shrimp culture practice in Bangladesh where lot of fin, shell fish and crabs are found. Farmers no worried about the shrimp disease or less production, because by production from other species they earning lot of money and economically benefit able which is called "Environmental Risk Assessment".

The health score card of shrimp pond prepared on the basis of Aquatic Health Index (AHI) (Table 5) indicates the order of health in the sequence Ilishia (Stn. 9)> Badarkhali (Stn. 6) > Maghnama (Stn. 10)> Saharbill (Stn. 5)> Ciringa (Stn. 4)> Dulhajara (Stn. 3) > Khutakhali (Stn. 2)> Paschim Bara Veola (Stn. 7)> Fansiakhali (Stn. 8)> B.M. Char (Stn. 1). The main reason for this variation may be attributed to the proximity of the station to the urbanized and industrialized area of Chakaria sub-district and relases wastages, oils and chemicals from fishing, travelour and engine boat of cargo launch of Maheskhali-Cox's Bazar-Chakria riverine zone. This sewage contaminated water from the matmhuri river sluice gate near to fishing market of

Kutakhli and B.M. Char area diverted to the ponds located at Khutakhali (Stn. 2), Paschim Bara Veola (Stn. 7), Fansiakhali (Stn. 8) and B. M. Char Minakhan (Stn. 1), which may be one probable reason for lower AHI values in these ponds. The ponds at Dlhajara (Stn. 3) and Ciringa (Stn. 4) are under severe anthropogenic stress as these two places are the gateway of the eastern part of Sundarbans with maximum tourism pressure. The ponds here use this water as the source water, which deteriorated the environmental health of the ponds. The comparatively higher AHI values at Ilishia (Stn. 9) and Badarkhali (Stn. 6) may be attributed to two important causes: (a) location of these ponds far away from the Chakaria urban area almost in the mangrove dominated region of Chakaria Sundarbans and (b) use of specially formulated rich feed to grow the shrimps. The specially formulated feed prepared from highly nutritional feeds accelerated the growth of cultured shrimp indicating efficient conversion of food materials in to shrimp biomass and negligible residual materials for settlement at the pond bottom (as per the expression dF/db, where df = change in feed and db = change in biomass of the cultured shrimps). The residual feed matter, which are basically responsible for spoiling the bottom (Mitra, 1995) through generation of H_2S, NH_3 and increased organic load is the key player behind lowering the AHI values in the shrimp ponds. The left over feed not only increases the organic carbon of the pond bottom soil, but also stimulates the microbial load resulting in the acceleration of BOD and subsequent lowering of DO values. All these negative alterations are reflected in the lowering of individual quality rating of organic load, pH, DO, transparency, BOD concentrations in the shrimp ponds of B.M. Char (Stn. 1), Saharbill (Stn. 5), Dlhajara (Stn. 3) and Badarkhali (Stn. 2). In these ponds, the culture is carried on in traditional way with no scientific backup. The feed applied is prepared from beef extract, flour and trash fishes with no binders or chelating substances. The feed management in the shrimp ponds of these localities is also not done scientifically as per the biomass of the stocked shrimp seeds. Hence a large amount of the feed is wasted that deposits at the pond bottom and reduces the individual rating of organic load, pH, DO, transparency and BOD concentrations in the shrimp ponds.

Research finding of the present study suggest that the present level of coastal shrimp culture practice no longer risk of exceeding environmental l capacity. The water quality in shrimp ponds and aquatic system during culture cycle in this experiment was also in acceptable range. Present status of nutrient concentration for shrimp farming is less and the aquatic environment is able to accommodate the preset level of aquaculture practice. However, it was found that there is close relationship between nutrient load and growth, survival and production of shrimp pond. Generally very few amount of feed (some ingredients) applied into he pond which provides nutrient is significantly lower, that results in the low aquaculture production. Because of less production and having less to no chance of environmental capacity degradation shrimp farms should be provided with adequate fertilizer and feed to increase shrimp production.

CONCLUSION

Coastal shrimp aquaculture is an important industry in Bangladesh because it is an important source of earning foreign currency. However, the present practice of shrimp aquaculture is not sustainable, because it has damaged the local socioeconomic, environmental, ecological and cultural environment of costal Bangladesh on a long term basis. The main reason behind this unsustainable aquaculture is the unplanned and unscientific methods of shrimp cultivation, and lack of integration among various components of local ecosystem. The integration optimizes the use of land and water resources such as wastes produced by aquaculture systems minimize by other components of the ecosystem. In addition, the integration will enhance the protection and restoration of coastal ecosystems, ensure ecologically sustainable development, mitigate coastal resources use conflicts, increase employment opportunities and develop public participation in coastal management processes.

Research finding of the present study suggest that the present level of coastal shrimp culture practice no longer risk of exceeding environmental capacity. The water and soil quality in shrimp ponds and aquatic system during culture cycle in this experiment was also in acceptable range. Nutrient enrichment, growth performance, water and soil quality and production of shrimp were found very poor in pond connected pond which practiced reused water from another shrimp pond. So, farmers must need to stop use of reused water as a water source for shrimp culture. Effective strategies to control the occurrence and spread of disease are primarily related to proper management of the production system. To ensure that the shrimps are under a limited amount of stress, it is necessary to establish and implement good management practices.

Sustainable aquaculture development can bring real and lasting benefits to real and coastal communities. But the environmental consequences of inappropriate or excessive development will adversely impact on the wider communities and the farmers themselves through poor farm performance or failure. There is therefore an increasing need for good planning an management of aquaculture in our countries. Environmental capacity is being used in some progressive developed countries to inform the management of aquaculture as it provides a more objective basis on which to plan and regulate aquaculture conditions. , recognizing the cumulative impacts of resource users and the assimilative capacity of the environment.

The present article suggests the necessity of a combined approach rather than giving thrust towards the individual parameters for managing the health of the shrimp ponds. Basically, the quality of the aquatic system can never be a function of the individual parameters, as several parameters may have synergistic or antagonistic effects amongst themselves that ultimately determine the rating of the water body. The aquatic health index (AHI) is a reflection of such rating in which the importance of all the relevant parameters has been considered equally.

Table1: Shrimp production in the South-east coast of Bangladesh (1990-2010) (*)

Season	No of farms	Area of farm (ha)	Total production (mt)	Average production (kg/ha)
1990	1855	26673.45	4698.61	175.15
1991	1879	27388.91	4185.10	196.32
1992	1889	27410.53	5381.40	196.32
1993	1901	27359.62	5454.16	199.35
1994	2040	28466.57	5451.16	191.52
1995	2055	28521.22	4174.36	160.95
1996	2055	28521.24	4490.38	157.44
1997	2055	28521.24	3683.355	129.14
1998	2150	29025.09	6301.42	217.10
1999	2174	29025.09	6700.00	230.83
2000	2184	29131.28	5086.47	174.60
2001	2184	29131.28	4809.55	165.09
2002	2184	29131.28	4972.94	170.71
2003	2403	32018.21	7107.69	221.51
2004	2560	33335.41	8586.88	257.59
2005	2580	33350.50	9086.89	272.46
2006	2580	33367.00	9090.90	272.5
2007	2590	33390.00	9150.00	274.00
2008	2600	33400.00	10500.50	314.37
2009	2610	33450.00	12540.00	374.90
2010	2620	33500.00	13450.00	401.50

* District fisheries office of Cox' s Bazar and Chittagong

Table 2 : Significant ratings and weights of the relevant parameters in connection to shrimp culture

Parameter	**Ranking**	**Temporary weight**	**Final weight**	**Optimum value (*)**
Dissolved oxygen (DO) (mg/l)	1.2	1.000	0.1876	5.0
pH	1.9	0.6315	0.1185	8.00
Temperature (^{0}C)	2.6	0.4615	0.0866	32.0
Transparency (cm)	2.8	0.4286	0.0804	30.0
BOD (5-day)	2.9	0.4138	0.0776	3.0
Sediment organic carbon (%)	2.9	0.4138	0.0776	2.0
Salinity (%)	3.0	0.4000	0.0750	10.0
NO_3 (ppm)	4.5	0.2667	0.0500	15.0
PO_4 (ppm)	4.8	0.2500	0.0469	1.5
SiO_3 (ppm)	5.5	0.2182	0.0409	80.0
		4.481	0.8411	

(Note : Wi = weight of ith parameter)

* Boyd and Tucker (1992) ; DoF (2005)

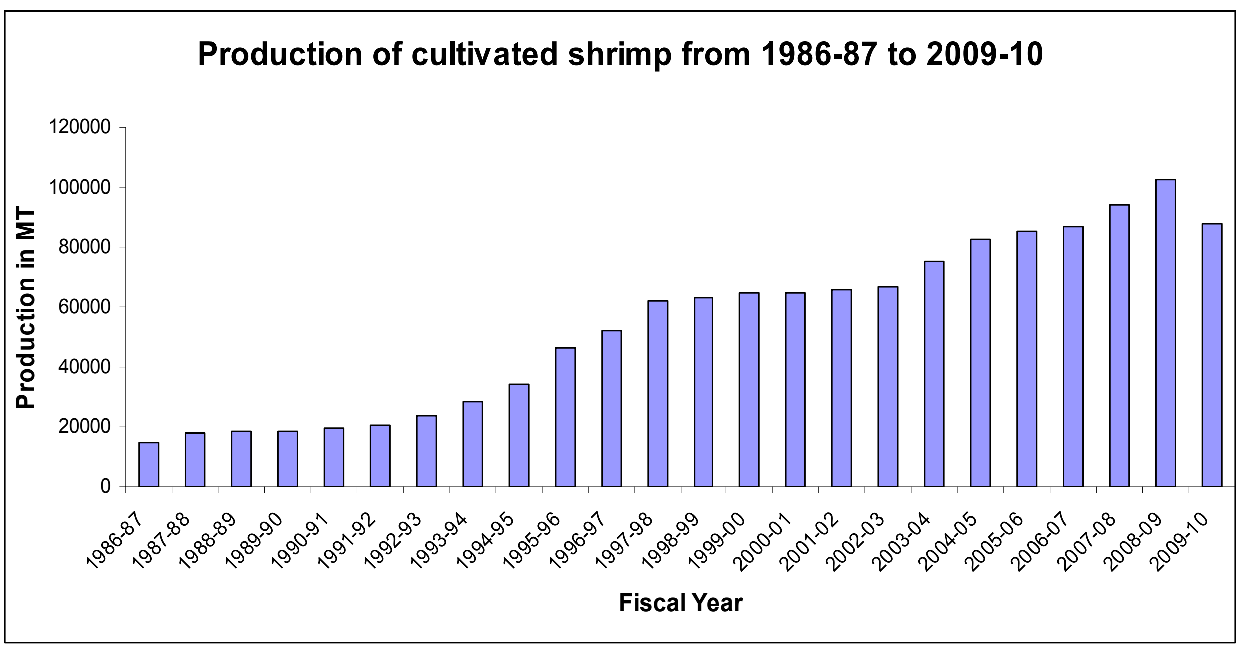

Table 3 : Individual quality rating (qi) on the basis of measured and optimum values for the selected ponds

Parameter	Stn. 1		Stn. 2		Stn. 3		Stn. 4		Stn. 5		Stn. 6		Stn. 7		Stn. 8		Stn. 9		Stn. 10	
	Mv	IQR	Mv	IQR	Mv	IQR	Mv	IQR	Mv	IQR	Mv	IQR	Mv	IQR	Mv	IQR	Mv	IQR	Mv	IQR
Dissolved oxygen (DO) (mg/l)	4.01	80	5.28	100	4.80	96	5.36	100	4.94	99	5.56	100	5.73	100	3.96	79	6.05	100	5.97	100
pH	8.00	100	8.12	80	8.18	80	8.21	80	7.99	100	8.20	80	8.26	80	8.02	100	8.28	85	8.23	87
Temperature (^{0}C)	34.5	90	34.6	90	34.6	90	34.7	90	34.8	90	34.6	90	34.8	90	34.8	90	34.8	90	34.7	90
Transparency (cm)	15.2	51	22.4	75	21.8	73	22.2	74	20.0	67	23.8	80	24.7	82	19.3	64	29.8	90	27.2	91
BOD (3-day at 27^{o}C)	6.9	40	6.0	40	5.4	40	5.3	40	4.9	80	5.0	80	5.5	40	6.6	40	2.9	95	3.4	90
Sediment organic carbon (%)	3.9	60	2.9	80	2.1	80	2.6	85	2.7	87	2.3	90	3.2	60	3.8	60	1.6	100	1.9	100
Salinity (%0)	7.91	79	8.70	87	10.98	90	12.02	80	7.33	73	12.85	80	21.56	60	7.48	75	24.39	70	22.14	60
NO_3 (µg at/l)	19.48	90	16.84	90	17.29	90	16.11	90	18.02	90	14.76	98	15.23	95	18.56	90	11.85	79	9.62	64
PO_4 (µg at/l)	2.90	60	2.34	60	2.83	60	2.16	60	2.79	60	1.90	90	2.05	85	2.84	60	1.30	87	0.98	65
SiO_3 (µg at/l)	40.52	51	47.84	60	53.16	66	67.51	84	52.29	65	63.70	80	59.14	74	48.55	61	38.28	48	42.06	53

Mv - Measured value; **IQR -** Individual quality rating

Table 4 : Aquatic Health Index (AHI) of the selected ponds

Parameter	**Stn. 1 W_i X q_i**	**Stn. 2 W_i X q_i**	**Stn. 3 W_i X q_i**	**Stn. 4 W_i X q_i**	**Stn. 5 W_i X q_i**	**Stn. 6 W_i X q_i**	**Stn. 7 W_i X q_i**	**Stn. 8 W_i X q_i**	**Stn. 9 W_i X q_i**	**Stn. 10 W_i X q_i**
Dissolved oxygen (DO) (mg/l)	15.008	18.760	18.009	18.760	18.572	18.760	18.760	14.820	18.760	18.760
pH	11.850	9.480	9.480	9.480	11.850	9.480	9.480	11.850	10.073	10.309
Temperature (^{0}C)	7.794	7.794	7.794	7.794	7.794	7.794	7.794	7.794	7.794	7.794
Transparency (cm)	4.1004	6.030	5.869	5.940	5.387	6.432	6.593	5.146	7.236	7.316
BOD (3-day at 27^{o}C)	3.104	3.104	3.104	3.104	6.208	6.208	3.104	3.104	7.372	6.984
Sediment organic carbon (%)	4.656	6.208	6.984	6.596	6.751	6.984	4.656	4.656	7.760	7.760
Salinity (%0)	5.925	6.525	6.750	6.000	5.475	6.000	4.500	5.625	5.250	4.500
NO_3 (µg at/l)	4.500	4.500	4.500	4.500	4.500	4.900	4.750	4.500	3.950	3.200
PO_4 (µg at/l)	2.814	2.814	2.814	2.814	2.814	4.221	3.986	2.814	4.080	3.049
SiO_3 (µg at/ l)	2.086	2.454	2.699	3.436	2.658	3.272	3.027	2.495	1.963	2.168
∑ Wi.qi	61.837	67.639	68.003	68.423	72.009	74.051	66.651	62.804	74.238	71.84

Note : Wi = weight of ith parameter and qi= quality of the ith parameter (a number between 0 and 100).

Table 5: Score card of the selected stations according to Aquatic Health Index

(Source: DOF 2011)

Station	∑ Wi.qi	Score
Stn. 9	86.418	1
Stn. 6	80.171	2
Stn. 10	79.368	3
Stn. 5	77.006	4
Stn. 4	74.553	5
Stn. 3	74.124	6
Stn. 2	72.405	7
Stn. 7	68.336	8
Stn. 8	64.349	9
Stn. 1	61.837	10

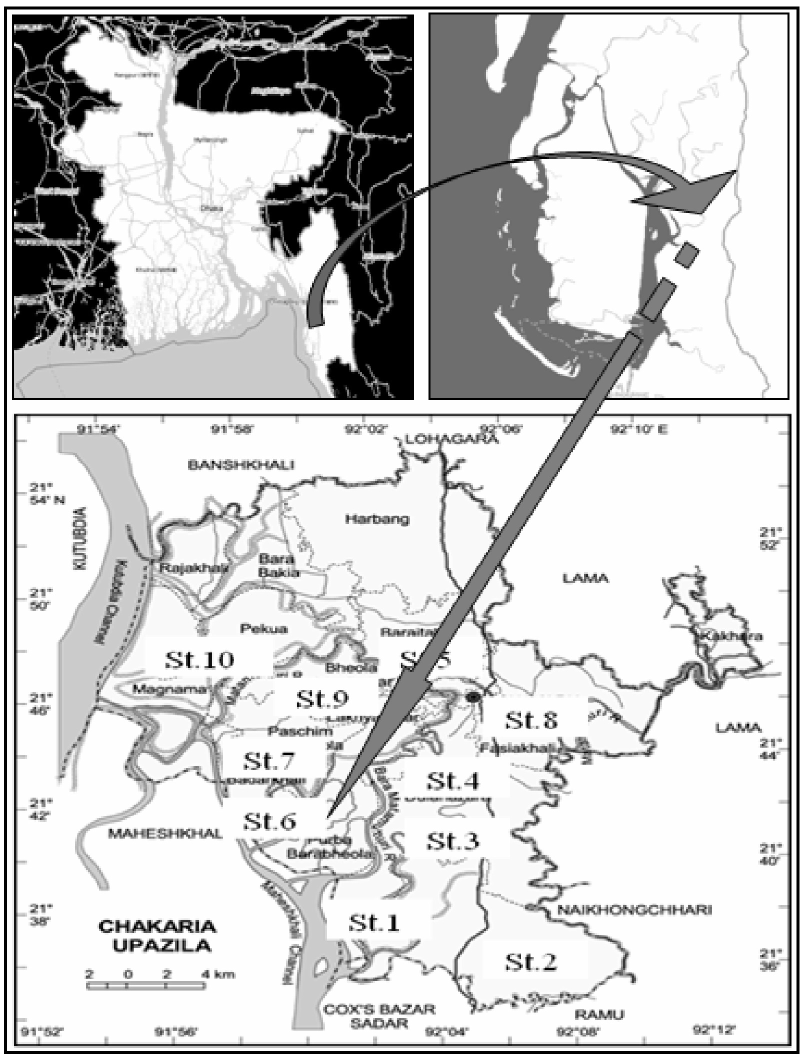

Figure 1: Map of the study area, Chakaria upazila of Bangladesh

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