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Study on water and soil quality parameters of shrimp and prawn farming in the southwest region of Bangladesh

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Abstract

Water and soil quality parameters play a vital role for sustainable shrimp and prawn production which together is the leading exportable seafood product in Bangladesh contributing to a significant amount of foreign currency earnings. However, this sector is often negatively criticized by the consumers of importing countries for farm (locally called *gher* in Bengali) environment. In this context, an investigation was carried out to assess water and soil quality parameters of shrimp and prawn farms in southwest Bangladesh. This study was conducted at Dumuria and Paickgacha Upazila of Khulna district during dry and wet season in 2012. The data were collected from 9 shrimp and prawn farms and they were categorized in three different groups (as treatments) including 3 prawn (T_1), 3 shrimp & prawn (T_2) and 3 shrimp farms (T_3). Water temperature, dissolved oxygen, pH, ammonia, nitrate, nitrite, alkalinity, salinity, total phosphorous and total hardness were measured using portable advanced HACH water quality test kit in both dry and wet season. Farm soil (sediment) quality parameters including pH, organic carbon, total nitrogen and available phosphorus were measured in the laboratory in wet season. It was found that most of the water quality parameters were in suitable range in both seasons for prawn, shrimp & prawn and shrimp farming. However, the ammonia content was 0.009 to 0.45 ppm and 0.2 to 0.6 ppm in shrimp farm during dry and wet season, respectively which was higher than the other category of farms. The higher ammonia content in shrimp farm might be due to the decomposition of aquatic weeds, organic matter, uneaten feed etc. creating stress to shrimp. Different co-relationships found between the water quality parameters in all the farming systems in the both seasons. In terms of soil quality parameters such as pH, organic carbon and total nitrogen, there was no significant difference between the farm categories. However, available phosphorous content was significantly higher in shrimp & prawn farm. Phosphorous content was found negatively correlated with pH and organic carbon content of farm sediment (soil). From the present study, it could be argued that ammonia is the main problem for shrimp farms that may cause severe disease outbreak which need to be addressed from the view point of research and development towards sustainable seafood production in Bangladesh.

Keywords: Shrimp, Prawn, Water and Soil quality parameters, Sustainability, Aquaculture, Bangladesh

Introduction

Bangladesh is a vast delta having 1,47,570 square km area, of which coastal brackish water covers roughly 17%. The wider coastal tidal area of Bangladesh is considered favorable for shrimp farming and 0.276 million hectares of land are currently under brackish water shrimp cultivation (Kabir and Eva, 2014). The coastal region, especially the south-western part including Khulna, Bagherhat and Satkhira, is one of the most promising areas for shrimp and prawn farming for two main reasons. The first reason is the mangrove ecosystems with unique feature of biodiversity, and the second one is the suitable habitat for shrimp, prawn faming (Islam and Haque, 2004). Now-a-days, shrimp and prawn is one of the leading exportable products of Bangladesh. Bangladesh earns millions of foreign currency annually exporting shrimp. After the garments industry, frozen seafood is the second largest export commodity which plays a dominant role in the economy of Bangladesh. The contribution of this sector was 4.37% and 2.01% for GDP and export earnings, respectively. About 16 million people are directly or indirectly dependent on this sector (DoF, 2014). About 50,333 MT of frozen shrimp and prawn was exported in the fiscal year 2012-2013 which was worth of about USD 422.03 (DoF, 2014).

According to Rahman et al. (2013) shrimp and prawn farming in Bangladesh has proven to be dynamic and increase foreign currency earning but the rapid growth of shrimp and prawn farming is likely to lead both short and long-term negative environmental impacts leading to ecological imbalance, environmental pollution, increase salinity and land degradation, destruction of mangrove forest, sedimentation and disease outbreaks (Paul and Vogl, 2011). Most of the mangrove destruction occurred before the rise of shrimp farming and is associated with agricultural expansion (Islam and Haque, 2004). However, mangrove wetlands are still being converted to *gher* for shrimp aquaculture (Rahman and Hossain, 2015).

Nevertheless, in the south-eastern parts, an area of 18,200 ha of mangrove (Chakaria Sundarbans) has almost completely been destroyed to find the land for shrimp aquaculture (Akhtaruzzaman, 2000). Prawn culture in Bangladesh relies on the supply of artificially formulated feed application of agrochemicals, antibiotics and disinfectants (Paul and Vogl, 2011). Shrimp farmers apply different types of chemicals and drugs to protect their farms (locally called *gher* in Bengali) from various diseases. The farmers are not aware of the impacts of the use of those chemicals on farms' environment. A survey conducted by CARE International showed that about 21% farmers used potassium permanganate, 18% used aqua-nourish, 17% used capsule and 14% agro-fish and almost all chemicals were used mainly for improving water quality and preventing diseases. Indiscriminate and overuse of the chemicals and drugs might be the cause of death of many living organisms (Rahman *et al*., 2013). The long-term use of different chemicals and drugs in the shrimp and prawn farming has long term negative impacts on the environment as well as the human being. Therefore, this sector has been highly criticized by the seafood importing countries in terms of negative social and environmental issues. In 2009, EU which is the largest importer got nitrofuran in prawn and Bangladesh had to adopt self-imposed ban on seafood export. As a result, this shrimp and prawn farming and trade became vulnerable in the export market. Therefore, it is now a critical issue to identify the major sources of the contaminants in the shrimp and prawn farms.

The present study was conducted to assess the impacts of shrimp and prawn farming on water and soil quality parameters of *gher* in the south western region of Bangladesh particularly in Khulna district which is expected to contribute to knowledge generation for sustainable seafood farming and trade in Bangladesh. The specific objective of the present study was to assess the effects of shrimp and prawn farming on water and soil quality parameters as well as to assess the relationships between the different physico-chemical parameters.

Materials and Methods

The study was conducted at Dumuria and Paickgacha Upazila in Khulna district during dry and wet season in 2012 (Fig. 1). For the study, 9 farms were randomly selected which were categorized in three different groups of prawn, shrimp & prawn and shrimp farms according to the existing farming systems. In each category (Treatment) of farms, three farms were considered as replicates. Water samples were collected from the selected farms using 500 ml plastic bottles between 09-11AM. After collection of the samples dissolved oxygen (DO) was measured immediately in the sampling site. Other physico-chemical parameters of the water samples such as water pH, ammonia, nitrate, nitrite, alkalinity, total phosphorous and total hardness were measured by using HACH test Kit (Model FF-1A Cat. No. 2430-02**).** Temperature and salinity were recorded by using mercury thermometer and refractometer, respectively. For the measurement of soil quality parameters, soil samples were collected from the same shrimp and prawn farms during the wet season. The appropriate time of soil sample collection was chosen in the wet season, while shrimp and prawn *ghers* were full of water, post larvae were released, supplementary feeding was going on and soil-water interaction was functioning. Following air drying, the soil samples were analyzed in the Soil Science Laboratory under the Department of Soil Science, Bangladesh Agricultural University, Mymensingh. One-way analysis of variance (ANOVA) was carried out to test the significant difference between three farming systems (i.e. treatments) for water and soil quality parameters. Correlation analysis was done to determine the positive or negative relationships between water quality, and soil quality parameters of the farms. Statistical tests were performed using computer based statistical software SPSS (Statistical Package for Social Science) version 16.5.

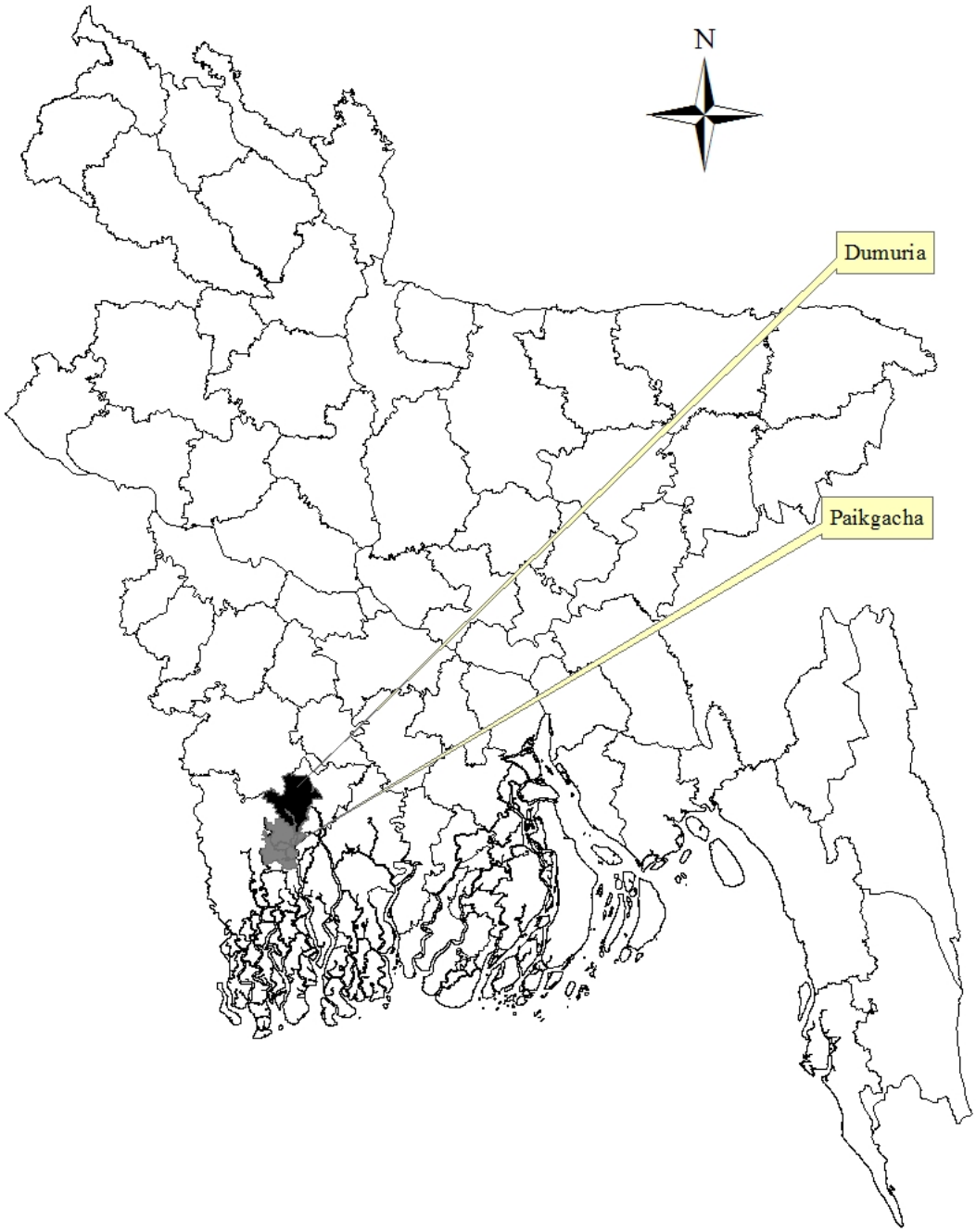

Fig. 1. Map of Bangladesh showing the study sites, Paikgacha and Dumuria Upazila under Khulna district

Results

The average size of prawn, shrimp & prawn and shrimp farms were 0.45, 0.40 and 10.93 ha with average water depth of 2.04, 1.80 and 1.15 m, respectively. Temperature of prawn, shrimp & prawn and shrimp farms was found more or less similar during the dry and wet season. The temperature was found higher in shrimp & prawn farm and shrimp farm during dry and wet season (Table 1 and 2). However, the temperature varied significantly in prawn, shrimp & prawn and shrimp farms during dry season (Table 1).

Table 1. Mean value (±SE) of water quality parameters during dry season

Parameters	Water treatments			
	Prawn	Shrimp & Prawn	Shrimp	ANOVA significance
Temperature (ºC)	30.00±0.00	32.67±0.88	31.00±0.00	NS
DO (ppm)	7.67±0.33	9.67±1.68	6.303±0.34	NS
pH	8.17±0.17	8.33±0.61	8.37±0.08	NS
NH_3 - N (ppm)	0.12±0.09	0.06±0.03	0.20±0.13	NS
NO_3 - N (ppm)	0.02±0.01	0.01±0.00	0.23±0.06	**
Alkalinity (ppm)	335.20±56.46	389.83±15.66	161.37±23.45	**
Salinity (ppt)	0.43±0.03	8.27±3.73	27.33±27.33	**
PO_4 - P (ppm)	0.28±0.10	0.08±0.03	0.18±0.09	NS
Total hardness(ppm)	238.27±7.76	899.10±357.76	5006.67±254.97	**

** Indicates significant difference between prawn, shrimp & prawn and shrimp farms at $p < 0.05$.

Water temperature had a positive relationship with DO (r = 0.696) indicating DO increased with increasing temperature during dry season (Table 1). The DO content was found higher in shrimp & prawn and shrimp *ghers* however, the lowest content was recorded in shrimp and prawn *ghers* in both seasons (Table 1 and 2). Dissolved oxygen content significantly different ($p<0.05$) between the treatments in both dry and wet seasons.

Table 2. Mean value (±SE) of water and soil quality parameters during wet season

Parameters	Treatments			
	Prawn	Shrimp & Prawn	Shrimp	ANOVA significance
		Water quality		
Temperature (ºC)	32.33±1.20	31.67±0.68	32.67±0.88	NS
DO (ppm)	4.67±0.34	5.33±0.34	7.00±1.53	**
pH	7.00±0.28	7.30±0.15	8.33±0.16	**
NH_3- N (ppm)	0.01±0.00	0.01±0.00	0.53±0.13	**
NO_3 - N (ppm)	0.02±0.00	0.03±0.01	0.11±0.05	NS
Alkalinity (ppm)	148.20±31.74	172.13±17.67	149.53±16.11	NS
Salinity (ppt)	0.00±0.00	0.67±0.68	9.33±0.68	**
PO_4 - P (ppm)	0.15±0.02	0.14±0.05	0.12±0.05	NS
Total hardness (ppm)	313.50±134.04	293.70±41.93	1846.80±84.35	**
	Soil (sediment) quality			
Soil pH	7.19±0.21	6.23±0.33	7.47±0.35	NS
Organic carbon (%)	0.82±0.03	0.63±0.06	0.71±0.05	NS
Total nitrogen (%)	0.20±0.12	0.51±0.21	0.08±0.00	NS
Available phosphorous (ppm)	0.20±0.12	23.46±0.89	8.54±0.57	**

The value of pH was found higher in shrimp and shrimp & prawn farms than prawn farm in both dry and wet season. pH showed a positive relationship with total hardness (r = 0.86) suggesting that total hardness increased with increasing pH during wet season (Table 4). During wet season, pH differed significantly ($p<0.05$) between the treatments however, no significant difference was found in dry season (Table 5 & 6). The level of ammonia content was higher in shrimp farm compared to other farm categories in both seasons (Table 1 & 2).

Table 3. Correlation matrix of water quality parameters in dry season

Parameters	PO_4	NO_3	NH_3	Temp.	Salinity	DO	pH	Alkalinity	Hardness
PO_4	1								
NO_3	.112	1							
NH_3	.660	.440	1						
Temp.	-.583	-.177	-.103	1					
Salinity	-.211	.895(**)	.317	.250	1				
DO	-.248	-.577	-.149	.696(*)	-.310	1			
pH	-.818(**)	.169	-.271	.538	.471	.124	1		
Alkalinity	-.229	-.846(**)	-.359	.215	-.761(*)	.452	-.013	1	
Hardness	-.126	.949(**)	.299	.024	.947(**)	-.400	.325	-.814(**)	1

Table 4. Correlation matrix of water quality parameters in wet season

Parameters	PO_4	NO_3	NH_3	Temp.	Salinity	DO	pH`	Alkalinity	Hardness
PO_4	1								
NO_3	-.431	1							
NH_3	-.210	.862(**)	1						
Temp.	.137	.332	.390	1					
Salinity	-.328	.682(*)	.882(**)	.135	1				
DO	-.344	.925(**)	.831(**)	.520	.567	1			
pH	-.009	.742(*)	.879(**)	.125	.856(**)	.647	1		
Alkalinity	.501	-.204	-.166	-.031	-.138	-.142	.212	1	
Hardness	-.242	.696(*)	.909(**)	.299	.973 (**)	.595	.86(**)	-.096	1

Ammonia had a significant correlation with pH (r = 0.879) and salinity (r = 0.882) suggesting that NH_3-N enhanced the pH and salinity of farm water during wet season (Table 4). The nitrate level was higher in shrimp farms in both seasons (Table 1 and 2). Nitrate content showed inverse relationship with total alkalinity (r = -0.846) in dry season. However, nitrate had a positive and significant ($p<0.05$) correlation with salinity and total hardness.

The alkalinity content was higher in shrimp & prawn farms compared to shrimp and prawn farms in both dry and wet seasons (Table 1 and 2). Alkalinity has a significant ($p<0.05$) inverse correlation with total hardness (r = -0.814) and chloride (r = -0.829) indicating that higher alkalinity content reduced the hardness and chloride level of farm water in dry season (Table 3). The highest salinity was found in shrimp farm in both seasons (Table 1 & 2). Salinity differed significantly ($p<0.05$) between the treatments in both seasons. The phosphorous content did not differ significantly ($p<0.05$) between prawn, shrimp & prawn and shrimp farm in both seasons. The highest value of hardness was recorded in shrimp farm and the lowest in prawn farm in both seasons. Hardness differed significantly ($p<0.05$) between the treatments both in dry and wet season.

Among the soil quality parameters such as pH, organic carbon and total nitrogen, there was no significant ($p>0.05$) difference between the farm categories. However, available phosphorous content was significantly ($p<0.05$) higher in shrimp & prawn farms (Table 2).

Soil pH was inversely correlated with total nitrogen (r = -0.670) and available phosphorous (r = -0.694) which reveals that pH increased with decreasing level of total nitrogen and available phosphorous in prawn, shrimp & prawn and shrimp farm in wet season (Table 5). The highest value of organic carbon ($p>0.05$) was found in prawn farm followed by shrimp and shrimp & prawn *ghers* during wet season. Total nitrogen content was higher in shrimp & prawn farm that had positive relationship with available phosphorous.

Table 5. Correlation matrix of sediment (soil) quality parameters during wet season

Parameters	Soil pH	Organic carbon (%)	Total nitrogen (%)	Available phosphorous (ppm)
Soil pH	1			
Organic carbon (%)	.412	1		
Total Nitrogen (%)	-.670(*)	-.640	1	
Available Phosphorous (ppm)	-.694(*)	-.421	.576	1

Discussions

Water quality for aquaculture refers to the quality of water that enables successful growth and production of the desired organisms. The maintenance of good water quality is essential for both survival, growth and production of commercial aquaculture species. Being cold-blooded animals, the metabolic rate of aquatic animal is closely related to the water temperature. Water temperature varies with the season, length of the day, water depth and meteorological condition. In the present study, water temperature varied from 30 to 34°C during the dry season and 31 to 34°C during the wet season in prawn, shrimp & prawn and shrimp farms which was due to the fluctuations of seasonal variations in sunlight exposure and length of the day. The optimum production of both shrimp and prawn found at temperature range of 25-30°C (Mazid, 2009; DoF, 2009), which was slightly higher than the present study. According to Rather et al. (2012) the dissolved oxygen ranged over 6 ppm during dry season and over 4 ppm during wet season in prawn, shrimp & prawn and shrimp farms, which was similar to the findings of the present study. Other studies reported that the optimum range of dissolved oxygen for shrimp and prawn is >4 ppm which is very similar to finding of the present study (Lazur, 2007; DoF, 2009).

pH is the concentration of hydrogen ions (H^+) present in water is a measure of acidity or alkalinity. The pH scale extends from 0 to 14 with 0 being the most acidic and 14 the most alkaline. In the present study, pH ranged from 8 to 8.5 ppm during dry season and 6.5 to 8.5 ppm during wet season in prawn, shrimp & prawn and shrimp farms, which was similar to the recommended level of pH for shrimp and prawn farms (Mazid, 2009; DoF, 2009). Ammonia in water exists in two forms, as ammonium ions (NH_4^+), which are nontoxic, and as the un-ionized toxic ammonia (NH_3). The desirable range of ammonia for shrimp farming is < 0.1 ppm and for prawn farming is 0 ppm. It was reported that the half of shrimp production was reduced in Bangladeshi farms due to the presence of ammonia at 0.45 ppm (Mazid, 2009). In this experiment, average ammonia content was 0.12 and 0.0, 0.06 and 0.01, and 0.20 and 0.53 ppm in prawn, shrimp & prawn and shrimp farm in dry and wet season, respectively. This level of ammonia in shrimp farm was higher than the optimum level which might be due to the decomposition of organic matter and undesirable aquatic weeds in the bottom of shrimp farms that causes stress to shrimp.

Among the various form of nitrogenous nutrients, NO_3 is the most important factor for shrimp and prawn culture. It is the available form of nitrogen for phytoplankton and other plants. Nitrate is the final product of the aerobic decomposition of organic nitrogen compounds, which are generated from nitrite by oxidation and reduce to ammonia by bacterial action. The recommended level of nitrate for shrimp farming is 0.0 to 0.3 ppm and for prawn farming <0.1ppm (Mazid, 2009; McNevin, 2004). The observed value of average NO_3 was 0.02 and 0.02, 0.01 and 0.03, and 0.23 and 0.11 ppm in dry and, wet season in prawn, shrimp & prawn and shrimp farm, respectively. The findings of the present study were similar to the optimum level of nitrate requirement for shrimp and prawn farming. Alkalinity is the buffering capacity of water and represents its amount of carbonates and bicarbonates. The suitable range of alkalinity for shrimp farming is 60 -180 and for prawn farming is 20 to 300 ppm (Mazid, 2009). In this study, average alkalinity content was 335.20 and 148.20, 389.83 and 172.13, and 161.37 and 149.53 ppm in dry and wet season in prawn, shrimp & prawn and shrimp farms, respectively. The research finding was slightly higher than the recommended level of alkalinity of shrimp and prawn farming which might be due to the use of excessive amount of agricultural limestone and fertilizer in shrimp and prawn farms. Salinity represents the total concentration of dissolved inorganic ions, or salts in water. The optimum range of salinity for prawn farming is 12-16 ppt and for shrimp farming 5-30 ppt (Mazid, 2009; DoF, 2009). In this experiment, the

average salinity was 0.43 and 0, 8.27 and 0.67, and 27.33 and 9.33 ppt in dry and wet season in prawn, shrimp & prawn and shrimp farms, respectively. The finding of the present study was more or less similar to the recommended salinity level in shrimp and prawn farming. The desired level of PO_4 content for shrimp and prawn farming is 0.005 to 0.2 ppm and <0.2 ppm, respectively (Mazid, 2009). The average PO_4 content of prawn, shrimp & prawn and shrimp farms was 0.28 and 0.15, 0.08 and 0.14, and 0.18 and 0.12 ppm in dry and wet season, respectively which seems alike to the optimum level of phosphate content for shrimp and prawn farming. Hardness refers to the concentration of calcium and magnesium in water. The optimum range of hardness for prawn farming is <120 ppm, and for shrimp farming ranges from 2325 to 2715 ppm (Mazid, 2009). In this study, average total hardness of prawn, shrimp & prawn and shrimp was 238.27 and 313.50, 899.10 and 293.70, and 5006.67 and 1846.80 ppm in dry and wet season, respectively. The total hardness was higher in the dry season but moderately similar with the optimum level in wet seasons in this experiment. The higher level of hardness content in shrimp farming was might be due to the high salinity content. The observed value of soil pH varied from 6.23 to 7.47 in prawn, shrimp & prawn and shrimp farms in wet season which is similar to the findings of Islam et al. (2003) who reported that optimum range of pH for shrimp production at 7.8 to 8.0. The average value of organic carbon in the present study was 0.82, 0.63 and 0.71% in prawn, shrimp & prawn and shrimp farms in wet season. Banerjea (1967) reported that soil with less than 0.5% organic carbon is low productive, 0.5 to 1.2% average productive, 1.5 to 2.5% high productive and greater than 2.5% as less productive which is very identical to the present study. The findings of the present study revealed that the amount of dead plankton and the uneaten feed was lower in the shrimp and prawn farm. The average value of total nitrogen in the present study of prawn, shrimp & prawn and shrimp farms was 0.20, 0.12 and 0.80% which was slightly higher than the findings of Islam *et al*. (2003) who reported that the total nitrogen content ranged from 0.11 to 0.18% in shrimp farming. The average phosphorous content was 0.02, 23.46 and 8.54 ppm in prawn, shrimp & prawn and shrimp farms, respectively which was similar to the finding of Islam *et al*. (2003).

Conclusion

From the present study, it could be argued that the optimum level of water and soil quality parameters play a vital role for better production of shrimp and prawn. Bangladesh earns lot of foreign currency annually exporting of frozen seafood products. However, this sector has been highly criticized by the importing countries. This is mainly because of the lack of adequate knowledge of farmers about shrimp and prawn farming particularly about water quality parameters. Farmers often use different types of chemical and drugs in their farms to improve water and soil quality parameters however, they need proper training and skills to assess soil and water quality parameters towards adopting best aquaculture practices and producing healthy seafood.

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