Journal of Fisheries
Volume 4 Issue 1 Pages: 309-318 April 2016
Peer Reviewed | Open Access | Online First

eISSN 2311-3111
pISSN 2311-729X

Original article
DOI: dx.doi.org/10.17017/jfish.v4i1.2016.81

Water and sediment quality characteristics of medium saline traditional shrimp culture system (*bheri*)

Leesa Priyadarsani • Thangapalam Jawahar Abraham

Department of Aquatic Animal Health, Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, Kolkata-700094, West Bengal, India

Correspondence: Thangapalam Jawahar Abraham, Department of Aquatic Animal Health, Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences; Email: abrahamtj1@gmail.com

Received: 25 Apr 2015, Received in revised form: 01 Jan 2016, Accepted: 15 Jan 2016, Published online: 24 Feb 2016

Citation: Priyadarsani L and Abraham TJ (2016) Water and sediment quality characteristics of medium saline traditional shrimp culture system (*bheri*). Journal of Fisheries 4(1): 309-318. DOI: dx.doi.org/10.17017/jfish.v4i1.2016.81

Abstract

Quality of water in shrimp culture ponds depends on several physical, chemical and biological processes. In this study, the physico-chemical characteristics of water and sediment samples from inlet, pond and outlet of a traditional shrimp culture pond, locally called as *bheri,* were examined for nine months from March to November 2011. Majority of the physicochemical parameters of *bheri* were well within the optimum levels. The average BOD values in pond water and outlet water were 2.03 ppm and 2.33 ppm, respectively. In pond water, the levels of ammonia were from 0.012 to 0.033 ppm, which was well within the safe level (<0.1 ppm). The present study recorded low levels of nitrite (0.0037 to 0.0043 ppm) and nitrate (0.056 - 0.091 ppm) in pond water, which was within the safe levels recommended for shrimp farming. These physicochemical parameters did not affect the cultured shrimp as there was no incidence of diseases or growth retardation during the culture period. The effluent water characteristics also did not vary much and well within the recommended levels for protecting the coastal ecosystem. It is unlikely that the traditional shrimp culture pose any adverse environmental effect when effluents are discharged into the open coastal ecosystem.

Keywords: *Bheri*, *Penaeus monodon,* water quality, sediment quality, physico-chemical parameters

INTRODUCTION

Fisheries sector plays a significant role in the economy, food and livelihood security by its contribution to income and wealth through the supply of nutritious food (Pillai and Kathia 2004). As the yield from capture fisheries have come to stagnancy, the pressure on aquaculture production has increased. Aquaculture has the high potentiality of meeting the growing need for food from aquatic resource for the ever increasing world population. Penaeid shrimp farming practice is economically rewarding due to its alluring profit and short gestation period. This has been possible due to the spectacular technology development and favorable environment for the utilization of farming technology in South East Asia over the last 20 years (Alauddin and Hamid 1999, FAO 2013).

Since the 1970s, shrimp aquaculture has grown significantly in the coastal countries with significant impacts on the environment and on the lives of local people. Biologically rich mangrove ecosystems have been affected and continue to be affected by growth of shrimp aquaculture to detriment of certain stakeholders and local communities that rely on them for their livelihood (Alauddin and Hamid 1999). The interactions occurring in the water and their effect on biological community of the pond are in a continual state of flux and are all interdependent. The shrimp production in such system is a mathematical function of farm management, which directly relates to the water characteristics (Das and Saksena 2001). Simultaneous to the development, the industry has been seriously threatened by the occurrence of infectious as well as non-infectious diseases. This negative impact of viral and bacterial diseases of penaeids started to get recognized with the advent of high density aquaculture (Flegel 2009, FAO 2013).

Since late 1980's, a rapid progress has been made in shrimp culture in India. As a result, the traditional method of brackishwater shrimp culture in West Bengal, India has been replaced by extensive system to a greater extent and by modified extensive and semi-intensive system to some extent (Chakraborti *et al*. 1985). The intensification coupled with unscientific farming practices has led to serious environmental and shrimp health related problems in most of the farms. Therefore, the potential monitoring of environmental parameters in shrimp farms are most important for determining the dynamics of farm management, microbial ecology and economics of the health of the shrimp farming system as a whole. The present study was carried out to investigate the water and sediment quality characteristics of a traditional brackishwater pond, locally called as *bheri,* culturing *Penaeus monodon* in West Bengal, India.

METHODOLOGY

Sampling area and samples: The present study was carried out for a period of 9 months between March 2011 and November 2011 in a traditional medium saline (brackishwater) *bheri* culturing *Penaeus monodon* Fabricius in Malancha (Lat. 22^0 30'11" N and Long. 88^{0}46'22" E), South 24 Parganas district, West Bengal, India (Figure 1). The total area of the *bheri* was 5.33 ha with water spread area of 4.67 ha. The *bheri* was a seasonal one and almost rectangular shaped with 1.0–1.5 m deep. The source water was drawn from Bidyadhari River. The sampled *bheri* was surrounded by other *bheries* and few brick kilns. Shrimp post-larvae (PL) of wild and hatchery raised were stocked repeatedly at 15 days interval. The total stocking density was approximately 55,000 PL/ha. No aeration and artificial feed was given. Repeated harvesting was done up on reaching the marketable size of about 30 g. The survival rate was about 60%.

Pond, inlet and outlet water samples from the column region in four places each were collected in sterile 250 ml polypropylene bottles. Sediment samples were collected aseptically using sterile plastic containers from four places, *viz.*, inlet, outlet and two different places within the *bheri* along the sides, transferred to sterile polythene bags and brought to the laboratory within 3 hrs of collection in insulated containers.

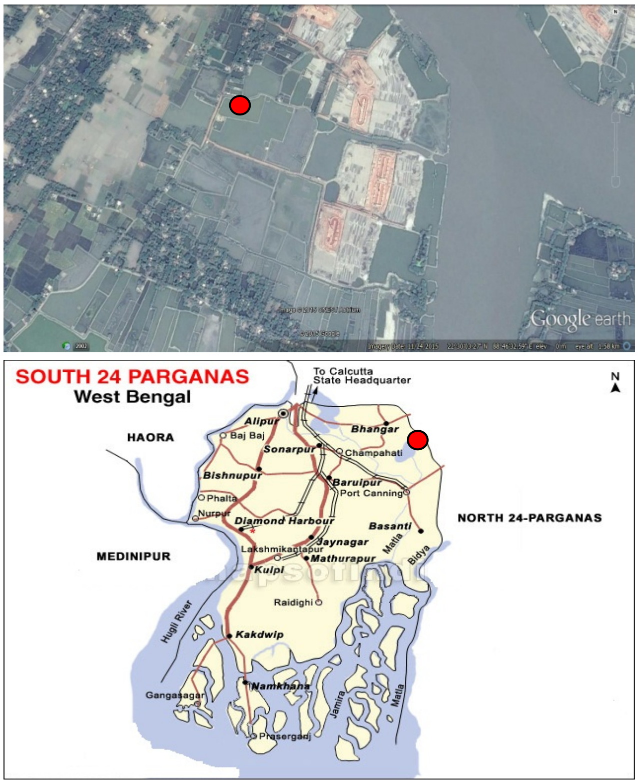

Figure 1: Location of the (above) traditional brackishwater shrimp farm (●) in (below) South 24 Parganas district, West Bengal, India

Physico-chemical analyses: The physico-chemical parameters such as pH, temperature, salinity, transparency, dissolved oxygen (DO), salinity, ammonia–nitrogen (NH_3-N), nitrite-nitrogen (NO_2-N), nitrate-nitrogen (NO_3-N), total suspended solids (TSS), biological oxygen demand (BOD) of water and pH, total organic carbon (TOC), oxidation reduction potential (ORP) of sediment were analyzed as per Jhingran *et al.* (1969) and APHA/AWWA/WEF (2005).

Statistical analyses: Two way ANOVA was followed to test the level of significance among the physicochemical parameters. The critical difference was calculated to examine which of the source and month differed significantly. Simple correlation was used to correlate the parameters using the Data Analysis Toolpak in Microsoft Excel.

RESULTS AND DISCUSSION

The results of physico-chemical characteristics of water and sediment samples of traditional shrimp culture system are presented in Tables 1 and 2, respectively. The correlation coefficient (r) values of water and sediment quality parameters are presented in Tables 3 and 4, respectively.

Water quality: Temperature is an important component, which greatly influences and directly affects the pond dynamics. Temperature has a pervasive controlling effect on the rates of both food consumption and metabolism and so has effects on growth (Das and Saksena 2001). The water temperature values were mainly influenced by ambient temperature, which ranged from 27 °C to 31.5 °C at the time of sample collection during the study period. Though there were fluctuations in water temperature (26-32.33 °C), it was more or less alike during the different months of culture period in the pond with a depth of 1-1.5 m. The pond water temperature ranged between 26 and 32 °C in the *bheri*, which was well within the optimum levels (26-32 °C) recommended for *P. monodon* culture (Chiu 1988). Significant differences existed in water temperature among months ($p<0.01$), but not among sources ($p>0.05$). Increase in temperature beyond 30 °C increases the activity level and the metabolism. If the temperature still increases then the shrimp reaches a threshold of physical and nutritional tolerance.

Table 1: Physico-chemical characteristics of inlet, pond and outlet water samples of traditional shrimp culture system

Month	DOC	*Mean±standard deviation*									
		Temperature (°C)	*pH*	*Salinity (ppt)*	*Transparency (cm)*	*DO (ppm)*	*BOD (ppm)*	*Ammonia (ppm)*	*Nitrite (ppm)*	*Nitrate (ppm)*	*TSS (g/l)*
Inlet water											
Mar	0	28.50±0.50	8.31±0.20	18.33±0.29	18.33±1.52	5.80±0.20	2.80±0.70	0.018±0.0006	0.0051±0.0001	0.212±0.0010	0.54±0.04
Apr	30	28.83±0.29	8.34±0.23	18.83±0.29	18.33±1.52	5.79±0.20	3.11±0.63	0.018±0.0006	0.0053±0.0001	0.203±0.0006	0.64±0.07
May	60	32.33±0.29	8.23±0.06	19.33±0.29	22.00±2.64	7.30±0.27	5.49±0.82	0.015±0.0015	0.0046±0.0001	0.221±0.0006	0.24±0.01
Jun	90	30.67±0.58	8.00±0.18	8.33±0.58	23.33±0.58	5.51±0.14	1.94±0.31	0.020±0.0021	0.0058±0.0001	0.241±0.0006	0.26±0.04
Jul	120	32.00±0.00	7.93±0.06	5.33±0.58	27.00±1.00	6.17±0.60	3.87±0.83	0.022±0.0010	0.0044±0.0001	0.242±0.0006	0.31±0.01
Aug	150	31.00±0.00	7.93±0.16	0.33±0.58	43.33±2.51	4.21±0.38	1.44±0.46	0.021±0.0006	0.0046±0.0001	0.225±0.0006	0.33±0.01
Sep	180	29.00±0.00	8.50±0.10	1.67±0.58	10.50±2.30	7.83±0.29	1.60±0.40	0.023±0.0006	0.0049±0.0001	0.258±0.0006	0.41±0.01
Oct	210	30.67±0.58	8.17±0.06	0.00±0.00	17.50±0.87	7.51±0.29	1.37±0.26	0.018±0.0015	0.0039±0.0001	0.302±0.0006	0.52±0.01
Nov	240	27.00±0.00	8.37±0.11	1.00±0.00	7.43±0.40	5.97±0.26	1.00±0.20	0.024±0.0010	0.0042±0.0001	0.309±0.0006	0.77±0.03
Pond water											
Mar	0	29.47±0.50	8.51±0.09	18.50±0.50	29.67±1.52	7.15±0.22	2.19±0.08	0.012±0.0006	0.0038±0.0001	0.067±0.0001	0.63±0.09
Apr	30	30.17±0.29	8.52±0.08	18.17±0.29	29.67±1.52	7.53±0.41	2.17±0.06	0.014±0.000	0.0038±0.0001	0.084±0.0001	0.59±0.11
May	60	32.33±0.77	8.37±0.06	18.00±0.87	40.67±4.61	6.61±0.60	2.63±0.50	0.021±0.0006	0.0037±0.0001	0.074±0.0001	0.43±0.13
Jun	90	30.67±0.58	7.97±0.21	8.67±1.16	38.67±6.27	5.81±0.20	2.24±0.21	0.018±0.0026	0.0037±0.0001	0.056±0.0001	0.21±0.04
Jul	120	31.67±1.16	8.63±0.16	5.00±0.00	43.33±2.89	5.97±0.26	2.09±0.08	0.019±0.0001	0.0039±0.0001	0.067±0.0001	0.22±0.03
Aug	150	30.00±0.00	9.00±0.00	1.33±0.58	53.00±5.59	7.93±0.70	1.86±0.21	0.025±0.0032	0.0043±0.0001	0.073±0.0001	0.22±0.02
Sep	180	27.33±0.58	8.33±0.06	1.67±0.58	28.00±6.27	7.26±0.13	1.80±0.20	0.032±0.0001	0.0039±0.0001	0.076±0.0001	0.27±0.01
Oct	210	30.33±1.16	8.23±0.06	0.00±0.00	27.33±3.79	6.56±0.52	1.64±0.28	0.029±0.0002	0.0042±0.0001	0.091±0.0001	0.48±0.01
Nov	240	26.00±0.00	8.00±0.10	2.00±0.00	13.50±1.80	6.59±0.20	1.73±0.11	0.033±0.0021	0.0039±0.0001	0.089±0.0001	0.86±0.07
Outlet water											
Mar	0	28.17±0.29	8.03±0.06	15.67±0.29	13.667±1.52	5.86±0.21	4.07±0.16	0.024±0.002	0.0047±0.0011	0.207±0.006	0.44±0.03
Apr	30	28.67±0.29	8.07±0.11	15.17±0.29	13.00±2.64	5.79±0.20	4.14±0.06	0.023±0.001	0.0049±0.0004	0.215±0.009	0.50±0.06
May	60	32.33±0.29	8.30±0.00	18.33±0.58	9.67±0.58	6.97±0.20	3.40±0.20	0.026±0.002	0.0050±0.0006	0.309±0.021	0.31±0.06
Jun	90	30.83±0.29	7.97±0.16	10.00±1.00	20.00±1.00	6.72±0.33	3.01±0.20	0.024±0.003	0.0044±0.0003	0.296±0.008	0.23±0.03
Jul	120	30.67±0.29	8.13±0.06	5.33±0.58	13.33±0.77	6.26±0.21	2.32±0.20	0.027±0.002	0.0046±0.0004	0.324±0.012	0.27±0.01
Aug	150	30.00±0.00	7.87±0.20	1.67±0.58	14.83±1.04	6.04±0.67	1.33±0.61	0.028±0.001	0.0052±0.0006	0.341±0.007	0.30±0.01
Sep	180	28.00±0.00	7.93±0.06	2.00±0.00	8.57±0.81	7.11±0.14	0.97±0.16	0.025±0.001	0.0048±0.0002	0.351±0.011	0.32±0.04
Oct	210	28.33±0.58	8.10±0.00	1.33±0.58	13.00±0.87	7.16±0.28	0.99±0.18	0.031±0.002	0.0044±0.0001	0.346±0.005	0.54±0.02
Nov	240	28.33±0.58	8.37±0.06	2.00±0.00	8.30±0.81	7.40±0.20	0.80±0.01	0.036±0.002	0.0056±0.0004	0.309±0.013	0.79±0.01

DOC=Days of culture, DO=Dissolved oxygen, BOD=Biological oxygen demand, TSS=Total suspended solids.
Values are mean±standard deviation of four observations.

According to Moore (1991) the temperature level should not exceed 30 °C in shrimp culture effluents before discharge. The inlet and outlet water temperature ranged from 27 to 32.33 °C, and 28 to 32.33 °C, respectively, whereas Islam *et al.* (2004) recorded the temperature from 19.53 to 30.67 °C, and 21.10 to 31.83 °C, respectively in inlet and outlet water from Bangladesh. Outlet water temperature was observed to be always higher than that of the inlet water, might be due to shallower depth, as the lower water depth contributes to higher thermal conductivity of water. The temperature values recorded in pond water were well within the optimum level, thereby ruling out this factor as an inducer of shrimp diseases or growth retardation in the *bheri* condition.

Table 2: Physico-chemical characteristics of sediment samples of traditional shrimp culture system

Month	*DOC*	*Inlet (Mean±SD)*			*Pond (Mean±SD)*			*Outlet (Mean±SD)*		
		pH	*ORP (mV)*	*TOC (%)*	*pH*	*ORP (mV)*	*TOC (%)*	*pH*	*ORP (mV)*	*TOC (%)*
Mar	0	8.11±0.10	-93.00±2.64	0.26±0.03	8.31±0.21	-94.33±13.31	0.37±0.06	8.23±0.09	-112.00±8.71	0.23±0.01
Apr	30	8.10±0.10	-96.33±5.50	0.26±0.03	8.36±0.22	-99.00±11.36	0.40±0.03	8.49±0.39	-110.33±7.38	0.23±0.01
May	60	8.06±0.06	-106.67±7.58	0.23±0.01	8.18±0.69	-128.67±2.51	0.30±0.04	8.16±0.06	-168.00±7.54	0.24±0.06
Jun	90	8.67±0.30	-174.33±3.51	0.27±0.04	8.47±0.41	-195.33±1.16	0.20±0.03	8.87±0.11	-190.00±2.64	0.27±0.07
Jul	120	8.47±0.30	-173.33±2.09	0.24±0.03	9.27±0.11	-221.33±6.66	0.31±0.04	9.50±0.27	-191.00±1.00	0.26±0.01
Aug	150	8.47±0.50	-181.00±19.31	0.30±0.04	9.20±0.20	-196.33±6.66	0.24±0.01	9.00±0.20	-196.67±9.87	0.30±0.03
Sep	180	8.10±0.10	-177.00±1.03	0.22±0.01	9.27±0.47	-215.67±2.09	0.30±0.04	9.47±0.11	-191.33±6.11	0.26±0.01
Oct	210	9.07±0.11	-190.00±2.06	0.26±0.01	9.20±0.20	-243.33±4.17	0.23±0.05	9.13±0.11	-203.33±6.11	0.26±0.01
Nov	240	8.77±0.06	-215.33±6.80	0.27±0.03	8.93±0.11	-275.33±5.03	0.29±0.01	9.20±0.60	-231.67±0.58	0.27±0.03

DOC=Days of culture, DO=Dissolved oxygen, BOD=Biological oxygen demand, TSS=Total suspended solids; SD: Standard deviation. Values are mean±standard deviation of four observations.

Table 3: Correlation coefficient (r) between inlet/pond/outlet water quality parameters of traditional shrimp culture system

Parameters	*Temperature*	*pH*	*Salinity*	*Transparency*	*DO*	*BOD*	*Ammonia*	*Nitrite*	*Nitrate*	*TSS*
Inlet water										
Temperature	1									
pH	-0.699*	1								
Salinity	0.062	0.206	1							
Transparency	0.642	-0.826**	-0.059	1						
Dissolved oxygen (DO)	0.066	0.547	-0.002	-0.649	1					
Biological oxygen demand (BOD)	0.570	-0.105	0.740*	0.145	0.207	1				
Ammonia	-0.431	0.037	-0.730*	-0.162	-0.172	-0.637	1			
Nitrite	-0.089	0.013	0.505	0.068	-0.316	0.107	-0.143	1		
Nitrate	-0.288	0.159	-0.743*	-0.479	0.371	-0.591	0.488	-0.639	1	
Total suspended solid (TSS)	-0.870**	0.594	-0.056	-0.599	-0.010	-0.452	0.261	-0.241	0.392	1
Pond water										
Temperature	1									
pH	0.335	1								
Salinity	0.420	0.063	1							
Transparency	0.717*	0.684*	0.055	1						
Dissolved oxygen (DO)	-0.265	0.633	0.083	0.098	1					
Biological oxygen demand (BOD)	0.660	0.051	0.834**	0.390	-0.203	1				
Ammonia	-0.601	-0.279	-0.814**	-0.356	0.027	-0.695*	1			
Nitrite	-0.131	0.483	-0.697*	0.220	0.430	-0.726*	0.473	1		
Nitrate	-0.417	-0.104	-0.272	-0.588	0.326	-0.546	0.545	0.416	1	
Total suspended solids (TSS)	-0.508	-0.356	0.250	-0.799**	0.128	-0.142	0.076	-0.161	0.618	1
Outlet water										
Temperature	1									
pH	0.182	1								
Salinity	0.389	0.199	1							
Transparency	0.278	-0.542	0.133	1						
Dissolved oxygen (DO)	-0.020	0.473	-0.429	-0.454	1					
Biological oxygen demand (BOD)	0.296	-0.001	0.942**	0.347	-0.655	1				
Ammonia	-0.219	0.564	-0.623	-0.425	0.622	-0.730*	1			
Nitrite	-0.085	0.430	-0.134	-0.579	0.149	-0.269	0.534	1		
Nitrate	0.187	-0.050	-0.748*	-0.196	0.640	-0.844**	0.465	0.028	1	
Total suspended solids (TSS)	-0.603	0.589	-0.208	-0.493	0.329	-0.276	0.714*	0.532	-0.179	1

**(p<0.05), ** (p<0.01)*

pH is considered to be the best indicator to assess the quality of an aquatic ecosystem (Boyd 1989). pH is also an important parameter for successful shrimp farming. The pH of brackishwater is usually not a direct threat to the health of shrimp, since brackishwater is well buffered against pH changes (Chien 1992). The ideal pH range for shrimp culture is suggested to be 7.50-8.50 (Boyd 1989; Chien 1992). In the present study, the pH range of pond water was found to be 7.97-9.00, mostly within the optimum ranges (Boyd 1989; Chien 1992), except the higher limit of 9.00 observed during monsoon. While in inlet (7.93–8.50) and outlet (7.87–8.37) waters, the pH was observed to be lower than the pond water. No significant differences existed in pH among months and sources (p>0.05). Das and Saksena (2001) observed a direct significant correlation (p<0.01) between pH and growth of *P. monodon.* Fluctuation of pH around the neutral value during culture period does not affect the growth of shrimp. Exceedingly alkaline water (greater than pH 9) is dangerous as ammonia toxicity increases rapidly. Also at higher temperatures shrimp are more sensitive to pH changes. The results of the present study corroborate the observations of Islam *et al.* (2004). It has been suggested that the pH level should not exceed 8.0 in shrimp culture effluents (Moore 1991). The results, however, indicated slightly higher pH in outlet (effluent) water.

Table 4: Correlation coefficient (r) between inlet/pond/outlet sediment quality parameters of traditional shrimp culture system

Parameters	***pH***	***ORP***	***TOC***
Inlet sediment			
pH	1		
ORP	-0.760*	1	
TOC	0.443	-0.239	1
Pond sediment			
pH	1		
ORP	-0.781*	1	
TOC	-0.394	0.643	1
Outlet sediment			
pH	1		
ORP	-0.721*	1	
TOC	0.604	-0.769*	1

**(p<0.05); ** (p<0.01)*
ORP, Oxidation reduction potential; *TOC,* Total organic carbon

Salinity plays a vital role in pond dynamics of shrimp culture system. The early life stages of shrimp require standard seawater salinities, but while growing they can withstand to brackishwater or even to freshwater (Chien 1992). Relatively lower values were observed during monsoon due to rainfall and an increasing trend in summer. The optimum range of salinity most suitable for shrimp culture is about 15-25 ppt (Boyd 1995, Baliao 2000), while Chien (1992) recommended a salinity level of 10–25 ppt for shrimp culture. However, the range of salinity recorded in the *bheri* (0-18.50 ppt) was lower than the recommended levels and the shrimp was to grow at a salinity of 1.67-5.00 ppt during the monsoon months. On the other hand, the higher levels of salinity recorded in the *bheri* during the summer months were within the desirable limit. Significant differences existed in salinity among months (p<0.01), but not among sources (p>0.05). *Penaeus monodon* has been reported to grow well at salinities ranging from 15–30 ppt (Chen 1985). The salinity range of 6.5–25.5 ppt favoured the growth of shrimp. However, the growth of *P. monodon* may be retarded at low salinities (Das *et al*. 2001). Das and Saksena (2001) recorded a significant correlation (p<0.01) between salinity and growth of shrimp. The results of the present study corroborate the observations of Islam *et al.* (2004) made in Bangladesh traditional shrimp farms.

The recommended transparency for shrimp pond is 20-40 cm (Limsuwan 1994). An ideal range of 30-40 cm has been suggested for shrimp culture ponds (Chien 1992). The observed transparency values in the *bheri* were in the range of 13.50–53.00 cm, which was not complying the recommended level, possibly due to the surface run off and no fertilization for augmenting the primary productivity. Mean transparency level was found relatively higher in inlet water (20.87 cm) than outlet water (12.70 cm). The minimum transparency values recorded in inlet and outlet waters were 7.43 and 8.30 cm, respectively during the end of culture period, which might have been caused by harvesting and draining out the waters. Significant differences existed in the levels of transparency among sources (p<0.003) and months (p<0.001). The growth of *P. monodon* is significantly related with dynamics of transparency because higher values of transparency cause more photosynthetic activities leading to the occurrence of more natural food in the pond (Das *et al*. 2001).

The DO concentration is the major critical water quality variable in aquaculture (Boyd 1989). It regulates the respiratory metabolism of aquatic organisms including shrimp and also plays a significant role in the breaking down of organic matter and toxic metabolites (Chiu 1988). Law (1988) suggested that the DO level should be kept above 2 mgL^{-1} at all times. Chien (1992) recommended that minimum DO should be 4 mgL^{-1} in shrimp ponds. Although there was no provision of aeration or water exchange, the *bheri* recorded DO level in the range of 5.81-7.93 ppm, which was within the recommended level for shrimp culture (Boyd and Green 2002). The oxygen dynamics of brackishwater shrimp culture ponds depend on the balance of the autotrophic and heterotrophic production. The quantity of flushing of freshwater, tidal flow, temperature, salinity and algal growth together influences the DO content of water in shrimp ponds (Banerjee and Roychoudhury 1996). The mean DO levels of inlet and outlet water were 6.23 and 6.59 mgL^{-1}, respectively. No significant differences existed in DO levels (p>0.05) among months and sources.

Biological oxygen demand (BOD) in the shrimp ponds assume a very high significance because they give an idea of quality of biodegradable organic matters present in the ponds, which is subjected to aerobic and anaerobic decomposition by microorganisms. BOD is reliable for judging the extent of water pollution (Banerjee and Roychoudhury 1996). The optimum level of BOD in shrimp pond should be less than 10 ppm (Chien 1992). In the present study the average BOD values of pond water, inlet and outlet water were 2.03 ppm, 2.51 ppm and 2.33 ppm, respectively. This implied that the inlet water brings lot of biodegradable organic matters into the pond and facilitate their settlement in pond bottom. The lowest BOD level in the inlet water was 1.00 ppm and in outlet water, it was 0.80 ppm. The recorded BOD levels were, however, lower than those reported in Andhra Pradesh and Tamil Nadu (Anon 1997). The fluctuations in BOD values in the present study might be due to surface run-off during monsoon and periodic harvesting process. Significant differences existed in BOD levels among months (p<0.008), but not among sources (p>0.05). The effluent water with high BOD levels, when discharged might create drastic changes in the discharge site and adjacent environment. It is suggested that BOD should be below 5 or 6 mgL^{-1} in shrimp pond effluent for protecting coastal aquatic ecosystems (Boyd and Green 2002) and the present results are conforming the recommended levels.

Ammonia is the main end product of protein catabolism in crustaceans. In water, ammonia is also derived from microbial metabolism of the nitrogenous compounds under low oxygen condition. High ammonia levels can arise from overfeeding and protein rich excess feed decays to liberate toxic ammonia gas, which in conjunction with excreted ammonia may accumulate to dangerously high levels under certain conditions. An ammonia concentration of 0.13 mgL^{-1} is safe for *P. monodon* post-larvae (Chin and Chen 1987). The recommended safe levels of NH_3-N for *P. monodon* is <0.10 mgL^{-1} and the total ammonia-nitrogen level for optimum growth is <4.3 mgL^{-1} (Boyd 1989, Chien 1992). In pond water of the present study, the levels of ammonia were from 0.012 to 0.033 ppm, which was well within the safe (<0.1 ppm) level (Chien 1992). There existed significant differences in ammonia levels among sources (p<0.003) and months (p<0.01). The levels of ammonia were found relatively higher, but within the safe level, in outlet water (0.023-0.036 ppm) than in inlet water (0.015-0.024 ppm) and pond water (0.012-0.033 ppm), possibly due to the discharge of organic rich effluents and the liberation of ammonia by decomposition processes. Krishnani *et al.* (2011) recorded much higher ammoniacal nitrogen (0.27-0.35 ppm) in Kerala extensive shrimp culture system than those of the present study. On the other hand, the levels of ammonia recorded by Islam *et al.* (2004) in inlet water (0.01-0.016 ppm) and in outlet water (0.01-0.017 ppm) in Bangladesh were lower than the present study. The discharge of nutrients from shrimp farms along Indian estuaries has reportedly caused severe impacts on the environment (Das *et al*. 2004). The average ammonia concentration in shrimp farm effluents was reported to be 0.90 ppm in Thailand (Briggs and Funge-Smith 1994). It is suggested that the ammonia level should not exceed 0.5 mgL^{-1} in shrimp culture effluents (Boyd and Clay 1998). The recorded ammonia level in the effluent was less than 0.5 mgL^{-1}.

Nitrite is less toxic to shrimp compared to fish because, in fish, nitrite oxidizes haemoglobin to form methaemoglobin, which is incapable of transporting oxygen (Smith and Russo 1975). The safe concentration of nitrite recommended for *P. monodon* growth varies between 1.28 and 3.80 mgL^{-1} (Law 1988). The present study recorded low nitrite levels in pond water (0.0037 to 0.0043 ppm) than the level (<1.0 ppm) proposed by Chien (1992) and those of the levels observed in the extensive shrimp culture of ponds (0.006-0.199 ppm) in Kerala (Krishnani *et al.* 2011). Significant differences existed in NO_2-N levels among the sources (p<0.001). The observed levels were comparable to those of Islam *et al.* (2004) recorded (0.001-0.009 ppm) in Bangladesh. Being an intermediate product and unstable, nitrite usually had little accumulation and was low in concentration. Moore (1991) suggested that nitrite should not exceed 0.06 mgL^{-1} in shrimp pond effluent for protecting coastal aquatic ecosystems. The recorded levels of nitrite in inlet (0.0039-0.0058 ppm) and outlet (0.0044-0.0056 ppm) waters of the present study were well within such recommended levels.

Nitrate is a nitrogenous compound which is considered as one of the nutrients in sea waters and has the least toxicity to aquatic animals even in large concentrations (Boyd and Clay 1998). Among all the nitrogenous nutrients, NO_3-N is considered to be the limiting nutrient because of its regulatory influence on organic production in aquatic ecosystem. Compared to nitrate, both ammonia and nitrite are extremely toxic to shrimp but high concentrations of nitrate are also toxic to shrimp (Kuhn *et al*. 2011). Although the present study recorded the nitrate levels in the range of 0.203-0.309 ppm in inlet water, the pond water had low nitrate concentration, possibly due to the uptake by primary producers. Significant differences existed in nitrate levels among sources (p<0.001) and months (p<0.05). A safe nitrate level of <1.0 mgL^{-1} has been suggested for penaeid shrimp (Karthikeyan and Srimurali 1995). The recorded nitrate levels in pond water (0.056 - 0.091 ppm), although within the safe levels recommended for shrimp farming, was lower than the levels recorded in Thailand (Briggs and Funge-Smith 1994) and Iran (Khodami *et al*. 2011), but higher than the level (0.004 ppm) recorded in China (Biao *et al*. 2009). The present study recorded high nitrate levels in inlet water (0.203-0.309 ppm) than that of Biao *et al*. (2009) in China. The nitrate levels of outlet water of the present study (0.207-0.351 ppm) were higher than the average nitrate concentration (0.11 ppm) reported in shrimp farm effluents of Thailand, but comparable to those of the one recorded in Iran. Environmental regulations associated with effluent discharge for aquaculture have permissible nitrate levels as low as 11.3 ppm (European Council Directive 1998).

Managing the concentration of TSS in water is beneficial to shrimp and system stability. As solids increase, so does the BOD, potentially leading to decreased oxygen availability for shrimp (Chien 1992). Also increased turbidity can lead to higher infestation rates by nuisance zooplankton, potentially fouling gills and acting as stressors to shrimp (López-Téllez *et al*. 2009). The TSS concentration was significantly high in *bheri* initially and gradually decreased, then increased at the end of the culture period. Significant differences existed in TSS levels among months (p<0.001). The recorded TSS levels in pond water were between 0.21 and 0.86 gL^{-1}. The results of the present study corroborate the observations of Islam *et al.* (2004) made in inlet water (0.33-1.22 gL^{-1}) and outlet water (0.24-0.42 gL^{-1}) from Bangladesh. It appears from the results of DO, BOD, NH_3-N, NO_2-N, NO_3-N and TSS of the present study that the traditional shrimp culture in *bheri* and its effluent is unlikely to pose adverse effect when discharged into the open coastal environment.

Sediment quality

Bottom soil quality is an important factor as the shrimp spend most of their time burrowing in the bottom and also ingest some of it (Boyd 1989). Decreasing sediment pH or acidification of sediment (7.0–6.0) increases the hemolymph osmotic pressure of shrimp. The pH range of 6.5-7.5 has been suggested for optimum decomposition of organic matter in shrimp ponds (Banerjea 1969). The sediment pH range of 7.8-8.6 (Chakraborti *et al.* 1985, Chattopadhyay and Mandal 1986) has been reported in the shrimp ponds of West Bengal. The results (8.18-9.27) of the present study, although high, are more or less, in conformity with the results (8.9-9.0) of Sharmila *et al*. (1996) from shrimp farms in Tamil Nadu. Significant differences existed in sediment pH values among sources (p<0.004) and months (p<0.001). The inlet sediment pH (8.06-9.07) and outlet sediment pH (8.16-9.50) was also followed the similar trend.

Redox potential is an index indicating the status of oxidation or reduction. Oxygen consumption and redox reactions are essential features of fish pond sediments. Fish production is affected by the presence of anaerobic conditions in the sediment (Avnimelech and Zohar 1986). It was estimated that oxygen penetrates several centimeters into the sediment (Hussenot and Martin 1995). The oxidation reduction potential level of the pond sediment was in the negative side ranging from -275.33 to -94.33 mV, thus indicating the fact that the sediment environment is increasingly anaerobic. A similar observation on the levels of oxidation reduction potential (–160 to –190 mV) in extensive shrimp culture systems of Kerala has been reported (Krishnani *et al.* 2011). The redox potential of the inlet sediment (-215.33 to -93.00 mV) and outlet sediment (-231.67 to -110.33 mV) followed the similar trend although with statistically significant (p<0.05) differences.

The organic carbon represents the status of organic matter in the pond. The TOC of sediment plays a vital role in brackishwater aquaculture system by influencing growth and survival of cultured organisms (Ameeri and Cruz 1992). The TOC content also decides the microbial flora and benthos of pond bottom. The optimum TOC for shrimp pond soil is 1.5-2.5% (Banerjea 1967). Chattopadhyay and Mandal (1986) recorded the TOC values in the range of 0.24-0.59% from shrimp ponds of West Bengal. Sharmila *et al.* (1996) found that TOC levels in pond sediment increased from an initial level of 0.24% to 0.49% during the culture period. In the present study also, the TOC levels of the inlet, pond and outlet sediments increased from 0.20 to 0.40%. No significant differences existed in TOC levels among months and sources (p>0.05). Nevertheless, the TOC levels were far less than the optimum level (Banerjea 1967), thus making the culture system less productive.

In general, the levels of physicochemical parameters like ammonia, nitrate, nitrite, etc increased with increasing days of culture, but remained within the safe levels. As majority of the physicochemical parameters of the medium saline *bheri* were well within the optimum levels, they did not affect the cultured shrimp. There was no incidence of shrimp diseases or growth retardation during the culture period. The shrimp production was 1,015 kg $ha^{-1}crop^{-1}$. Therefore, it can be concluded that the traditional shrimp culture in medium saline *bheri* may not pose any adverse environmental effect when discharged into the open coastal system.

ACKNOWLEDGEMENT

The research work was supported by the Indian Council of Agricultural Research [10(12)/2012-EPD], Government of India, New Delhi under the Niche Area of Excellence programme. The authors thank the Vice-Chancellor, West Bengal University of Animal and Fishery Sciences, Kolkata for providing necessary infrastructure facility to carry out the work.

REFERENCES

Alauddin M and Hamid MA (1999) Coastal aquaculture in South Asia: experiences and lesions. In: Alauddin M and Hasan S (Eds). Development, Governance and Environment in South Asia: A focus on Bangladesh. MacMillan Press, New York.

Ameeri AAA and Cruz EM (1992) Effect of sand substrate on growth and survival of *Penaeus semisulcatus* (de Haan) juveniles. Journal of Aquaculture in the Tropics 13: 239-244.

Anon (1997) Assessment of Ground Realities Regarding the Impact of Shrimp Farming Activities on Environment in Coastal Areas of Andhra Pradesh and Tamil Nadu: Final Report. Central Institute of Fisheries Education, Mumbai and Central Institute of Brackishwater Aquaculture, Chennai.

APHA/AWWA/WEF (American Public Health Association, American Water Works Association and Water Environment Federation) (2005) Standard Methods for the Examination of Water and Waste Water (20th edition). Washington, USA.

Avnimelech Y and Zohar G (1986) The effect of local anaerobic conditions on growth retardation in aquaculture systems. Aquaculture 58: 167–174.

Baliao D (2000) Environment Friendly Schemes in Intensive Shrimp Farming. SEAFDEC AQD. ISBN 971-8511-46-6.

Banerjea SM (1967) Water quality and soil condition of fish ponds in some states of India in relation to fish production. Indian Journal of Fisheries 14: 115-144.

Banerjee AC and Roychoudhury A (1996) Observations on some physico-chemical features of the Chilka lake. Indian Journal of Fisheries 13: 395-429.

Biao X, Tingyou L, Xipei W and Yi Q (2009) Variation in the water quality of organic and conventional shrimp ponds in a coastal environment from eastern China. Bulgarian Journal of Agricultural Science 15: 47-59.

Boyd CE (1989) Water Quality Management and Aeration in Shrimp Farming. Fisheries and Allied Aquaculture Departmental Series No. 2, Alabama Agricultural Experiment Station, Auburn University, Alabama, 120 pp.

Boyd CE (1995) Bottom Soils, Sediment and Pond Aquaculture. Chapman and Hall, New York.

Boyd CE and Clay JW (1998) Shrimp aquaculture and the environment. Scientific American 278: 42-49.

Boyd CE and Green BW (2002) Coastal water quality monitoring in shrimp farming areas, an example from Honduras. Consortium Program on Shrimp Farming and the Environment. Word Bank, NACA, WWF, FAO.

Briggs MRP and Funge-Smith SJ (1994) A nutrient budget of some intensive marine shrimp ponds in Thailand. Aquaculture and Fisheries Management 25: 789-811.

Chakraborti RI, Ravichandran P, Halder DO, Mondal SK and Sanlui D (1985) Some physicochemical characteristics of Kakdwip brackishwater ponds and their influence on survival, growth and production of *Penaeus monodon* (Fabricus). Indian Journal of Fisheries 22: 224-235.

Chattopadhyay GN and Mandal LN (1986) Distribution of nitrogen in brackishwater fish pond soils of West

Bengal. Indian Journal of Fisheries 27: 140-144.

Chen HC (1985) Water quality criteria for farming the grass shrimp, *Penaeus monodon*. In: Proceedings of the First International Conference on Culture of Penaeid Prawns/ Shrimps. Taki Y, Primavera JH and Llobrera JA (Eds.), Aquaculture Department, Southeast Asian Fisheries Development Centre, Iloilo City, Philippines, 165 pp.

Chien YH (1992) Water quality requirements and managements for marine shrimp culture. In: Proceedings of the Special Session in Shrimp Farming. Wyban J (Ed.), World Aquaculture Society, Baton Rouge, LA USA. pp. 30-42.

Chin TS and Chen JC (1987) Acute toxicity of ammonia to larvae of the tiger prawn *Penaeus monodon.* Aquaculture 66: 247-253.

Chiu YN (1988) Water quality management for intensive prawn ponds. In: Chiu YN, Santos LM and Juliano RO (Eds.) Technical Considerations for the Management and Operation of Intensive Prawn Farms. VP Aquaculture Society, Iloilo city, Philippines, pp. 102-128.

Das B, Khan YS and Das P (2004) Environmental impact of aquaculture-sedimentation and nutrient loadings from shrimp culture of the southeast coastal region of the Bay of Bengal. Journal of Environmental Sciences (China) 16: 466-470.

Das SK and Saksena DN (2001) Farm management and water quality in relation to growth of *Penaeus monodon* in modified extensive shrimp culture system. Journal of the Inland Fisheries Society of India 33: 55-61.

Das SK, Sahoo JK and Saksena DN (2001) Sediment characteristics and benthic biomass in relation to growth of *Penaeus monodon* Fabricius in low saline confined pond. Indian Journal of Fisheries 48: 55-61.

FAO (2013) Report of the FAO/MARD Technical Workshop on Early Mortality Syndrome (EMS) or Acute Hepatopancreatic Necrosis Syndrome (AHPNS) of Cultured Shrimp (under TCP/VIE/3304). Hanoi, Viet Nam, on 25–27 June 2013. FAO Fisheries and Aquaculture Report No. 1053. Rome, 54 pp.

Flegel TW (2009) Current status of viral diseases in Asian shrimp aquaculture. The Israeli Journal of Aquaculture - Bamidgeh 61(3): 229-239.

Hussenot J and Martin JLM (1995) Assessment of the quality of pond sediment in aquaculture using simple, rapid techniques. Aquaculture International 3: 123-133.

Islam ML, Alam MJ, Rehman S and Ahmed SU (2004) Water quality, nutrient dynamics and sediment profile in shrimp farms of the Sundarbans mangrove forest, Bangladesh. Indian Journal of Marine Science 33: 170-176.

Jhingran VG Natarajan AV Banerjea SM and David A (1969) Methodology on reservoir fisheries investigations in India. Bulletin of the Central Inland Fisheries Research Institute, Barrackpore 12: 1-109.

Karthikeyan J and Srimurali M (1995) Environmental impact analysis statement and environmental management plan report of a proposed aqua farm at Nellore in Andhra Pradesh. Indian Journal of Environmental Health 37: 251-264.

Khodami S, Attaran-Fariman G, Ghasemzadeh J and Mortazavi MS (2011) Comparison of different nitrogen compounds in three different environments of the Gwatar shrimp farms complex in the Gwatar Gulf region (Baluchestan-Iran). Iranian Journal of Fisheries Science 10: 663-677.

Krishnani KK, Gupta BP, Muralidhar M, Saraswathy R, Pillai SM, Ponnusamy K and Nagavel A (2011) Soil and water characteristics of traditional paddy and shrimp fields of Kerala. Indian Journal of Fisheries 58: 71-77.

Kuhn DD, Smith SA and Flick Jr GJ (2011) High nitrate levels toxic to shrimp. Global Aquaculture Advocate Nov/Dec 2011: 36-37.

Law AT (1988) Water quality requirements for *Penaeus monodon* culture. In: Proceedings of the Seminar on Prawn Farming in Malaysia, Malaysian Fisheries Society, Serdang, Malaysia. pp. 53-65.

Limsuwan C (1994) Shrimp disease and health management. In: Subasinghe RP and Shariff M (Eds.) Diseases in Aquaculture: The Current Issues. Pub-8, Malaysian Fish. Soc., Kuala Lumpur, Malaysia, pp. 71-96.

López-Téllez NA, Vidal-Martínez VM and Overstreet RM (2009) Seasonal variation of ectosymbiotic ciliates on farmed and wild shrimp from coastal Yucatan, Mexico. Aquaculture 287: 271–277.

Moore JW (1991) Inorganic Contaminants of Surface Water: Research and Monitoring Priorities. Springer-Verlag, New York.

Pillai NGK and Kathia PK (2004) Evolution of Fisheries and Aquaculture in India. Central Marine Fisheries Research Institute, Kochi, India. 240 pp.

Sharmila R, Abraham TJ and Sundararaj V (1996) Bacterial flora of semi-intensive pond-reared *Penaeus indicus* (H. Milne Edwards) and the environment. Journal of Aquaculture in the Tropics 11: 193-203.

Smith CE and Russo RC (1975) Nitrite induced methaemoglobinemia in rainbow trout. Progressive Fish Culturist 37: 150-152.

CONTRIBUTION OF THE AUTHORS

Leesa Priyadarsani

Generated laboratory and field data

Thangapalam Jawahar Abraham

Designed the experiment and drafted the article