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Effect of sediment and water quality parameters on the productivity of coastal shrimp farm

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ABSTRACT

The present study deals with the sediment and water characteristic of selected shrimp farms. The study envisaged to assess the sediment and water quality, productivity and fertility of the culture ponds and to understand the fluctuations in the values of sediment and water related parameters during the shrimp farming. Results have showed significant monthly variations at all four stations. Positive correlation was found between water temperature and salinity, salinity and primary productivity, primary productivity and dissolve oxygen, dissolve oxygen and nitrate, nitrate and total available phosphorous, soil salinity and soil organic carbon. However a negative correlation was observed between soil organic carbon and pH. Overall mean values of the nutrients in the sediment and water indicated that ponds are fertile and productive for shrimp culture operations.

Keywords: water quality, primary productivity, nitrate, available phosphorous,

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INTRODUCTION

Aquaculture is one among the fastest growing food sectors in the world. Amongst the various branches of aquaculture, shrimp culture has expanded rapidly across the world because of faster growth rate of shrimps, short culture period, high export value and demand in the market. In developing countries of east and south – east Asia, shrimp culture has become an important industry and contributes for the majority of the export both in terms of quantity and value. Currently more than 70 % of global shrimp production is coming from these countries and most is exported to developed countries. China is the leading producer of farmed shrimp in the world.

India has vast potential in terms of species diversity and total marine and brackish water culture environment. In India, total production of shrimp was 1,85,990 metric tonnes from an area of 1,84,115 ha during 2005-2006 [1] . Although shrimp aquaculture has significant contribution in the export earning still there is a room for improvement in the total production through lateral expansion and better management practices. In this regard, the state of Gujarat has the longest coast line in India and it can be for its suitability for the expansion of shrimp aquaculture.

Sediment and water quality plays an important role in increasing the productivity of pond. It provide nutritionally balanced and healthy environment to cultured animals. Sediment and water quality has a significant role in increasing the total production of pond. However, in India, much less efforts have been made to assess the role of these parameters in productivity of shrimp farms, and it necessitates attention for further research. Water quality management is important in aquaculture. The pH in water and sediments determine the healthy survival and growth of aquatic animals. Physical and chemical factors like temperature, salinity, total suspended solids (TSS), dissolved gases and nutrients influence the water quality directly or indirectly, which ultimately govern the healthy survival of organisms in aquatic ecosystems. Salinity plays an important role on the physiological functions of culture organisms. The balance of salt and water in a tissue is very essential for maintaining the coordination in its physiological functions. Total suspended solids (TSS) increase in the shrimp ponds as a result of phytoplankton blooms, zooplankton biomass and other suspended solid particles of clay or silt. Recently study have carried out on Nutrient status evaluation of Nagzari dam water of Maharashtra also show importance of nitrate for phytoplankton growth [2].

Quality of the pond sediment is one of the vital factors for the success of the aquaculture. The physical and chemical characteristics of pond water are very much influenced by the properties of bottom sediments. The bottom sediments provide food and shelter for the benthic organisms and also act as the reservoir of nutrients for the growth of benthic algae which constitute food for aquatic organisms. The sediment also functions as a buffer and governs the storage and release of nutrients into the water. It serves as biological filter through the adsorption of organic residues of food, excretory products and algal metabolites. The sediment holds high bacterial load which helps in the decomposition and mineralization of organic deposits at the bottom. The nature and composition of pond sediment have important role on the balance of coastal aquaculture systems and in determining the fertility of culture ponds and consequently on the growth and to release nutrients into the water from sediments by bacterial action. Organic cycling in the shallow brackish water ponds is governed by the rate of conversion of living tissues into detritus and secondarily the rate of conversion of detritus into dissolved organic and inorganic forms of nutrient.

The essential components of aquatic ecosystem are organic and inorganic form of potassium and calcium which influence organic productivity at the primary and secondary level in shallow coastal ponds traditionally used for shrimp and fish culture practices. Organic contents of the bottom sediments are reflected in the determination of organic carbon. The structure and composition of bottom sediment are important criteria to determine the suitability of the site for aquaculture. In this regard, adequate information about physico-chemical parameters of sediment and water, the dynamic interaction between sediment and overlying water and ecological interaction of cultured animals living in that environment are essential component to understand the suitability for development and management of shrimp aquaculture.

This research work was carried out with the objective to study the sediment and water characteristics of selected shrimp ponds. Information gathered from the study would be useful to understand the fertility of shrimp culture ponds with reference to sediment and water characteristics

MATERIALS AND METHODS

Site of the experiment
Shrimp (*Penaeus monodon*) farms located at Patelwadi village, Diu (U.T.) were selected for the present study. It is situated at N = 20^0 43’ 866” to N = 20^0 44’ 102”. Latitude and E = 070^0 54’ 529” to E = 070^0 54’ 512” longitude. Experiment was conducted for over a period of 120 days from February to May 2008. Three different ponds were studied. Each pond had an area of 0.8 ha and stocking density of 6-8 numbers/m^2. Ponds were fertilized with single super phosphate at the rate of 25 kg/ha.

Stations were fixed at four corners of ponds for regular collection of water and sediment samples.

Collection and analysis of water samples
Water samples were collected fortnightly in separate plastic containers (3 L) from all stations with the depth ranging from 70 cm to 100 cm. Water was allowed to stand still in the container for about 5 minutes. Temperature of the water was recorded directly from pond while collecting water samples. For estimation of primary productivity and dissolved oxygen, water samples were collected in labelled BOD bottle (125 ml.) carefully without entrapment of water bubbles. Water samples were taken in clean plastic container for analysis of various water quality parameters and were brought to laboratory for analysis.

Water quality parameters such as salinity (ppt), pH, total suspended solid (mg/l), dissolved oxygen (mg/l)), primary productivity (mg C/ m^3/day), nitrate (µg/l) and reactive phosphorus (µg/l) were analysed using standard methods [3]

Collection and analysis of sediment samples
Sediment was collected fortnightly from all the stations of different ponds starting from February to May 2008. Collected samples from all the stations were kept in separate labeled polyethylene bags. Samples were brought to the laboratory and stored in refrigerator for analysis. Collected sediment sample parameters analyzed in the laboratory condition were pH, salinity (ppt), organic carbon (%), available phosphorus (ppm), and available potassium (ppm).

Available phosphorus
Available phosphorus was determined by Olen's method as described by Jackson (1958). 2.5 gm of air dried, powdered soil was transferred to 250 ml Erlenmeyer flask. To this, 50 ml of $NaHCO_3$ solution was added along with one teaspoon of carbon black. Suspension was shaken for a period of 30 minutes. The solution was filtered through Whatman No. 1 filter paper and the filtrate was taken for determining the available phosphorus with the help of a Chemito digital flame photometer.

Available potassium
Available potassium was estimated by ammonium acetate extraction method. 10 g of oven dried, powered soil was transferred to 250 ml Erlenmeyer flask. To this flask, 100 ml of 1 N neutral ammonium acetate was added and shaken well in an electric shaker for half an hour. This solution was then filtered through Whatman filter No. 1 and the filtrate was then taken for determining the available potassium with the help of a Chemito digital flame photometer.

Salinity
Sediment sample was dried in hot air oven at 50-60 ^{0}C to remove the moisture. 5 gm of dried soil was transferred in a conical flask and 25 ml of distilled water was added to it. Mixture was shaked properly and filtered through No - 42 Whatman filter paper. Salinity of the filtrate was determined by titrimetric method [3]. In this method the halogen ions in seawater was titrated with silver nitrate using potassium chromate as indicator. Following formula was used for the calculation:

$$\text{Salinity} = \frac{X \times 0.144 \times 35.46 \times 25}{10 \times 5} \text{ mg/g or ppt.}$$

Where, X = volume of $AgNO_3$; 0.144 = normality of $AgNO_{3;}$ 35.46 = equivalent wt. of Cl; 25 = distilled water used for extraction; 10 = volume of the filtrate used for titration (in ml). 5 = quantity of sediment taken (in gm).

Organic carbon
Organic carbon of the sediment was estimated by wet oxidation method (Walkly and Black method) as described by Jackson [4] . Organic matter was calculated by following formula:

$$\text{\% of carbon in soil} = \frac{(x\text{-}y) \times N \times 0.003 \times 100}{W}$$

Where; W = weight of the soil, x = volume of ferrous ammonium sulphate for blank; y = volume of ferrous ammonium sulphate for sample; N = normality of ferrous ammonium sulphate.

RESULTS AND DISCUSSION

The present study aimed to evaluate the sediment and water parameters of selected shrimp farms of Patelwadi village, Diu region. Periodical data obtained were statistically analysed and presented as follows. Data are presented with standard deviation values.

Analysis of water parameters
Temperature and salinity
Water temperature (ºC) recorded from four stations each from the different ponds .Water temperature (ºC) was found lowest 17.4 ± 0.3 SD in pond A in the month of February, 2008. The highest temperature (ºC) i.e. (29.8 ± 0.8) in pond B in the month of May, 2008. The water temperature increased with the increase in culture period.

Statistical analysis of the data revealed that there was significant difference ($p<0.05$) observed for water temperature recorded between all the treatment ponds during February 2008 to May 2008.

Significant correlation ($p<0.05$) was found between water temperature (ºC) and salinity (ppt), primary productivity, (mgc/m^3/day), dissolved oxygen (mg/l), reactive phosphorus (µg/l), nitrate (µg/l), pH and total suspended solids (mg/l), respectively.

Moreover, there was a significant correlation ($p<0.05$) found between water temperature (ºC), soil available phosphorus, (ppm), soil available potassium (ppm), and soil salinity (ppt) respectively. However, no significant correlation ($p>0.05$) was observed between water temperature (ºC) and soil pH as well as soil organic carbon (%) respectively.

The mean water salinity (ppt) recorded from the different ponds. Water salinity (ppt) was found lowest 28.5 ± 0.1 ppt in pond A in February, 2008 and highest 31.0 ± 0.6 ppt in pond B in the month of May, 2008 The water salinity increased with the increase in culture period.

Statistical analysis of the data revealed that there was significant difference ($P<0.05$) observed for water salinity recorded between all the treatment ponds during February, 2008 to May, 2008.There was a significant correlation ($p<0.05$) found between water salinity (ppt), soil available phosphorus, (ppm) and soil available potassium (ppm) respectively. However, no significant correlation ($p>0.05$) was observed between water salinity (ppt), and soil pH as well as soil organic carbon (%) respectively.

Primary productivity (mgc/m3/day)

Primary Productivity (mgc/m^3/day) was recorded from four stations each from the different ponds are shown in Table 1. Primary productivity was found to be lowest 6.5 ± 0.1 mgc/m^3/day in pond A in February, 2008 and highest 9.4 ± 0.1 mgc/m3/day in pond C in the month of May, 2008 The primary productivity increased with the increase in culture period. Moreover, there was a significant correlation ($p<0.05$) found between soil salinity (ppt), soil available phosphorus, (ppm) and soil available potassium (ppm) respectively. However, no significant correlation ($p>0.05$) was observed between water pH, total suspended solids (mg/l), soil pH as well as soil organic carbon (%) respectively.

Dissolve oxygen (mg/l)

Dissolve oxygen (mg/l) was recorded from four stations each from the different ponds.The mean Dissolve Oxygen (mg/l) recorded from the different ponds. Dissolve Oxygen was found to be lowest 5.2 ± 0.1 mg/l in pond A in February, 2008 and highest 7.1 ± 0.1 mg/l in pond B in the month of May, 2008 The dissolved oxygen increased with the increase in culture period.

Reactive phosphorous (µg/l)

The mean Reactive Phosphorous (µg/l) recorded from the different ponds. Reactive phosphorous was found to be lowest 7.4 ± 0.1 µg/l in pond A in February, 2008 and highest 8.4 ± 0.2 µg/l in pond C in the month of May, 2008 The reactive phosphorous increased with the increase in culture period.

Nitrate (µg/l)

Nitrate (µg/l) was recorded from four stations each from the different ponds are shown Figure 1. The mean Nitrate (µg/l) recorded from the different ponds. Nitrate value was found to be lowest 0.70 ± 0.02 µg/l in pond A in February, 2008 and highest 0.87 ± 0.01 µg/liter in pond C in the month of May 2008 The nitrate increased with the increase in culture period.

Statistical analysis of the data showed that there was significant difference ($P<0.05$) observed for nitrate recorded between all the treatment ponds during February, 2008 to May, 2008.

Total suspended solids (mg/l)

Total suspended solids (mg/l) was observed from four stations each from the different ponds are shown in Figure 2 .The mean Total Suspended Solids (mg/l) recorded from the different ponds. Total suspended solids was observed to be lowest 67 ± 0.2 mg/l in pond C in February, 2008 and highest 75.1 ± 0.1 in pond B in the month of April, 2008 The total suspended solids increased with the increase in culture period.

Analysis of sediment parameters

Available phosphorous (ppm)

Soil Available phosphorous (ppm) was observed from four stations each from the different ponds are shown in Figure 3. The mean Soil Available phosphorous (ppm) recorded from the different ponds. The available phosphorous in sediment was found to be lowest 91.0 ± 0.1 ppm in pond B in February, 2008 and highest 92.6 ± 0.6 ppm in pond C in the month of May, 2008 The soil available phosphorous increased with the increase in culture period.Significant correlation ($p<0.05$) was found between Available Phosphorous (ppm) and soil salinity (ppt). No significant correlation ($p>0.05$) was observed between Available Phosphorous (ppm) and soil pH, soil organic carbon (%) and soil available potassium (ppm) respectively.

Available potassium (ppm)

Soil Available potassium (ppm) was observed from four stations each from the different ponds are shown in Table 2. The available potassium in sediment was found to be lowest 750.8 ± 1 ppm in pond C in February, 2008 and highest 778.0 ± 1.4 ppm in pond A in the month of May, 2008. The soil available potassium increased with the increase in culture period.

Organic carbon (%)

Soil organic carbon (%) was recorded from four stations each from the different ponds are shown in Figure 4. The mean Soil organic carbon (%) recorded from the different ponds. Soil organic carbon was found to be lowest 2.2 ± 0.2 % in pond A in February, 2008 and highest 2.6 ± 0.1 % in pond B in the month of March, 2008. The soil organic carbon increased with the increase in culture period.

Statistical analysis of the data revealed that there was significant difference (P<0.05) observed for soil organic carbon recorded between all the treatment ponds during February, 2008 to May, 2008.

Table 1. Primary productivity (mgc/m^3/day) of the three ponds recorded during February, 2008 to May, 2008. (n=4 Stations)

	Feb 1	Feb 15	Feb 29	Mar 15	Mar 30	Apr 15	Apr 30	May 15	May 30
Pond A									
1	6.4	7.1	7.3	7.7	7.9	8.1	8.4	8.9	9.3
2	6.5	7.0	7.4	7.6	7.8	8.2	8.3	8.8	9.4
3	6.5	7.0	7.3	7.7	7.8	8.1	8.4	8.9	9.4
4	6.4	7.1	7.5	7.5	7.9	8.0	8.2	8.8	9.3
Pond B									
1	6.5	7.0	7.5	7.7	7.8	8.2	8.4	8.6	9.2
2	6.6	7.1	7.3	7.6	7.8	8.0	8.2	8.9	9.3
3	6.6	7.2	7.2	7.5	7.9	8.1	8.2	8.8	9.4
4	6.5	7.0	7.4	7.7	7.7	8.2	8.4	8.7	9.2
Pond C									
1	6.4	7.1	7.3	7.6	7.9	8.2	8.5	8.7	9.3
2	6.5	7.1	7.4	7.4	7.7	8.0	8.4	8.7	9.4
3	6.5	7.0	7.2	7.5	7.8	8.2	8.4	8.6	9.3
4	6.4	7.1	7.3	7.6	7.9	8.4	8.5	8.6	9.5

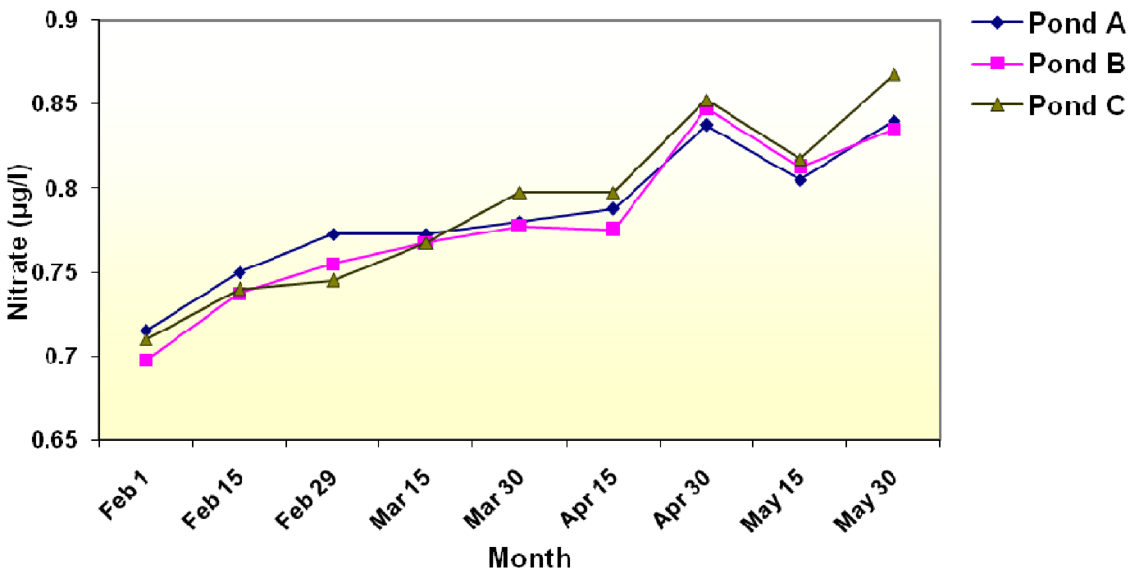

Fig. 1. Mean nitrate (µg/l) of the three ponds observed during

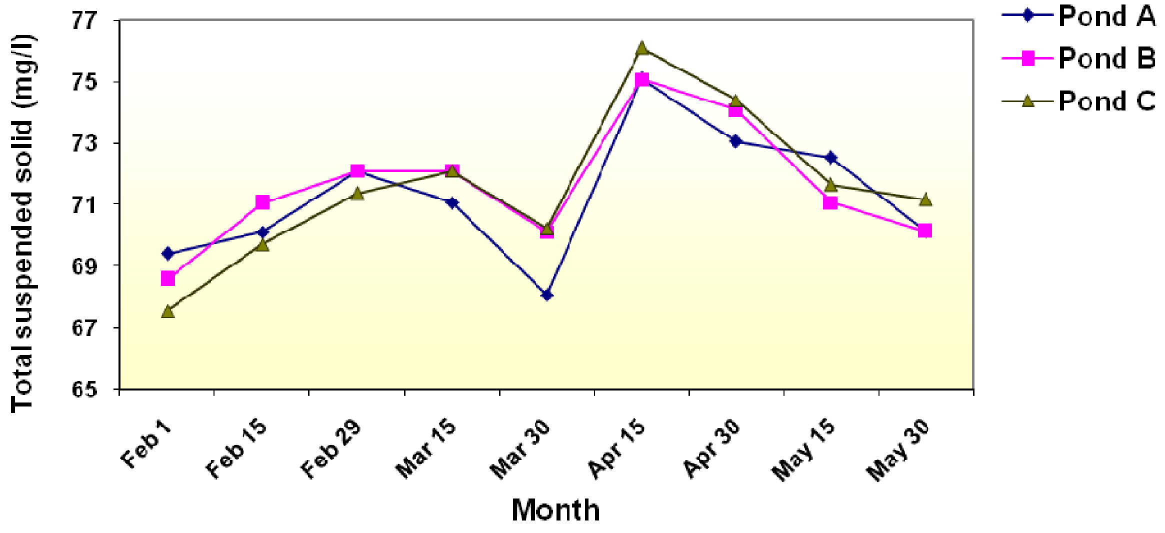

Fig. 2. Mean total suspended solid (mg/l) of the three ponds observed

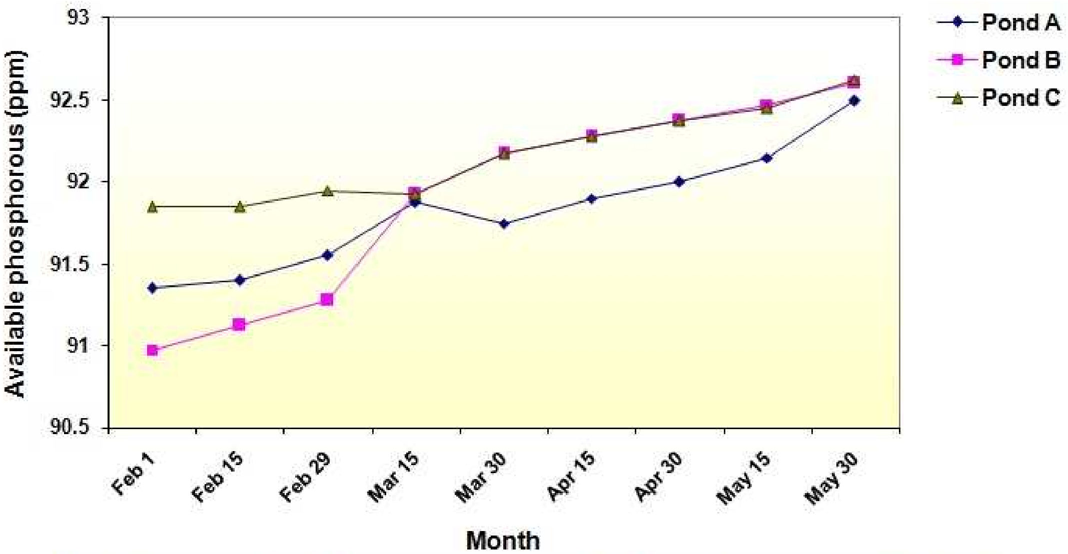

Fig. 3. Mean available phorphorous (ppm) of the three ponds observed during February, 2008 to May, 2008.

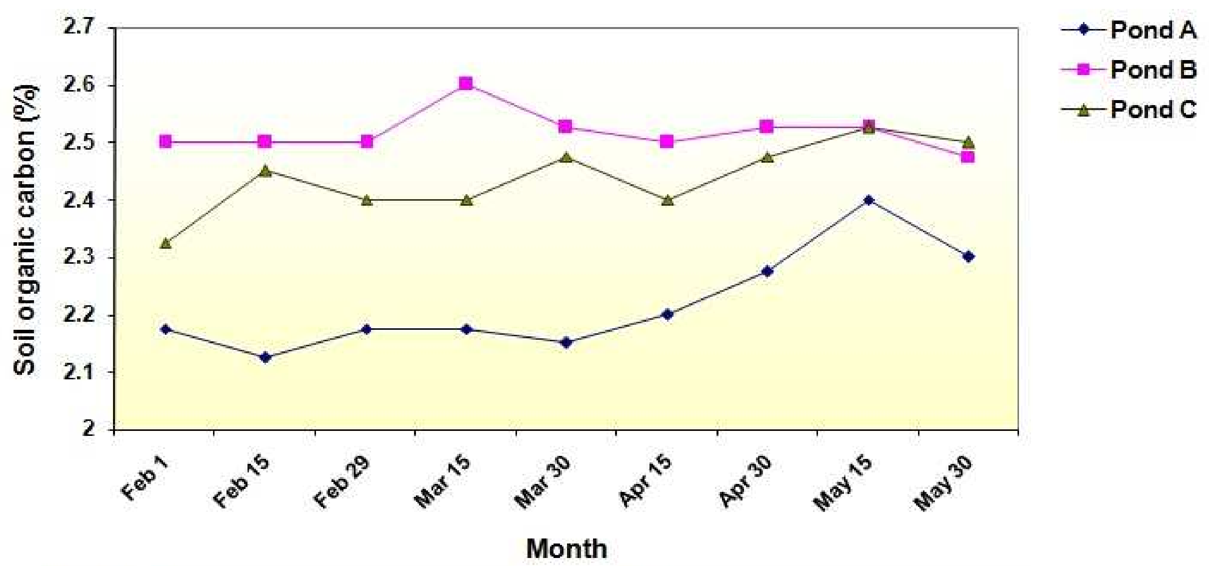

Fig. 4. Mean Soli Organic carbon (%) of the three ponds observed during February, 2008 to May, 2008.

Table 2 : Available potassium (ppm) of the three ponds recorded during February, 2008 to May, 2008. (n=4 Stations)

	Feb 1	Feb 15	Feb 29	Mar 15	Mar 30	Apr 15	Apr 30	May 15	May 30
Pond A									
1	760	765	768	767	770	765	768	765	759
2	762	763	768	766	770	767	767	766	758
3	765	763	765	765	771	768	766	768	756
4	765	764	766	767	772	765	768	765	759
Pond B									
1	765	764	767	768	775	770	775	772	768
2	763	765	765	768	774	771	776	770	767
3	765	763	766	766	773	772	775	771	767
4	766	765	767	766	775	770	778	771	768
Pond C									
1	750	755	754	755	765	770	769	775	774
2	752	752	750	754	767	768	770	773	775
3	751	752	751	754	766	768	769	772	776
4	750	753	751	753	765	767	768	775	776

DISCUSSION

Temperature is an essential parameter to influence the photosynthesis in water, physiological responses of culture organisms and decomposition of organic mater and subsequent bio-chemical reactions. It is also one of the most important factors controlling growth of marine shrimp [5]. In the present study, the temperature was recorded between 17.4 to 29.8 ºC. In all the shrimp ponds. A significant seasonal variation in the water temperature has been noticed among all the treatment ponds from February to May due to the onset of summer. Asha and Diwakar [6] also observed a similar impact of atmospheric temperature on inshore water of Tuticorin coast from January to August. Increase in temperature has shown a positive impact on salinity which might be due to the higher amount of evaporation at elevated atmospheric temperature. Increase in dissolved oxygen concentration and primary productivity may have resulted from augmentation in production of phytoplankton from strong and longer light period during summer months. Recently study carried out on physico-chemical characterization of irrigation tanks and fishponds of Gujarat have also show same results [7].

In the present investigation, range of gross primary productivity was observed between 6.5 to 9.4 mgc/m^3/day. Increase in the primary productivity was noticed among the treatment ponds from February to May. This is in agreement with the observation of [8] with high values of primary production recorded during May – July in Cochin estuarine system. The increase in the primary production might be due to the enclosed nature of pond ecosystem and due to regular feeding and fertilization of culture pond. Positive correlation between primary productivity and dissolved oxygen was probably due to the production of phytoplankton which was evident from higher nutrients level and lower secchi disc transparency.

Reactive phosphorus in the water was recorded between 7.4 to 8.4 µg/l. This range fall within the range observed by [9]. According to Moyle [10] inorganic phosphate concentration ranging from 0.05 to 0.1 ppm and between 0.1 to 2 ppm is considered as good and very good in culture ecosystems respectively. Monthly increase in reactive phosphorus was observed in the present study shows the high input of feeds and fertilization in the culture system. Similar gradual increases have been observed by [11] . It was also evident from high primary productivity and low secchi disc transparency. There was a positive correlation between reactive phosphorus and nitrate, reactive phosphorus and potassium and reactive phosphorus and total phosphorus, these correlations might be due to decomposition and mineralization of nutrients. It seems high level of decomposition of organic matter should negatively affect the water pH but stable pH of water indicates to be a well managed farm

The main source of nitrate in the ponds is from land drainage and through tidal influence from the neighboring environments apart from the *in situ* recycling process. According to Qasim et al. [8] there is little or trace of nitrate content in the productive coastal waters during most part of the year. In the present study, the range of water nitrate from February to May was found between 0.70 to 0.87 µg/liter which is relatively low as compared to the range obtained by [8]. Smith [12] stated that biologists tend to favour nitrogen over phosphorus as the limiting factor controlling primary productivity in the brackish water and marine environments. Monthly increase in nitrate was observed in the present study shows the high input of feeds and fertilization in the culture system. It was also evident from high primary productivity and low secchi disc transparency in the later part of study. Positive impact of nitrate on water pH was observed and it was possibly due to high level of oxidation process. Increase in total suspended solids with increase in nitrate level indicates to be an essential nutrient for productivity of the pond water. Positive correlation of nitrate on other nutrients might be due to high level of mineralization of nutrients in pond water. Recently [13] Nitrates concentration were detected minimum value during in rainy and reaching maximum in summer season . Same observation was found out in present study also

The results showed that the total suspended solid (TSS) in water was found to be varying between 67 to 76 mg/l. According to Alabaster and Lioyed [14] , maintenance of moderate to good shrimp farming is possible in water containing 25 to 80 mg/l suspended solid particles while TSS values of 80-100 mg/l and above do not support good fisheries. According to their views, present investigation could be treated as moderate to good based on TSS value. As per Jones *et al*. [15] shrimp ponds usually have very high loading of suspended solids and high densities of phytoplankton. High concentration of inorganic nutrients in association with higher phytoplankton density reflect a probable rich and productive environment supporting the notion that there was active mineralization of pond effluent. Similar observation is also reported by [16] and [17]. Monthly increase in total suspended solid was recorded in the present investigation. No correlation of total suspended solid with nutrient level was observed. It assumed to be due to the sufficiency of nutrients in the water for phytoplankton production. Recently [18]study carried out on Growth comparison of the seaweed Kappaphycus alvarezii in nine different coastal areas of Gujarat coast have also show same result.

The capacity of sediment to retain or release phosphorus is one of the important factors which influence the concentration of inorganic and organic phosphorus in the overlying water. Studies on the rate of absorption of phosphorus by lake muds under aerobic condition have been carried out by [19]. The available phosphorus in brackish water ponds assumes comparatively higher value over fresh water ponds as reported by [20] . In the present investigation, the range of available phosphorus was found between 91.0 to 92.6 ppm. This is in agreement with the observation of [9]. Banerjea [21] classified aquaculture potential of a pond based on available phosphorus. According to him, available phosphorus content of less than 30 ppm in pond sediments shows low production, 30-60 ppm as average, and more than 60 ppm considered as highly productive. According to this classification all ponds studied are fall under highly productive range. Monthly increase in soil available phosphorus recorded in the present investigation indicates the high input of feeds and fertilization and its simultaneous mineralization in the pond [22]

In the present investigation, the available potassium in sediment ranged from 763.0 to 778.0 ppm. This shows that sufficient quantity of potassium is present in the bottom sediment of these ponds [23]. According to Chattopadhyay [24] , the nature of clay mineral appeared to be the main factor for the presence of high amount of cations like potassium. The present study revealing high amount of potassium in sediment is in conformity with the earlier report of [25] who observed potassium content of brackishwater pond soils in Bangladesh upto 640 ppm while [26] observed the range of 350 – 1002 ppm of potassium in brackish water culture ponds. Present investigation reveals that ponds are moderately fertile in the available potassium content of sediment.

Increase in the available potassium was noticed among the treatment ponds from February to May. Soil available potassium did not show any impact on soil salinity, soil organic carbon and soil pH.

Organic carbon is the most important factor determining the fertility status of soil. The range of organic carbon content in the present investigation was found to be between 2.2 to 2.5 %. Present results are found to be similar with the observation of [9]and [22]. Banerjea [21] reported that aquaculture production was found to be positively related with the soil organic carbon. According to him pond 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. Monthly increase in soil organic carbon in the present investigation may be due to accumulation of uneaten feed and dead plankton [27]

CONCLUSION

It can be concluded that the ponds under the present study appear to be highly productive in regard to water and sediment characteristics. They may be utilized for shrimp aquaculture purpose

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