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Physico–chemical analysis of soil and water in shrimp culture ponds and adjacent coastal waters in Thoothukudi district, Tamil Nadu, India

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Abstract
The water and soil samples were collected from the five (adjacent coastal waters – S3, S4, S5) selected stations and the sediment samples were collected only in station 1 and 2 (Shrimp ponds). The collected water samples were analysed for their various physico-chemical parameters such as water depth, light extinction coefficient (k), surface water temperature, total suspended solids, total dissolved solids, salinity, dissolved oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, nitrite, nitrate, phosphate, ammonia and chlorophyll-*a*. The collected sediment samples were analyzed for organic carbon, total nitrogen and C / N ratio. In the present study, in all the stations the recorded overall values of physical parameters such as depth, light extinction co-efficient (k), surface water temperature, salinity, total suspended solids and total dissolved solids ranged from 1.0 to 1.7 m, 1.05 to 6.52, 24.5 to 32ºC, 34.0 to 38.0 ppt, 0.22 to 7.7 mg/l and 38.22 to 59.5 mg/l respectively. The observed range of overall values of chemical parameters such as dissolved oxygen, BOD, COD, nitrite, nitrate, phosphate and ammonia were 3.15 to 6.70 ml/l, 0.55 to 5.1 mg/l, 2.2 to 20.5 mg/l, 0.17 to3.82 µg.at.NO_2-N/l, 0.01 to 1.12 µg.at.NO_3-N/l, 0.82 to 5.36 µg.at.PO_4-P/l and 0.01 to 4.8 µg.at.NH_3-N/l respectively. The values of C: N ratio varied from 1.43 to 5.41 in station 1 and from 0.07 to 11.16 in station 2. Among biological parameters, the values of chlorophyll-*a* content ranged from 1.15 to 310.66 mg/m^3 in all the stations.

Keywords: Shrimp Pond, Physico-Chemical Parameters, Biological Parameters, C/N Ratio

Introduction
Shrimp farming is one of the major aquaculture activity attracting huge investments worldwide as well as in India, owing to its greater economic returns. This industry is also known to provide tremendous opportunity for the economic as well as social upliftment of the rural population in the world. Though many earlier studies on the plankton of indian coastal water bodies are available only limited works are available on the plankton dynamics of the shrimp farming systems. Tookwinas and Songsangjinda (1999) [42] have studied on water quality and phytoplankton communities in intensive shrimp culture ponds in Kung Krabaen Bay, Eastern Thailand. The impact of shrimp pond effluent on water quality and phytoplankton biomass in a tropical mangrove estuary was made by Trott and Alongi (2000) [43]. Phytoplankton growth is regulated by several factors including temperature, light, turbidity and nutrient level of water. Phytoplankton are known to increase the dissolved oxygen levels and decrease toxic gases like ammonia, nitrite, hydrogen sulfide, methane and carbon dioxide in shrimp culture pond. Thus, phytoplankton plays a significant role in stabilizing the available nutrients of water quality. Phytoplankton also competes for nutrients with other microbes and lowers pathogenic bacterial population besides increasing the density of natural food to the culture species. Mass mortality of phytoplankton during warm days possesses a threat to shrimp. High temperature increases the rate of decomposition of the deposited dead plankton cells and leads to the consumption of oxygen, resulting in oxygen depletion. The resulting anaerobic sediment can release ammonia and sulphide, which is a stress to the benthic shrimp and prawn, necessitating rapid water exchange in the shrimp farms would create more investment of finance.

Further, the discharging of the effluent from the bloom affected shrimp ponds into the adjoining coastal waters would be a serious environmental concern as the dissolved protein from the bottom accumulated uneaten shrimp feed and ammonia along with metabolic wastes of the culture organisms into the water column and pond bottom sediments. When the effluent is released into the receiving coastal waters, eutrophication in the surrounding aquatic environment and formation of harmful algal blooms is resulted (Burford and Williams, 2001) [12]. The diversity of plankton varies from location to location and from pond to pond of the same location with similar ecological conditions (Boyd, 1982) [11]. Hence, the management of water quality parameters with ideal plankton productivity in the shrimp ponds is an important paramount factor.

Materials and methods

The present study was carried out to analysis the physico-chemical parameters of soil and water in *Litopenaeus vannamei* culture ponds and in the adjacent coastal waters near Kalaignanapuram, Thoothukudi district, Tamil Nadu from November 2013 to April 2014. For the present study, five stations were selected: station 1 and 2 are the shrimp ponds; station 3 – site of source water to the shrimp ponds; station 4 - site receiving the shrimp pond effluent and the station 5 is an unpolluted coastal water relatively free from any pollution, particularly not influenced by the effluents from the shrimp ponds.

Collection of Water Samples

The present investigation was under taken to study hydrographical parameters in the *Litopenaeus vannamei* culture ponds as well as in the coastal waters adjoining the coastal waters. Surface water and plankton samples were collected fortnightly from the selected Stations 1 to 5 for a period of 6 months from November 2013 to April 2014. The samples were collected during early morning hours between 7 and 9 a.m. The surface water temperatures were measured using a mercury thermometer with an accuracy of ± 0.1ºC (Sahu *et al.*, 2012) [32]. The water depth of these stations was also recorded with the help of a graduated rope tied with a weight at the bottom. The light penetration was determined with a secchi disc following the method of Pool and Atkins (1929) [29]. The sediment samples were collected from the culture ponds with the help of a small PVC pipe, which acted as a sediment collecting corer.

Water Sample Analysis

A clean plastic bucket was used for collecting surface water samples. The water quality parameters such as total suspended solids (TSS) and total dissolved solids (TDS) were analysed by following the procedure of APHA (1995) [4]. Salinity was estimated by Argentometric method (Strickland and Parsons, 1976). Dissolved oxygen was estimated by following the modified Winklers method (APHA, 1995). The COD and BOD were estimated by adopting the methods of Ramadhas and Santhanam (1996) [30]. The water samples were filtered using a Millipore filter paper (Pore size: 0.45 µm) analysed for nitrite, nitrate, ammonia and phosphate using spectrophotometer (Perkin Elmer) by following procedure of Ramadhas and Santhanam (1996) [30]. Chlorophyll-*a* concentration was estimated by adopting the methods of Strickland and Parsons (1976) [38].

Sediment Sample Analysis

The total organic carbon content of the collected sediment samples were estimated adopting the procedure of Ramadhas and Santhanam (1996). The total nitrogen was determined by the Kjeldahl method as given AOAC (1995) [3] using KEL PLUS (Pelican) digestion and distillation apparatus.

Result and discussion

Physico-Chemical Parameters

Light extinction co-efficient (k)

The monthly average light extinction co-efficient (k) values of the different stations ranged from 1.49 to 3.30 with the maximum and minimum value in station 1 and 5. This maximum and minimum values are mainly due to the presence of high amount of suspended particles due to continuous aeration and high level of chlorophyll-*a* in the shrimp ponds (average value of 3.26 in the shrimp culture ponds) and low amount of suspended particles in the control stations (station 5). Similarly, the Station 3 had an average k-value of 1.52, which was also due to the minimum or negligible amount of suspended particles. The overall maximum average k- value observed in the present study is similar to that of the value reported by Keawtawee *et al.* (2012) [19] in Thailand with 3.13. The present study showed the k-values with increasing trend in the shrimp culture ponds during the latter part of the culture period and also in the station 4 (coastal water) which receives the effluent discharge then and there. The similar observations were made by Coman *et al.* (2006) [15] in shrimp ponds with a value of 3.49. The average k-value recorded in station 3 and station 5 were 1.52 and 1.49 respectively, which is also in accordance with the value of 1.85 in Palk Bay observed by Sridhar *et al.* (2006) [37]. In general, the maximum k- value is mainly due to the agitation due to aeration, chlorophyll-*a*, plankton density and suspended soil particles in the ponds and wave action and water turbulence in the coastal waters.

Surface water temperature

Water temperature plays an important role on the distribution of aquatic organisms in any aquatic ecosystems. The pattern of variation of water temperature mainly depends on the variation in atmospheric temperature prevailing in that particular location as well as the nature of depth of the ponds or coastal waters. In the present study, the surface water temperatures ranged from 24.5 to 32°C were recorded in all the five stations. Among the different stations studied, the minimum temperatures recorded were 24.5 and 26.5°C in culture ponds during January and February in station 1 and station 2 respectively. However, the maximum temperature values of the shrimp ponds during the study period were 30.5 and 30.0ºC in station 1 and 2 in April and these values were as similar as reported by Babu *et al.* (2013) [7] with 31.0ºC in summer in Muthupetai coastal waters. In the case of coastal water stations of 3, 4 and 5, the average surface water temperature value of 29.2°C has been observed. The similar temperature in the coastal waters of east coast of India was also reported by Madhav and Kondalarao (2004) [22]. Similarly, Asha and Diwakar (2007) [5] reported the water temperature values between 26.5 and 32.5 from Tuticorin in the Gulf of Mannar. The high value of temperature in summer was due to the intensity of solar radiation and evaporation

(Senthilkumar *et al*., 2002; Santhanam and Perumal, 2003) [36, 33].

Total suspended solids (TSS)

In the present study, the values of total suspended solids were varied from 0.20 to 7.70 mg/l in all the five stations. The minimum values were recorded in station 1 and 5 and the maximum values were at station 1 and 2. In all the stations, the overall mean average value observed was 2.49 mg/l. However, the maximum values of total suspended values were recorded invariably in March / April in all the stations. This maximum value coincided with the phytoplankton density in shrimp ponds and in April in the coastal water stations. The maximum value during March in the station 1 and 2 of shrimp ponds might be due to the high plankton biomass as well as continuous aeration to avoid dissolved oxygen problem in the ponds. In the case of coastal waters, the recorded maximum value of total suspended matters in April, 2014 could have been due to the plankton abundance in the summer season as well as due to severe wave action in the coast cause by wind force on the open coast (Saha *et al.*, 2001) [31]. In contrary, the very high value of total suspended solids was reported by Kalaiarasi *et al.* (2012) [17] with 47.5 mg/l in Manalmelkudi of Palk bay coast.

Total dissolved solids (TDS)

The overall values of total dissolved solids were ranged between 38.2 mg/l and 59.5 mg/l in all the five stations. The maximum value was recorded in station 4 during January, 2014. The total dissolved values in this pond showed increasing trend in the beginning up to January, 2014 and started declining from February, 2014 to April, 2014, during the end of the culture period. Similarly, these values in the station 1 and 2 were also showed maximum values with 47.9 and 48.3 mg/l respectively. This high value was mainly because of input of the organic matter of nutrient rich feed material given to the shrimps and subsequent discharge of this effluent into the adjoining coastal waters station 4 might be the reason for the high value in station 4. Similarly, this value in the station 3, 4 and 5 were ranged between 38.2 and 59.5 mg/l. But, the overall mean of the total dissolved solids in all the coastal water stations was 44.39 mg/l. However, the overall average monthly maximum value of 46.71 mg/l was observed during February, 2014 and the maximum value was also reported by Kalaiarasi *et al*. (2012) [17] in Manalmelkudi coast in Palk Bay during February.

Salinity

Salinity is one of the important factors which profoundly influence the abundance and distribution of the plankton diversity (Meeran *et al*., 2011) [23], whereas, functional physiology and reproductive activity of the organisms (Kinne, 1971) [21]. During the present investigation, the water salinity values ranged from 34.0 to 38.0 ppt in all the five stations. The higher salinity value was observed in Station 1 and 2. The similar value of 36.30 ppt was reported by Coman *et al.* (2006) [15] and 35.6 ppt reported by Saraswathy *et al.* (2013) [34] in shrimp ponds. The maximum salinity value of 36 ppt was reported by Ashok kumar *et al*. (2014) [6] in Tuticorin coastal waters. Similar maximum salinity of (36 ppt) was also observed in station 3, 4 and 5. The high values of salinities recorded would be due to scarcity of rainfall, cessation of river water influx and high surface temperature besides its evaporation.

Dissolved oxygen

The dissolved oxygen content in the different stations was found ranging between 3.15 and 6.70 ml/l. The minimum and the maximum values were recorded during February and January in station 4 and in station 2 respectively. In shrimp ponds of station 1 and 2, the overall average value of dissolved oxygen was 5.33 ml/l. The maximum dissolved oxygen content values recorded were 6.1 ml/l and 6.7 ml/l in station 1 and 2 during December and January respectively. In the present study period, the minimum dissolved oxygen recorded was 5.0 ml / l in shrimp pond 1 and 3.85 ml/l in shrimp pond 2 during April. This minimum values observed were during the summer months which could be attributed to the prevalence of high temperature in the pond water. Similarly, the minimum values of dissolved oxygen were also invariably recorded in the stations 3 and 5 with 4.45 ml/l during April, 2014 (summer). Similar observation of minimum dissolved oxygen with 2.21 ml/l in June (summer) in the shrimp pond water of Muthupettai was reported by Babu *et al*. (2013) [7]. The maximum values of dissolved oxygen both in the shrimp ponds (station 1 and 2) as well as in the coastal waters were recorded invariably during the months of December/January and the similar situations were reported by Sridhar *et al.* (2006) [37] and Rajkumar *et al.* (2009) [29] and attributed the reason as the heavy rain fall coupled with mixing due to high wind velocity.

Biochemical oxygen demand (BOD)

Biochemical oxygen demand is the amount of oxygen taken up by microorganisms that decompose organic waste matter present in water. BOD is used as indicator of the organic matter load in ponds (Ainon and Saphri, 2008) [2]. The overall values of biological oxygen demand in station 1 and 2 were ranged between 1.70 and 5.10 mg/l. The minimum values of BOD in the shrimp ponds of station 1 and 2 during November 2013 is mainly because of the initial period of the culture as well as the presence of good amount of dissolved oxygen level in the pond water. Similarly, the maximum values of BOD in station 1 and 2 were observed during April 2014 and this may be because of the heavy accumulation of organic matter from uneaten shrimp feed as well as dead plankton in the bond bottom during the last phase of the culture period (Ting, 2001) [40]. This is also evidenced by the decrement in the level of dissolved oxygen content during the summer months which might have been caused by the effect of high temperature. The high value of BOD value was also reported by Ainon and Sapheri (2008) [2] in the shrimp ponds of Malaysia with the value of 6.7 mg/l. Similar the high value of biochemical oxygen demand of 8.0 mg/l in shrimp culture pond was also reported by Joseph *et al*. (2003) [16] in Thoothukudi.

The coastal water stations had a range of BOD values from 0.55 to 4.10 mg/l with minimum and maximum during April in station 5 and 4 respectively. The maximum value observed during April, 2014, in station 4 might have been due to the partial discharge of organically loaded effluent discharge and however this load is somewhat less when compared to the BOD level of the ponds which might be due to the tidal action of the coastal waters. The overall maximum value of BOD was recorded in coastal waters (station 3, 4 and 5) with value of 2.30 mg/l and this is in

accordance with slightly higher value of 3.12 mg/l as reported by Varadharajan and Soundrapandian (2013) [44] in Poombugar of South east coast of Tamil Nadu in the month of March 2011. In contrary, Meeran *et al.* (2011) [23] have reported the maximum BOD value of 6.66 mg/l in Thondi, Southeast coast of India.

Chemical oxygen demand (COD)

The chemical oxygen demand of water represents the amount of oxygen required to oxidize all the organic matter, both biodegradable and non-biodegradable by a strong chemical oxidant. In the present study, the overall values of chemical oxygen demand ranged from 2.20 to 20.50 mg/l in all the 5 stations. The maximum and the minimum values of COD values were recorded in station 2 and 5 during April 2014. The overall average maximum COD value of station 1 and 2 was 19.70 mg/l. The similar maximum COD value of 15.10 mg/l was reported by Joseph *et al*. (2003) in the ponds of *P. monodon* in Tuticorin. In shrimp ponds, this COD values were showed the increasing trend towards the increasing of days of the culture period because of the accumulation of organic matter in the pond bottom.

In the case of coastal water stations of 3-5, these values were ranged from 2.2 to 9.50 mg/l with minimum and maximum in station 4 and 5 respectively during April. The station 3 and 5 had a maximum value during December whereas the station 4 had a maximum in April, 2014. This maximum value observed in the station 4 might be due to the discharge of the effluent from the shrimp ponds during the period of observation and thus this station might have showed higher values when compared to the other coastal stations. However, this maximum value is low when compared to the values reported by reported by Meeran *et al*. (2011) [23] and Muralidharan *et al.* (2010) [24] in Thondi Palk Bay, Tamilnadu during the premonsoon period.

Nutrients

Nitrite (NO_2-N)

Nitrite is the intermediate oxidation state between ammonia and nitrate and unstable form of inorganic nitrogen present in the seawater. In the present study period, the average values of nitrite recorded were 2.07, 2.12, 0.50, 0.70 and 0.37 µg.at.NO_2-N/l in station 1, 2, 3, 4 and 5 respectively (Fig.1). The average values of nitrite recorded was 2.09 µg.at.NO_2-N/l and 0.52 µg.at.NO_2-N/l in shrimp ponds and coastal waters (station 3, 4 and 5) respectively. Joseph *et al.* (2003) [13] reported an average value of 3.21 µg.at.NO_2-N/l in Tuticorin shrimp culture system during 1993. This calculated maximum value in shrimp ponds could be due to increased phytoplankton excretion, oxidation of ammonia, recycling of nitrogen and bacterial decomposition of planktonic detritus present in the environment, which might be negligible in the coastal waters. Similar observation was also made by Rajdeep Dutta (2005) [28] in the unpolluted coastal with an average value of 0.54 µg.at.NO_2-N/l in Thoothukudi coast and by Tiwari and Nair (2002) [41] in the open sea of adjoining the Mumbai harbor with the value of 0.7 µg.at.NO_2-N/l. However in the effluent mixing coastal water the maximum value of nitrite (1.10 µg.at.NO_2-N/l) was noticed during the month of April 2014 and this value is also comparably similar to the observation made by Rajdeep Dutta (2005) [28] in the unpolluted coastal water, which is evidenced by not having any adverse algal blooms in this station during the study period. The same maximum value of nitrite was also observed by Subramanian and Kannan (1998) [39] in the unpolluted coastal water of Gulf of Mannar Marine Biosphere Reserve off Tuticorin coastal water with a maximum value of 1.08 µg.at.NO_2-N/l. This clearly shows that the discharged of the shrimp pond effluent is not having any adverse effect on the receiving coastal water though it is having considerably good biomass of plankton when compared to the source water for shrimp ponds as well as in the unpolluted control station. This might be because of the continuous aeration mechanism in the ponds which might have created well oxygenated system which in turn might have caused the improvement of oxidation of organic matter by bacterial decomposition.

Nitrate (NO_3-N)

Nitrate is an oxidized state nitrogenous element which also forms an essential nutrient for the primary producers of the aquatic systems. Among the various forms of nitrogenous nutrients, nitrate is the most important one, as it is the final form, being absorbed by plankton for their growth (Begum *et al*., 2003) [8]. During the present investigation, the calculated overall average of the maxima of all the stations was 0.20 µg.at.NO_3-N/l. Among the nitrate values of the shrimp ponds, the station 1 had a maximum nitrate value of 1.12 µg.at.NO_3-N/l, whereas the same value for the station 2 was 0.75 µg.at.NO_3-N/l during November (Fig.2). However, the average of the maxima of nitrate for the shrimp ponds is calculated as 0.94 µg.at.NO_3-N/l. This value is found to be very much lower than the value observed by Joseph *et al.* (2003) [16] with the maximum of 14.29 µg.at.NO_3-N/l in shrimp ponds in Thoothukudi during 1993 and by Saraswathy *et al.* (2013) [34] with the maximum of 10.71 µg.at.NO_3-N/l in shrimp ponds near Chennai. The trend in the level of nitrate in both station 1 and 2 (shrimp ponds) of the present study was almost similar with primary peaks during November and the secondary peaks during February. Further the maximum value of nitrate recorded was during November, which is the initial month of the culture of shrimps, *L. vannamei*. The reason for the high nitrate value during the initial phase of the culture period could be attributed to the fact that the phytoplankton development was in the initial phase with low density, which also evidenced by the minimum level of chlorophyll-*a*.

In the case of coastal water stations of 3 to 5, the maximum nitrate values recorded were 0.14 µg.at.NO_3-N/l, 0.51 µg.at.NO_3-N/l and 0.44 µg.at.NO_3-N/l respectively. The overall average value of the maxima of all the three station was 0.14 µg.at.NO_3-N/l. However the maximum value (0.51 µg.at.NO_3-N/l) was found in the station 4 during November which was influenced by the shrimp ponds effluent during the previous crop harvest and this may be the reason for the high value in this station. This maximum value of nitrate is also coinciding with the secondary maximum abundance of phytoplankton density. The minimum value of nitrate was recorded in the station 5 (0.01 µg.at.NO_3-N/l) might be due to the initial phase of oxidation of ammonia as the coastal water might have received organic matter during the monsoon period (Sridhar *et al*., 2006) [37].

Phosphate (PO_4-P)

Phosphate is one of the most essential inorganic nutrients for the productivity in any aquatic ecosystem which could limit the phytoplankton production in tropical marine ecosystem (Cole and Sanford, 1989) [14]. In the present

investigation, the overall value of phosphate in all the stations were ranged from 0.82 to 5.36 µg.at.PO_4-P/l with the minimum value in station 5 and the maximum value in Station 2 (Fig.3). The maximum value was recorded in April in station 2. In the case of shrimp ponds, the overall average of the maximum value was 4.76 µg.at.PO_4-P/l. The maximum value of phosphate was recorded during March 2014 in station 1 and the same was during April 2014 in station 2. These maximum values were almost coinciding with the value of phytoplankton abundance and this indicates that this nutrient was in steady supply due to the microbial decomposition of uneaten feed and the other organic matter which in turn support the phytoplankton biomass to a considerable level. This men value is somewhat high when compared to the maximum value (2.26 µg.at.PO_4-P/l) of Joseph *et al.* (2003) [16] in the shrimp ponds of Thoothukudi during April 1993. However, Babu *et al.* (2013) [7] have reported the maximum value as 1.68 µg.at.PO_4-P/l, which is somewhat less value when compared to the overall mean value of the station 1 and 2 of the present study.

Similarly, the overall values of the phosphate in the coastal waters ranged from 0.82 to 2.59 µg.at.PO_4-P/l with the minimum value during March 2014 in station 5 and the maximum during January 2014 in station 4. The overall mean of the maximum values of all the three stations of 3 to 5 was 1.90 µg.at.PO_4-P/l. However, the maximum value was recorded in station 4 as this is influenced by the discharge of effluent from the stations 1 and 2 (shrimp ponds). This maximum value in January (post monsoon) is comparable to some extent with the value of Babu *et al.* (2013) [7] who attributed the reason that the monsoonal fluctuation due to rain as well as due to the turbulence of the coastal water. Similarly, the station 5 of the present study showed high value of phosphate during December 2014 which was evidenced by the low density of phytoplankton and this low density might be mainly due to the high level of turbidity, an unfavorable condition for plankton to multiply. In contrary to the value of maximum and minimum during January and March, Sridhar *et al*. (2006) [37] also reported the maximum and minimum during summer and postmonsoon seasons in Kattumavadi coast of Palk bay, east coast of India.

Ammonia (NH_3-N)

The possible sources of ammonia input into the water from land run off, zooplankton excretion or demineralization of organic matter (Ketchum, 1962) [20]. The overall ranges of ammonia in all the stations were ranged between 0.01 and 4.8 µg.at.NH_3-N/l (Fig.4). In shrimp ponds the overall values of ammonia varied from 0.05 to 4.8 µg.at.NH_3-N/l. The maximum values were observed during February in station1 and during April 2014 in station 2. However, the overall average of the maxima of the station 1 and 2 was 4.28 µg.at.NH_3-N/l. This value is very low in the shrimp ponds when compared to the values observed by Joseph *et al.* (2003) [16] with 11.43 µg.at.NH_3-N/l in the shrimp ponds at Thoothukudi. Likewise, the high value of ammonia was also reported by Babu *et al.* (2013) [7] with a maximum of 8.1 µg.at.NH_3-N/l during June 2009 (summer) in the shrimp pond near Muthupettai, south east coast of India which is as same as that of the present study. The very low average value in shrimp ponds of the present study indicate the pond is well aerated as well as the dissolved organic matter gets oxidized. Further, the period of maxima were almost coinciding with the secondary peak of phytoplankton which indicates that the ponds were in the initial phase of nitrification and thus had higher value of nitrite.

The overall value of ammonia in the stations 3 to 5 were ranged between 0.01 and 1.14 µg.at.NH_3-N/l with minimum during March 2014 and the maximum during January 2014. The maximum value was recorded in Station 4 and the minimum value is at station 5.The overall average of the maxima of the three station was 0.51 µg.at.NH_3-N/l. In the present study, the station 4 had a maximum value which is low when compared with the maximum value (3.17 µg.at.NH_3-N/l) reported by Babu *et al.* (2013) [7] in the shrimp pond effluent mixing backwaters of Muthupettai, southeast coast of India during July 2009. Similarly, the maximum and minimum value of ammonia recorded in the station 5 (0.11 and 0.01 µg.at.NH_3-N/l) is also less when compared to the value (0.19 and 0.05 µg.at.NH_3-N/l) reported by Babu *et al.* (2013) [7] in open coastal water in Muthupettai. In contrary, Varadharajan and Soundrapandian (2013) [44] have reported a maximum value of ammonia (2.13 µg.at.NH_3-N/l) during the month of January and a minimum value (0.91 µg.at.NH_3-N/l) in the month of March in Poobuhar coast in South east coast of Tamil Nadu.

Carbon / Nitrogen ratio in shrimp pond sediments

In aquatic systems, sediment is known to play a major role as the storage reservoir of nutrients and helps in the cycling of nutrients in the water environment through soil water exchange (Boyd, 1982) [11]. The organic carbon content of the sediment is serving as an energy source for the microbes to decompose and release nutrients into the system for further plankton productivity. Hence, the level of organic carbon in aquaculture systems is an important one for assessing the health of the soil of a culture system. In the present study, the organic carbon content values were ranged between 0.04 to 0.625% in station 1 and 2 (Fig.5). The maximum values of 0.425 and 0.625 were recorded during February in both stations (ponds). The overall average value for this parameter is 0.26 %. This value is as similar as the average value of organic carbon (0.22 %) reported by Joseph *et al*. (2003) [16] in shrimp ponds of Tuticorin during 1993. The total nitrogen in the present study ranged between 0.056 and 0.224% in two stations. The overall average value for the ponds is 0.14 %. The calculated C: N ratio for these two stations were ranged from 0.07 to 11.16, with minimum during December and the maximum during February. However, the overall maximum average value for the shrimp ponds was 7.97: 1. In the present observation, this low C: N ratio value is mainly because of the intensive culture systems with usage of high nitrogenous feed (Boyd, 2009) [10]. Further, the overall maximum value of the pond soil organic carbon level indicate that this soil is a mineral soil as the organic carbon value falls below 1 % (Boyd, 2003) [9] and the soil condition will never create anoxic condition in the culture system as it will support quick mineralization of organic matter added to the system. If the overall average of the C: N ratio in these ponds are concerned, the calculated value was 3.12: 1 and this value is also possible in the culture systems using protein rich feed as reported by Schneider *et al*. (2004) [35]. Further, the present level of C: N ratio is less than 10 and thus the soil of these ponds will mineralise the organic matter very fast as reported by Adhikari (2003) [1].

Biological parameters

Chlorophyll-*a*

Short term chlorophyll variability is mainly controlled by winds and long term changes are related to rainfall and fresh water input. Generally, shrimp culture ponds exhibit higher level of chlorophyll-*a* and nutrients than do adjacent environments (Casillas–Hernandez *et al*., 2007) [13]. Chlorophyll-*a* is the primary photosynthetic pigment important for the primary production in the marine ecosystem (Prabhahar *et al*., 2011) [26]. The overall value of chlorophyll-*a* in all the stations were ranged from 4.25 to 310.66 mg/m^3. In the case of shrimp ponds, the observed overall average of the maximum chlorophyll-*a* value was 308.56 mg/m^3 whereas the same value for the coastal stations was 18.10 mg/m^3. Further, in stations 1 and 2, the low values (6.65 mg/m^3 in station 1 and 8.58 mg/m^3 in station 2) were observed during November (monsoon season) and high values were noticed during April (summer season) (Fig.14).

In the present study, the maximum value of chlorophyll-*a* was coinciding with the abundance of phytoplankton in the stations 1 and 2 during April (Fig.6). This high value in chlorophyll-*a* level might be because of the more penetration of light and high value of nitrite, phosphate and low value of secchi disc reading. However the value of nitrate was found decreasing as this nutrient might have been utilized by the phytoplankton in the pond water. In the case of coastal water stations the overall range of chlorophyll-*a* ranged between 1.15 and 45.11 mg/m^3. This maximum value was recorded in the station 4 during April 2014 (summer), which is influenced by the discharge of shrimp pond effluents. The overall mean minimum and maximum values of chlorophyll-*a* for all the stations is 3.70 and 18.01 mg/m^3 respectively. The similar over all maximum value (24.56 mg/m^3) was also reported by Rajdeep Dutta (2005) [28] in the coastal waters of Thoothukudi, Gulf of Mannar. The distribution of chlorophyll-*a* is not showing uniform trend in these coastal water stations of the present study. However, the maximum chlorophyll-*a* recorded is also similar to the observation made by Rajdeep Dutta (2005) [28] and Sridhar *et al*. (2006) [37]. The minimum value of the present study was in station 5 during December 2013 (monsoon) and the reason could be due to the low light penetration coupled with low value of light extinction coefficient. However the same minimum value has been reported by Kawabata *et al*. (1993) [18] and Rajasekar *et al*. (2005) [27] due to the river water flow to the coastal waters.

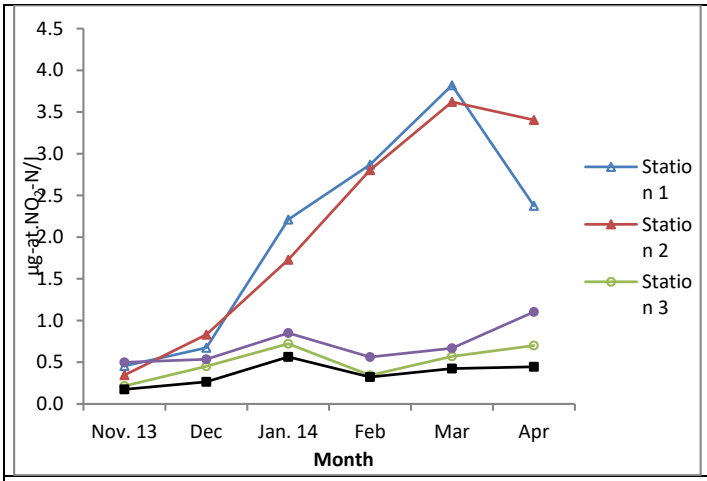

Fig 1: Monthly variations of nitrite in Station 1, 2, 3, 4 and 5

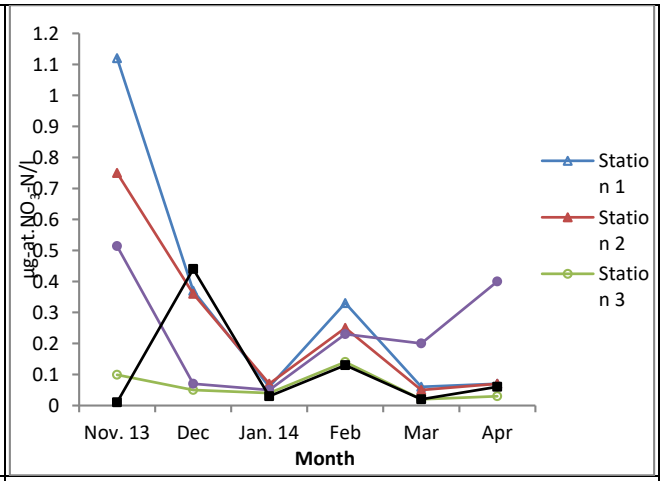

Fig 2: Monthly variations of nitrate in Station 1, 2, 3, 4 and 5

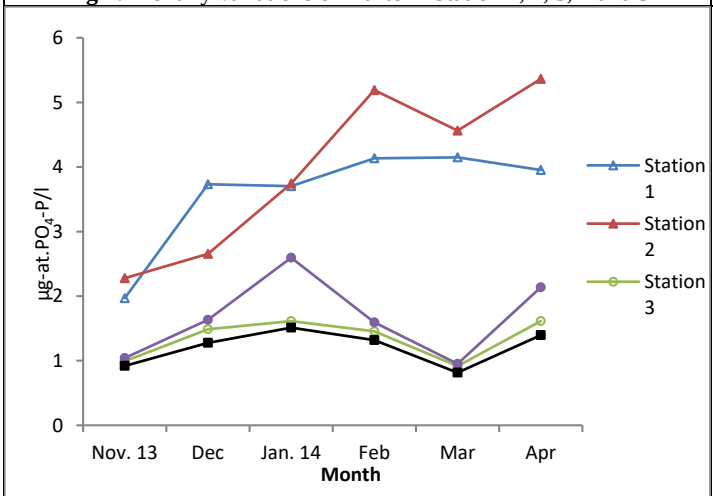

Fig 3: Monthly variations of phosphate in Station 1, 2, 3, 4 and 5

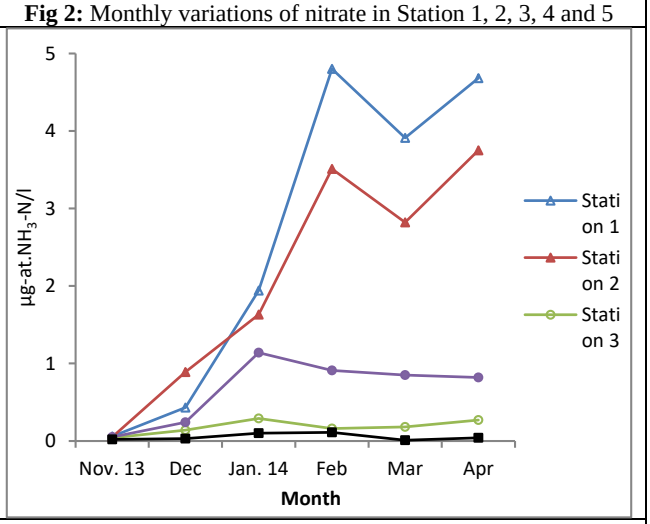

Fig 4: Monthly variations of ammonia in Station 1, 2, 3, 4 and 5

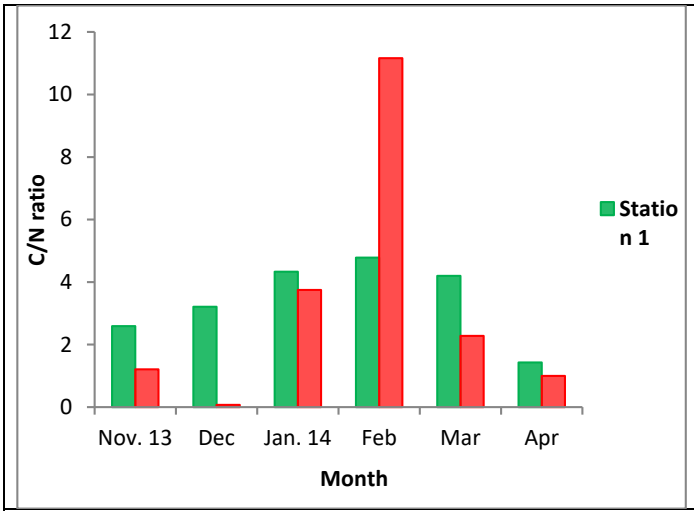

Fig 5: Monthly variations of Carbon / Nitrogen ratio in Station 1 and 2

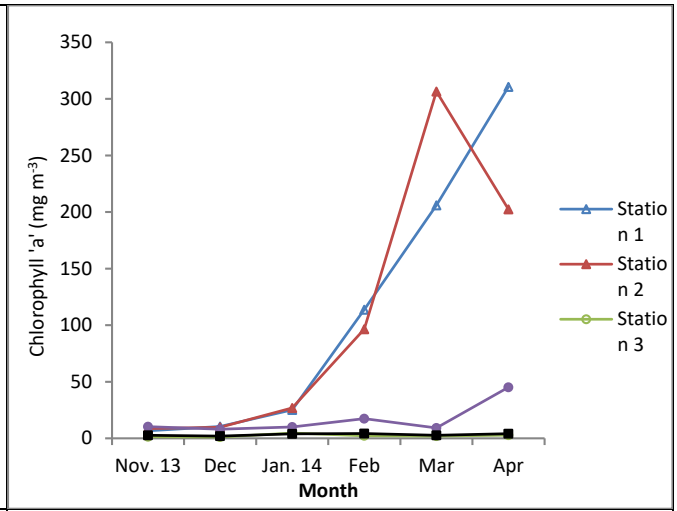

Fig 6: Monthly variations of chlorophyll-*a* in Station 1, 2, 3, 4 and 5

Conclusion

Thus in the present study on the soil and water quality of the shrimp ponds and adjacent coastal waters showed marked monthly variations in the physical, chemical and biological characteristics which revealed the typical shrimp ponds environmental condition. This indicates that the presence of Vannamei farm near coastal area of Kalaignanapuram, Thoothkudi district seemed to have no influence on aquatic life and plankton diversity of coastal waters receiving shrimp ponds effluent (station 4) as all the water quality parameters recorded in the above station were within the optimal range because high pollution potential due to shrimp pond activities can be minimized by conducting processing of shrimp pond waste. Alternative treatment for processing of shrimp pond waste can be done by ETP (Effluent Treatment Plant) to reduce pollutants that have high concentrations from the results of shrimp pond activities.

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Author's contributions

Sample collection, formal analysis and writing original draft of the manuscript: Ramesh P; Reviewing drafts of the manuscript: Triveni K & Deepthi A; Visualization and investigation: Anupama R R & Madhavi K; Critical reviewing of the research work and technical contribution on data analysis: Padmavathy P, Athithan S & Srinivasan A.

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