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Sediment characteristics of *Litopenaeus vannamei* shrimp culture systems in Thoothukudi District of Tamil Nadu

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Abstract

The pond bottom soil and the accumulated sediments are integral parts of ponds. Concentrations of nutrients, organic matter and microorganism density in the pond bottom are several orders of magnitude greater than in the water. Shrimp, as animals that normally live on or near the bottom, are exposed to conditions on the pond bottom. Exposure to toxic materials endangers the wellbeing of the cultured shrimp. Reduced feeding, slower growth, mortality and possibly higher sensitivity to disease. The present study carried out in Thoothukudi District of Tamil Nadu. The sediment characteristics such as pH, electrical conductivity (EC), sedimentary organic matter (SOM), sedimentary organic carbon (SOC) and sedimentary total nitrogen and sedimentary phosphorous were analyzed. There is significant difference between electrical conductivity and sedimentary total nitrogen values in both the farms ($P < 0.05$). The present study revealed that the sediment characteristics were found optimum, indicating the best management practices being followed in *Litopenaeus vannamei* culture systems.

Keywords

Shrimp pond, sediment characteristics, nutrients, *L. vannamei*

Introduction

The physico-chemical properties of pond water are more or less a reflection of the properties of pond bottom soil[1]**.** Sediment and water quality play an important role in increasing the productivity of pond. It provides nutritionally balanced and healthy environment to cultured animals. The successful growth, propagation, survival, reproduction and harvest of shrimps are heavily dependent upon the quality of the pond soil and water, degradation of which often limits the production in aquaculture systems[2,3,4].

In shrimp ponds, bottom soil is the storehouse of nutrients, which helps in organic mineralization process, adsorption and release of nutrients to water. 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.

Organic matter settles and accumulates on the pond bottom in extensive, semi-intensive and intensive ponds. The development of anaerobic condition limit production and is a barrier to further intensification[5]**.** Such development seems to be of special importance for shrimp culture, since shrimps live in the soil – water transition zone. Reactions and fluxes within and across the water – soil interface are very significant in intensive aquaculture systems. Disease management also plays an important role in the sustainability of shrimp culture systems.

Materials and Methods

The sediment samples were collected with the help of snapper/grab and brought to the laboratory in the polythene bags. The sediment samples were dried at room temperature for 24 h as per the procedure of[6] and grounded well by using a glass mortar. Later, the dried bulk sediment samples were sieved with plastic sieve having < 250 µm pore size and collected the fine fraction of the sediment for the analysis. The pH was measured by using 'ELICO' pH meter. The electrical conductivity was measured by 'ELICO CM 183-EC-TDS' Analyzer. The sedimentary organic carbon was analyzed by chromic acid oxidization method[7]**.** The sedimentary total nitrogen was estimated by K-Jeldahl method[8]**.**

Result and Discussion

Pond bottom conditions are more critical for shrimp than for other aquaculture species, because shrimp spend most of their time on the bottom soil[9]**.** The distribution of penaeid shrimp in the natural environment can be influenced by sediment characteristics. In intensive shrimp culture system the presence of sediment and other surface areas may have both positive and negative effects on shrimp production. The pH of the soil influences the pH of the water. The acidic pH of the water makes the added phosphorus to precipitate with iron and aluminum.

The bottom soil pH ranged between 6.62 to 7.90 with an average being 7.50 in Thailand tilapia culture ponds[10]. In the present study, the range of sediment pH values in Farm I and Farm II were 6.6 - 8.4 and 7.9 -8.4, respectively. High pH reflects the effect of the large and frequent applications of liming materials and suggests that the soils were essentially at equilibrium with calcium carbonate. Soils containing free calcium carbonate usually have a pH of 7-8[11].

An increase in the pH values from 6.5 to 7.1 in fish ponds fertilized with sodium nitrate, when compared to ponds without sodium nitrate[12]. Soil quality in two marine shrimp farms in Texas and found that pH reductions from 7.6 to 7.1 and 8.6 to 8.2 after consecutive culture cycles[13]. A reduction in the pH of the soil during consecutives cycles of production[14,15]. The soil pH varied from 4.8 to 8.2 in marine shrimp farms of Ecuador[16].

Electrical Conductivity is an index of the total ionic content of water and therefore indicates freshness of the water[17]. Conductivity can be used as an indicator of primary production (chemical richness) and thus fish production. Conductivity of water depends on its ionic concentration (Ca^{2+}, Mg^{2+}, HCO^{3-}, CO^{3-}, NO^{3-} and PO^{4}), temperature and on variations of dissolved solids. Conductivity of freshwater varies between 50 to 1500 dS/cm[18], but in some polluted waters, it may reach 10,000 dS/cm and seawater, around 35,000 dS/cm and above. As fish differ in their ability to maintain osmotic pressure, the optimum conductivity for fish production differs from one species to another. The average electrical conductivity values in their culture ponds ranged from 2.68 to 39.92 dS/m[19].

The conductivity range of 3.8 -10 dS/cm as extremely poor in chemicals[20]. The desirable range of 100-2,000 mSiemens/cm and acceptable range of 30-5,000 mSiemens/cm for pond fish culture[21]. In the present investigation, the values of electrical conductivity ranged between 5.53 to 15.48 mS/cm in Farm I and 2.08 to 14.35 mS/cm in Farm II. Limited reports are only available on the electrical conductivity in culture ponds.

Organic matter affects the phosphorous rates in the sediment. Organic matter in submerged latosolic soils by restricting fixation of added phosphorus into iron and aluminium phosphate occurs owing to reduction reactions and even chelating effects which inhibit phosphorus transformation into insoluble forms[22]**.** A survey of 58 channel catfish ponds in Alabama that were up to 30 years of age revealed an average organic carbon concentration of 1.02% and a maximum value of 4.10%[23]**.** The general recommendation of[24] is that organic matter concentrations in pond sediment vary between 1 to 3%. However, in ponds, where fish are fed, organic matter concentrations below 1% are acceptable. In the present investigation, the organic matter was below 1% level, wherein the shrimps were fed with artificial feed.

Channel catfish ponds in Mississippi had an average organic carbon concentration of 1.77% with a range of 0.71 - 2.89%[25]**.** Soils with organic carbon content below 0.5% are poor and needs organic manuring[26].

The mean organic matter, carbon and nitrogen were 2.62 ± 0.4, 1.52 ± 0.23 and 0.13 ± 0.02%, respectively[27]. The levels of organic matter found in both milkfish and shrimp ponds after harvest were moderate and favourable for pond culture. They suggested that the possibility of biomineralization of these substances, which in turn are converted into nutrients for natural production or are eventually flushed out during the regular water exchange. These conditions were also reflected by the moderate amounts of nutrients including nitrogen and available phosphorous, that are required for natural productivity. In the present study, the mean values of organic matter in two farms were 0.096 ± 0.06% and 0.111 ± 0.06%, respectively which indicated the well management of feeding practices in the culture ponds and also envisaged that there is no accumulation of excess feed in the pond bottom. The organic matter in age old ponds were 7.6 – 8.4% in 1 -5 years aged ponds and 10.6 – 11.3% and 12.9 – 13.4% of organic matter in 6 – 10 years and above 10 years aged ponds, respectively. The cause for increasing organic matter of soil might be due to use of artificial or supplementary feeds in the culture ponds. But in the present investigation, the organic matter was lower than the above values envisaging that there was no much settlement of feeds at the bottom[28].

The major sources of organic carbon in aquaculture ponds are settled, uneaten feed, feaces, and dead plankton[29]**.** Studies on the organic carbon concentrations in shrimp ponds[30] and fresh water ponds[31] the carbon concentrations do not accumulate at high rates. Total carbon steadily decomposed during the culture period and if pond bottoms are dried between crops, decomposition rate increases[32,33]**.**

The organic carbon is the most important factor determining the fertility status of soil. They observed that the range of organic carbon content varied from 2.2 to 2.5%[34]. 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% is average productive and 1.5 to 2.5% is high productive[35]. In the present investigation, the soil organic carbon was found to range between 0.05 and 0.34%. This low level of organic carbon in culture ponds may be due to the well management of feeding practices. The average organic carbon of shrimp pond bottom soils in Auburn was 0.02%[31] and that of Ecuador was 0.06%[36] and the values obtained in the present investigation coincided with these values. In the present study, the mean organic carbon values were 0.141 ± 0.09% and 0.159 ± 0.08% in Farm I and Farm II, respectively. The lower percentage of sedimentary organic carbon indicated that there was no accumulation of uneaten feeds in the bottom.

Nitrogen in soil is usually associated with organic matter. 86% of the nitrogen in shrimp pond soils was organic nitrogen and reported that the average nitrogen concentration in shrimp pond soils from Ecuador was 0.16% and 90% of the samples contained <0.25% nitrogen[37]. In the present study, the average total nitrogen concentration in shrimp pond soil at the beginning of the culture period was 0.042 and 0.028% in Farm I and Farm II, respectively. In the present study, the average nitrogen concentration was 0.056 and 0.029%, respectively at the end of the culture period. Up to 38% of the total nitrogen input accumulates in the sediments of a shrimp pond[38]. High nitrogen concentration in shrimp pond soils was mainly because of uneaten feed, shrimp feaces and dead plankton[39]**.** Nitrogen fertilizer is usually in the form of urea or ammonium, in which, urea quickly hydrolyzes to ammonium in pond water. Ammonium may be absorbed by phytoplankton, converted to organic nitrogen, and eventually transformed into nitrogen of fish protein via the food web. Ammonium may be oxidized to nitrate by nitrifying bacteria and nitrate may be used by phytoplankton or denitrified by anaerobic microorganisms in the sediment. Dead plankton and aquatic animal feaces may settle to the bottom to become soil organic nitrogen. Nitrogen in soil organic matter may be mineralized to ammonia and recycled to the pond water. The decomposition in bottom of aquaculture ponds usually does not result in mineralization of significant amounts of nitrogen[40,41,42].

Nitrogen and available phosphorous are primary nutrients in both fish and shrimp ponds. Organic matter supplies the bulk of nitrogen present in the soil. This nutrient undergoes many transformation and reactions in the pond soil, including nitrogen fixation, denitrification and nitrification, which are controlled by soil organisms. In the present study, the sedimentary total nitrogen increased during 90th day of culture and it evidenced from the maximum level of sedimentary organic matter in the culture ponds.

The concentration of extractable phosphorus increased with the lowering of redox potential of sediments[43]. The continued accumulation of phosphorous in sediment could reduce its ability to remove inorganic phosphorus from water[44]. 35% of organic carbon, 89% of nitrogen and 68% of phosphorous from the feed got accumulated in the pond bottoms[45]. In the present study, the sedimentary phosphorous in shrimp pond soil was 1.2 and 0.08 µg.at. P/g in Farm I and Farm II, respectively. The release of phosphorous from sediments under both aerobic and anaerobic conditions. Concentration of phosphorous in pond water could determine the availability of exchangeable phosphorous in sediments[46]. Present study indicated that the pond bottom conditions are not critical for shrimp culture. The present study revealed that the sediment characteristics were found optimum, indicating the best management practices being followed in *Litopenaeus vannamei* culture systems.

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