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Sediment Quality of Extensive and Modified Extensive Shrimp Culture Systems in Southwest Coast of Kerala

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Abstract

The physicochemical features of the sediments of extensive and modified extensive *Penaeus monodon* Fabricius culture systems on the southwest coast of Kerala was studied during shrimp culture season (June 2006 - May 2007). Mean sediment temperature in extensive and modified extensive system was at its lowest during monsoon and the highest during pre-monsoon. Sediment pH was below neutrality in both the systems all through the culture period. Sand was the main constituent (60.6 to 78.1%) of the sediment followed by silt (11.4 to 28.6%) and clay (10.6 to 13.7%) in extensive and modified extensive systems. There was significant seasonal difference in organic carbon, sand, silt and clay in both the culture systems ($P<0.01$). However, between the two culture systems, there was no significant difference in any of the parameters. The study showed that the two culture systems did not differ significantly with regard to their sedimentological features, which in turn suggests that the additional inputs in the modified extensive system did not enhance the sedimentological properties of the system.

Key words: Brackishwater, extensive culture, modified extensive culture, organic carbon, sediment texture, shrimp culture

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Introduction

Adequate water supply, quality of water and soil and the topography are the most important qualities of a good aquaculture site (Pillay, 1977; Gupta et al., 1999). Selection of a suitable site is the first step towards successful aquaculture (Rekha et al., 2005). Sediment is a mixture of living organisms and dead materials in a medium of sand, clay or silt or a combination of them, which functions as a buffer and serve as nutrient source (Francis et al., 2004). The nature of the bottom soil is of considerable importance in brackishwater aquaculture (Chattopadhyay & Mandal, 1986). The sediment characteristics influence the qualitative and quantitative nature of macrobenthos, which in turn influences the growth of shrimp in extensive shrimp culture systems (Das et al., 2001). The soil-water interface is an important zone, which regulates the success or failure of aquaculture (Hickling, 1971; Krishnani et al., 1997). Extensive shrimp culture systems are characterized by low stocking densities and little or no supplementary feeding or fertilizer. Modified extensive farming has inputs such as seed and feed, resulting in increase in nutrients and organic matter (MPEDA, 2011).

The hydrography or water quality of aquaculture holdings including shrimp culture ponds has been studied (Harish et al., 2003; Joseph et al., 2003; Islam et al., 2004). The characteristics of estuarine sediments along both the east and west coasts of India have also seen studied (Ramanathan et al., 2009; Reji & Kurian 2010). However, the sediment characteristics of brackishwater shrimp culture ponds are less studied. Hence, a comparative study was carried out on the physic-chemical features of the sediments of extensive and modified extensive *Penaeus monodon* culture systems of the southwest coast of Kerala.

Materials and Methods

Six culture ponds, growing *P. monodon* were selected from Kollam district, Kerala state (9.28'45º N and 76.28'0 E). In two ponds (0.7 ha each), located at Munrothuruthu, 30 km northwest of Kottiyam town and fed with water from the Ashtamudi lake,

extensive type of culture (stocking density = 5 m^{-2}) having neither specific management practices nor supplementary feeding was practiced. In four ponds (0.4 to 0.6 ha each), two located at Mayyanadu about 12 km southwest and two at Pathayakkoni five km south of Kottiyam town, all fed with water from the Paravoor Kayal, modified extensive type of farming (stocking density =10 m^{-2}) was done. In these ponds, pellet feed was given, thrice a day. Pond was dried before culture, limed and urea and soil probiotics were used.

Sediment samples were collected twice in a month from all the six ponds during shrimp culture season (June 2006- May 2007), by using a PVC corer of length 25 cm and diameter 7 cm. The sediment samples collected from four points were transferred into clean polythene bags and brought to the laboratory, pooled, air dried and sieved (sieve number-62 μm) before analysis. The temperature of the sediment was noted using a Celsius thermometer (calibrated before each collection) as soon as the corer was lifted out of water. Organic carbon content was estimated following Walkey & Black (1934) and the results were expressed in percentage. Soil texture was determined by the sieve and pipette method (Krumblin & Petti John, 1938). pH was measured as per Trivedy et al. (1987) using a hand-held calibrated pH meter (Model ip (1-198107) RI USA) before each set of measurement. To determine statistically significant differences, if any, of the sedimentological parameters between seasons and between systems, two way ANOVA was employed. Correlation analysis was done using standard statistical package.

Results and Discussion

In extensive system, mean sediment temperature ranged from 29.5 to 30.7^0 C while pH and organic carbon content ranged from 4.7 to 5.8 and 2.4 to 5.4% respectively. Sand was the main constituent (65.2 to 76.8%) of the sediment followed by silt (12.4 to 23.0%) and clay (11.0 to 12.4%). In modified extensive system, mean sediment temperature, pH and organic carbon content ranged from 29.2 to 31.1^{0}C, 4.9 to 6.0 and 1.1 to 4.9% respectively. In modified extensive system, sand content dominated (60.6 to 78.1%) followed by silt (11.4 to 28.6%) and clay (10.6 to 13.7%).

Mean sediment temperature in extensive and modified extensive system showed similar pattern with the lowest during monsoon and the highest during pre-monsoon. Except during monsoon, mean sediment temperature was slightly higher in modified extensive system than in extensive system (Fig. 1a). The temperature regime of sediment in the study area was somewhat similar to that reported by Unnithan et al. (2005) in selected backwaters of Kerala, which is attributable to the seasonal fluctuation in atmospheric temperature (Das et al., 2001). High temperature during pre-monsoon is a characteristic feature of the tropics, due to increased solar radiation and low rainfall (Bhargavan, 2007). During warmer season, the water overlying the sediments gets heated up and since there is absorption of heat from the overlying water, it leads to rise in the temperature of the sediment; during monsoon, the opposite phenomenon occurs (Bhargavan, 2007). During pre-monsoon months, the sandy sediments have faster conductance of heat from the overlying water (Wolff, 1973; Ramachandra, 1981; Reddy, 1983), which also might have contributed to rise in sediment temperature during premonsoon period.

Sediment pH was below neutrality in both extensive and modified extensive systems throughout the culture period. Mean pH was noticeably acidic (<5) during monsoon and premonsoon, while it slightly increased in both systems during post monsoon (Fig. 1b). Acidic pH was reported from Cochin backwaters (SunilKumar, 1997) and from Vembanadu lake (Unnithan et al. 2005). Boyd (1995) suggested that average production was achieved in ponds with soil pH in the range 5.5-6.5. Comparatively higher mean pH observed in modified extensive systems which were deeper than extensive systems, corroborate the findings of Gupta et al. (1999), who reported increase in pH with increase in depth. Krishnani et al. (2011) reported acidic soil from extensive shrimp culture ponds of Kerala. Low pH during monsoon might be correlated with relatively heavy rainfall (Mollah et al., 1979), while the low pH during pre-monsoon might be due to short supply of oxygen to the soil-water interface (Mollah et al., 1979), due to increased temperature and salinity (Damotharan et al., 2010) and microbial consumption of oxygen (Selvaraj & Molly, 1999). The observed differences in either sediment temperature or pH between the two culture systems and between seasons were not statistically significant (Table 1). The other sediment features also did not register any significant correlation with sediment temperature in both culture ponds (Table 2).

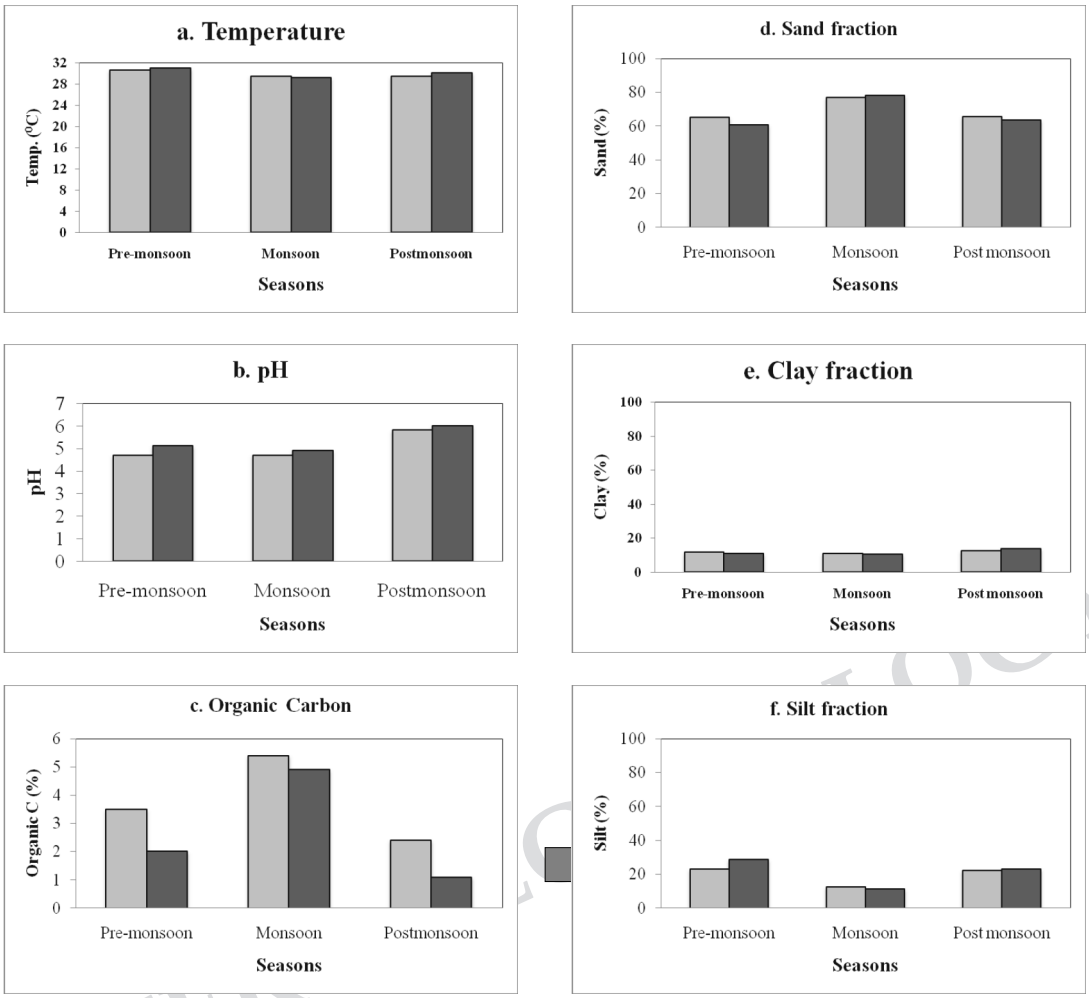

Fig. 1. Seasonal variation in mean sedimentological features of extensive ( ) and modified extensive ( ) *Penaeus monodon* culture systems

Mean organic carbon content (OC) registered the highest values during monsoon and the lowest during post-monsoon in both systems. Mean OC was higher in extensive system than in modified extensive system in all the seasons (Fig. 1c). In both systems, OC showed an apparent increasing trend with progress in the days of culture as reported by Das et al. (2001) and Gupta et al. (2001). The OC showed significant difference between seasons ($P<0.01$) while there was no significant difference in OC between the systems (Table 1). In both extensive and modified extensive systems, the mean organic carbon content was well above 1% during pre and post-monsoon periods and much higher during monsoon period (Fig. 1c). High organic carbon content in monsoon might be due to dead and decaying planktonic organisms accumulated following sudden drop in salinity and to large amount of humus transported by river and terrestrial land drainages (Mollah et al., 1979; Nagarajaiah & Gupta, 1983). The extensive system recorded higher organic carbon content (Fig. 1c) which is due to the presence of mangrove habitats near the culture ponds as reported by Sunilkumar (1998). Mean OC and pH in the extensive system had significant negative correlation ($P < 0.05$).

The sand content in extensive and modified extensive system showed similar pattern of variation, with the lowest during pre-monsoon and the highest during monsoon (Fig. 1d). Between the seasons, the difference in sand content was signifi-

Table 1. Results of ANOVA comparing various sedimentological features between *Penaeus monodon* culture systems and seasonal difference

Variable	Source of Variation	SS	DF	MS	*F*
Temperature	Total	33.650	19		
	Between Systems	0.191	1	0.191	0.108
	Between Seasons	8.154	2	4.077	2.312
	Systems x Seasons	0.615	2	0.308	0.174
	Error	24.689	14	1.764	
pH	Total	22.578	19		
	Between Systems	0.364	1	0.364	0.289
	Between Seasons	4.531	2	2.266	1.799
	Systems x Seasons	0.054	2	0.027	0.021
	Error	17.629	14	1.259	
Organic carbon	Total	77.682	19		
	Between Systems	6.061	1	6.061	3.054
	Between Seasons	42.445	2	21.223	10.695**
	Systems x Seasons	1.395	2	0.698	0.352
	Error	27.781	14	1.984	
Sand	Total	1161.488	19		
	Between Systems	16.152	1	16.152	1.134
	Between Seasons	914.951	2	457.475	32.129**
	Systems x Seasons	31.043	2	15.521	1.090
	Error	199.342	14	14.239	
Clay	Total	27.988	19		
	Between Systems	0.004	1	0.004	0.010
	Between Seasons	18.446	2	9.223	23.893**
	Systems x Seasons	4.134	2	2.067	5.354*
	Error	5.404	14	0.386	
Silt	Total	993.312	19		
	Between Systems	15.955	1	15.955	1.244
	Between Seasons	759.695	2	379.847	29.625**
	Systems x Seasons	38.158	2	19.079	1.488
	Error	179.505	14	12.822	

* $P < 0.05$; ** $P < 0.01$

cant (P<0.01) while it was not significant between the systems.

Both in extensive and modified extensive systems, sand fraction dominated followed by silt and clay, which is in agreement with the findings of Sunilkumar (1998) in a traditional prawn field near Cochin backwaters, Das et al. (2001) in low-saline confined ponds growing *P. monodon* in Orissa, Manjappa et al. (2003) in brackishwater impoundments along Nethravathi estuary, Muralidhar et al. (2005) in shrimp farming areas of coastal India and of Ramanathan et al. (2009) in tropical mangrove Sunderban ecosystem. In the present study, mean sand content was higher in the extensive system for most of the culture period. Sunilkumar (1998) reported a sandy substratum throughout the year in traditional prawn fields adjacent to Cochin backwaters. Earlier studies by George (1995) in mangrove habitats of Veli, Quilon and Kumarakom and by Rekha et al. (2005) in shrimp farms of Muttukadu, Kokilamedu and Nellore also reported dominance of sand fraction. The seasonal differences in mean sand content in both the systems (Table 1) were

Table 2. Correlation matrix for sedimentological features of extensive and modified extensive *Penaeus monodon* culture systems

	Temp.	pH	OC	Sand	Clay
Extensive system					
pH	0.027				
Organic carbon	-0.077	-0.706*			
Sand	-0.166	-0.144	0.342		
Clay	0.203	-0.195	-0.082	-0.719*	
Silt	0.157	0.186	-0.364	-0..995**	0.644*
Modified extensive system					
pH	0.325				
Organic carbon	-0.258	-0.301			
Sand	-0.532	-0.057	0.746*		
Clay	0.071	0.344	-0.666*	-0.490	
Silt	0.562	-0.002	-0.680*	-0.987**	0.343

* $P < 0.05$; ** $P < 0.01$

statistically significant (*P<0.01*). In the modified extensive system, OC and sand content were positively correlated (*P<0.05*; Table 2) but no such correlation was noted in the extensive system. Mean clay content was the highest in both the systems during post-monsoon and the lowest during monsoon (Fig. 1e). The seasonal differences in clay content within the two systems were statistically significant (*P<0.01*).

Mean silt content was the highest during premonsoon and lowest during monsoon in both the culture systems (Fig. 1f). Seasonal difference in silt content in both systems was statistically significant (*P <0.01*). The silty sediments during post and pre-monsoon might be due to lack of rain and rise in temperature, which increases turbidity of overlying water (Bhargavan, 2007) and the low silt content during monsoon is because of continuous removal of finer particles by incoming water (Gupta et al., 1999). In the extensive culture system, clay (*P<0.05*) and silt contents (*P<0.01*) were significantly negatively correlated with sand. Similar observations have been reported by Venkatesan et al. (2001) from selected prawn farming sites at Cochin. In the modified extensive system, however there was negative correlation between sand and silt contents and between OC and silt (*P<0.05*). Similar observations were made by Muraleedharan & Ramachandran (2002) in sediments of the Beypore estuary.

In the present study conducted at shrimp farms, sand fraction dominated the soil constituents followed by silt and clay in both the culture systems. In spite of the small differences in the management practices followed in the two systems, with regard to their sedimentological features there was no significant difference. However, the slightly high stocking density and supplementary feeding in the modified extensive system would be advantageous in realizing better harvest.

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