International Journal Of

Recent Scientific Research

ISSN: 0976-3031

Volume: 7(4) April -2016

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THE OFFICIAL PUBLICATION OF
INTERNATIONAL JOURNAL OF RECENT SCIENTIFIC RESEARCH (IJRSR)
http://www.recentscientific.com/ recentscientific@gmail.com

ISSN: 0976-3031

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 7, Issue, 4, pp. 10664-10669, April, 2016

International Journal of Recent Scientific Research

Research Article

SPATIAL AND TEMPORAL DISTRIBUTION OF RECENT FORAMINIFERA, SEDIMENT CHARACTERISTICS AND CLAY MINERALOGY OF YEDAYANTHITTU LAGOON - TAMIL NADU, INDIA

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ARTICLE INFO

Article History:

Received 11th January, 2016
Received in revised form
14th February, 2016
Accepted 18th March, 2016
Published online 28th
April, 2016

Keywords:

lagoon, foraminifera, sediment texture, Kaliveli, clay mineral, India

ABSTRACT

A detailed study on foraminiferal assemblage, textural characteristics and clay mineralogy have been carried out for 20 surface and two core samples recovered from Yedayanthittu lagoon. It is situated 3km north of Kaliveli Lake which is one of the largest brackish water lake in the peninsular India. The lagoonalforaminiferal assemblage comprises rotalids, miliolids and agglutinated formsof which some forms are specific to littoral to sublittoral zones of sea. *Ammonia beccarii*, *A. tepida*, *A. parkinsoniana*, *Rotalidium annectans* and *Elphidium advenum*are copious forms of rotalids, *Ammobaculites agglutinans*, *Ammobaculites persicus* and *Ammobaculites exiguus* are abundant agglutinated forms, and in miliolids *Quinqueloculina seminula*, *Miliammina fusca* and *Adelosina longirostra* are the dominant ones. Most of the sediments are characterized by medium sand, moderately to poorly sorted and negatively to positively skewed. Temporal variation of textural characters of the sediment reveals that the energy condition was moderate, and below 110 cm depth the lagoon has experienced either erosion or non-deposition. Kaolinite is the predominant clay mineral in the area followed by Illite, Smectite and Chlorite. Kaolinite would have been formed by chemical weathering of pre-existing rocks of adjacent upland areas under tropical humid climatic condition.

INTRODUCTION

Lagoons, estuaries, tidal flats and shore lines are sensitive and significant coastal ecosystems. The organisms found in these areas are influenced by the characteristics of sediment and physicochemical properties of water where it thrive. Mangrove ecosystems mainly found in tropical and sub-tropical regions of the world and which are salient natural resource for various organisms such as algae, fungi, microorganisms, birds, mammals and fish (Bhuvaneswari, 2013). The detritus generated by mangroves are the base of the wide food chain in the ecosystem and the detrital feeders include different vertebrates and invertebrates (Holguin *et al*., 2001). Foraminifera, single celled protozoa, is an important microorganism which lives in wide range of aquatic environment and the fauna found in marginal marine environment has implication on paleoclimate as well as shoreline shifting.

Several studies unveiled about the sensitivity of foraminifers to the ecological changes and becomes the best proxy for environmental monitoring (Ghosh *et al*., 2014). Woodroffe *et al*., (2005) elucidated the relationship between foraminifera and intertidal mangrove environment of central Great Barrier Reef shelf of Australia and Barbosa *et al*., (2005) documented quaternary sea level fluctuations through vertical zonation of modern foraminiferal assemblages in marginal marine environment of Brazilian mangroves and marshes. Culver (1990) also analyzed benthic foraminifera of Puerto Rican mangrove-lagoon systems for paleoenvironmental study.

Textural analysis reveals about the dynamic process governing the transport and deposition of sediments in various energy conditions. Many researchers have studied how the granulometric parameters be effective in differentiating various depositional environment (Mason and Folk, 1958; Friedman, 1961; Griffiths, 1962; Sly *et al*, 1982; Badarudeen 1997). In India granulometric analysis on various sedimentary environment have been attempted by many scientists (Sahu, 1964; Mishra, 1969; Rajamanickam and Gujar, 1985; Seralathan, 1988; Mislankar 1992; Hegde ea al., 2007; Dora *et al*., 2011).

Clay minerals are the most important solid weathering product of parent rock with grain size less than 2 micrometers (Drever and Zobrist 1992, Deepthy, 2008). It has been widely studied to reconstruct past climate as well as sedimentary provenance

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(Patchineelam and Neto, 2007). Clay mineral characteristics are very significant to determine weathering condition imparted on parent rock (Maldonado and Stanley, 1981; Stanley and Liyanage, 1986), and to establish continental sources and differentiate depositional site (Lange, 1982; Reddy and Rao, 2001).A multi proxy analysis has been attempted in the present study to document the foraminiferal assemblage and its distribution, sediment characteristics and clay mineralogy of the lagoon.

STUDY AREA

Kaliveli Lake is one of the largest brackish water lake in south India located between 12° 03' N to 12° 10'N and 79° 47' E to 79° 59' E along the Coromandel coast. The lakeis situated 20 km north of Pondicherryin Villupuram district of Tamil Nadu and oriented nearly parallel to the coastline. The petal shaped water body is a swampy wetland and spread over an area of 7,040ha which forms as a water storage unit during monsoon seasons, the maximum filling into the lake reaches by the end of north east monsoon and the water is being used for agricultural and domestic purposes.

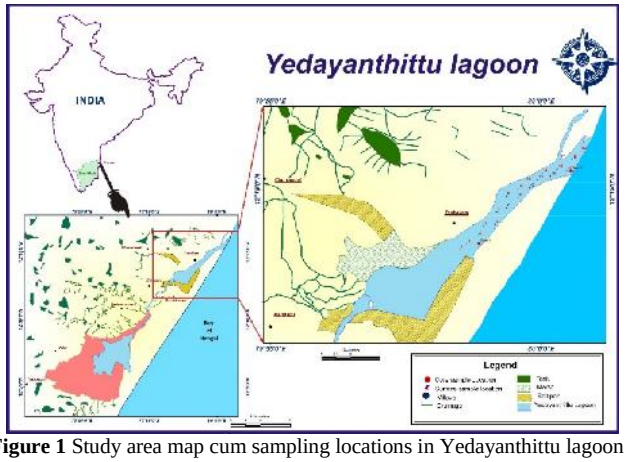

Figure 1 Study area map cum sampling locations in Yedayanthittu lagoon

Yedayanthittu lagoon is located around 3km north of Kaliveli Lake (Fig1). The study area begins from the premises of Marakkanam Road Bridge to Alamparai where it opens into the Bay of Bengal. The lagoon has the influence of mangroves which gives unique environment for many organisms to persist in the specific ecosystem. The study site enjoys subtropical climate with hot summer followed by monsoon and mild winter; and receives maximum rainfall during north east monsoon (nearly 63%), while the area has comparatively lesser effect of south west monsoon (around 27%).Vicinity to the Bay of Bengal and an inlet of sea waternear the area hasled to the development of salt pan (Ramanujan, 2005; Bhuvaneswari, 2013).

MATERIALS AND METHODS

A total of 20 surface sediment, bottom water and two core samples were collected from upstream to mouth of the Yedayanthittu lagoonon February 2014.The sample collected from the premises of the Marakkanam Road Bridge is marked as YD 1, the next one as YD 2 and the series goes on till YD 20 located at the mouth. Immediately after grabbing surface sediment, top portion is transferred to a cleaned vial and preserved in Rose Bengal - Ethanolsolution (2g rose Bengal stain added to around 730ml of 99% pure ethanol and made up to one litre with distilled water) to stain the cytoplasm of living foraminifera. The stained samples were kept fortnight in laboratory to discriminate living and dead forms (Walton, 1952). The bottom water samples were analyzed for temperature, pH and salinity from the field itself. Two core samples, one from mouth (160 cm length) and the other from upstream (165 cm) were cut into two equal halves and then subsampled at 5cm interval and preserved for further analysis. Folk and Ward (1957) methodology adopted for the textural analysis. Clay particles are separated at standard time interval and the < 2µm fractions were pipette on glass slides and underwent pretreatment for the confirmation of clay minerals (Moore and Reynolds, 1989).

RESULTS AND DISCUSSION

Surface assemblage of foraminifera

Spatial distribution of foraminifera in Yedayanthittu lagoon shows the predominance of rotalids in the entire area. *Ammonia beccarii, A. tepida, A. parkinsoniana, Rotalidium annectans* and *Elphidium advenum*are in the order of increasing abundance and the rest of the forms constitutes< 5 %. *A. beccarii* and *A. tepida* are the common benthic foraminifera having global distribution and will survive over a wide range of environmental settings (Murray, 1991; Wu *et al*., 2015). *Nonionoidesgrateloupii* is counted as more in number towards mouth (YD 19 and YD 20) which indicates environmental conditions closest to the open marine environment (Carvalho *et al*., 1999). *Haynesina depressula* is observed in all the samples and the foraminiferal assemblage between *Ammonia*/*Elphidium* and *Ammonia*/ *Haynesina*directs very shallow water lagoon of near marine salinity (Zlinská *et al*., 2010).

In miliolids a total of ten species have been identified, among those *Quinqueloculina seminula*, *Miliammina fusca* and *Adelosina longirostra*are comparatively more in number and the remaining forms are *Q. vulgaris, Q. bicarinata, Triloculina circularis, T. oblonga, T. tricarinata, T. insignis* and *Spiroloculina antillarum*. The species *Miliammina fusca* which is acquired from the lagoon is considered as porcellaneous form, since actin study on the taxon revealed that it is closely related to porcellaneous rather than agglutinated form (Fahrni *et al*., 1997).

Seven agglutinated species viz. *Textularia agglutinans, Ammobaculites agglutinans, Trochammina inflata, Ammobaculites exiguus, Ammoglobigerina globigeriniformis, Ammobaculites persicus* and *Quinqueloculina agglutinans* have been identified from the study area. Of whichthe abundance of *Ammobaculites agglutinans, A. persicus* and *A. exiguous* are 39.29%, 24.76% and 18.33% respectively and these forms were found to be morein the middle part of the lagoon. Agglutinated forms are good indicators of littoral zonethan calcareous forms and these are influenced by fresh water runoff associated by brackish water with moderate water energy (Wu *et al*., 2015). Besides these benthic foraminiferal assemblage, two planktonic species *Globigerina bulloides* and *Globigerina sp.* are found to occur in the samples recovered from two location near the mouth.

Temporal distribution of foraminifera

In core samples the three species of *Ammonia*, *Rotalidium annectans* and *Elphidium crispum* are more in number while *Elphidium advenum* is less when compared to surface sediments. The vertical distribution of foraminifera in the Yedayanthittu lagoon shows that the top portion of the core contains relatively less number of taxa whereas between 30 cm to 125 cm level of the core it is increased (120 to 310 counts), laterat 135 cm level it exhibitsa decreasing trend followed by a gradual increase in deeper level(Fig.2.a). The five abundant forms shows an increment and reaches peak at the depth of 125 cm (Fig.2.b). *Ammonia* group is tolerant to wide range of salinity and temperature but the *Elphidium* which are larger in size and more in number at 70 cm and 125 cm depth and this peak (Fig.2.c) indicates the invasion of water either by waves and tides or by sea level rise which might have caused the affluence of the fauna. Myers (1936, 1943) reported that

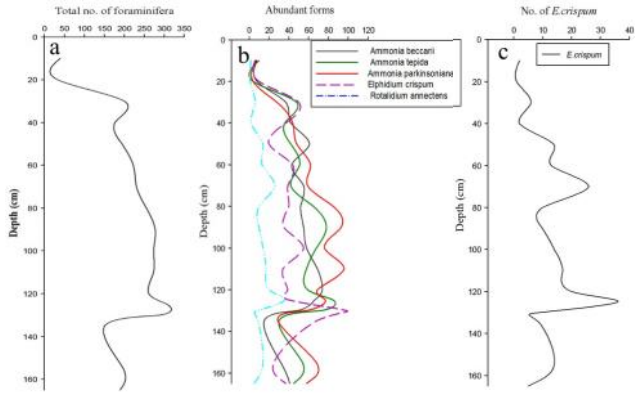

Figure2 (a) Temporal distribution of total number of foraminifera, (b) down core variation in abundant forms and (c) *E. crispum* in Yedayanthittu lagoon.

larger *E. crispum* is found to be more in sublittoral zone than in littoral zone which is due to the good nutritional condition in the area.

The physico-chemical parameters of water samples such as temperature, pH, salinity and TDS values of Yedayanthittu lagoon ranges between 32.1°C to 33.9°C, 7.24 to 8.4, 30.1ppt to 30.6 ppt and 23.5 ppt to 23.7 ppt respectively. There is no gradational changes in these parameters because the area lies parallel to the sea and the higher salinity of the lagoon might be due to the invasion of saline water to the area through the Marakkanam salt pan.

Textural Analysis

Granulometric study has critical role in understanding the spatial and temporal distribution of sediments in various depositional environment (Allen and Duffy, 1998). Inter relationships between different grain size parameters viz.mean, standard deviation (sediment sorting), skewness, kurtosis and different depositional environment have been well established by several studies (Folk and Ward, 1957; Friedman, 1967; Visher, 1969; Rajamanickam and Gujar, 1985; Hegde ea al., 2007; Dora *et al*., 2011).

Surface sediments

Bivariate plots of standard deviation vs. mean grain size, skewness vs. standard deviation and kurtosis vs. skewness have beenmade to determine the depositional environment and energy condition of Yedayanthittu lagoon.

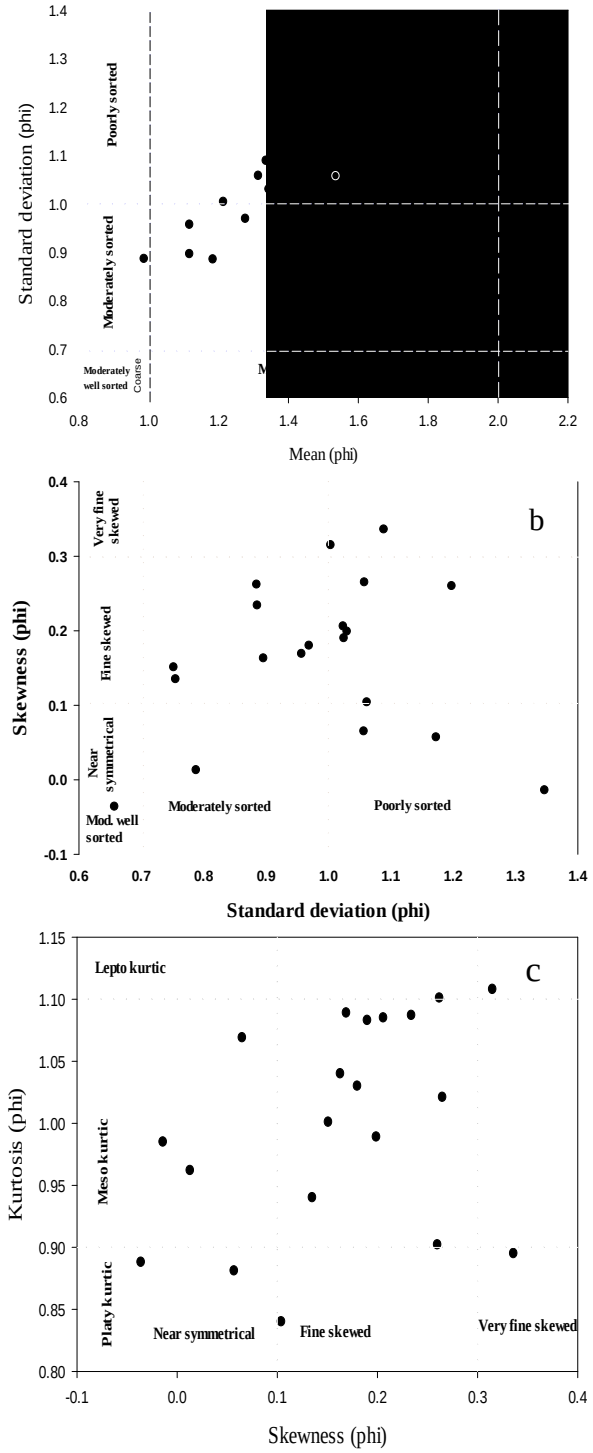

Figure 3 Bivariate plot between a) standard deviation vs. mean grain size, b) skewness vs. standard deviation and c) kurtosis vs. skewness.

Sorting vs mean grain size of sediment shows that samples are clustering in medium grained, moderately sorted to poorly sorted and one sample which is collected from the mouthfalls in moderately well sorted rangesince sediment sorting enhances

with dropping of mean size (Friedman 1967). Skewness vs standard deviation of the surface sediments illustrate 65% of fine skewed sediments are moderately to poorly sorted and25%are near symmetrical. The relationship between kurtosis and skewnessshows 70% of the sediments are mesokurtic of which60% of the sediments are clustered around fine skewed – mesokurtic range. It reveals that the major part of the sediments are of unimodally distributed in low to moderate energy condition.

Core samples

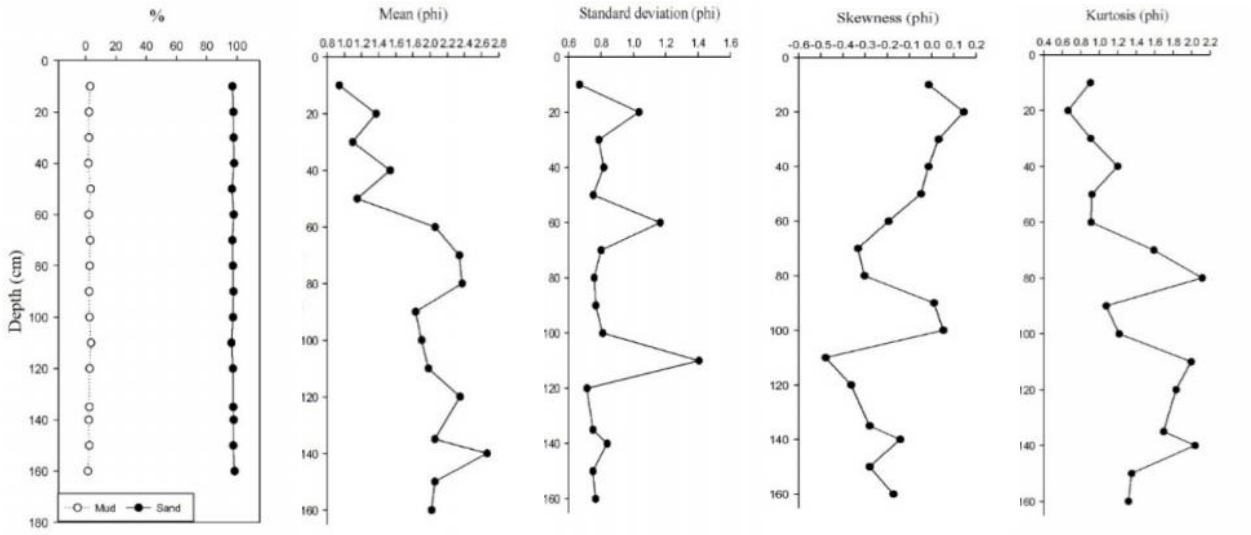

Figure 5 Down core variation in percentage of sand, mud and grain size statistical parameters

Textural analysis of core 2 (collected near mouth) shows significantly high percentage of sand (96.73 % - 98.52 %) with lesser amount of mud. The finer particles near mouth must be washed out due to the influence of tidal currents which lowered the affluence of finer particles in the entire core. The statistical parameters of sediments such as mean size, sorting, skewness and kurtosis varies from coarse to fine sand, moderately well to poorly sorted, fine skewed to strongly coarse skewed and very platy kurtic to very lepto kurtic respectively. Top portion of the core (10 cm depth) alone is moderately well sorted which might be due to the input of marine sediments and the wave action might have increased the energy at the particular level, remaining 80% sediments in the down-core is moderately sorted which shows the fluvial input of sediments with moderate energy. Poorly sorted sediments obtained onlyat 20 cm, 60 cm and 110 cm depth interval indicates the additional contribution of fluvial sediments in low energy condition. In the entire core (except up to 10 cm)standard deviation ranges from moderately sorted to poorly sorted which reveals the mouth experienced low to moderate energy condition in deeper level. Below 110 cm, sediments are fine sand, moderately sorted, negatively skewed and leptokurtic to very lepto kurtic. The finer size with dominant leptokurtic distribution of sediment reflects the maturity of sand (Prabhakara Rao *et al*., 2001), and negative skewness indicates the down core area below 110 cm experienced either erosion or non-deposition.

Clay Mineralogy

Clay minerals are the important constituent of sediments which are formed either by weathering or hydrothermal alteration of parent rock. The X-ray diffractograms of clay minerals in the lagoon reveals that the surface as well as core sediments are characterized by the dominance of kaolinite followed by illite and smectite with minor amount of chlorite. The surface sediment collected from upstream YD1 shows the presence of illite and smectite, while the other surface samples YD 9 and YD 16 are characterized by kaolinite, illite and chlorite.

Table 1 Clay minerals of surface and core sediments, Yedayanthittu lagoon

Sample	Depth (cm)	Clay minerals
Surface sample		
YD 1	-	Kaolinite, Illite, Smectite
YD 9	-	Kaolinite, Illite, Chlorite
YD 16	-	Kaolinite, Illite, Chlorite
Core 1 (upstream)	*20 – 25*	Kaolinite, Illite
C-1-7	*155 – 160*	Kaolinite, Illite, Smectite, Chlorite
C-1-6	40 – 45	Kaolinite, Illite, Chlorite
Core 2 (near mouth) C-2-5	110 - 115	Kaolinite, Illite
C-2-4		

In core samples, 155 – 160cm depth of Core 1 only shows the presence of four clay minerals such as kaolinite, illite, smectite and chlorite altogether, remaining all sediments are characterized by the unanimous presence of kaolinite and illite either with smectite or chlorite (Table 1). Kaolinite is the indicator of intense chemical weathering of hinterland parent rocks in tropical regions (Chamley, 1989; Kessarkar *et al*., 2010). Yedayanthittu lagoon sediments shows the predominance of kaolinite and illite in all the samples while smectite is less. Smectite has smaller size and lower density

and will be transported to longer distance and flocculate on distal part of the stream whereas kaolinite and illite will flocculate rapidly (Gibbs 1977; Kessarkar *et al*., 2010).

CONCLUSIONS

Foraminiferal assemblage of the Yedayanthittu lagoon comprises of a total of 48 species which belong to 28 genera, 18 families and 4orders. Faunal association such as *Ammonia*/*Elphidium* and *Ammonia*/ *Haynesina* indicates the prevalence of marine salinity in the studyarea. The abundance of the agglutinated taxa in the middle part of the lagoon suggests that it is of littoral zone with moderate energy condition. Most of the forms in the study area preferred sandy substrate, alkaline and medium energy condition of water as evidenced from the present study. Temporal distribution of *E. crispum* indicates the sublittoral zone with high nutrient influx prevailed in the deeper level. Surface distribution of moderately to poorly sorted medium sand indicates the major input of lacustrine sediments to the lagoon in low to medium energy condition. Temporal variation of textural characters of the sediment reveals that the energy condition was moderate, and below 110 cm depth the lagoon has experienced either erosion or non-deposition. Kaolinite as the major clay mineral in the Yedayanthittu lagoon indicates the intense chemical weathering of hinterland rock in tropical humid environment.

Acknowledgement

The authors acknowledge UGC for providing fund and we obliged to friends those who helped to complete the field work.

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How to cite this article:

Rabina C., Senthil Nathan D and Faizal Khan A.2016, Spatial and Temporal Distribution of Recent Foraminifera, Sediment Characteristics and Clay Mineralogy of Yedayanthittu Lagoon - Tamil Nadu, India. *Int J Recent Sci Res.* 7(4), pp. 10664-10669.

TSSN 0976-3031