Journal of the Palaeontological Society of India
Volume 64(1), June 30, 2019: 121-128 ISSN 0552-9360

DOWNCORE DISTRIBUTION OF DIATOMS IN THE MANGROVE ECOSYSTEM OF PULICAT LAGOON, TAMIL NADU, SOUTH-EAST COAST OF INDIA

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ABSTRACT

Diatoms are key components of nearly all fresh and saline environments. Most of the species are good indicators for a range of water quality, because they have narrow optima and tolerance for many environmental variables such as habitat, salinity, pH, nutrients and temperature. Diatoms respond quickly to environmental changes because they immigrate and replicate rapidly. The growth of diatoms is responsible for about 25% of the world's primary food production. In order to study the distribution of diatoms, one core of 81 cm length was retrieved from the Pulicat Lagoon, where sparse mangroves are present. The study area consist of 66 diatom species belonging to 32 genera, 21 families, 18 orders, 4 subclasses and 2 classes, of which pennates are more dominant than the centric forms. Distribution pattern of individual species were examined and their sediment relationship was determined for ecological/environmental interpretation. Sediment parameters such as $CaCO_3$, organic matter and sand-silt-clay ratios were estimated and their downcore distribution is discussed. An attempt has been made to evaluate the favorable substrate for the abundance of diatom populations in the present study.

Keywords: Diatoms, sand-silt-clay, $CaCO_3$, organic matter, distribution; Pulicat Lagoon.

INTRODUCTION

Diatoms are interesting, useful and relatively un-crowded field for study. Future work in micropaleontology will stress on the solution to problems concerning correlation and paleoecology in high latitude regions which contain few, if any, calcareous microfossils, but are exceedingly rich in diatomaceous remains (Stoermer and Smol, 1999). In spite of this, even in low latitudes, the study of diatoms lags far behind than the other major microfossil groups, like calcareous algae (Humane and Kundal, 2010), foraminifera (Culver, 1987; Nigam *et al*., 1995), Ostracods (Hussain *et al.,* 2003, 2015, 2016). Because of their intricate siliceous cell walls and their global distribution in aquatic and terrestrial environments, diatom microalgae have attracted the interest of naturalists and researchers alike since the 18th century. In recent decades, the major role of diatoms in global primary productivity (Lazarus, 2014) and the carbon cycle has been demonstrated (Round *et al*., 1990; Reid 2005; Cunningham *et al*., 2010).

These ecosystems are all perceived as being threatened indirectly or directly by human activities and time space changes in the distribution of diatom species can provide valuable evidence about the nature and pace of global environmental change (Flower, 2005). There are several ways in which diatoms are particularly relevant to global change and biodiversity issues (Flower, 2005; Weckstrom, 2006; Bennion and Simpson 2010). They are species diverse and because of their well known ecological tolerances, they can indicate the nature of environmental change, viz., climate, pollution and habitat loss etc. (Thakur *et al.,* 2017, Humane *et al.,* 2009; Humane *et al.,* 2010; Humane *et al.,* 2015). The present study has been undertaken to know the distribution of diatoms in the sub-surface samples of Pulicat Lagoon. Pollution from sewage, pesticides, agricultural chemicals and industrial effluents are gradually becoming major threats. It is speculated that the Arani and Kalangi rivers draining into the lagoon bring in fertilizers and pesticides with the runoff from the agricultural fields in the drainage basin.

The domestic sewage forms a more diffuse input. Effluents and wastes from numerous fish processing units are also major sources of pollutions. The oil spills from mechanized boats are always a potential hazard (Olita *et al.,* 2012). Till date, there has, however, been little effort to either quantify the various pollutants or even identify their probable sources. Thus, the enormous flora and fauna of this lagoon ecosystem are presently being disturbed by both natural and anthropogenic factors and call for immediate conservation measures.

METHODOLOGY

In order to study the distribution of diatoms in the sub-surface sediment samples of Pulicat Lagoon, south-east coast of India, one core with a total length of 81 cm was collected. The location of the core was recorded using a GPS (Latitude 13° 24' 56" N and Longitude 80° 19' 19" E). The core sample was sub-sampled at 3-cm interval and thus 27 samples were obtained. All the sediment samples were subjected to standard micropaleontological techniques and various sedimentological techniques so as to record the occurrence of diatoms and to know the nature of the collected sediment samples. Calcium carbonate and organic matter in the sediment samples were determined by adopting procedures proposed by Piper (1947) and Gaudette *et al.* (1974), respectively. Sand, silt and clay contents were determined using a combination of sieving and pipette procedures, the later in accordance with Krumbein and Pettijhon (1938). Trilinear plots were prepared and description has been given based on Trefethen's (1950) textural nomenclature (Flemming, 2000). For diatom analysis, 5 gm of the each sub-sample was taken. These sediments were treated with 10% HCl to remove calcium carbonate and washed several times with distilled water. Later, the sample was boiled in 30% (15 min.) H_2O_2 in order to digest the organic matter, and the samples were again washed several times with distilled water. Finally, the samples were ready for making permanent microscope slides (Batterbee, 1986).

The species were arranged predominantly according to the system of classification proposed by Hendey (1964), Round *et al*. (1990), and various contemporary researchers (Flower, 2006, Fourtanier and Kociolek, 2009, Jacob John, 2012, Gandhi, 1998, Archibald, 1983, Gasse, 1986, Round *et al.,* 1990, Priygiel and Coste, 2000 and Taylor *et al*., 2007).

The percentage of the diatom population has been calculated by given formula.

Daitom% = Diatom present in each sample/Total diatoms in all samples*100

RESULTS AND DISCUSSION

Total population of diatoms in Pulicat Lagoon

From the distribution of diatoms in the core collected from Pulicat Lagoon, Tamil Nadu, India, the following species namely, *Grammatophora occeanica* (36.99%)*, Cocconeis heteroidea* (7.2%)*, Cocconeis scutellum* (13.63%)*, Tabularia fasciculate* (5.28%)*, Petroneis granulate* (2.09%)*, P. marina* (3.74%) and *Navicula cinta* (2.59%) , were abundant in the core. All these are pennate forms. *Tryblionella hungarica, Discostella stelligera, D.* sp.*, Cyclotella striata, Plagiogramma minor, Amphora* sp.*, Auliscus* sp.*,* and *Cymbellainitschzia diluviana* were the less abundant species (Table 1). *Cyclotella menenghiniana, C. oscillata* and *C. striata* are the centric forms present in the core and these were present rarely but in all samples. From the core, total populations of diatom species in each sub-sample were counted and are presented and discussed (Table 2).

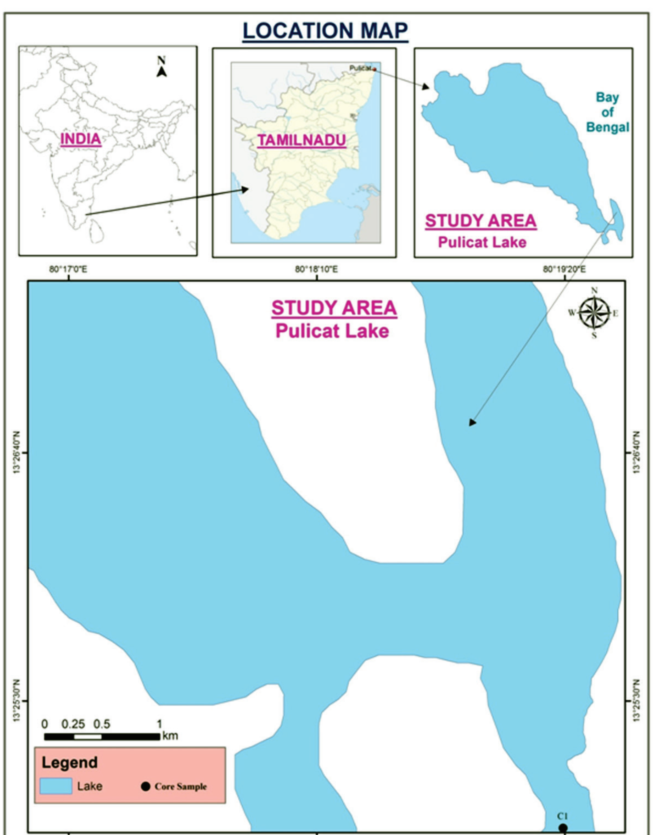

Fig. 1. Map of the study area showing the location of the core.

Sediment Characteristics

Some of the factors most often found to be important for distribution of diatoms are water chemistry (particularly pH, ionic strength and nutrient concentration), substrate, food supply, sediment, organic matter, current velocity, light and grazing. In order to find out whether the organic matter and calcium carbonate contents of the sediments and nature of substrate reflect the abundance of diatoms in them, an effort has been made to determine the same in all the sub-samples of the core.

Organic matter

Coastal sediments are considered to be major reservoirs of organic carbon since they account for 80% of global organic carbon burial (Berner, 1982). A major portion of the deposited organic matter is again re-oxidized and released into the atmosphere as carbon dioxide. The remaining portion is preserved in the sediments. Estimation of re-mineralization rate of organic carbon in coastal sediments could yield vital information with regard to the amount of CO_2 released into the atmosphere every year. This could aid in the understanding of the changes in the earth's climate both in the longer as well as in the shorter run. Organic matter in lake sediment is generally described as a binary mixture of terrestrial and aquatic end members. Once the metals are released to the environment, they are transferred to the sediments through adsorption onto suspended matter and subsequent sedimentation. The adsorption and sedimentation processes of metals mainly depend on the composition, grain size, carbonate content, level of organic matter etc (Jonathan and Ram Mohan, 2003).

In the present study, organic matter content was determined for all the 27 sub-surface samples collected. The organic matter content ranged from 0.41 to 1.23% (Table 2) and its down core profile is presented have been plotted (Fig. 2). Overall, the organic matter content in the upper part of the core shows higher values and decreases with depth, except at a depth of 78–81 cm.

The organic matter percentage in Pulicat Lagoon ranged from 0.68 to 0.03%. The organic matter decreased from 0.68 to 0.14% within the top 18 cm of the core, but it was almost uniform below this depth (Periakali and Padma, 1998). Higher levels of organic matter in the top 18 cm of the core sediments are due to its low maturity (Prasad *et. al.,* 2017). About 80% decrease in organic matter within the top 18 cm is due to the high reactivity of the organic matter in the top layers of sediment, as indicated by heavy reduction of Fe-Mn oxides in the sediments due to organic matter oxidation. Below this depth, the organic matter oxidation must remain low and be negligible as indicated by an almost constant profile of organic matter. This is due to a reduction in the reactivity of organic matter with time; the effects of bioturbation, pressure, temperature and redox conditions are considered to be only of secondary importance (Middelburg, 1989).

The ultimate source of organic matter incorporated in the sediments is some form of plant life thriving on the surface waters of the sea or on land, or both. In shallow water sediments, the organic matter is, to a great extent, related to the plant material of terrigenous origin, while for the ocean as a whole, it is the planktic photosynthetic organisms, which are the chief source of organic matter. In either case, the amount of organic matter content of the sediments depends upon: a) rate of deposition of

Table 1. Species wise population percentage of Diatoms.

SPECIES NAME	% OF SPECIES	SPECIES NAME	% OF SPECIES
Grammataphora occeanica	36.99	*Cocconeis pseudomarginata*	0.87
Cocconeis scutellum	13.63	*Nitzschia dissipata*	0.27
Cocconeis heteroidea	7.2	*Pleurosigma longum var*	0.27
Tabularia fasciculata	5.28	*Bacillaria* sp.	0.27
Petroneis marina	3.74	*Biddulphia* sp.	0.27
Navicula cincta	2.59	*Auliscus sculptus*	0.27
Petroneis granulata	2.09	*Cocconeis molesta*	0.24
Seminaris sp.	1.72	*Achanthes lacunarum*	0.24
Cocconeis sp.	1.61	*Amphora subturgida*	0.24
Ardisonea formosa	1.58	*Cyclotella meneghiniana*	0.28
Diploneis suborbicularis	1.55	*Catenulla adhaerens*	0.24
Plagiogramma rhombicum	1.35	*Amphora deccusata*	0.2
Psammadictyon panduriforme	1.28	*Lyrella lyra*	0.2
Achanthes brevipes	1.13	*Rhopalodia* sp.	0.19
Melosira sp.	1.01	*Melosira distans*	0.17
Ardisonea fulgens	0.88	*Diploneis ovalis*	0.17
Achanthes reidensis	0.84	*Amphora holsatica*	0.13
Pleurosigma deccorum	0.73	*Rhopalodia suborbicularis*	0.13
Delphineis surrirella	0.64	*Synedra henedyana*	0.13
Navicula cancellata	0.61	*Gyrosigma spencerii*	0.13
Amphora coffeaeformis	0.57	*Diploneis subovalis*	0.13
Plagiogramma tenuistriatum	0.57	*Eunotia curvata*	0.13
Petroneis sp.	0.57	*Nitzschia obtusa*	0.1
Gyrosigma balticum	0.54	*Plagiogramma appendiculum*	0.1
Dimmegramma minor	0.54	*Diploneis chersonensis*	0.1
Achanthes reidensis	0.5	*Placoneis gastrum*	0.1
Amphora bigibba	0.47	*Navicula elegntoides*	0.08
Nitzschia linearis	0.4	*Tryblionella punctata*	0.07
Cyclotella ocelleta	0.4	*Biddulphia pulchella*	0.07
Ardisonea crystallina	0.4	*Cymbellointzia diluviana*	0.1
Thalassionema nitzschiodes	0.4	*Auliscus* sp.	0.07
Pleurosigma sp.	0.38	*Amphora* sp.	0.03
Lyrella roberstiana	0.37	*Plagiogama minor*	0.03
Hantschia virgata	0.3	*Cyclotella striata*	0.03
Nitzschia palea	0.4	*Discotella stelligera*	0.03
Pleurosigma longum	0.3	*Discostella* sp.	0.03
Striatella unipunctata	0.3	*Tryblionella hungarica*	0.03

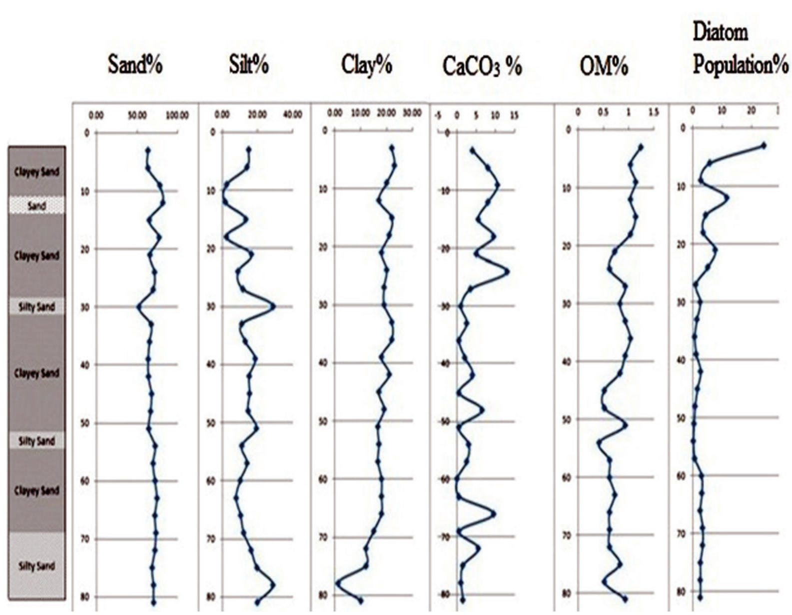

Fig. 2 Downcore variations in organic matter, CaCO3, sand-silt-clay and diatom populations in Pulicat Lagoon.

Table 2. Distribution of Sand, Silt, Clay %, CaCO3%,OM% and Diatom Population %.

SAMPLE NO.	DEPTH IN cm.	SAND %	SILT %	CLAY %	$CaCO_3$ %	OM %	DIATOM POPULATION%
1	0-3	63.12	14.88	22	4	1.24	24.18
2	3-6	63.12	13.88	23	8	1.03	5.78
3	6-9	77.82	2.18	20	10.5	1.13	2.72
4	9-12	81.54	1.46	17	8	1.03	11.55
5	12-15	64.78	13.22	22	5.5	1.13	4.37
6	15-18	76.92	2.08	21	9.5	1.03	3.49
7	18-21	65.56	16.44	18	5	0.72	7.59
8	21-24	71.3	8.7	20	13	0.62	5.07
9	24-27	69.48	11.52	19	3.5	0.93	0.97
10	27-30	52.02	28.98	19	1	0.82	2.48
11	30-33	67.1	10.9	22	2.5	0.93	1.38
12	33-36	65.12	12.88	22	0.5	1.03	0.60
13	36-39	63.38	18.62	18	2	0.93	1.11
14	39-42	63.82	15.18	21	4	0.82	2.62
15	42-45	67.64	15.36	17	0.5	0.51	1.54
16	45-48	66.42	14.58	19	6.5	0.51	0.74
17	48-51	64.14	19.26	16.6	0.5	0.93	0.40
18	51-54	72.08	10.92	17	3	0.41	0.17
19	54-57	69.52	13.88	16.6	2.5	0.62	0.60
20	57-60	72	10	18	0	0.62	2.92
21	60-63	74.32	7.68	18	0.5	0.72	3.06
22	63-66	71.78	10.22	18	9.5	0.62	2.48
23	66-69	73.02	11.98	15	0.5	0.62	3.29
24	69-72	71.78	16.24	11.98	5.5	0.62	3.29
25	72-75	68.34	19.66	12	1.5	0.82	2.55
26	75-78	70.02	28.78	1.2	1	0.51	2.52
27	78-81	70.16	19.84	10	1.5	0.93	2.52
MAXIMUM		**81.54**	**28.98**	**23**	**10.5**	**1.23**	**24.18**
MINIMUM		**52.02**	**1.46**	**1.2**	**0.5**	**0.41**	**0.17**
AVERAGE		**68.75**	**13.67**	**17.56**	**4.07**	**0.8**	**3.70**

organic matter, b) rate of deposition of inorganic matter and c) rate of decomposition of organic matter, following deposition (Meyers, 1997).

The rate of deposition of organic matter depends upon the production within the upper layers, and the rate of destruction during descent through the water column. Abundant supply of oxygen will cause decomposition of the organic matter that has reached the bottom. The sediment texture also plays a major role, i.e., comparatively coarse-grained sediments are more permeable than fine-grained ones and hence, the later are more suitable for preservation of organic matter. According to Sverdrup *et al.* (1942), the under mentioned conditions favor the formation of sediments rich in organic matter: a) good supply of organic matter, b) relatively rapid rate of accumulation of organic material, especially in fine-grained sediments, and c) less supply of oxygen to the water in contact with the sediments.

Decomposition products of macroflora and algae living in this lake are probably the major source of organic matter, as terrigenous contribution is negligible (Durga Prasada Rao and Poornachandra Rao, 1974). Subba Rao (1960) recorded 1.05% to 1.34% organic matter content for the sandy sediments collected from a depth of 10–15 fathoms (18.3–27.4 m) off east coast of India. However, he observed that the silty-clay material of the Pennar, Krishna and Godavari rivers, even though fine in nature, is poor in organic matter. In the sediments of Suddagedda River estuary, sandy sediments were found to be poor in organic matter content, while fine-grained materials were rich (Venkata Rao and Subba Rao, 1974). Later, they (1976) analyzed the Chipurupalle Stream sediments and established that the sandy types were poor in organic matter, while materials containing higher amount of clay were rich in the same.

Calcium carbonate ($CaCO_3$)

In the present study, it has been found that the $CaCO_3$ in the sediments of Pulicat Lagoon ranged from 0.5 to 10.5% (Table 2); the higher values are attributed to broken shell fragments in the sub-samples. The determined values are also plotted (Fig. 2).

Calcium carbonate deposition in the sediments could be enhanced due to higher productivity in the water column, which decreases CO_2 (Broecker, 1982). In addition, as Pulicat is a shallow lagoon with an average depth of around 1.5 m, evaporation of lake water could also have resulted in the deposition of $CaCO_3$ in the sediments (Padma and Periakali, 1999). The major sources of carbonate in the sediments of the study area are the shells and broken shell fragments of organisms and mollusks, in addition to dilution of biogenic calcite by detrital material in the sediments. The association of sand particles with $CaCO_3$ indicates the major contribution of shell fragments to the sand fraction.

Subba Rao (1958) made a study of $CaCO_3$ content of the sediments collected from off the east coast of India, north of

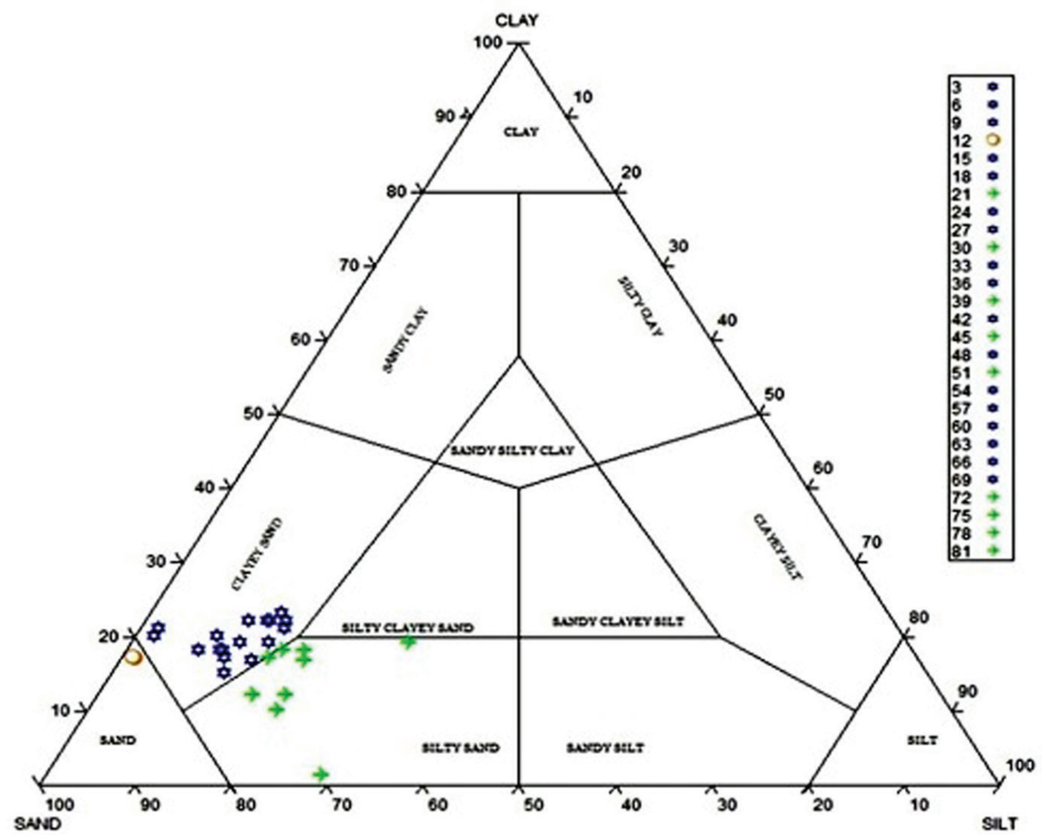

Fig. 3. Trilinear plot of sand-silt-clay contents of Pulicat Lagoon (after Trefethen, 1950).

Chennai and stated that the sediments from depths of less than 20 fathoms (36.6 m) were, in general, poor in $CaCO_3$ content. Likewise, Madhusudana Rao and Murthy (1968) studied many sediment samples collected from off Chennai and Karaikal. They observed that samples collected from depths of 36 feet (11 m) and 54 feet (16.5 m), off Madras present-day Chennai), contained 1.75% and 3.0% $CaCO_3$, respectively; sediments collected off Karaikal from depths of 48 feet (14.6 m) and 96 feet (29.2 m) contained 6.0% and 8.0% $CaCO_3$, respectively. Rasheed and Ragothaman (1978) observed that the calcium carbonate percentage varied from 0.5 to 5.5%, in the inner shelf sediments, off Porto Novo, Tamil Nadu. They found the same to show a seaward increase from the shore. They also stated that, in general, the sediments off Porto Novo were poor in $CaCO_3$ content than those recorded from other areas off Tamil Nadu.

Substrate and Diatom Population

In the sub-samples of Pulicat Lagoon, the sand-silt-clay contents were estimated and the trilinear diagram (after Trefethen, 1950) for sand-silt-clay was prepared (Fig. 3). It was observed that the samples fall under clayey sand with a variable range of 52.02% to 81.54% sand, silt with a range of 1.46% to 28.98% and clay with a range of 1.2% to 23% (Table 2). Downcore variations of organic matter, $CaCO_3$ sand-silt-clay and diatom populations are shown in Table 2 as well as in Figure 2.

CONCLUSIONS

A total of 66 diatom species belonging to 32 genera, 21 families, 18 orders and 4 subclasses were identified from a core of 81 cm length retrieved from Pulicat Lagoon, Tamil Nadu. Among these, *Grammatophora occeanica, Cocconeis heteroidea, Cocconeis scutellum, Tabularia fasciculata, Petroneis granulata*, *P. marina* and *Navicula cinta* were the abundant species present in the study area. *Tryblionella hungarica, Discostella stelligera, D.* sp.*, Cyclotella striata, Plagiogramma minor, Amphora* sp.*, Auliscus* sp. and *Cymbellainitschzia diluviana* were rare. The pollution of the lagoon is indicated by the presence of diatom species belonging to different genera like *Melosira, Achnanthes, Cocconeis, Navicula, Nitzschia* and *Tryblionella.*

The substrates found in the Pulicat Lagoon are clayey sand and silty sand, indicating medium energy condition of sediment deposition in the lagoon. The silt and clay have been mainly derived through River Kalangi. They were deposited on the sand which had been deposited earlier in an open marine, littoral environment. The silt and clay were mixed up in different proportions in different parts of this lake; this process is mainly controlled by wave energy and depth of the water column.

The major source of carbonate in the sediments of the study area is the broken shell fragments of organisms. The organic matter profile shows a fluctuating trend. Higher levels of organic matter in the core sediments are due to its low maturity. Decrease in organic matter is due to the high reactivity of the organic matter in the upper sediment layers. At the bottom of the core, organic matter oxidation remains low as indicated by an almost constant profile of organic matter. This is due to a reduction in the reactivity of organic matter with time and the effects of bio-turbation, pressure and temperature (Ganesan, 1992). Decomposition products of macroflora and algae living

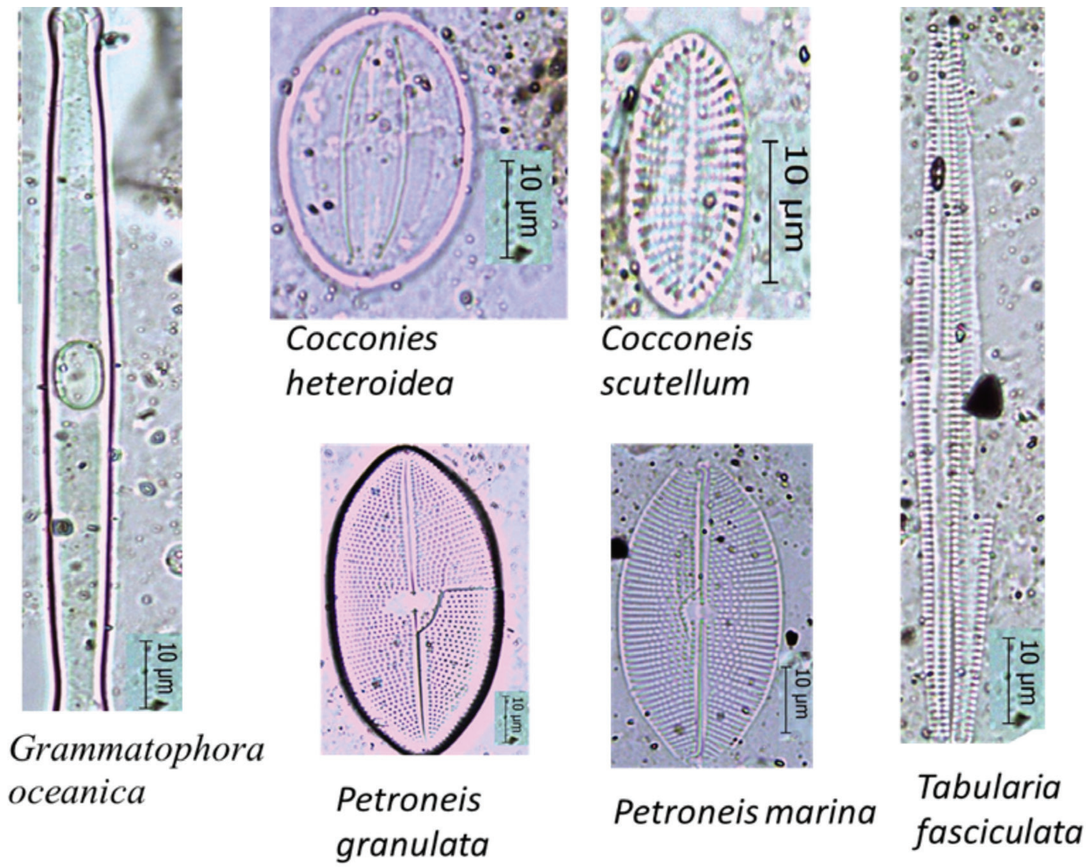

Fig. 4. Abundant diatom species found in Pulicat Lagoon.

in this lake are probably the major source of organic matter while terrigenous contribution is negligible. From the above observations, it may be inferred that clayey sand and silty sand are the favorable substrates for diatom populations.

ACKNOWLEDGEMENTS

The authors are thankful to the UGC–CPEPA programme and Prof. S. Ramasamy, Co-ordinator, Department of Geology, University of Madras, Chennai, for financial support and also for the facilities provided to carry out this work. Authors are thankful to the Head of the Department, RTM Nagpur University, Nagpur, for the laboratory facility for the identification of the diatom species.

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Manuscript received : November 2017

Manuscript accepted : March 2019