International Journal of
Science Inventions Today
www.ijsit.com
ISSN 2319-5436
Research Article

DISTRIBUTION OF CHL A IN VELLAR ESTUARY AND COASTAL WATERS OF PARANGIPETTAI AND SOUTHEAST COAST OF INDIA

A. Arokiasundaram, T.Lenin, N.Veerapandian and P.Sampathkumar*

CAS in Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai. TamilNadu, India.

ABSTRACT

The present study was aimed to study the distribution of Chl *a* in Vellar estuary mouth and coastal waters of Parangipettai, at Southeast coast of India, Tamil Nadu, in relationship with other hydrographical parameters. Water samples were collected from estuarine in the period of May 2011 to April 2012, mouth and Coastal waters and collected using Niskin water sampler. The hydrographical parameters, nutrients and total suspended solids were also studied.

The results of the investigation carried out during May 2011 to April 2012 on Hydrography, community structure of phytoplankton and chlorophyll 'a' (Chl-a) content and primary productivity (PP) at the Parangipettai estuary Mouth and coastal waters (Southeast coast of India) are reported. Surface water temperatures varied from 26.2 - 29.2 ^{o}C. Salinity values varied from 26.6 - 36.8 ‰ and the pH ranged between 7.9 - 8.6. Variation in dissolved oxygen content was 3.4 - 5.3 mg/l. The monthly variation of Nitrate was 0.339 - 4.688, Nitrite was 0.223 - 1.818 and other parameters like Phosphate, Silicate and Ammonia were studied respectively. The ranges of Chlorophyll 'a' (mg m-3) and the primary productivity (mgCm-3hr-1) values were between 3.4 - 12.8 and 55 - 119 respectively. The monthly distribution and abundance of Chlorophyll *a* are discussed in relation to Physico-chemical parameters.

Keywords: Chlorophyll *a,* Vellar estuary, Coastal waters, Southeast coast of India.

INTRODUCTION

Chlorophyll *a* is the main green photosynthetic pigment, found in all plants including phytoplankton. The concentration of chlorophyll *a* in estuarine, coastal and marine waters is used as an indicator of photosynthetic plankton biomass. Phytoplankton initiates the marine food chain, by serving as the food source to primary consumers like zooplankton, shellfish and finfish (Sridhar *et al*., 2006; Mathivanan *et al*., 2007; Tas and Gonulol, 2007; Saravanakumar *et al*., 2008). Chlorophyll is one of the green molecules in plant cells that carry out the function of energy fixation in the process of photosynthesis. Chlorophyll itself is actually not a single molecule, but a family of related molecules, designated chlorophyll *a, b, and c*. Phytoplankton cells play a significant role in determining the optical properties of the ocean. The chlorophyll specific absorption coefficient of Phytoplankton is crucial for calculating the contribution of phytoplankton, to the absorption coefficient of seawater as well as, used for estimating the amount of light absorbed by the phytoplankton, in bio optical models of marine primary production (Sakshaug *et al*., 1997).

Estuaries are areas of the most intensive exchange of matter and energy, between the continents and oceans and therefore represent very biologically dynamic environment. Sharp gradients in physico-chemical properties, occurring in estuaries at the freshwater and sea water interface have been shown to cause dramatic changes in the distribution of non-conservative constituents such as oxygen, carbon, nutrients and trace metals (Morris et al. 1978, Mantoura 1987, Legovie 1987).

Phytoplankton pigments that capture and transform solar energy in the water column (Hall *et al*. 1999) store valuable palaeoclimatic and palaeoenvironmental information, if undeveloped in sediments (Fietz *et al*. 2007; Soma *et al.* 2007). Carotenoids are useful biomarkers in different classes of phytoplankton, while chlorophyll *a* (Chl *a*) is not class-specific and is commonly used to estimate the total amount of phytoplankton in aquatic systems (Jeffrey *et al.* 1997; Bianchi *et al.* 2002; Reuss *et al.* 2005).In the last decade, the use of pigment-related methods to identify different taxonomic groups of phytoplankton as increased, mainly due to improvement in modern analytical techniques such as HPLC, which yields, expending on the procedure provide quantitative data on lipophilic (chlorophylls and carotenoids or water-soluble phycobiliproteins) pigments (Wright *et al,.* 1991, Jeffrey 1997, Descy et al. 2000, Teubner et al. 2003). Quantification of pigments is a necessary first step in determining the contribution of individual taxonomic groups, with most attempts concentrating mainly on using multiple linear regression analysis between marker pigments and chl *a* (Gieskes et al. 1988, Woitke et al. 1996, Descy et al. 2000). These studies have shown that the individual contribution to total chl *a* by a given established, primary productivity is present. .

MATERIALS AND METHODS

Monthly samples were taken at a fixed station, at Parangipettai Estuary, mouth (2 km away from the estuary) and coastal waters. The monthly samples were taken from May2011 to April 2012. Water samples were collected using Niskin water sampler. The chlorophyll was extracted using 90% of Acetone and spectrophotometrical quantification was done at 630,645, and 665 nm, and were compared with estuary waters and coastal waters . 90% acetone was used in this method, as the extraction solvent, because of its efficiency for most types of algae. However, 90% acetone was an effective extractant when the extraction period was optimized for the dominant species present in the sample. The water samples were taken for hydrographical analysis. Water temperature was recorded using a standard mercury centigrade thermometer. Salinity was estimated with the help of hand Refracto meter (Atago. Co. Ltd., Japan). Dissolved oxygen was estimated by modified Winkler's method (Strickland and Parsons, 1972). The pH of water has been recorded in the field itself using an Elico pH meter. Nutrients like Nitrite, Nitrate, Silicate, Phosphate and Ammonia were estimated by adopting the methods described by Strickland and Parsons (1972).

Statistical Analysis:

The data collected was charted into an excel spreadsheet and analyzed using the Linear regression was carried out in order to observe if there was a relationship and correlation between dissolved oxygen, salinity and temperature with Chl *a*. It was used to measure the response of the dependent variable, Chl *a* changes in the independent variables, dissolved oxygen, salinity, and temperature.

RESULTS

Physicochemical parameters:

Temperature:

The water temperature varied from 24.133 to 34.8˚C during the collection period May 2011 to April 2012. The minimum value of sea surface temperature is 24.133˚C during January 2012 and was recorded in Parangipettai mouth waters. The maximum value was 34.8˚C at May 2011, recorded in Parangipettai coastal waters at 3.0 km distance.

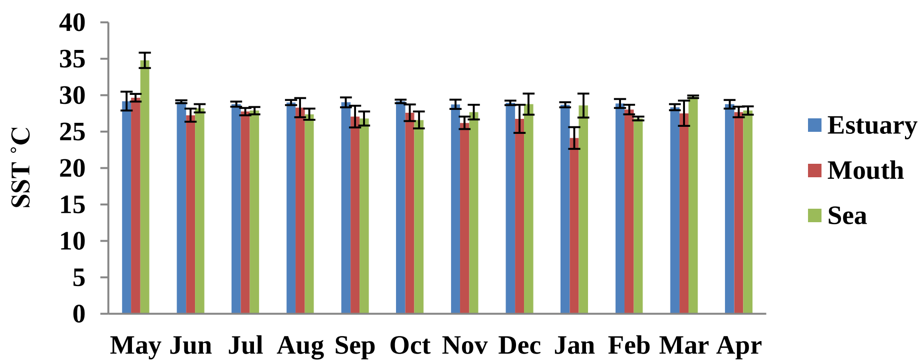

Figure 1: Monthly variation of sea surface temperature in vellar estuary, mouth and coastal waters of Parangipettai during May 2011-April 2012.

pH

The concentration of pH ranged between 7.5 to 8.6 during the collection period from May 2011 to April 2012. The minimum value of pH was 7.5 during January2012, recorded in estuary waters. The maximum value was 8.6, during the May2011, recorded in coastal waters at 3.0km distance

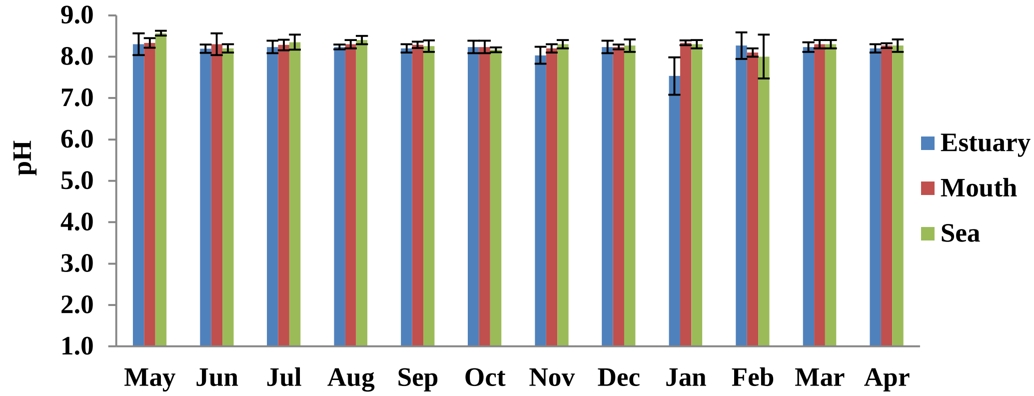

Figure 2: Monthly variation of pH vellar estuary, mouth and coastal waters of Parangipettai during May 2011-April 2012.

Salinity:

The concentration of sea surface water salinity, varied from 26.6psu to36.8psu during the collection period May 2011 to April 2012. The minimum value was 26.6psu, during October 2011 recorded in vellar estuary waters .The maximum value was 36.8psu May 2011 recorded in Parangipettai coastal waters at 3.0 km distance.

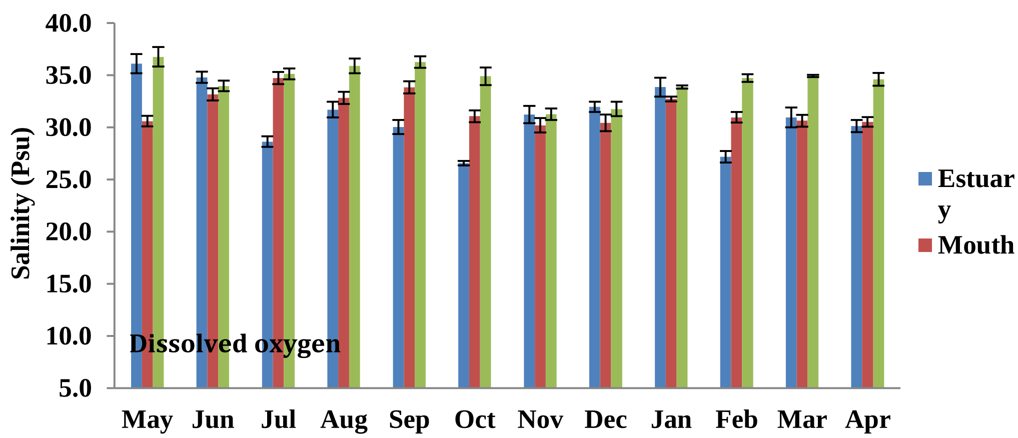

Figure 3: Monthly variation of salinity vellar estuary, mouth and coastal waters of Parangipettai during May 2011-April 2012.

The concentration of dissolved Oxygen varied from 3.4mg/l to 5.3mg/l during the collection period of May 2011 to April 2012. The minimum value was 3.4mg/l during April 2012, recorded in estuary waters. The maximum value was 5.3mg/l during September 2011, recorded in Parangipettai coastal waters at 3.0 km distance.

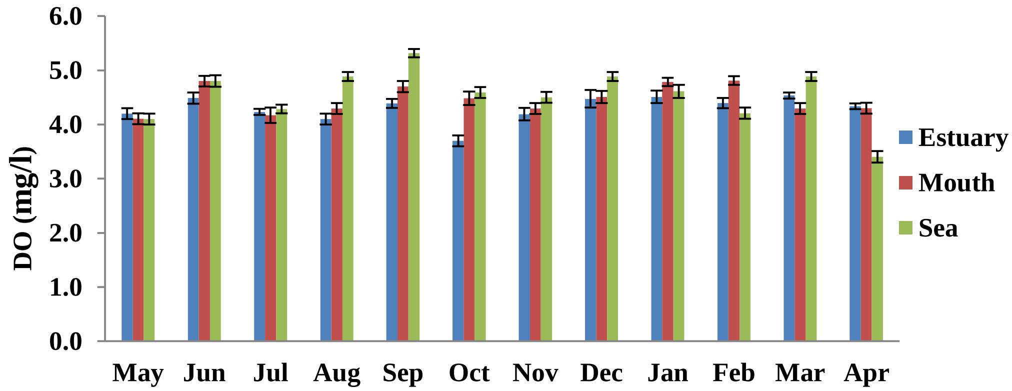

Figure 4: Monthly variation of Dissolved oxygen vellar estuary, mouth and coastal waters of Parangipettai during May 2011-April 2012.

Nitrite:

The concentration of Nitrite varied from 0.509µm/L to1.682 µm/l during the collection period from May 2011 to April 2012. The minimum value is 0.509 µm/l April 2012 recorded in Parangipettai coastal waters at 3.0 km distance. The maximum value was 1.682µm/l during December 2011 recorded in Parangipettai estuary waters.

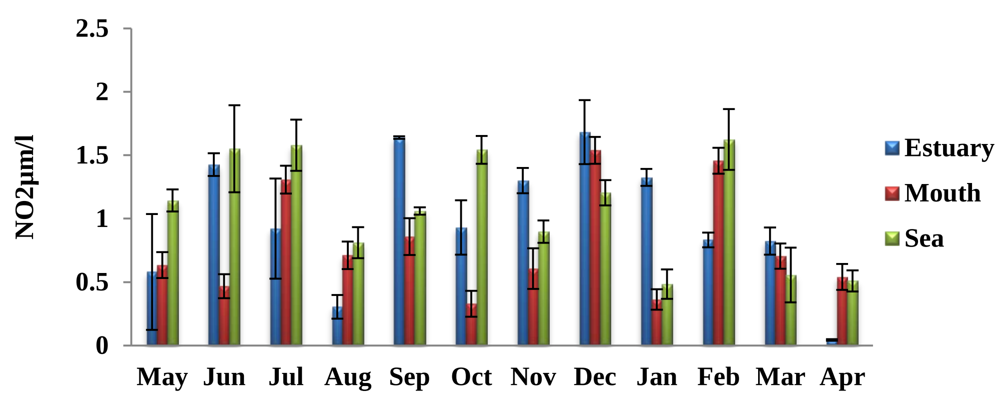

Figure 6: Monthly variation of Nitrite vellar estuary, mouth and coastal waters of Parangipettai during May 2011-April 2012.

Nitrate:

The concentration of Nitrate varied from 0.339µm/l to 4.75µm/l during the collection period from May 2011 to April 2012. The minimum value was 0.339 µm/l March 2012 recorded in mouth waters. The Maximum value was 4.75 µm/l during July 2011 recorded in Parangipettai estuary waters.

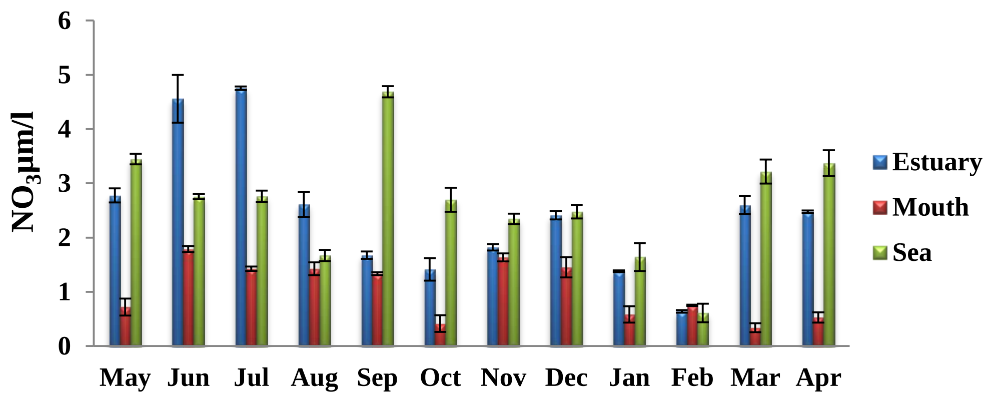

Figure 7: Monthly variation of Nitrate Vellar estuary, mouth and coastal waters of Parangipettai during May 2011-April 2012.

Ammonia:

The concentration of Ammonia varied from 0.042 µM/L to 0.926 µM/L during the collection period from May 2011 to April 2012.The minimum value was 0.042 during May 2011 recorded in Parangipettai coastal waters at3.0 km distance. The maximum value was 0.926 µM/L during September 2011, recorded in Parangipettai estuary waters.

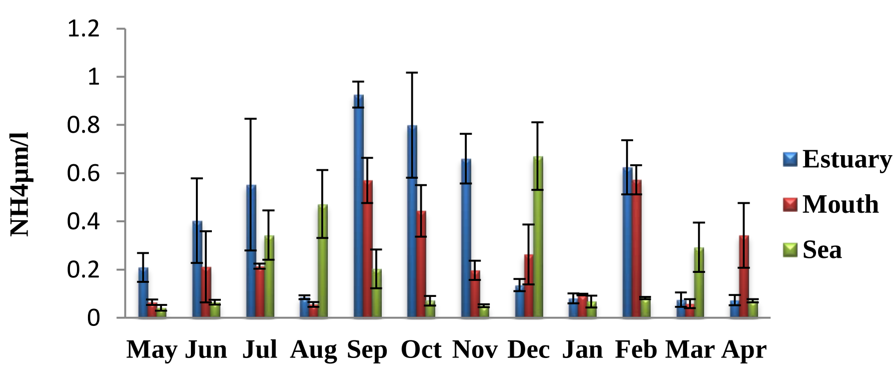

Figure 8: Monthly variation of Ammonia vellar estuary, mouth and coastal waters of Parangipettai during May 2011-April 2012.

Phosphate:

The concentration of phosphate varied from 0.058µM/L to 1.880µM/L during the collection period from May 2011 to April 2012. The minimum value was 0.058 µM/L during November 2011 recorded in Parangipettai estuary waters. The maximum value was 1.880µM/L during March 2012, recorded in estuary waters.

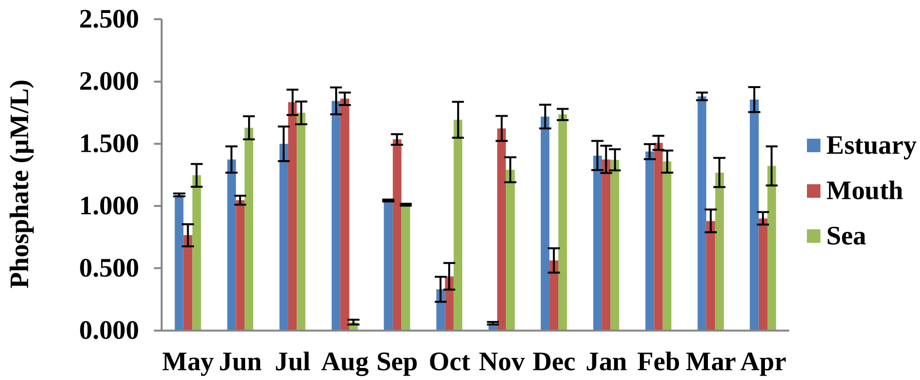

Figure 9: Monthly variation of Phosphate vellar estuary, mouth and coastal waters off Parangipettai during May 2011-April 2012.

Silicate:

The concentration of silicate varied 0.5377µM/L to 8.673µM/L during the collection period May 2011 to April 2012. The silicate minimum value was 0.5377µM/L during September 2011, recorded in estuary waters. The maximum value was 8.673µM/L during December 2011, recorded in Parangipettai estuary waters.

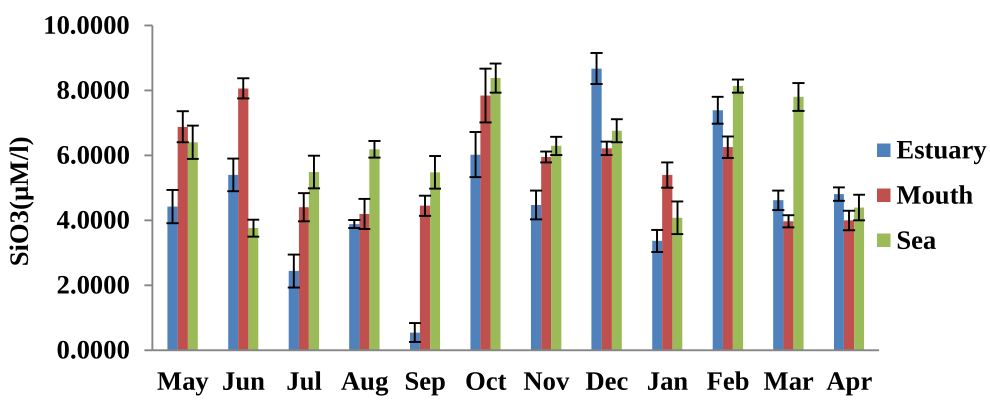

Figure 10: Monthly variation of Ammonia vellar estuary, mouth and coastal waters of Parangipettai during May 2011-April 2012.

Total alkalinity:

The concentration of total alkalinity varied from 48.0mg/L to 123Mg/l during the collection period from May 2011 to April 2012. The minimum value was ranged from 48.0mg/L during December 2011, recorded in Parangipettai mouth waters. The maximum value was 123.0mg/L March 2012 recorded in estuary waters.

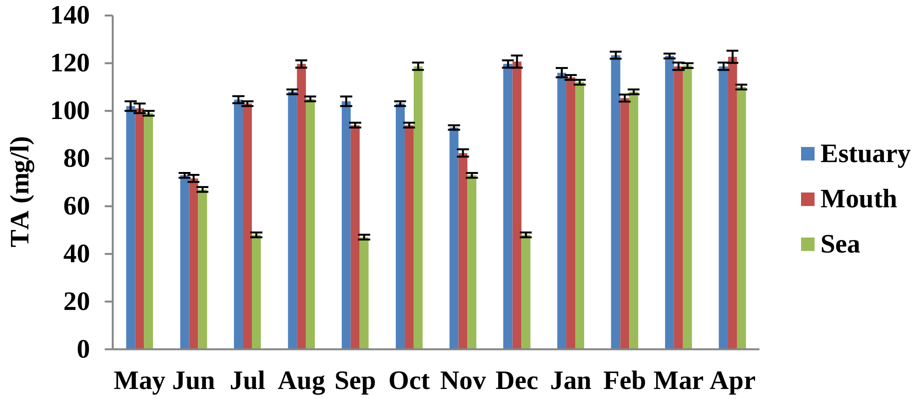

Figure 11: Monthly variation of Total alkalinity vellar estuary, mouth and coastal waters of Parangipettai during May 2011-April 2012.

Primary productivity:

The distribution of primary productivity varied from 14.579 to168.246 Mgcm^3/hr during the collection period from May 2011 to April 2012. The minimum value was ranged from 14.579 Mgcm^3/hr in April 2012 recorded in Parangipettai mouth waters. The maximum value was 168.246 Mgcm^3/hr during February 2012, recorded in Parangipettai estuary waters.

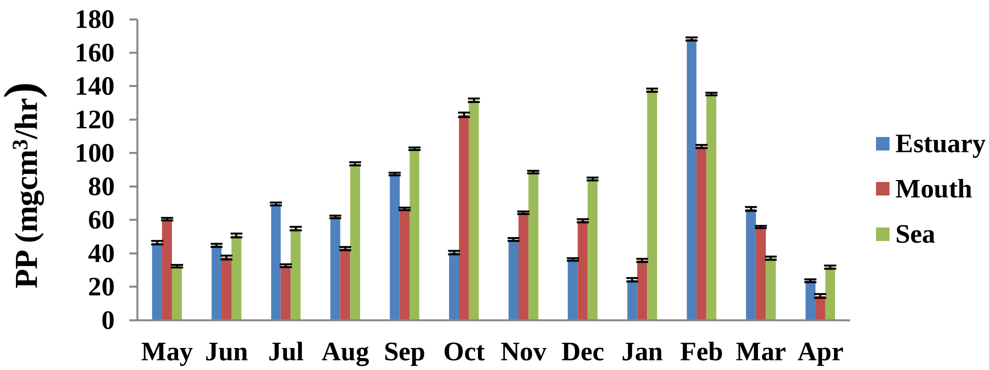

Figure 12: Monthly variation of primary productivity vellar estuary, mouth and coastal waters of Parangipettai during May 2011-April 2012.

Chlorophyll (Chl *a*):

The distribution surface waters of chlorophyll varied from 0.617 to 2.967 Mg/m^3 during the collection period from May 2011 to April 2012. The minimum value was ranged from 0.617 Mg/m^3 during March 2012 recorded in Parangipettai mouth depth waters. The maximum value was 2.967 Mg/m^3 in January 2012 recorded in Parangipettai estuary surface waters.

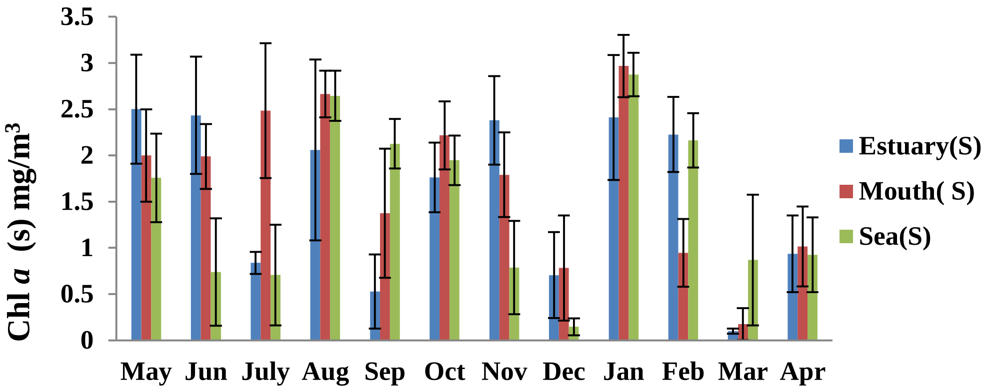

Figure 13(a): Monthly variation of Chlorophyll *a* vellar estuary, mouth and coastal surface waters of Parangipettai during May 2011-April 2012.

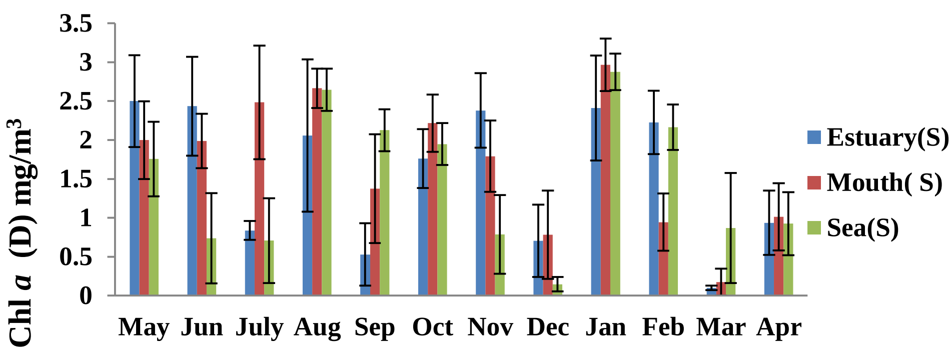

Figure 13 (b): Monthly variation of Chlorophyll *a* vellar estuary, mouth and coastal surface waters of Parangipettai during May 2011-April 2012.

DISCUSSION

The distribution of chl *a* and physical features, regarding variation of water temperature recorded in three stations chosen for the present study highly resembled that of temperature. This observation confirmed that water temperature could highly modified by climatologically condition, due to the shallow nature of the sampling stations (Veerabahu, 2000). The temperature variation is one of the factors in the coastal water, which may influence the physico-chemical characteristics and also influence the distribution and abundance of flora and fauna (Soundarapandian *et al.,* 2009). In the present study, it has been observed that high temperature was noticed in the months of May, at all stations of coastal waters. The high value could be attributed to the solar radiation, and lower temperature in the months of January to December was due to cloudy sky and rainfall brought down the temperature to the minimum at Parangipettai mouth waters. The maximum salinity value was recorded during May, could be described to the higher degree of evaporation in the study area and less tidal action (Mohammed *et al.,* 2007). Salinity is one of the important factors which profoundly influence the abundance and distribution of the animals in Marine environment. In the present study, the lower salinity was recorded during the months of October to December, was due to heavy rainfall and large quantity of freshwater inflow. The low pH observed during January-2012 in the coastal waters was due to the influence of fresh water influx, dilution of sea water, low temperature and organic matter decomposition, as suggested by (Ganesan 1992). Similar trend in pH was reported by Seenivasan 1998 from the Vellar estuarine system, Mathevan 1994 from Cuddalore Uppanar waters, Ananthan 1994 from waters of Pondicherry coastal water and (Kannan and Kannan1996), (Palanichamy and Rajendran 2000), (Sulochanan and Muniyandi 2005) from Palk Bay. The pH in marine and brackish water system is always taken as the function of salinity. The result of the present study also showed that the increase and decrease of pH followed the same trend as that of the salinity, which was reported earlier. The low dissolved oxygen concentration observed during summer could be ascribed to the higher salinity of the water and higher temperature in Palk bay (Sulochana and Muniyandi, 2005; Sridhar *et al.,* 2008; Sithik *et al.,* 2009). The trend noticed in the present study is in confirmed with the findings of dissolved oxygen concentration, which varies according to many factors. The main factors are due to photosynthesis and respiration by organisms.. Nutrients are considered as one of the most important parameters in the estuarine environment influencing growth, reproduction and metabolic activities of living beings (Ketchum1951), (Jayaraman1954). Distribution of nutrients is mainly based on the season, tidal condition and fresh water flow from land source. The highest nitrate value recorded during December in Parangipettai estuary waters could be mainly due to the organic materials received from the catchment area during ebb tide (Ashok Prabu *et al.,* 2005, 2008).The recorded low values of nitrates during the summer season may be due to its utilization by phytoplankton as evidenced by high photosynthetic activity and also neritic water dominance, which contained only negligible amount of nitrate. (Dhamotharan *et al*, 2010). The low values of nitrites, during April may be due to less freshwater inflow and high salinity (Saravanakumar *et al.,* 2008). In the present study, the highest value of nitrite, during the

December could be due to the increased phytoplankton excretion, oxidation of ammonia, reduction of nitrate, and the recycling of nitrogen and bacterial decomposition of planktonic detrithes (Govindasamy et. al., 2000;Asha and Diwakar, 2007).The recorded high concentration of phosphate during the April to intrusion of upwelling in to the creek, which in turn increased the level of phosphate. The recorded in low values of phosphate, during the August recorded in Parangipettai coastal waters could be attributed to the limited flow of freshwater, high salinity and utilization of phosphate by phytoplankton (Rajasegar, 2003). In the present investigation, the reactive silicate concentration was found to be much higher than estuary waters in station 1 more silicate concentration in the station. The high silicate concentration recorded during December 2011, may be due to the addition of silica material by land run-off caused by flooding during the monsoon season. Further more silicate available at the bottom sediment might go in to the upper water layers, when the bottom is agitated by wind action during the monsoon season. Low values of silicate recorded during the September 2011 may be due to the sizeable reduction in the fresh water input and greater utilization of the nutrient by the abundantly available phytoplankton for their biological activity in the previous work (Gowda and Panigrahy, 1991; Gowda and Panigrahy, 1992).

Many parts of the estuaries complied with chlorophyll *a* upper estuary water quality objectives. However, the vellar estuary had chlorophyll *a* levels, greater than water quality objectives. Further investigation is recommended near urban influenced areas and particularly in the wet season, when nutrient influx is much greater than in the dry season. Chlorophyll *a* concentrations of up to 70 g/L associated with fresh water inflow during the early 2007, wet season in tributary of the Elizabeth River estuary has been recorded (Drewry et al. 2010b). Seasonal variations in chlorophyll *a* concentrations may occur depending on increases in solar radiation, freshwater inflows and depth of euphotic zone (Masson and Pena 2009). Studies have shown that chlorophyll *a* concentrations can be greater under near surface stratification conditions, due to freshwater inflows (e.g. Masson and Pena 2009). The presence of elevated concentrations of chlorophyll in these estuaries could be associated with algae present in the treated wastewater discharge, or from algal growth in the estuary, or a combination. Further research is required to determine the processes such as algal decay and cycling, and sources of phytoplankton present in the estuary such as freshwater and estuarine species. Burford et al. (2009). However, the current spatial distribution study shows that chlorophyll *a* concentrations can still be much greater within the estuary, than outside the estuary entrance.

REFERENCES

1. Ananthan, G., 1994. Plankton ecology and heavy metal studies in the marine environments of Pondicherry, India, Ph.D. Thesis, Annamalai University, India, pp: 125.
2. Ashok Prabu, V., P. Perumal and M. Rajkumar: Diversity of microzooplankton in Parangipettai coastal waters, Southeast coast of India. J. Mar. Biol. Ass. Ind., 47, 14-19 (2005).
3. Ashok Prabu, V., M. Rajkumar and P. Perumal: 2008 Seasonal variations in physico – chemical

characteristics of pichavaram mangroves, southeast coast of India. J. Environ, Biol., 29, 945 – 950.Dhamotharan et al, 2010

4. Bianchi, T. S., Rolff, C., Widbom, B. & Elmgren, R. 2002. Phytoplankton pigments in Baltic Sea seston and sediments: seasonal variability, fluxes, and transformations. Estuarine, Coastal and Shelf Science, **55**, 369.383. Reuss, N. & Conley, D. J. 2005. Effects of sediment storage conditions on pigment analyses. Limnology and Oceanography Methods, **3**, 477.487.]
5. Descy, J. P., Higgins, H. W., Mackey, D. J., Hurley, J. P. & Frost, T. M. 2000. Pigment ratios and phytoplankton assessment in Northern Wisconsin lakes. J. Phycol. 36:274–86.
6. Fietz, S., Nicklisch, A. & Oberhansli, H. 2007. Phytoplankton response to climate changes in Lake Baikal during the Holocene and Kazantsevo Interglacials assessed from sedimentary pigments. Journal of Paleolimnology, **37**, 177.203.
7. Gieskes, W. W. C., Kraay, G. W., Nontji, A., Setiapermana, D. & Sutomo, D. 1988. Monsoonal alteration of a mixed and a layered structure in the phytoplankton of the euphotic zone of the Banda Sea (Indonesia): a mathematical analysis of algal pigment fingerprints. Neth. J. Sea Res. 22:123–37.
8. Hall, R. I., Leavitt, P. R., Quinlan, R., Dixit, A. S. & Smol, J. P. 1999. Effects of agriculture, urbanisation, and climate on water quality in the northern Great Plains. Limnology and Oceanography, **44**, 739.756.
9. Jeffrey, S. W., Mantoura, R. F. C. & Bjørnland, T. 1997. Data for the identification of 47 key phytoplankton pigments. In Phytoplankton Pigments in Oceanography: Guidelines to odern Methods (Jeffrey, S. W., Mantoura, R. F. C. & Wright, S. W., eds), pp. 449.559. UNESCO Publishing, Paris.
10. Kannan, R. and L. Kannan, 1996. Physico-chemical characteristics of sea weed beds of the Palk Bay, Southeast coast of India. Ind. J. M ar. Sci., 25: 358-362Palanichamy S, Rajendran A (2000). Heavy metal concentration in seawater and sediments of Gulf of Mannar and Palk Bay, southeast coast of India. Indian J. Mar. Sci., 29: 116-119.
11. Ketchum, B.H. 1951. The exchange of fresh water and salt water in tidal estuaries. J. Mar.Res., 10: 19-38.
12. Legovic T, Zutic V, Grietic 2, Cauwet G, Precali R (1994) Eutrophication In the Krka estuary. Mar Chem 46:203-215 Mantoura RFC (1987) Organic f~lmsa t the halocline. Nature 328:579-580
13. Mantoura RFC (1987) Organic f~lmsa t the halocline. Nature 328:579-580
14. Mathevan, P.M., 1994. Hydro biological investigation on the intertidal diatoms of the Cuddalore Uppanar estuary India. Ph.D. Thesis, Annamalai University, India. pp: 159.
15. Mathivanan, V., P. Vijayan, Selvi Sabhanayakam and O. Jeyachitra: An assessment of plankton population of Cauvery river with reference to pollution. J. Environ. Biol., 28, 523-526 (2007).
16. Morris AW, Mantoura RFC, Bale AJ, Howland RJM (1978) Very low salinity regions of estuaries: important sites for chemical and biological reactions. Nature 274:678-680
    a. Physico-chemical parameters of Holy places Agnitheertham and Kothandaramar temple, southeast coast of India. Amer. Eurasian J.Scientif. Res., 4(2): 108-116.
17. Rajasegar, M.: 2003 Physico – Chemical characteristics of the Vellar estuary in relation to shrimp

farming. J. Environ. Biol., 24, 95 – 101.

18. Sakshaung, E., A. Bricaud, Y. Dandonneau, P. G. Falkowski, D. A. Kiefer, L. Legendre, L. Legendre, A. Morel, J. Parslow and M. Takahashi (1997): Parameters of photosynthesis: definitions, theory and interpretation of results. J. Plankton Res., **19**, 1637–1670.
19. Saravanakumar, A., M. Rajkumar, G. A. Thivakaran and J. Sesh Serebiah: Abundance and seasonal variations of phytoplankton in the creek waters of western mangrove of Kachchh-Gujarat. J. Environ. Biol., 29, 271-274 (2008).
20. Saravanakumar, A., M. Rajkumar, J. Sesh Serebiah and G.A> Thivakaran: 2008 Seasonal variations in physico – chemical characteristics of water, sediment and soil texture in arid zone mangroves of Kachchh – Gujarat. J. Environ. Biol., 29, 725 – 732.
21. Schlu¨ ter, L., Møhlenberg, F., Havskum, H. & Larsen, S. 2000. The use of phytoplankton pigments for identifying and quantifying phytoplankton counts in coastal areas: testing the influence of light and nutrients on pigment / chlorophyll a ratios. Mar. Ecol. Prog. Ser. 192:49–63.
22. Seenivasan, R., 1998. Spectral reflectance properties of the Vellar estuarine environment, southeast coast of India, M.Phil. Thesis, Annamalai University. India. pp: 35.
23. Sitik, A.M.A., Thirumaran, G., Arumugam, R., Kannan, R.R.R. and P.Anantharaman. 2009.
24. Soma, Y., Tani, Y., Soma, M., Mitake, H., Kurihara, R., Hashomoto, S., Watanabe, T. & Nakamura, T. 2007. Sedimentary steryl chlorin esters (SCEs) and other photosynthetic pigments as indicators of paleolimnological change over the last 28,000 years from the Buguldeika Saddle of Lake Baikal. Journal of Paleolimnology, **37**, 163.175.
25. Soundarapandian, P., Premkumar, T. And Dinakaran, G.K. 2009. Studies on the Physico-chemical Characteristic and Nutrients in the Uppanar Estuary of Cuddalore, South East Coast of India. Curr. Res. J. Biol. Sci., 1(3): 102-105.
26. Sridhar, R., T. Thangaradjou, S. Senthil Kumar and L. Kannan: Water quality and phytoplankton characteristics in the Palk Bay, southeast coast of India. J. Environ. Biol., 27, 561-566 (2006).
27. Sridhar, R., Thangaradjou, T. and Kannan, L. 2008. Comparative investigation of physico-chemical properties of coral reef and seagrass ecosystems of Palk Bay. Ind.J.Mar.Sci., 37(2): 207-213.
28. Sulochana B, Muniyandi K (2005). Hydrographic parameters off Gulf of Mannar and Palk Bay during an year of abnormal rainfall. J. Mar. Biol. Assoc. India, 47(2): 198- 200.
29. Tas, Beyhan and Arif Gonulol: An ecologic and taxonomic study on phytoplankton of a shallow lake, Turkey. J. Environ. Biol., 28, 439-445 (2007).
30. Teubner, K., Tolotti, M., Greisberger, S., Morscheid, H., Dokulil, M. T. & Morscheid, H. 2003. Steady state phytoplankton in a deep pre-alpine lake: species and pigments of pilimnetic versus metalimnetic assemblages. Hydrobiologia 502:49–64.
31. Veerabahu, C. 2000. Environmental characteristics of Tuticorin coastal waters (South India) Ph.D Thesis, Manonmaniam Sundaranar University, India. pp.33-49.

32. Woitke, P., Schiwietz, T., Teubner, K. & Kohl, J. G. 1996. Annual profiles of photosynthetic lipophilic pigments in four freshwater lakes in relation to phytoplankton counts as well as to nutrient data. Arch. Hydrobiol. 137:363–84.