Mahasagar–Bulletin of the National Institute of Oceanography, **18**(1), 1985, 37–48.

SEASONAL AND TIDAL VARIATIONS OF PHYTOPLANKTON IN THE GRADIENT ZONE OF VELLAR ESTUARY*

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ABSTRACT

The phytoplankton variations in relation to other environmental parameters were studied from January 1977 to December 1978 in the gradient zone of the Vellar estuary. Among 155 species of phytoplankton, diatoms (102 spp) and dinoflagellates (35 spp) were the dominant groups and occurred throughout the year except in some collections during the monsoon season. Phytoplankton population density varied from 22 cells/l to 138 x 10^4 cells/l and the density was high during summer and premonsoon season and low during monsoon season. Although the density was found to be higher in day collections than night collections, it was statistically not significant. Wide fluctuations in species diversity (0.3 to 4.3 bits/individual), species richness (0.16 to 4.0) and evenness (0.1 to 0.98) were observed. Species diversity at high tide was higher than at low tide. Salinity was found to play a major role in determining the species composition, succession and density of phytoplankton.

Key-words : Phytoplankton, Tidal variation, Vellar estuary.

INTRODUCTION

Distribution and seasonal variation of phytoplankton in the Vellar estuary was studied initially by Seshadri (1955) in the marine zone, followed by Krishnamurthy (1964), Vijayalakshimi (1973), Santhanam (1976), Ramadhas (1977) and Sundararaj (1978). However, studies on the distribution with reference to tides are very few (Rangarajan, 1958; Vijayalakshimi and Venugopalan, 1973) and they are fundamental in scope. The present study was planned to bridge this hiatus information on seasonal and tidal variations in phytoplankton population in relation to various environmental parameters which were monitored for a period of two years from January 1977 to December 1978.

MATERIALS AND METHODS

The station selected for the present study, its location, collection schedule and sampling methods are described elsewhere (Chandran and Ramamoorthi, 1984). One litre of surface and near bottom water samples were collected in polythene bottles, preserved in 5% neutralised formalin and the bottles were kept undisturbed for three days. The plankton settled at the

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bottom were used for both qualitative and quantitative analyses. Quantitative analysis was made in an Utermohl's inverted plankton microscope and the phytoplankton were identified as far as possible to species level.

Species diversity (D) was computed using the formula of Margalef (1967)

$$D = 1/N \log_2 \frac{N!}{Na! \quad Nb! \ldots\ldots NS!}$$

Where, Na ! Nb ! .... Ns ! are the number of individuals of species a, b, ... s, and N the total number of individuals.

Species richness was worked out using Gleason's (1922) formula.

$$\text{Species richness} = \frac{S - 1}{\ln N}$$

Where, S is the number of species and In N is the natural logarithm of total number of individuals.

Equitability or Evenness was calculated using the formula of Pielou (1966).

$$\text{Equitability} = \frac{H'}{\log S}$$

Where, H' is the species diversity and S is the number of species.

RESULTS

Species composition: In the present investigation, 155 species of phytoplankton comprising of 102 species of diatoms, 35 species of dinoflagellates, 2 species of silicoflagellates, 9 species of Cyanophyceae and 7 species of Chlorophyceae were identified. Among these, diatoms followed by dinoflagellates were dominant and occurred throughout the year except during the monsoon season. Further, during the monsoon season, species of Chlorophyceae and Cyanophyceae were found to be maximum.

Among the diatoms, species like *Asterionella japonica*, *Bacteriastrum hyalinum*, *Biddulphia mobiliensis*, *B. sinensis*, *Chaetoceros curvisetum*, *C. lorenzianum*, *C. diversum*, *Coscinodiscus excentricus*, *Lauderia annulata*, *Leptocylindrus danicus*, *Pleurosigma directum*, *P. elongatum*, *Rhizosolenia alata*, *Skeletonema costatum*. *Thalassiothrix frauenfeldii* and *Thalassiosira subtilis* were found to be common and dominant. Although 35 species of dinoflagellates were recorded, *Ceratium furca*, *Gonyaulax polyedra*, *Peridinum depressum* and *Prorocentrum micans* were dominant during most of the period. The blue green algae *Trichodesmium erythraeum* was found to bloom during February, March/April months of both the years. Other Cyanophyceae and Chlorophyceae were found only during the monsoon months particularly during heavy freshwater runoff periods. The common forms which occurred during this period were species of *Pediastrum*, *Nostoc*, *Anabaena*, *Oscillatoria*, *Ulothrix* and *Spirogyra*.

Tidal variation in species composition of phytoplankton population were not pronounced except in some collections, particularly during late premonsoon and monsoon months. During early October and December in 1977 and October to December in 1978, diatom populations, consisting of *T. frauenfeldii, A. japonica, S. costatum, B. mobiliensis* and *Coscinodiscus jonesianus* were abundant at high tide, whereas freshwater forms such as *Ulothrix, Pediastrum. Nostoc, Spirogyra* and *Oscillatoria* were abundant at low tide. Species composition with reference to tidal variation was more pronounced only in surface water. During other seasons, the variation in species composition was independent.

Species succession: From a critical scrutiny of the phytoplankton data obtained, a generalised pattern of phytoplankton succession was discernible. During postmonsoon season (January–March), dominance of diatoms like *S costatum, C. excentricus, A. japonica, T. franenfeldii* and *Pleurosigma* sp., were evident. Besides, dinoflagellates such as *C. furca, Gonyaulax* sp., *P. depressum* and *P. micans* were also found to be high in number. In this season (late February and March) predominance of *T. erythraeum* was also noticed. At the same time, species belonging to the genus *Chaetoceros* were found to increase and occur throughout the year except during the monsoon season (October–December). In this genus, species like *C. curvisetum, C. lorenzianum. C. diversum* and *C sicialis* were found to be common and at times (June/July) *C. socialis* constituted a considerable quantity ($>$ 60%) of the phytoplankton population.

During summer (April–June), phytoplankton was dominated mainly by larger centric diatoms like *Rhizosolenia stolterfothii, L. annulata. L. danicus, Schroederella delicatula, T. subtilis, Bellerochea malleus* and *B. mobiliensis*. The dominance of these forms were observed during early premonsoon months (July and August) also. In the late premonsoon (September) as the salinity declined, a subtle change in the phytoplankton population was noticed and forms like *A. japonica, S. costatum, T. frauenfeldii. C. furca, Peridinium* sp., and *P. micans* were dominant.

During monsoon months (October–December), besides the incidence of *T. frauenfeldii, A. japonica, Navicula* sp., *Nitzschia* sp., and *Pleurosigma* sp., freshwater phytoplankters were found dominant.

Species diversity, richness and evenness: The seasonal variation of the above values both at surface and bottom waters with reference to tides are illustrated in Fig. 1. Species diversity values varied from 0.1614 to 4.2958 bits/individual. In general, diversity values were high during summer and premonsoon (April–September) and low during postmonsoon and monsoon seasons. Diversity values were comparatively higher in 1978 than those observed during 1977. Surface and bottom waters showed a similar pattern in seasonal variation in species diversity during both the years. Species diversity at high tide generally showed higher values than at low tide. When compared to night, the values observed during day time were higher. Low diversity

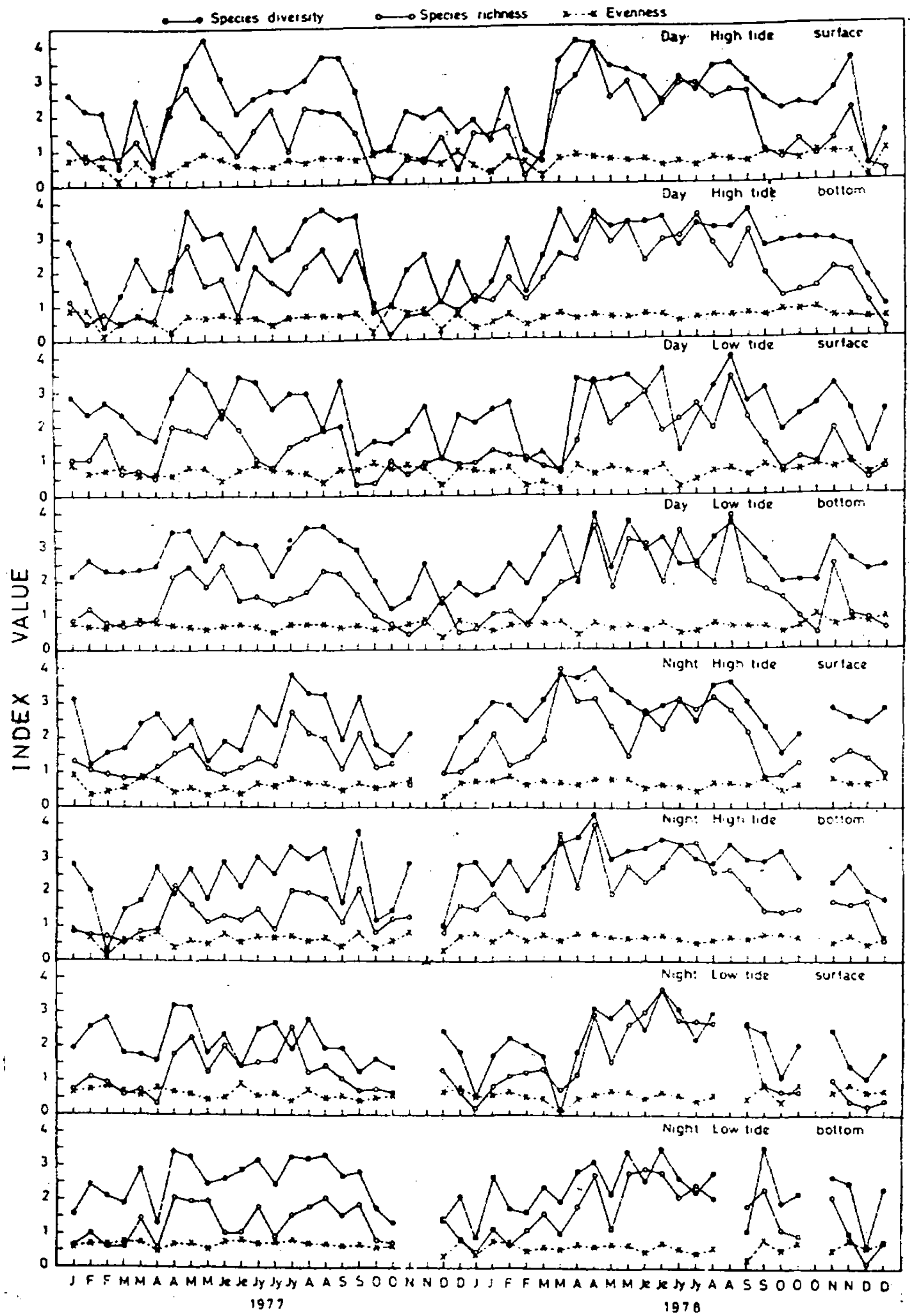

Fig. 1. Seasonal and tidal variations in species diversity, richness and evenness.

values observed during the monsoon period were not only due to the flushing of the endemic species of this zone but also due to the occurrence of monospecific bloom of *Asterionella japonica.*

Species richness varied from 0.1630 to 3.9980 with high values in summer and premonsoon seasons and low values in postmonsoon and monsoon seasons, thus following the trend encountered in species diversity. During heavy floods, species richness was very low. Comparatively, the species richness values were higher during day high tides than at night high tides.

Evenness occasionally showed low values when the population density was dominated by some bloom forming species. The values fluctuated between 0.1128 and 0.9905. Evenness generally followed the trend exhibited by diversity. Fluctuations in eveness was mainly observed during the postmonsoon and monsoon months and during other periods it showed more or less high values and the total population density was equally represented by the species present.

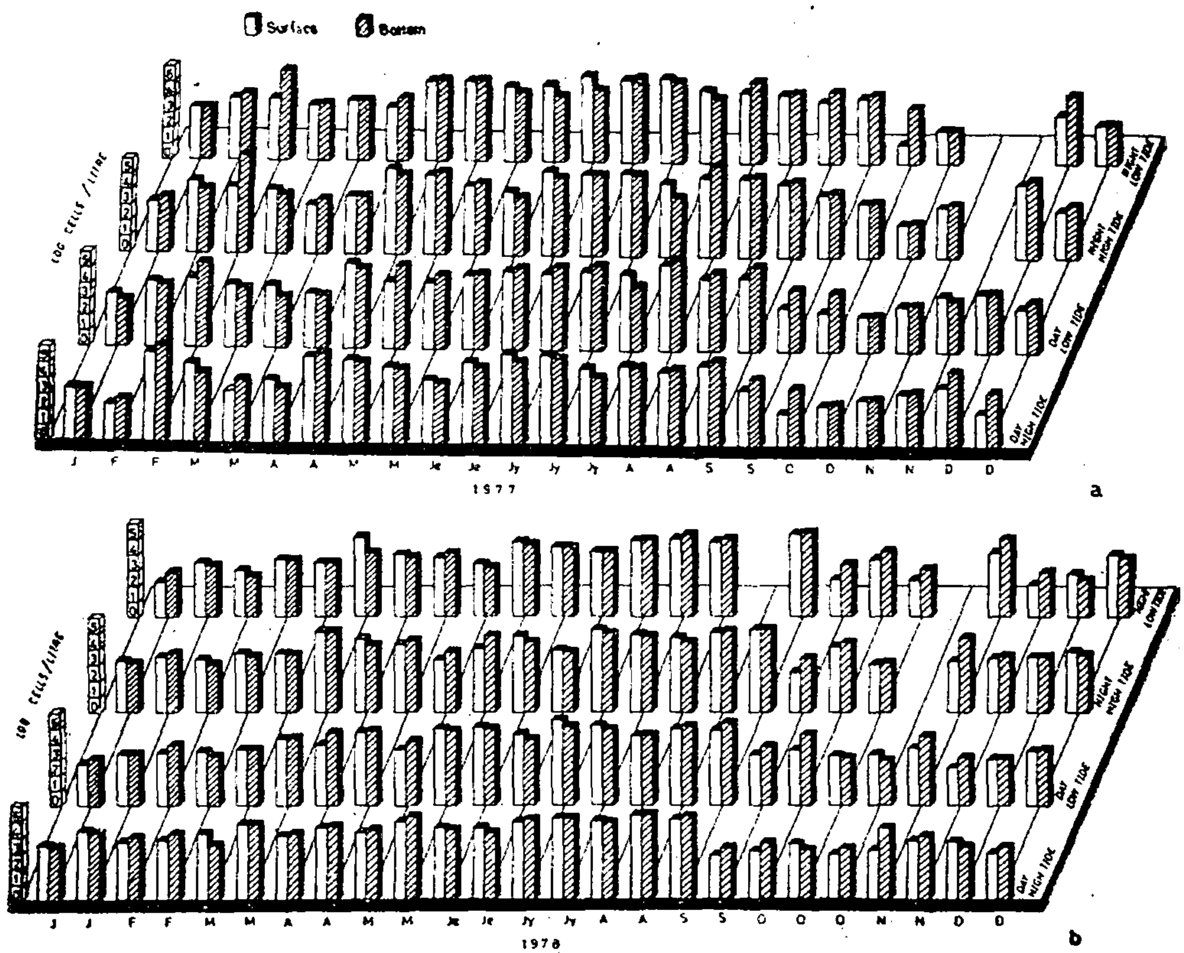

Fig. 2. Seasonal and tidal variations in phytoplankton population density (a) during 1977 and (b) 1978.

A maximum number of 35 species were recorded at one collection during May 1977 and 48 species during March/April 1978. Very low number of 2 species was recorded during November and December months of both

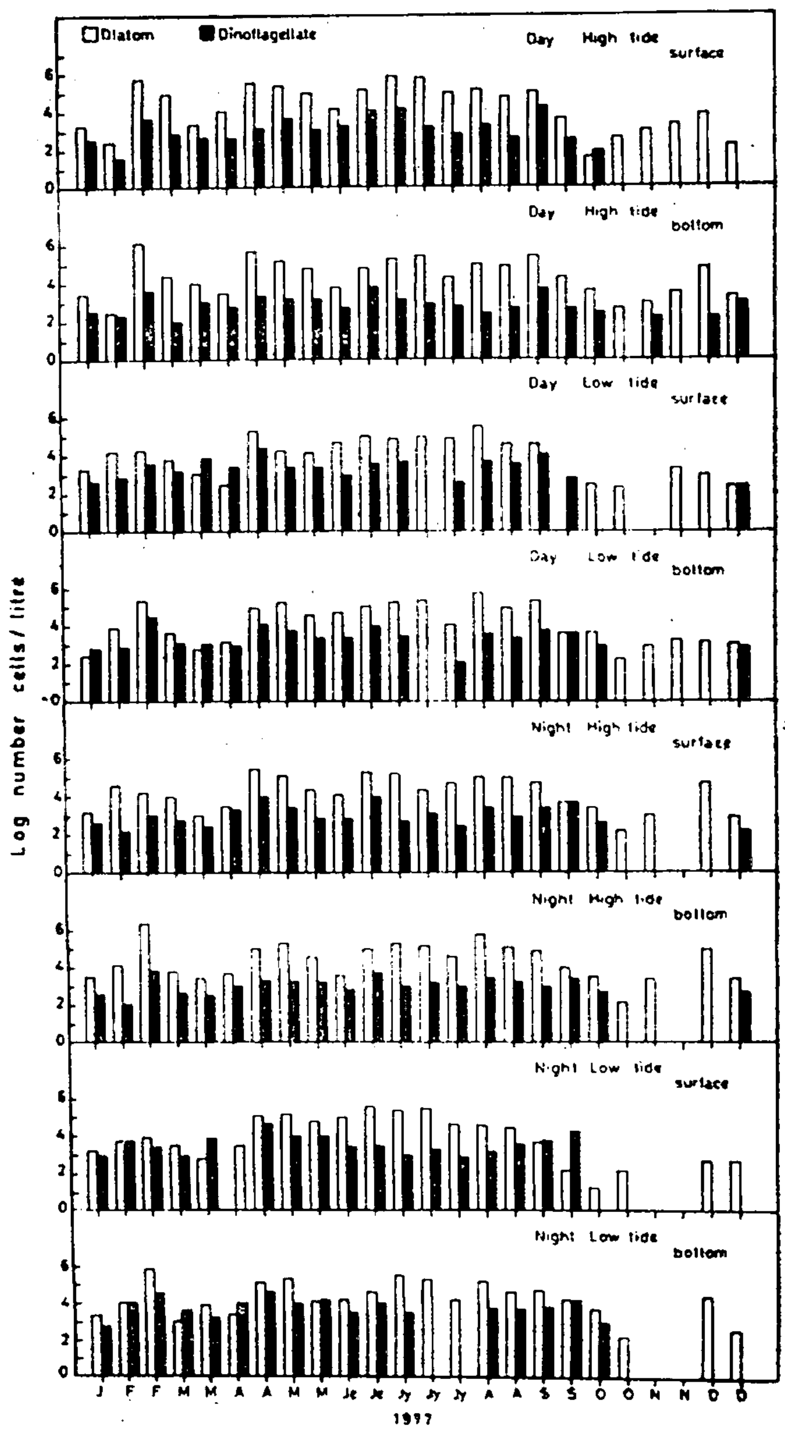

Fig. 3. Seasonal and tidal variations in diatom and dinoflagellate population density during 1977.

the years. It was also noticed that at high tide, the number of species was higher than at low tide.

Population density: Seasonal variations in phytoplankton population density with respect to tidal changes are illustrated in Fig. 2. Phytoplankton

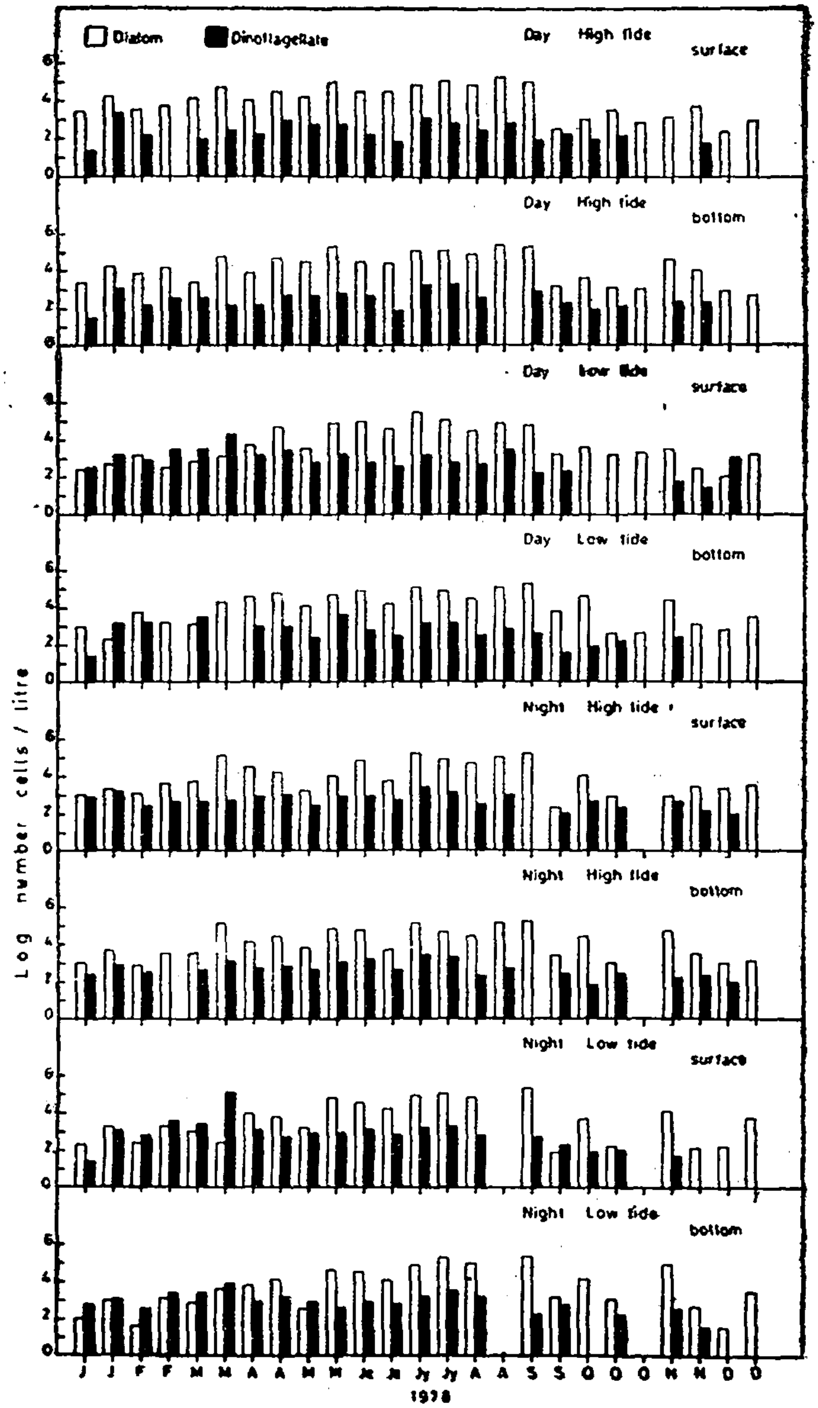

Fig. 4. Seasonal and tidal variations in diatom and dinoflagellate population density during 1978.

density varied from 22 to 138 × 10^4 cells/l during 1977 and from 140 to 29 × 10^4 cells/l during 1978. It was high during summer and premonsoon seasons whereas during the postmonsoon season with a few exceptions, the density was relatively low. During February 1977, high population was recorded due to the bloom of *A. japonica* and *T. farauenfeldii*. Very low density was recorded during the monsoon season (October–December) particularly at the time of heavy floods (late October and November in 1977 and December in 1978).

Seasonal variations in the diatom and dinoflagellate population density are shown in Figs. 3 & 4. During the monsoon months, dinoflagellates showed very low or even nil population but during the post and premonsoon months, they showed a high density. On the other hand, the diatoms showed a high density during premonsoon months. Generally, variations in the density of diatoms and dinoflagellates, were not pronounced with reference to tides. However, dinoflagellates, particularly *C. furca* showed a high population density during low tide periods. The difference between surface and bottom values were not much pronounced.

Statistical analysis showed that the tidal variation in population density was not significant both in surface ($F = 0.49481$; $P > 0.05$) and bottom water ($F = 0.3171$; $P > 0.05$). Further, the difference in population density between day and night collections was also not significant ($F = 0.0906$; $P > 0.05$ in surface water and $F = 0.2429$; $P > 0.05$ in bottom water).

DISCUSSION

A noteworthy finding of the present study was the higher productivity of Vellar estuary with reference to species composition of phytoplankton when compared to other estuaries of the east coast. Interestingly, the species composition of phytoplankton was more or less similar to that of estuaries of the west coast of India (Devassy and Bhattathiri, 1974; Gopinathan, 1975). While some of the earlier workers (Vijayalakshimi, 1973; Ramadhas, 1977) reported species of diatoms, dinoflagellates and the Cyanophyceae *T. erythraeum*. Santhanam (1976) identified some more species of Cyanophyceae, Chlorophyceae and silicoflagellates besides the aforesaid forms as observed in the present study. However, diatoms and dinoflagellates were the predominant forms found almost throughout the year in most of the Indian estuaries (Dutta, Malhotra and Bose, 1954; Rajendran, 1974; Gopinathan, 1975; Santhanam, 1976; Sundararaj, 1978). The higher number of species recorded in the present study could be due to rainfall in this region when more number of fresh water forms of Chlorophyceae and Cyanophyceae were also recorded. Although the species composition during both the years were similar, a higher number of neritic forms were recorded in 1978 due to the free flow of neritic water into the estuary as a result of change in the location of the river mouth (Chandran and Ramamoorthi, 1984a).

The nature of species diversity in relation to species composition and phytoplankton density is a notable feature in any aquatic environment. The computation of species diversity index is normally restricted to the net phytoplankton since according to Santhanam (1976), net collections are considered representative. The nannoplankton and other photosynthetic forms are chiefly responsible for the quantitative ecological evaluation of the autotrophic level of the sea rather than to serve as a measure in the determination of species diversity (Hulbert, Ryther and Guillard, 1960). Herrera and Margalef (1963) showed that species diversity of samples obtained with a fine meshed net and in sediment samples were well correlated. In the present study, diversity values calculated from the samples obtained by sedimentation showed a similar range to that reported earlier (Ignatiades, 1969; Santhanam, 1976; Devassy and Bhattathiri, 1974; Vijayalakshimi and Venugopalan, 1973). The low species diversity observed in the present study may be due to the presence of very less allochthonous species as reported earlier by Santhanam (1976) and Sundararaj (1978). This may also be substantiated by the higher species diversity observed in 1978 than in 1977 due to the presence of more neritic forms in the estuary caused by a change in the opening of the mouth which permitted free flow of seawater into the estuary (Chandran and Ramamoorthi, 1984a).

Generally, species diversity increases with an increase in the population density. Likewise, in the present study also a high species diversity was observed during summer and early premonsoon seasons (April–July) when the population density was high. Results of the present investigation paralleled the findings of Ignatides (1969) and Santhanam (1976) since species diversity was low at the early stages of succession (January and February) due to the dominance of certain species and later at the advanced stages of succession (May–July) when no species was particularly successful. the values were found to be high.

Generally, phytoplankton showed two distinct peaks in their seasonal abundance in these waters which is a unique feature of Indian coastal waters (Dutta, Malhotra and Bose, 1954; Gopinathan, 1975; Santhanam, 1976; Sundararaj, 1978). The depletion of population during the monsoon season was mainly due to heavy runoff which flushed out the phytoplankton population into the sea. The summer maximum of phytoplankton population density might probably be due to the more stable conditions prevailing during this season. The variation in environmental parameters due to tide was very less and the residence time was more during this season which increases the phytoplankton density (Ketchum, 1954; Simmons and Thomas, 1962; Texeira, Tundisi and Yeaza, 1967).

Studies on diurnal variation in phytoplankton population in estuaries have revealed an increase in the density during high tide and a decrease during low tide (Rangarajan, 1958: Vijayalakshimi and Venugopalan, 1973). Although similar variations in phytoplankton population were observed in the present study, they were not so pronounced and in some collections during monsoon season (when there was freshwater flow), the variation was well marked between tides.

The appearance of the blue green alga *Trichodesmium erythraeum* in the late postmonsoon or early summer season (February to April) seem to be a regular feature in this estuary (Vijayalakshimi, 1973; Rajendran, 1974; Santhanam, 1976; Ramadhas, 1977; Sundararaj, 1978). Fogg (1965) suggested that the ability of blue green algae to fix atmospheric nitrogen might be the reason for predominance of these algae particularly at times when shortage of nitrogen tended to limit the growth of other phytoplankton. However, in the present study, the absolute concentration of nitrogen was high when blooms of *T. erythraeum* appeared (Chandran and Ramamoorthi, 1984b). Hence, it might be conceivable that such a nutrient limitation could not be the general factor in their seasonal succession. In this context, Ramadhas (1977) has pointed out that intrinsic biological factors inherent in specific algal genera were far more important in determining phytoplankton succession pattern than others.

While evaluating the influence of environmental factors on the production of phytoplankton, it is essential to assess the collective influence of factors that give rise to specific values as the parameters individually may affect the physiology of phytoplankton or inhibit or accelerate their production. Loftus, Subba Rao and Seliger (1972) stated that phytoplankton organisms have short regeneration time and therefore, their growth and physiological state might strongly be coupled to the physiological and chemical parameters of their environment. Among the environmental parameters, salinity plays the major role in determining the species composition, succession and population density. Although many species bloom at lower salinities, maximum population was observed when the salinity was high during summer and premonsoon seasons. A variety of species was observed during this season with the domination of large celled centric diatoms. However, during the early postmonsoon and premonsoon seasons when the salinity was moderate or intermediate (15 to 30‰), the diatoms such as *A japonica*, *S. costatum*, *T. frauenfeldii* and *Thalassionema nitzschioides* were found to be dominant. Similar observations were also made by Dutta, Malhotra and Bose (1954), Vijayalakshimi (1973) and Santhanam (1976).

During the monsoon season, the estuary was enriched with nutrients due to heavy rainfall and the consequent land runoff (Chandran and Ramamoorthi, 1984a). In spite of higher concentration of nutrients (phosphate, nitrate, silicate), the species composition, bloom formation and population density were low because of the greater seaward flushing and poor light penetration due to high turbidity. However, the nutrients added during the monsoon months triggered the bloom formation of many phytoplankton species during the postmonsoon season and blooms of several species were noticed successively. During the summer and premonsoon seasons when the phytoplankton population density was high, the concentration of nutrients, particularly nitrate and silicate was low mainly due to rapid utilisation by phytoplankton. However, at no time in the present study,complete depletion of nutrients was observed. Ketchum (1947) had opined that the instantaneous concentration of nutrients did not seem to have a direct bearing on the phytoplankton population, because the nutrients are not the limiting factors due to regeneration and considerable exchange from the bottom water interface.

Apart from the influence of physico-chemical factors, grazing by herbivores particularly zooplankters, also causes some changes in the phytoplankton population. Therefore, the rapid decline in phytoplankton cell numbers during a short interval of March, May, June and September might partly be due to grazing as the zooplankton population was found to be maximum during these months (Chandran, 1982). Further, the slight decline in phytoplankton density during night time may also be due to the grazing by zooplankton since the latter were abundant during night collections.

ACKNOWLEDGEMENTS

The author wish to thank Prof. K. Ramamoorthi, Emeritus Scientist, CAS in Marine Biology for his valuable guidance and Dr. R. Natarajan, Director for the facilities provided. Thanks are also due to Dr. G.S. Thangaraj, Research Associate, ZSI, Madras and Dr. V. Sivakumar, DOD Research Fellow for their valuable help in collection and analyses of samples. I wish to thank my wife Mrs. C. Narmadha, for her help in the preparation of figures. At last, I thank Annamalai University for the facilities provided and the UGC for the award of fellowship.

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