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Temporal Variability of Phytoplankters in Vellar Estuary*

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Seasonal variation in the numerical abundance of 42 spp of phytoplankters (18 centric, 20 pennate diatoms, 3 dinoflagellates and 1 *Trichodesmium*) at the mouth of the Vellar estuary has been followed for 3 yr. Quantitative distribution of diatoms follows trimodal annual patterns. Negative correlations exist between diatom density and blooms of dinoflagellates and *Trichodesmium*. Variations in quantity and settling volume correspond to changes in ambient salinity. Shannon-Wiener indices are linearly related to number of species, phytoplankton density and settling volume. Temporal variations in the community largely depend on the salinity and to a lesser extent on the ambient surface water temperature. The correlation matrix reveals the presence of atleast 5 diverse components in the phytoplankton community.

Some data are available on seasonal variabilities of phytoplankton inhabiting estuaries and backwaters of Indian coasts[1-13]. In an earlier study the seasonal distribution of 9 species of phytoplankters belonging to the genera, *Chaetoceros*, *Coscinodiscus* and *Rhizosolenia* in the Vellar estuary has been reported[13]. The present paper deals with the temporal variations in the abundance of 42 species other than those reported earlier.

Materials and Methods

Phytoplankton samples were collected twice a week during high tide at the mouth of the Vellar estuary, using a standard plankton net for 3 yr (Jan. 1966 to Dec. 1968). The net, made of bolting silk No. 25 (aperture 64 μm), had a diameter of 0.5 m. The details of the treatment and analysis of samples were described earlier[13]. Measurements of temperature and salinity were made at the time of plankton collection. Species diversity index was calculated using the Shannon-Wiener function[14]

$$H' = -\Sigma Pi \log Pi$$

Results

Temporal distribution and abundance—Data on the seasonal distribution of centric (16 gen., 18 spp) and pennate (16 gen., 20 spp) diatoms are presented in Figs. 1 and 2 respectively. The hierarchical diversity showed variations within and between the years.

Occasional blooms of pennate forms *Gyrosigma balticum*, *Pinnularia alpina*, *Amphora lineolata*, *Surirella eximia* and *Campylodiscus iyengarii* were observed during all the 3 yr of study. Two pennate species, viz. *Trachyneis aspera* and *Tropidoneis semistriata*, were present only during June 1967. Blooms of blue green alga *Trichodesmium erythraeum* appeared sporadically during March in all the 3 yr. Three species of dinoflagellates, *Noctiluca miliaris*, *Ceratium tripos*, and *Peridinium depressum*, were recorded in fairly good numbers in all the years. Blooms of *N. miliaris* were observed in Aug. 1966 and 1967 and May 1968. *C. tripos* appeared during Feb. April and July - Sept. 1966, Feb., May and Dec. 1967 and May 1968. *P. depressum* appeared during Feb. 1967 and May 1968. During Oct. 1967 the population consisted of only *Melosira granulata*.

Fig. 3 illustrates the temporal distribution of diatom population, dinoflagellates and *Trichodesmium erythraeum*. Quantitative distribution of diatoms followed trimodal annual patterns. The peaks of abundance were in July 1966, May 1967 and June 1968. The periods, July - Sept. 1966, April - May 1967 and June 1968 witnessed maximum number of centric diatoms. However, there was an overall abundance of pennate diatoms during the period of study. These were abundant during Feb. and July 1966, May 1967 and Jan., May and June 1968. A marked negative correlation existed between *T. erythraeum* blooms and diatom density. High *T. erythraeum* densities were recorded during March in all the 3 yr. A similar negative correlation was apparent between dinoflagellate blooms and diatom density during Aug. 1966 and 1967.

Settling volume and phytoplankton density—Seasonal variations in the values of settling volume of plankton are represented in Fig. 4 along with data on surface water temperature, salinity and species diversity. A direct correlation existed between settling volume on one hand and salinity - temperature combination and diatom density on the other. Decrease in settling volume was noticed during October - November in all the years, when the salinity was $< 3.5‰$ and temperature 26°C. The lowest values

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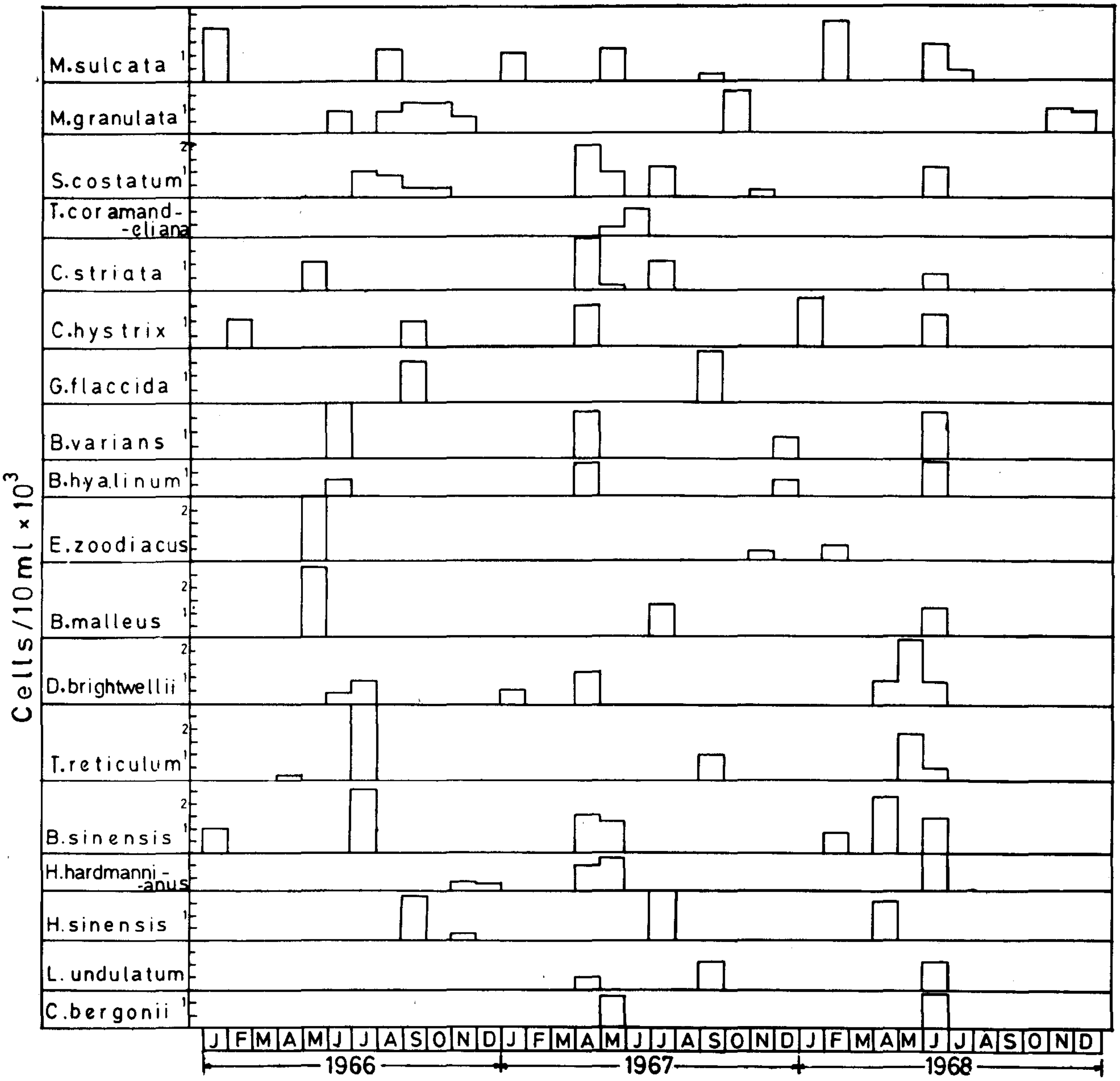

Fig. 1—Seasonal distribution of 18 species of centric diatoms

of diatom densities coincided with the decline in salinity and temperature (see Fig. 3).

Species diversity—Seasonal variations in the species diversity are expressed as Shannon-Wiener indices[14] in decits and presented in Fig. 4. The values ranged from 0 (Oct. 1967) to 1.56 (Jan. 1968). Since the Shannon-Wiener index is an unweighted measure and takes into account not only the number of species but also the relative quantities of species, variations in the indices may be considered to reflect the changes in the biomass. Fig. 5a illustrates relationship between the Shannon-Wiener index (H′) and the number of species. In general, a linear relationship existed between the number of species and diversity at levels higher than 0.6 decits indicating that when more number of species are present, their relative proportions in the population are also fairly high. Hence during most part of the year, large number of species in relatively greater quantities were present at the site of study. H′ values <0.6 were noticed only during 5 instances when the species number ranged from 10 to 16. These values were recorded during March in all the 3 yr and Aug. 1966 and 1967. It is clear from Fig. 3 that during March blooms of *T. erythraeum* occurred in all 3 yr. Similarly, during August dinoflagellate blooms in densities $>20,000$ cells/10 ml were recorded in 1966 and 1967. These explain the deviations from the otherwise linear relationship. H′ values >1.4 decits were recorded in July 1966 and Jan. 1968. During these months the diatom densities were also fairly high (Fig. 3). Therefore, the general trend in the population was to reflect qualitative changes with quantitative variations.

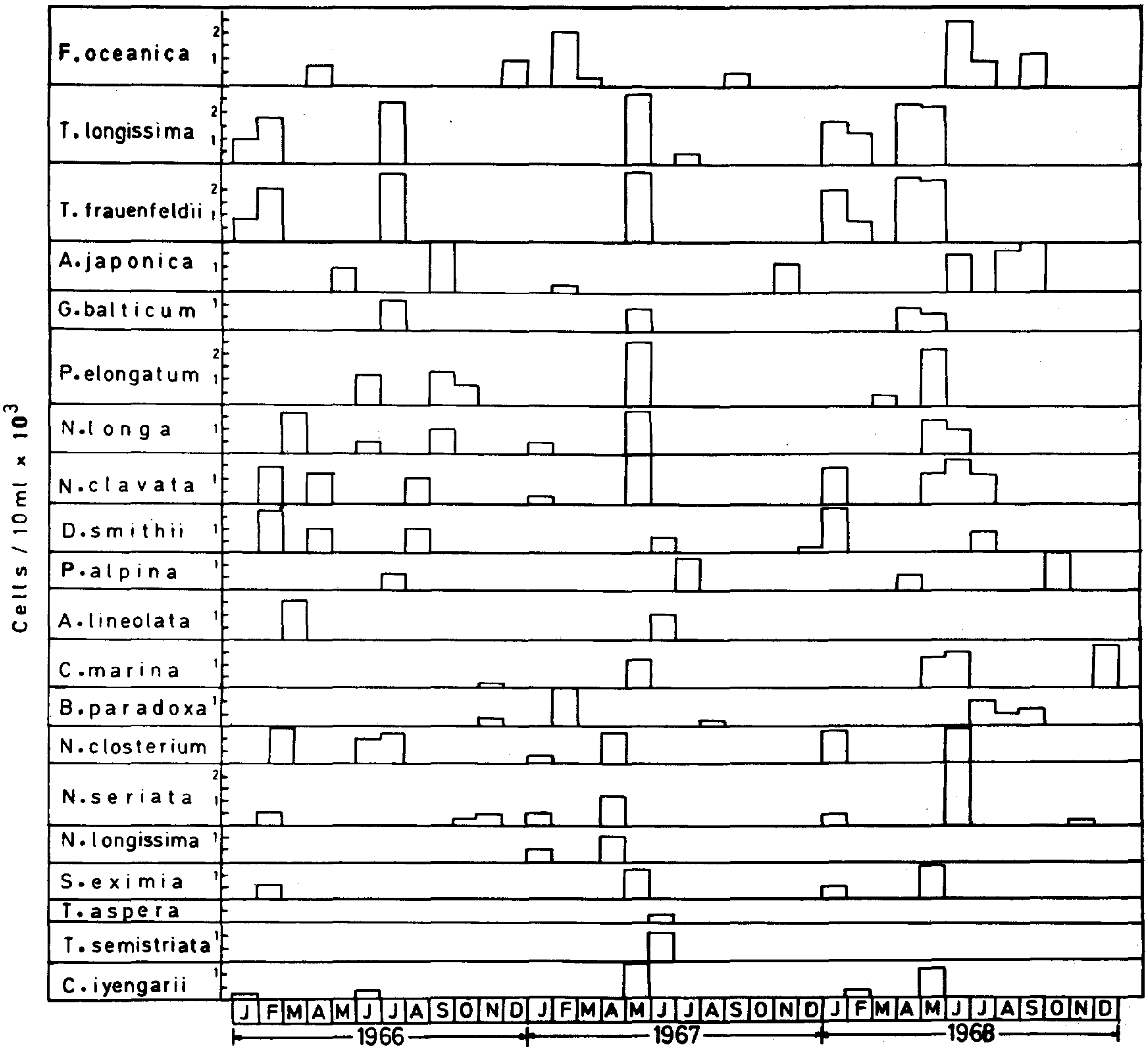

Fig. 2—Seasonal distribution of 20 species of pennate diatoms

Diversity index ⩾ 4 has been reported for phytoplankton in the Cochin backwaters during monsoon periods[8]. In Fig. 5b relationship between phytoplankton density and H′ is presented. A relationship similar to the one described above was noticed in this case also, the periods of algal blooms coinciding with the reduction in the species number and density of diatoms. Fig. 5c shows relationship between settling volume and H′. Except during March of all the 3 yr and August of the first 2 yr, the relationship appeared linear. This indicates that the plankton population is more heterogeneous when the settling volume is maximum and more homogeneous during the periods of *Trichodesmium* and dinoflagellate blooms. From these relationships, it becomes apparent that annual variations in the quality and quantity of phytoplankton are linearly related. This relationship is obliterated only during the periods of algal blooms.

Environmental parameters and phytoplankton abundance—Seasonal distribution of surface water temperature and salinity is shown in Fig. 4. The striking feature in the annual variability of the environmental parameters is the sudden and sharp decline in the surface water salinity during October - November. The phytoplankters are subjected to an annual salinity variation of *c*. 28‰ from April - May to October - November. The period of decline in salinity coincides with the peak of the northeast monsoon when large scale influx of freshwater reduces the salt content of coastal and estuarine waters of this region[4,15,16]. During the low saline period, polyhaline species such as *Melosira granulata*, *Sceletonema costatum* and *Pleurosigma elongatum* have been recorded in comparatively low concentrations. As the salinity increases during the succeeding months, mesohaline species such as *Navicula clavata*, *Nitzschia*

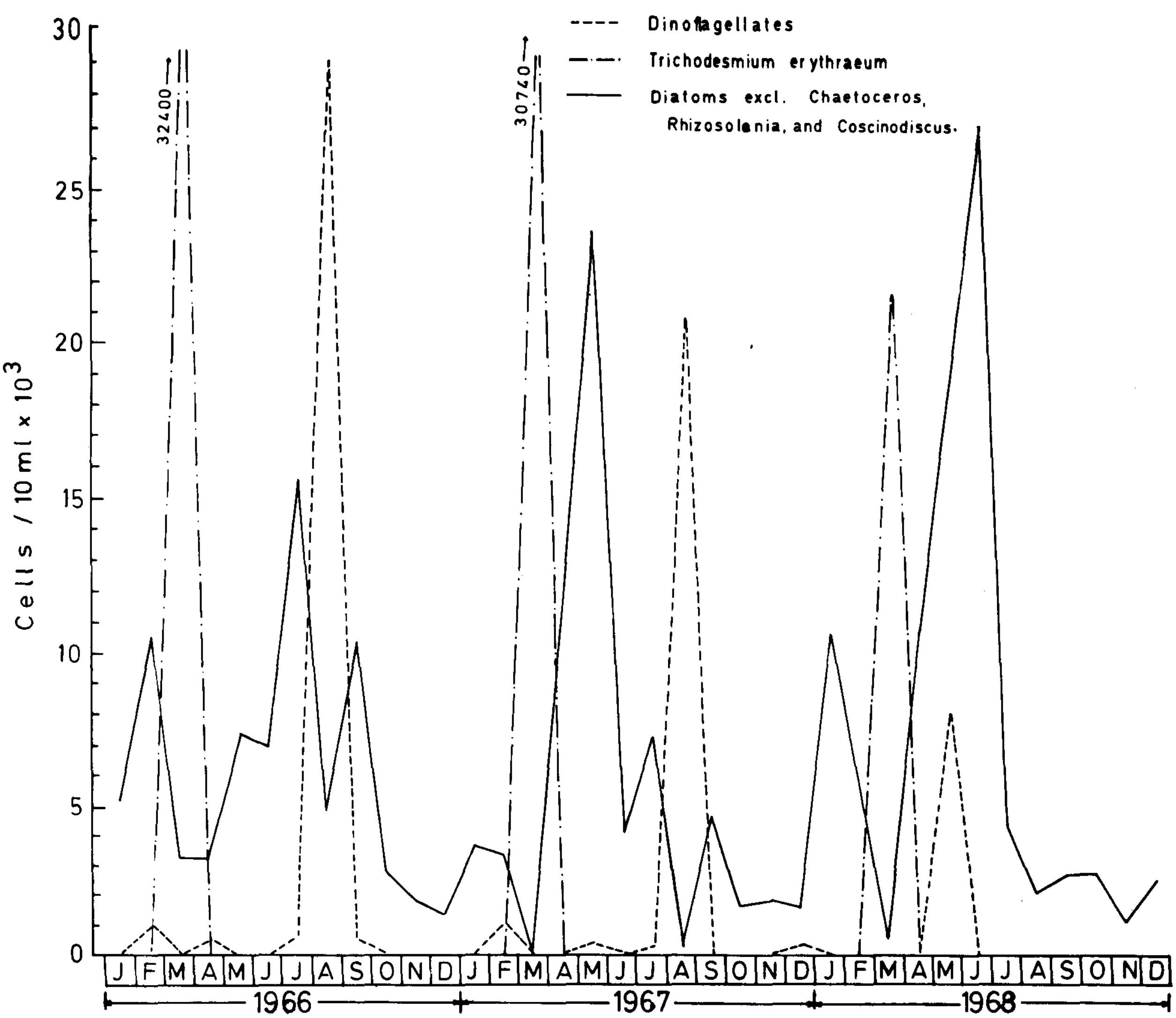

Fig. 3—Seasonal distribution of dinoflagellates, *Trichodesmium erythraeum* and diatoms

closterium, *N. longissima* and *Surirella eximia* appear in appreciable quantities. During the period of maximum salinity when the estuary is markedly seawater dominated, neritic species such as *Thalassiosira coramandeliana*, *Cyclotella striata*, *Corethron hystrix*, *Eucampia zoodiacus*, *Triceratium reticulum*, *Biddulphia sinensis* and *Lithodesmium undulatum* appear in good numbers. Several polyhaline species such as *Cymbella marina*, *Bacillaria paradoxa*, *Asterionella japonica*, *Pinnularia alpina*, *Hemidiscus hardmannianus* and *Bacteriastrum varians* appear sporadically irrespective of the salinity conditions. The minimum number of species recorded was 1 (Oct. 1967) and the maximum 29 (June 1968). From the data presented in Figs. 3 and 4 it is evident that the reduction in the salinity results in a decrease in the phytoplankton density, settling volume and species diversity index in all the 3 yr. On the other hand, the peaks in the surface water temperature during March - May coincide with the blooms of *Trichodesmium* or diatoms. *T. erythraeum* blooms during March coincided with temperatures above 28°C. The periodicity of *Trichodesmium* bloom in the Vellar estuary is similar to that reported for the west coast of India[23]. An unusually large diatom bloom immediately following the *Trichodesmium* bloom was noticed in May 1967 when the temperature reached the annual peak (28.58°C). Abundance of diatoms immediately after the *Trichodesmium* bloom has recently been reported from the coastal waters of Goa[23]. No relationship was evident in the present study between the blooms of dinoflagellates and environmental parameters.

Discussion

Tropical estuaries are unique environments where spatial and temporal changes in physical, biological and chemical properties are extreme and therefore the extent to which environmental parameters influence the phytoplankton production forms an important aspect of study. In the present investigation, temporal

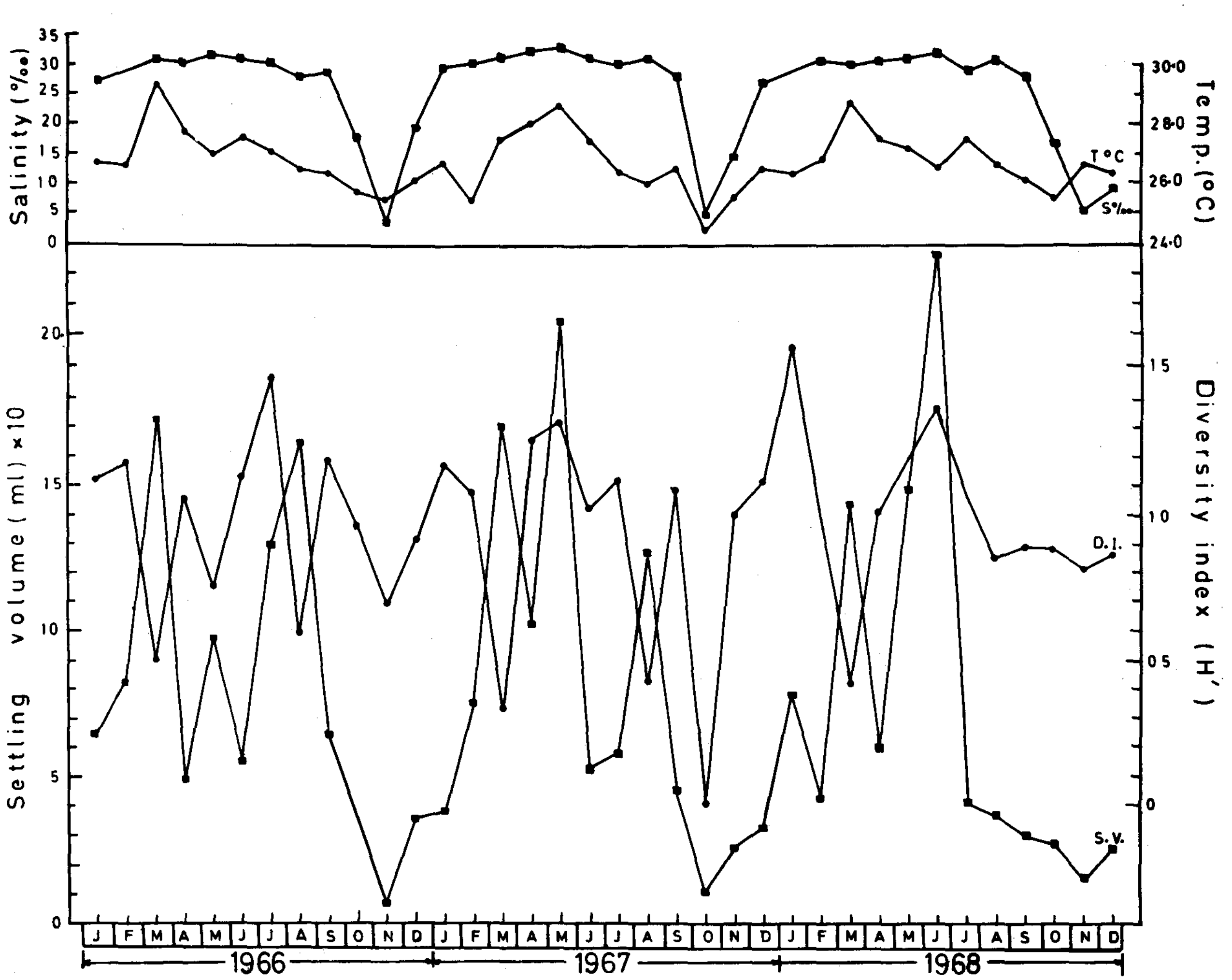

Fig. 4—Seasonal variation in the surface water temperature, salinity, settling volume and diversity index (H')

distribution of phytoplankton appears to depend greatly on the degree of variation in the temperature and salinity of the surface water at the site of sampling. In order to determine the probable dependence of phytoplankton quality and quantity on individual as well as combinations of environmental parameters, simple, partial and multiple correlation coefficients between these variables were calculated. Highly significant ($P<0.001$) correlation was found between the number of species and salinity, indicating that several species recorded during the present study are probably of marine origin. There was no significant correlation between species number and temperature, although the relationship between temperature and salinity was highly significant ($P<0.001$). Partial correlation coefficient between species number - salinity and temperature was highly significant ($P<0.001$) indicating that the changes in one are related with those in the other, although not as pronounced as in the case of salinity. The negative correlation observed between species number - temperature and salinity ($r=-0.4119$) indicates that under typically marine conditions, several species prefer lower temperatures. The multiple correlation between species number and salinity - temperature combinations was highly significant. This confirms that the changes in the quality of the phytoplankton are directly related to salinity and to some extent temperature fluctuations and that these 2 factors together explain a great deal of variations that occur in the phytoplankton community of the estuary.

Highly significant correlation coefficient values ($P<0.001$) were found between total number of cells and salinity as well as between total number of cells and temperature, indicating that the quantity of phytoplankton directly depends on the variations in these 2 environmental factors. Similarly, the partial correlation between total number of cells - temperature and salinity was also significant, although at a lower level ($P<0.01$). It appears that variations in the quantity of phytoplankton and temperature are directly related to variations in salinity. The multiple correlation coefficient between the combination of environmental factors and total number of cells was also highly significant ($P<0.001$), indicating that the abundance of phytoplankton in the estuary is related to the salinity and temperature conditions prevailing at the site of observation.

The general picture that emerges from these observations shows that the phytoplankton community at the mouth of the Vellar estuary is predominantly marine oriented and that variations in the quality and quantity depend on the changes in the salinity and temperature conditions. Estuarine diatoms have the widest adaptability to any change in salinity[17], and in some tropical estuaries diatom blooms are reported to occur during periods of low salinities[5,8]. negative correlation between salinity and phytoplankton concentration has been reported in the Cochin backwaters by Devassy and Bhattathiri[8]. They showed that the phytoplankton population increases with decrease in salinity. However, marine flora are unable to tolerate a lowering of salinity[18,19] and during periods of hightide, several neritic euhaline species are introduced in to the mouth of estuaries[7,9,20]. Under such conditions when mixing of water bodies takes place, the diversity indices are known to increase[7,21]. That the endemic population gets diluted with the high tide water[22] and diatom abundance is directly correlated with low salinity[5,8], is apparently the case in purely estuarine habitats. However, in tropical estuaries salinity is the most important factor controlling the species composition and succession of marine phytoplankton, and a direct correlation exists between this environmental parameter and phytoplankton abundance[4,7,10,11,20]. This generalisation holds good in the present case also.

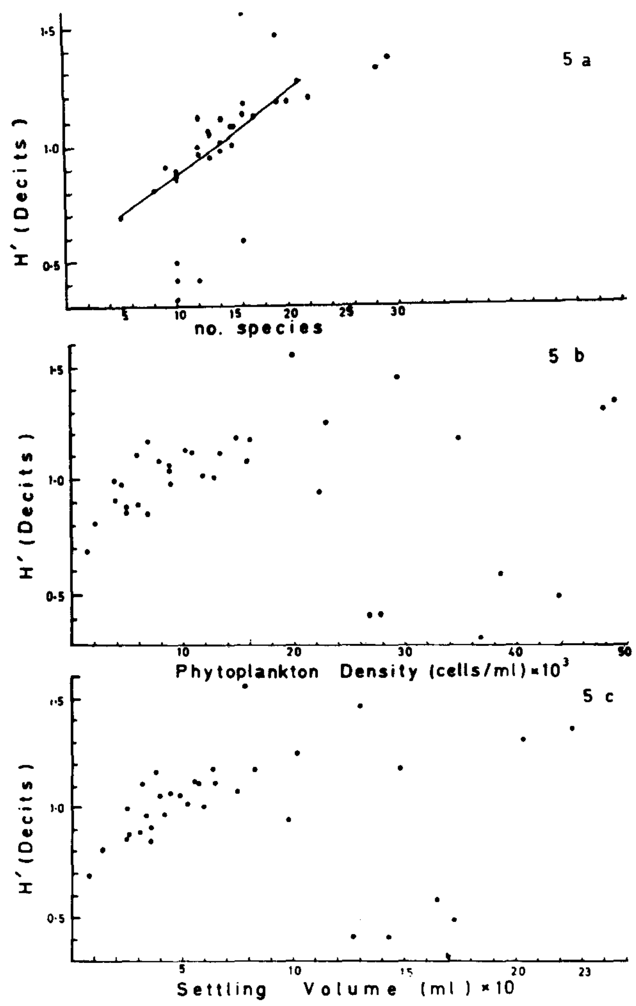

Fig. 5—Relationship between diversity index (H') and number of species (5a), phytoplankton density (5b) and settling volume (5c)

Table 1 presents the correlation matrix in between 10 major groups of phytoplankters. Interdependent groups have positive correlation coefficients and therefore positive or negative variabilities in one are reflected in the other by corresponding positive or negative changes. Negative correlations between groups denote the inverse relationships where increase in one results in decrease in the other. Positive correlations between several groups are highly significant indicating that in the natural habitat these groups coexist. Positive correlations between a good number of families such as Hemiaulineae, Fragilarioideae, Biddulphieae, and Naviculoideae indicate that these families combine to form a group by

Table 1—Correlation Matrix for Ten Major Groups of Phytoplankters

Family/group	Coscino-disceae	Solenieae	Chaeto-cereae	Biddul-phieae	Hemiau-lineae	Fragila-rioideae	Naviculo-ideae	Nitzschi-aceae	*Tricho-desmium*	Dinofla-gellates
Coscinodisceae	—	−0.0615	0.4483†	0.3736	0.4548	0.2245	0.2074	0.6456†	0.7027	0.3181
Solenieae	—	—	0.0560	0.3931	0.5605‡	0.5536†	0.5264†	−0.0964	−0.8137‡	−0.1265
Chaetocereae	—	—	—	0.3138	0.7497†	0.3805‡	0.6252†	0.6837*	0.8402‡	0.2417
Biddulphieae	—	—	—	—	0.5090	0.4505‡	0.3501‡	0.3182	0	−0.1984
Hemiaulineae	—	—	—	—	—	0.3658‡	0.4023‡	0.5047‡	0	−0.2942
Fragilarioideae	—	—	—	—	—	—	0.7911*	−0.6069†	0	−0.3933
Naviculoideae	—	—	—	—	—	—	—	0.5558†	0.5201	−0.0806
Nitzschiaceae	—	—	—	—	—	—	—	—	0	−0.9725*
Trichodesmium	—	—	—	—	—	—	—	—	—	0
Dinoflagellates	—	—	—	—	—	—	—	—	—	—

*$P<0.001$, †$P<0.01$, and ‡$P<0.1$

themselves. Most of the genera included under these families are typically estuarine forms and their occurrence and coexistance probably follow similar trends depending on the salinity conditions. Among the diatoms, negative correlations exist between Solenieae, Coscinodisceae and Nitzschiaceae as well as between Fragilarioideae and Nitzschiaceae. The fact that members of family Solenieae such as *Corethron*, *Guinardia* and *Rhizosolenia* are euhaline while those of Coscinodisceae and Nitzschiaceae such as *Coscinodiscus*, *Cyclotella*, *Bacillaria* and *Nitzschia* are brackish and coastal representatives probably explains these inverse relationships. The same is true in the case of the Fragilarioideae - Nitzschiaceae relationship also. *Trichodesmium erythraeum* showed positive correlations with Coscinodisceae and Chaetocereae indicating that several species of *Chaetoceros* and *Coscinodiscus* which are well adjusted for coastal and estuarine conditions can coexist with this species of blue green algae. It has been shown that several species of diatoms appear along with blooms of *Trichodesmium* in the coastal waters of Goa and during the peaks of the blooms, the diversity index ranges from 0.05 to 0.96 while during the rest of the season the values are >2 (ref. 23). In contrast to this, significant negative correlation between *Trichodesmium* and Solenieae suggests that species belonging to the genera *Corethron*, *Guinardia* and *Rhizosolenia* which are neritic species do not coexist with the blue green alga. Similarly, the dinoflagellates also show negative correlations with all families except Coscinodisceae. Apparently, the majority of diatoms, except probably members of the widely distributed Coscinodisceae, do not endure the presence of dinoflagellates. *Trichodesmium* and dinoflagellates never coexist and therefore they probably represent 2 additional components of the phytoplankton community.

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