STUDIES ON THE PHYTOPLANKTON OF THE COCHIN BACKWATER A TROPICAL ESTUARY

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ABSTRACT

The paper deals with the seasonal and spatial variation of phytoplankton, based on the observations at four stations (Aroor to Fairway Buoy) in the Cochin backwater during 1972-73. Two peaks of phytoplankton abundance are usually observed, with the diatoms playing the major role in determining the pattern of seasonal variations. An analysis of variance indicates that the spatial variation is as high as the seasonal variation. The usefulness of chlorophyll *a* in relation to the phytoplankton counts as a measure of the phytoplankton abundance has been studied by using the correlation coefficients; it has been found from an analysis of covariance that a common relationship exists between phytoplankton and chlorophyll *a* for the estuary. The fluctuations in some of the environmental characteristics have been discussed with their relative influence on the production of phytoplankton. In the light of the results obtained, outlines of modifications in the sampling procedure have been given to make the study of phytoplankton production in the estuary more comprehensive.

INTRODUCTION

Cochin backwater is one of the most productive estuarine systems in the tropical environment with an estimated annual gross production of nearly 300 gC/m^2 (Qasim *et al* 1969). Among the earlier studies on the variation and distribution of the phytoplankton in this backwater, that of Qasim and Reddy (1967) showed the variations in chlorophyll stock from place to place and time to time as a result of the water masses being constantly renewed by an inflow of fresh water from the rivers and sea water from the adjoining sea. Gopinathan (1972) studied on enumeration basis from collections made, using a net and flow-meter, the seasonal, qualitative and quantitative variations of about 120 species of phytoplankters (excluding nannoplankters) which commonly occur in the estuary. These cell-counts and chlorophyll studies cover the seasonal and spatial variations and also the factors influencing the phytoplankton distribution.

Works on different types of ecosystems have shown that none of the parameters, cell volume, cell numbers or chlorophyll, can independently give a true picture of the standing crop, because of the inherent drawbacks in each method. So it was thought desirable to determine the relationship between phytoplankton counts and chlorophyll values by means of the correlation coefficient and, if possible, to give a general relationship between these two variables for the estuary as a whole. This study covers a part of the estuary from the bar-mouth to about 15 km interior and tries to test the significance of the spatial variation in phytoplankton by analysis of variance.

Materials and Methods

One-litre water samples from the surface were collected every fortnight for a year from May 1972 to April 1973 at four stations in the backwater (Fig. 1). The phytoplankton crop was estimated for 1 litre from the counts in 50-ml sample obtained after the organisms settled in special chambers for 24 h. For chlorophyll *a*, 500 ml of water sample was filtered by using a millipore filter paper, the filtrate dissolved in 90% acetone, centrifuged and measured in a Unicam SP 500 Spectrophotometer. Duplicate samples were analysed for hydrological properties. Determination of salinity, oxygen and nutrients were made according to Strickland and Parsons (1960). As the organic production rates are given in terms of carbon, the chlorophyll values have been converted into their carbon equivalents by the conversion factor given by Cushing (1958).

Standing Crop

The magnitude of standing crop of phytoplankton, as represented by cell numbers, varied from season to season and station to station (Table 1). An analysis of variance (given below) showed that the spatial variation was almost as high as the seasonal variation.

Analysis of variance

Source	d.f.	S.S.	M.S.	F
Between stations	3	1,306,430	435,477	5.7*
Between months	11	4,533,165	412,106	5.4*
Error	33	2,520,808	76,388	
Total	47	8,360,403		

* Significant at 1% level.

Two peak periods were noticed in the phytoplankton abundance, one in January-February and the other in July-August. During these peak periods the phytoplankton was largely made up of diatoms. The nannoplankters formed the next important constituent. Dinoflagellates, silicoflagellates, coccolithophores and blue-green algae were rare. The primary peak was dominated by a monospecific bloom of the diatom, *Skeletonema costatum*. During the secondary peak, the dinoflagellates such as *Prorocentrum micans* and *Ceratium furca* formed the major components, along with *Skeletonema costatum*. Silicoflagellates such as *Dictyocha fibula* and *Destephanus speculum* were present during February, May, June and October. The chlorophycean members, mainly *Spirogyra*, and desmids such as *Euastrum, Cosmarium, Closterium* and *Micrasterias* were abundant in

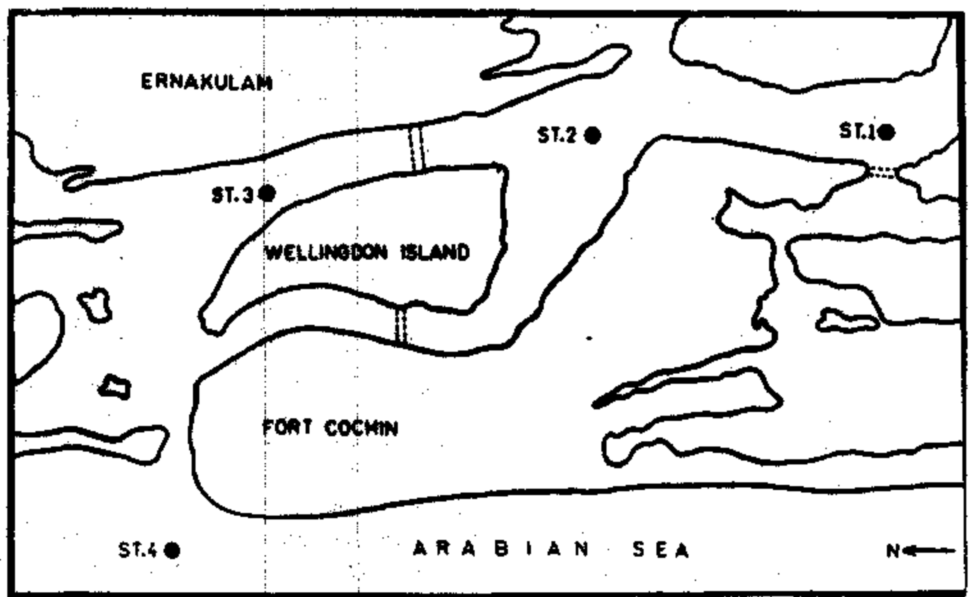

FIG. 1. Map of Cochin backwater showing sampling stations.

August, December and April and the blue-green algae, such as, *Trichodesmium theibautii, Oscillatoria* sp. and *Meresmopedia* sp. were abundant in July, September and November.

The maximum value obtained for cell-counts in January resulted from the blooming of the diatom, *Skeletonema costatum.* The minimum was in March for all the stations except station 4. Thus the trends in cell numbers are more homogeneous between stations than the trends in the chlorophyll values. The observations of Qasim *et al* (1969), based on the primary-production values in the lower reaches of the estuary, however, indicate three small peaks, in April, July and October, but, as these authors themselves suggest, the fluctuations may not be consistent from year to year and more often may depend on meteorological conditions and the resultant environment.

The places of observations were so chosen as to represent the varying environments between a backwater and marine region i.e., the stretch of varying influence of tide. Consequently, the species composition varied from station to station. The magnitude of the standing crop, expressed in terms of carbon converted from chlorophyll *a*, showed that at station 1, the values ranged from 74 $mgC|m^3$ in April to 444 $mgC|m^3$ in July. At the second station, the minimum value of 41 $mgC|m^3$ was observed in August and the maximum of 465 $mgC|m^3$ in September; at the station 3, the minimum of 58 $mgC|m^3$ was found in April and the maximum 577 $mgC|m^3$ in February and at station 4, where the environment is more of a marine nature, the range was from 49 $mgC|m^3$ (in April) to 490 $mgC|m^3$ (in August).

TABLE 1. *Total number of phytoplankters (surface/1) at four stations.*

	Months	St. I.	St. II.	St. III.	St. IV.
1973	January	521500	863700	898800	780500
	February	454500	367200	340800	319800
	March	109100	90600	100700	142300
	April	204500	191100	191700	229800
1972	May	162580	167500	136100	148900
	June	252000	207400	533800	473400
	July	443500	479400	400400	429900
	August	471500	606400	161200	210300
	September	214100	322800	412800	464000
	October	366200	276600	332200	350900
	November	208100	184800	203000	179900
	December	118900	110300	108000	95700

A statistical analysis was carried out to determine the correlation between the total cell counts and chlorophyll *a*. A preliminary plot of the phytoplankton counts (number of cells per litre) against chlorophyll *a* (mgC/m^3) showed an exponential relationship. Therefore, the logarithm of these two variables shows a linear relationship. But as the phytoplankton counts showed variations from station to station, it has to be examined whether the form of relationship between phytoplankton cells and chlorophyll *a* also differs from station to station. Therefore, four separate regression lines of log. (phytoplankton) on log. (chlorophyll *a*) were fitted for the different stations. The four regression equations (fitted by the 'method of least squares'), the standard errors of the regression coefficients and the correlation coefficients are:

Station	Regression line	Standard error of the regression coefficient	Correlation coefficient
I	log (phyto) = 4.85 + 0.55 log (chl. a)	0.29	0.51
II	" = 4.93 + 0.43 "	0.30	0.41
III	" = 4.92 + 0.41 "	0.33	0.37
IV	" = 4.65 + 0.63 "	0.35	0.50

Note: log refers to common logarithm

The standard errors relative to the respective regression coefficients are rather high; the regression coefficients for the individual stations are, thus, not very reliable. The difference between the regression lines was tested by the analysis of covariance. The relevant table drawn up according to Snedecor and Cochran (1967) is given (Table 2).

TABLE 2. *Comparison of Regression lines.*

	d.f.	Σx^2	Σxy	Σy^2	Regression coefficient	Deviation From Regression d.f.	S.S.	M.S.
Within station								
I	11	0.5421	0.2969	0.6206	0.5477	10	.4580	.04580
II	11	0.8727	0.3753	0.9442	0.4300	10	.7828	.07828
III	11	0.7673	0.3186	0.9547	0.4152	10	.8224	.08224
IV	11	0.4853	0.3070	0.7816	0.6326	10	.5874	.05874
						40	2.6506	.06627
Pooled, W	44	2.6674	1.2978	3.3011	0.4865	43	2.6697	.026697
			Difference between slopes			3	0.0191	.006367

$$F = \frac{.006367}{.06627} = 0.961 \quad (\text{d.f.} = 3{,}40)$$

Note: Σx^2 Σxy and Σy^2 have the usual meaning.

As the sum of squares due to the difference between the regression coefficients is less than "within sum of squares", the relationship from station to station is not significantly different. Therefore, by pooling the stations, a general relationship for the estuary can be set up as:

$$\log(\text{phytoplankton}) = 4.91 + 0.45 \log(\text{chlorophyll } a)$$

Here the standard error of the regression coefficient is 0.14 giving a confidence interval for the population regression coefficient as approximately 0.45 $\pm$ 0.28. The correlation coefficient (0.42) between log (phytoplankton) and log (chlorophyll *a*) is highly significant, though only about 18% of the variations in the phytoplankton counts can be accounted for by the variations in chlorophyll *a*.

As the water in the estuary is highly turbid, it is not possible to differentiate how much of the pigment came from the living cells. Qasim and Reddy (1967) in their study on plant pigments of the backwater during the monsoon months had suggested that the extracts contained a large amount of detritus and mud pigments. Further, the extent of the contribution of the dead chlorophyll to the total chlorophyll values has not been determined. The presence of dead chlorophyll will not be reflected in the phytoplankton counts and this may explain at least a part of the remaining 82% of the variations in the phytoplankton counts. A plot of the log (phytoplankton) on log (chlorophyll *a*) with the common regression line is given in Fig. 2.

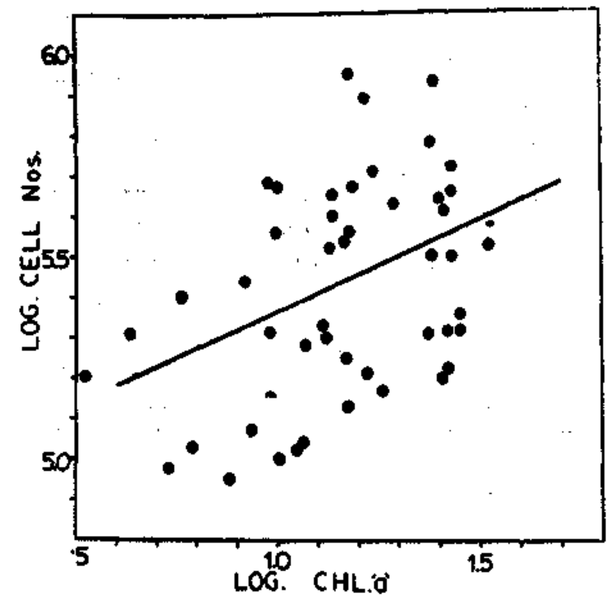

FIG. 2. A plot of the log on log with the common regression line.

FACTORS AFFECTING PHYTOPLANKTON PRODUCTION

It is now apparent that some of the commonly measured environmental factors such as temperature, salinity, oxygen and nutrients can be used in the assessment of quantitative seasonal variations of phytoplankton.

Temperature

The fluctuations in the surface temperature during the period of observation were small and were within a range 27-31°C (Fig. 3). The temperature was at its maximum during the pre-monsoon months (January-April). With the onset of the monsoon, the temperature tended to fall due to reduced insolation and precipitation. In the estuary, being a tropical one, the temperature by itself seemed to have no direct influence on the phytoplankton production unlike in higher latitudes. In the estuaries of higher latitudes, temperature has a negative effect on phytoplankton production because increased respiration uses up part of the energy that is stored up by photosynthesis which would otherwise be used up in the production of new cells. However, in shallow regions where the bottom is in direct contact with overlying water, the indirect influence of temperature is observed, by which there is an enhancement in the regeneration processes to a certain extent which reflects in the rate of primary production (Steemann Nielsen and Jensen 1957).

Salinity

Among the hydrological parameters salinity is the most important factor regulating the entire ecosystem of the estuary. The salinity fluctuations in the

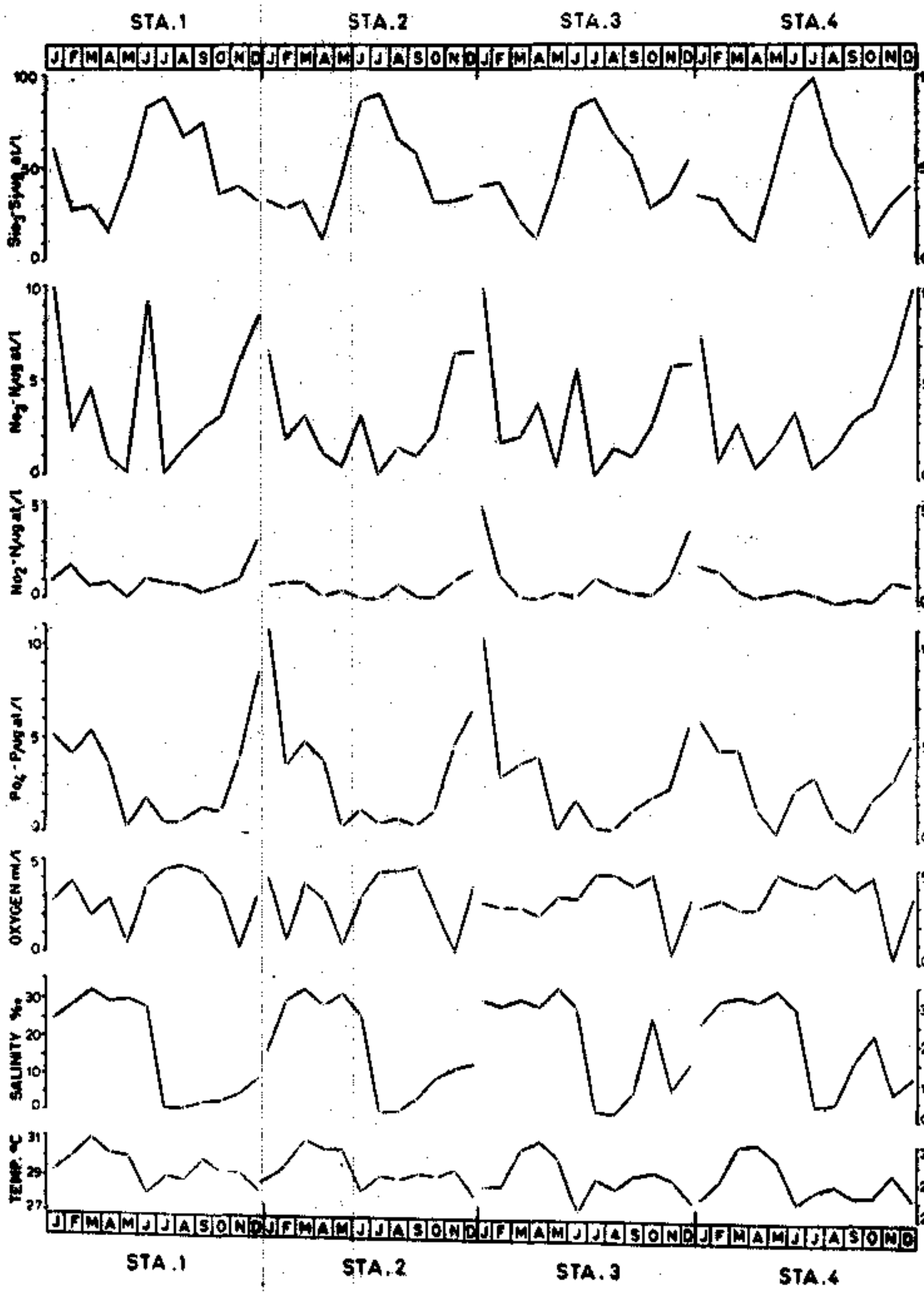

FIG. 3. The monthly distribution of the hydrographic properties at the four sampling stations.

backwater are very wide because of the influence of monsoon and consequent run off from land. During the pre-monsoon period, the backwater shows a clear homogeneity in salinity throughout the water column. During the monsoon, large quantities of fresh water enter the estuary from the nearby rivers and from the rain fall, resulting in very low saline water at the surface and dense water at the bottom. By August near freshwater condition exists in the surface layers. There-after there is a gradual increase in salinity, and maximum values are attained in March (Fig. 3).

A horizontal gradient in salinity is observed from station 1 to station 4; the former being more brackish while the latter is close to the sea and is more akin to marine environment. Thus in the backwater the salinity variations from one place to another and from the surface to bottom are very wide.

Recent studies conducted by Qasim *et al* (1972) showed that many organisms bloom successively at exceptionally low salinities in the backwater indicating that waters of low salinity support a greater abundance of phytoplankton. In a population of diatoms and dinoflagellates studied *in vitro* maximum rates of photosynthesis were observed in the lower salinity ranges. This adaptation of phytoplankton for maximum photosynthesis in response to low salinity may be to ensure their peak production during a time when high concentrations of nutrients are available in the environment (Qasim *et al* 1972).

Oxygen

The dissolved oxygen does not show much fluctuations especially in surface waters. However, a sudden drop in the values was noticed uniformly at all the stations (Fig. 3) during November. The phytoplankton production does not seem to have any direct bearing on the dissolved oxygen concentration probably because of considerable admixture of alien waters.

Nutrients

In the present investigation, phosphates, nitrites, nitrates and silicates were measured. The inorganic phosphorus showed a single peak at the first station, whereas at station 4, where there is influence of the sea, a secondary paek was observed with the onset of the monsoon. The No_2 -N also indicate a similar trend of distribution, having two peak periods, one in June-July and the other in December-January, the latter being of a higher order. But No_3 -N is found to be high during November-January. In all the four stations the silicate values were found to be high during June-August, coinciding with the peak production of phytoplankton (Fig. 3).

The nutrients of the Cochin backwater in relation to the environmental characteristics have been dealt with in detail by Sankaranarayanan and Qasim (1969). According to them, the instantaneous concentration of nutrients as inorganic salts does not seem to provide a significant source for the phytoplankton

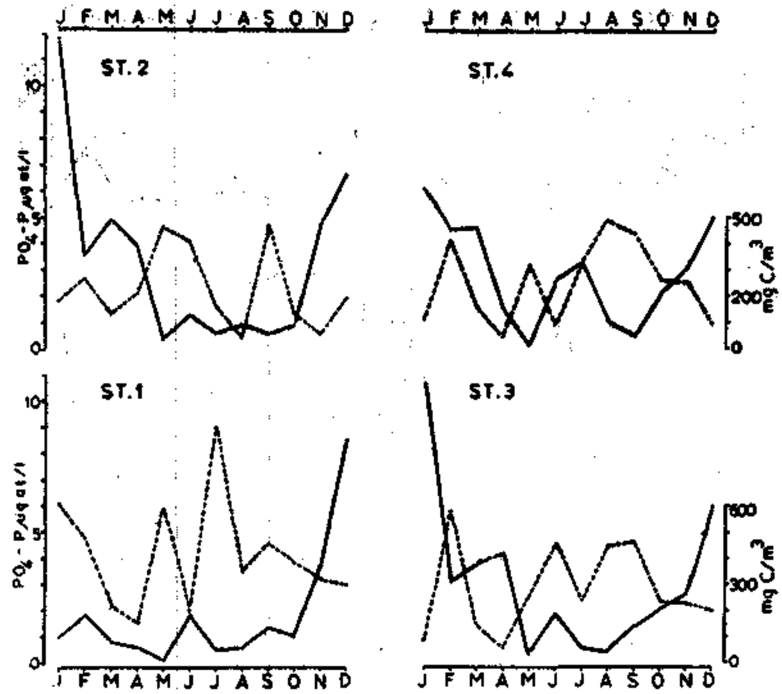

FIG. 4. The monthly trend in standing crop, expressed in terms of carbon, and the environmental phosphates.

bloom. But in several ecosystems, the nutrient-phytoplankton relationship is one in which the cause and effect are not clearly separable as available nutrients stimulate growth; growth utilization process will reduce the quantity of nutrients, so that the relationship sometimes become negative. Such a negative relationship is clearly illustrated in Figs 4, 5 and 6, where the standing crop in terms of

TABLE 3. *N|P ratio.*

	Months	St. I.	St. II.	St. III.	St. IV.
1973	January	2.13	0.63	1.39	1.38
	February	0.99	0.81	1.04	0.56
	March	1.01	0.84	0.61	0.74
	April	0.41	0.32	0.93	0.41
1972	May	0.26	3.61	3.62	5.68
	June	4.94	2.53	3.18	1.36
	July	0.15	0.11	2.20	0.16
	August	2.25	1.83	3.62	1.41
	September	1.83	2.49	0.96	6.67
	October	2.83	3.25	1.38	1.71
	November	1.77	1.58	2.59	2.38
	December	1.36	1.24	1.64	2.18

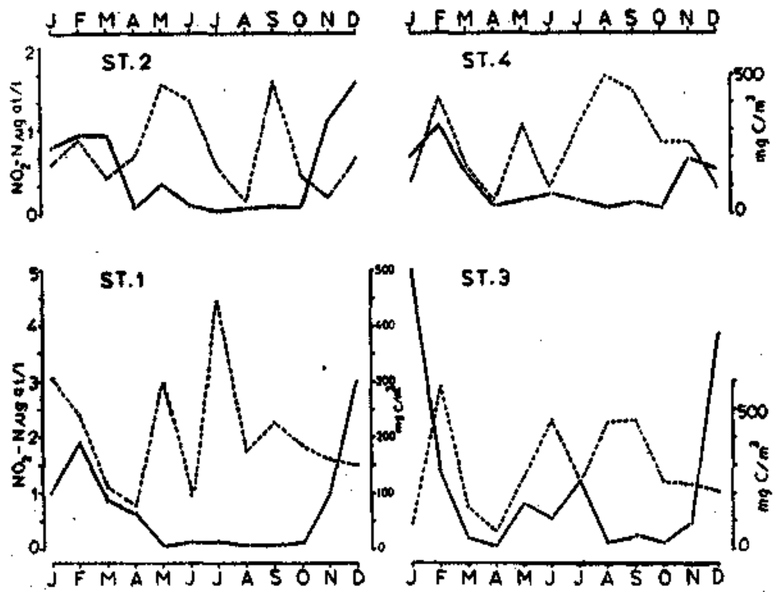

FIG. 5. The monthly trend in standing crop, expressed in terms of carbon, and environmental nitrites.

carbon is plotted against phosphates and nitrites. No₃ -N does not indicate any particularly strong relationship which would perhaps suggest that nitrogen is supplied in the form of nitrite and ammonia. A table on the N by P ratios also demonstrate this (Table 3). The highest ratio for all the stations has been found to be only 6.7. The very low ratios suggest that the phosphate is regenerated much faster than the pooled values of nitrites and nitrates.

General Discussion

While evaluating the influence of environmental factors on the production of phytoplankton, what is needed is to assess the collective influence of the factors that give rise to specific values, as the parameters, individually, may directly affect the physiology of phytoplankton organisms or inhibit or accelerate the production.

The annual cycle of events in the estuary follows a regular pattern with three distinct seasons, the pre-monsoon during February-May, the monsoon season during June-Sept. and the post-monsoon season during October-January. During the pre-monsoon a stable condition prevails in the estuary without any vertical gradients in salinity or temperature with the hydrological conditions almost similar to those of the inshore waters. During monsoon there is considerable influx of fresh water from precipitation and land run off and during post-monsoon, there is reduction in the discharge of fresh water and the earlier brackish condition is restored by the incursion of sea water.

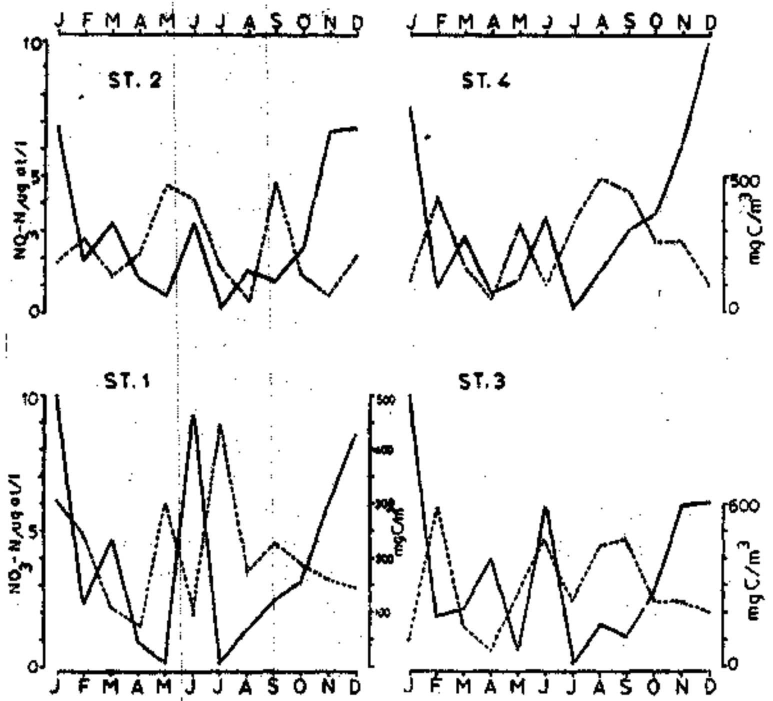

FIG. 6. The monthly trend in standing crop, expressed in terms of carbon, and environmental nitrates.

In addition, the environmental characteristics are influenced to a large extent by the tidal cycle. The tides are of a mixed semi-diurnal type with a maximum range of 1 m (Qasim and Gopinathan 1969) at the upper reaches of the estuary, decreasing towards station 1. During ebb tide brackish water from the estuary is discharged into the sea and during flood tide, the sea water enters into the estuary. Besides, upwelling, monsoon piling and sinking in the Arabian sea also influence to some extent the seasonal pattern of the hydrological conditions in the backwater (Ramamirtham and Jayaraman 1963). The changes in the nutrient concentration are thus affected by the seasonal and tidal cycles. Further, the exchange of nutrients with the bottom mud is another factor and this depends on the ambient temperature and mixing process.

As indicated earlier, the instantaneous concentration of nutrients does not seem to have a direct bearing on the phytoplankton production, because the nutrients do not become the limiting factor, due to regeneration and considerable exchange from the bottomwater interface (Ketchum 1947).

From observations made on the inshore waters and the estuarine regions of the Indian seas, it is seen that the abundance occurs during the monsoon months, when the phytoplankton peaks coincide with low salinity and temperature and high concentration of nutrients (Subrahmanyan 1959). Qasim *et al* (1972) have indicated that the direct relation of phytoplankton production with low salinity and temperature may be an adaptation by the phytoplankton to utilize the available nutrients. While using chlorophyll as an indicator of phytoplankton production, the effects of dead chlorophyll and pigments in the mud are to be taken into account. Though chlorophyll may not serve as effectively for an absolute measure as, say, phytoplankton counts, it appears suitable as a measure of production irrespective of variations from place to place.

From these quantitative studies, some lines of future work with regard to sampling could be indicated. As the spatial variation is as prominent as the seasonal variation, the effect of variations in the factors which are specific to space, such as depth and species composition is also to be studied simultaneously with the factors already mentioned. Vollenweider (1971), while laying out the general principles of sampling techniques and methods for estimating the quantity and quality of biomass, has indicated that as counting is time-consuming the effort spent to obtain a certain counting precision for an individual sample should be relative to its representative value. He also observed that it is far better to collect a number of samples from the same locality, varying the sampling place slightly for every individual sample, and counting them at a lower precision level, rather than put too much of effort into counting a single sample with high accuracy. To get a realistic picture of the production cycle, the time and place of sampling are to be selected by taking into account the variability over space and time and also the factors causing this variability. For this purpose, the samples are to be collected at different hours of the day at different places for a few days in the beginning, taking into account the differences due to high and low tides. But the final choice of the time and place of sampling will, however, depend upon the results of the first survey (pilot survey). This survey will also be useful to determine the number of samples required to arrive at a given level of accuracy in the estimated production rates. The number of samples required for a specific period will depend on the extent of variability in the phytoplankton production.

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References

Cushing, D. H. 1958. The estimation of carbon in phytoplankton. *Repp. Proc. Verb. Cons. Expl. Mer.*, **144**: 82-83.

Gopinathan, C. P. 1972. Seasonal abundance of phytoplankton in the Cochin Backwater. *J. mar. biol. Ass. India*, **14** (2): 568-577.

KETCHUM, B. H. 1947. The biochemical relation between marine organisms and their environment. *Ecol. Monogr.*, **17**: 309-315.

QASIM, S. Z. AND C. V. G. REDDY. 1967. The estimation of plant pigments of Cochin Backwater during the monsoon months. *Bull. mar Sci.*, **17** (1): 95-110.

QASIM, S. Z., S. WELLERSHAUS, P. M. A. BHATTATHIRI AND S. A. H. ABIDI. 1969. Organic production in a tropical estuary. *Proc. Indian Acad. Sci.*, **69B** (2): 51-94.

QASIM, S. Z. AND C. K. GOPINATHAN. 1969. Tidal cycle and the environmental features of Cochin Backwater (a tropical estuary). *Proc. Indian Acad. Sci.*, **69B**: 336-348.

QASIM, S. Z., P. M. A. BHATTATHIRI AND V. P. DEVASSY. 1972. The influence of salinity on the rate of photosynthesis and abundance of some tropical phytoplankton. *Marine Biology*, **12** (3): 200-206.

RAMAMIRTHAM, C. P. AND R. JAYARAMAN. 1963. Some aspects of the hydrographical conditions of the backwaters around Wellingdon Island (Cochin). *J. mar. biol. Ass. India*, **5**: 170-177.

SANKARANARAYANAN, V. N. AND S. Z. QASIM. 1969. Nutrients of the Cochin Backwater in relation to environmental characteristics. *Marine Biology*, **2** (3): 236-247.

SNEDECOR, G. W. AND W. G. COCHRAN. 1967. *Statistical Methods.* Oxford and IBH Publ. Co., pp. 593.

STEEMANN NIELSEN, E. AND E. A. JENSEN. 1957. Primary Oceanic production. The autotropic production of organic matter in the oceans. *Galathea Repts.*, **1**: 49-136.

STRICKLAND, J. D. H. AND T. R. PARSONS. 1960. A mannual of seawater analysis. *Fish. Res. Bd. Canada, Bull.* No. 125, pp. 185.

SUBRAHMANYAN, R. 1959. Studies on the phytoplankton of the west coast of India. Part I. *Proc. Indian Acad. Sci.*, **50B** (3): 113-187.

VOLLENWEIDER, R. A. (Ed.) 1971. *A mannual on methods for measuring primary production in aquatic environments.* IBP Hand Book, No. 12, Blackwell Sci. Publ. Oxford, pp. 213.