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THE PLANKTON PRODUCTION IN THE VEMBANAD LAKE AND ADJACENT WATERS IN RELATION TO THE ENVIRONMENTAL PARAMETERS

V. KUNJUKRISHNA PILLAI, K. J. JOSEPH AND A. K. KESAVAN NAIR

Central Marine Fisheries Research Institute, Cochin-18

ABSTRACT

The Vembanad Lake and its eonnected backwater system around Cochin are well known as the nursery grounds for the commercially important fishery resources of this area.

This account embodies the results of studies on the environmental parameters of the estuarine system around Cochin extending over an area of 300 sq. km. Observations were made on the hydrography, primary and secondary productions. The relative influence of the environmental factors like, temperature, salinity, dissolved oxygen and nutrients on the plankton production is interpreted from the correlation coefficients.

INTRODUCTION

The Vembanad Lake and connected backwaters around Cochin are well known for its role as a nursery ground for important fishery resources of this area. The fishery resources of any area is mainly dependent on the magnitude of primary and secondary productions which in turn are influenced by various physical, chemical and biological factors. Being part of a tropical estuary, its waters have a comparatively high rate of primary production.

In the past few years, the hydrography, primary productivity, plankton and benthos of the Cochin backwater have been the subjects of intensive study. However, a detailed investigation on the primary and secondary producers of the entire backwater system and the Vembanad Lake for all the seasons of the year is lacking. In this communication an attempt is made to project an overall picture of the primary and secondary productions of the Vembanad Lake and adjacent backwaters as well as to discuss the influence of physical, chemical and biological factors on the production.

Our knowledge on the plankton of Cochin backwaters is mainly based on the works of George (1958), Nair and Tranter (1971), Haridas *et al*, (1973) and Pillai *et al*., (1973). Considerable work on the hydrography has been carried out by Ramamritham and Jayaraman (1963), Qusim *et al*., (1967, 1968 and 1969) on the various aspects of productivity, solar radiation, tidal ranges, chlorophyll and nutrients. Wellershaus (1974) studied the seasonal changes in the zooplankton population in the Cochin backwaters. Josanto (1971) studied the bottom salinity characteristics of the Vembanad Lake and connected areas south of Cochin. However, this is the first investigation of the type referred to above for the area north of Cochin.

The Environment

The area of present investigation includes the backwaters running almost parallel to the Arabian Sea from Alleppey in the south to Azhicode in the north (90 km. S - N) of Kerala (Fig. 1). The depth varies from 1.5 to 10 m. and the total area of water spread is about 300 sq. km. On the northern half there are two permanent passages to the Arabian Sea, one at Cochin and the other at Azhicode. Six rivers empty into the backwaters, each through their tributaries and branches. On the southern half, the rivers Muvattupuzha, Manimala, Meenachil, Pamba and Achancoil join the Lake, while the Periyar river joins at the northern half. All these rivers empty large quantity of flood waters during the monsoon season enriched with nutrients and considerable quantity of silt. The nature of the bottom is mostly muddy, with an admixture of fine sand granules in some locations. The tidal effect reaches all along the Lake upto the southern end beyond Alleppey.

Material and Methods

Seven stations were selected for this study (Fig. 1). Data on temperature, salinity, dissolved oxygen, nutrients, primary production and zooplankton were collected once in a month from February 1971 to January 1972 and analysed according to the standard methods. Carbon production was measured by C^{14} technique. 5μ curie of $Na\,H\,C^{14}\,O_3$ was added to samples taken in 60 ml bottles. The samples were incubated in natural light for two hours. Activity of the filter was determined on a Geiger counting system having an efficiency of 3.2 %. Zooplankton was collected using a $\frac{1}{2}$ metre nylon net and the total numbers were calculated for 1000 m^3. The variation in space and time of the primary production rates and zooplankton counts were studied using the technique of analysis of variance. The relative influence of environmental parameters such as salinity, temperature and nutrients on the primary and secondary producers is studied from the coefficients of correlation.

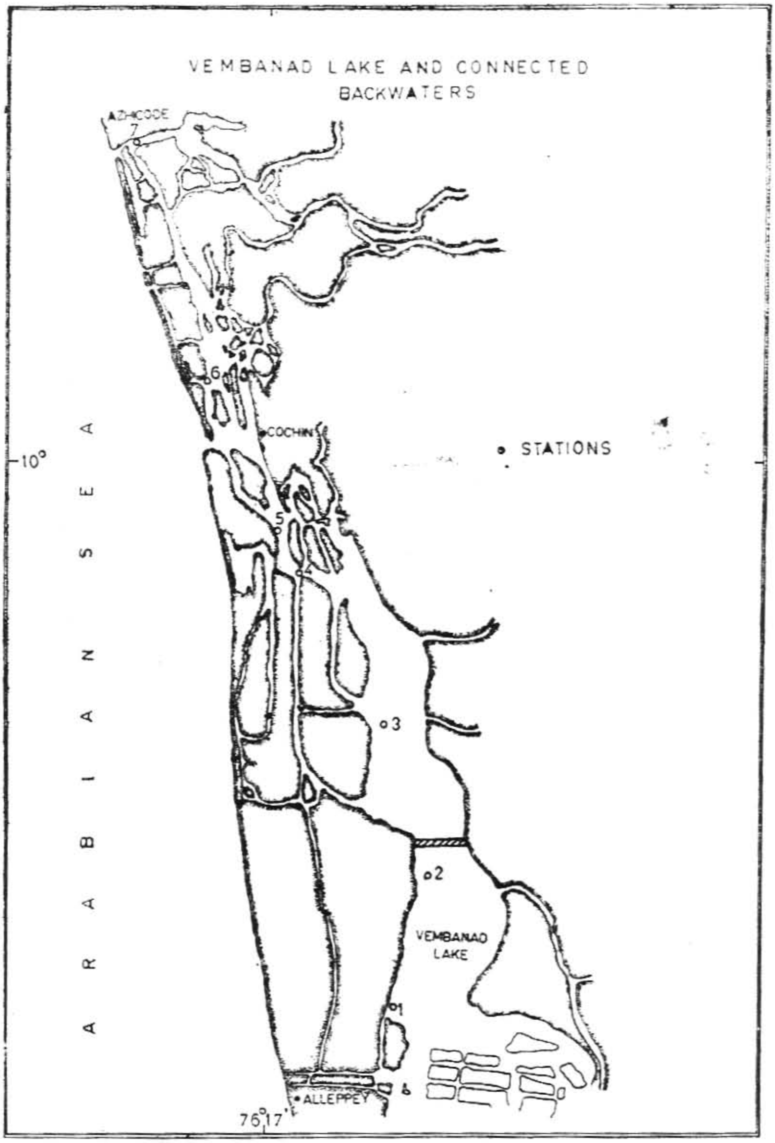

Fig. - 1. Map showing the station locations.

Environmental Parameters

The environmental parameters in estuaries vary to a large extent by the individual characteristics, controlled by the climate and the quantity of the fresh water influx. Naturally, the tidal fluxing also influences the environmental factors to a great extent.

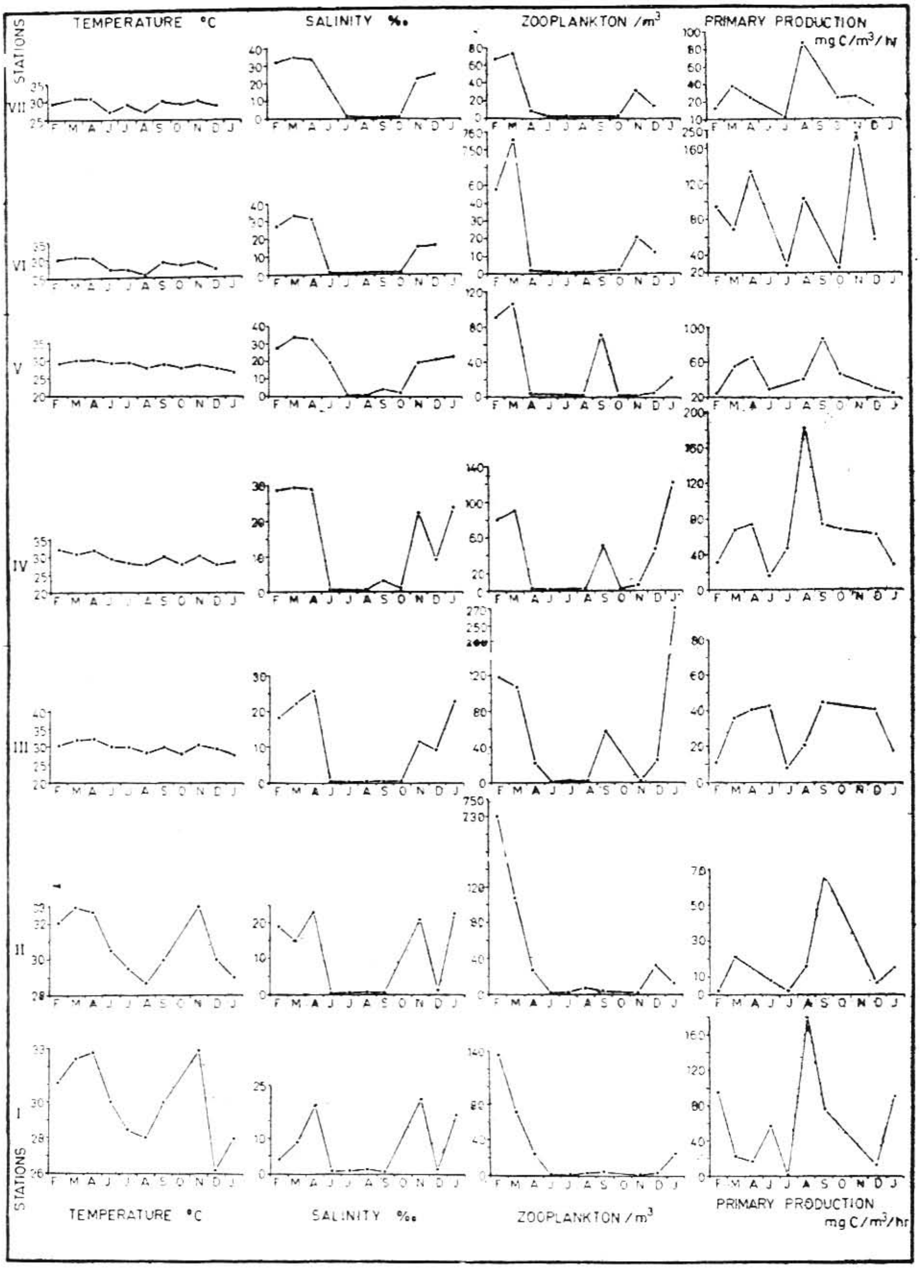

Fig. - 2. Station-wise month-wise distribution of Temperature, Salinity, Zooplankton and Primary production.

Temperature (Fig. 2).

The surface temperature values for the entire period of observation reflect to a certain extent the climatic variations. There was a gradual increase in temperature from February to April, followed by a fall during July – August. In general during the post-monsoon period of October – November there was a slight increase in surface temperature in the entire area. The fluctuation in the surface temperature during the monsoon months were highly significant. Sankaranarayanan and Qasim (1969) stated that the influx of fresh water into the estuarine system is not the sole factor in bringing down the water temperature in the estuary, but the influx of cold water from the sea may also be a significant factor. The lowest temperature recorded was 25.1 °C at station II during August, and the highest value of 33 °C was recorded at stations VI and VII during November.

Salinity (Fig. 2).

The salinity variations clearly indicate a bimodal fluctuation in all the seven stations. The effect of monsoon can be easily seen from the decreasing salinity gradients in the entire backwater area during June to August. During the months of February - April, the salinity distribution appears to be very stable, but in the other months especially during the post-monsoon period (October to January) there is a lot of unstability probably due to the mixing process continuing in the vertical profile. Invariably, the salinity pattern in the northern half (Cochin to Azhicode) was of a higher magnitude, may be due to the proximity to the sea and also the effect of two natural passages at Cochin and Azhicode.

The fluctuation in salinity was of such a magnitude that at station. I, incidentally the farthest station from the nearest passage to the sea, the salinity ranged from 0.19 ‰ during June - July to 19.7 ‰ in April and 21.7 ‰ in November.

Dissolved oxygen (Fig. 3).

Dissolved oxygen showed a distinct pattern of seasonal fluctuations in the entire area. Comparatively high values were found during monsoon season (June - August). Haridas *et al.*, (1973) also observed the same type of phenomena in the same area during the monsoon season. Qasim *et al.*, (1969) stated that thc higher oxygen concentration during this period can be due to the higher primary production occurring in the surface layers during monsoon season. The lowest value of 1.10 ml/1 dissolved oxygen was recorded at station VI during April and the highest value of 5.9 ml/1 at station I in June. In general, the higher values were recorded during

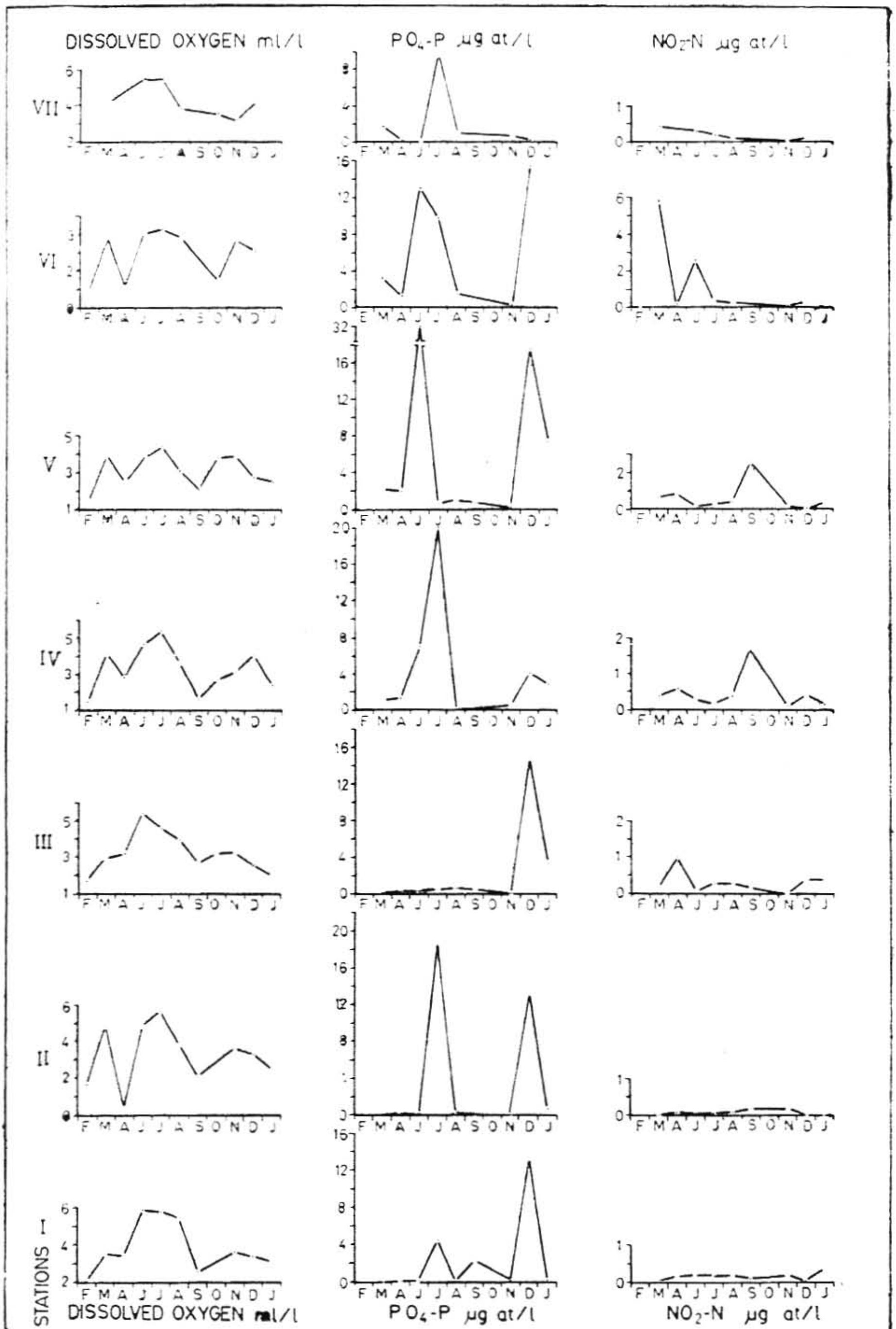

Fig. -3. Station-wise month-wise distribution of dissolved oxygen, inorganic phosphate and Nitrate - N.

monsoon period, the lowest during pre-monsoon season. The post-monsoon period appeared to be more stable pronouncing relatively lesser variations.

Inorganic phosphate (Fig. 3).

As seen in Figure 3, inorganic phosphate distribution showed a distinct bimodal fluctuation in almost all stations; one peak was during June - July and the other during November - December. In station III even during monsoon period the values were only moderate. Very high values were recorded in station V (32 µg at/l) during the month of June.

Nitrite nitrogen (Fig. 3).

Nitrite nitrogen values are shown in Fig. 3. The interesting feature of the NO_2-N distribution in these waters is the very low values in most of the periods except at one or two stations in the summer (pre-monsoon). The higher values were noted at stations IV and V during September and October.

PRIMARY PRODUCTION

Primary production measured by C^{14} showed considerable seasonal variation with post-monsoon season as the peak period. Comparatively lesser rates of production are estimated during the S. W. monsoon period. This is in contrast with the observations on the inshore environment of the west coast of India where high production occurs during the monsoon period (Nair *et al*, 1968). Considering the magnitude of production, station VI stands out to be the most productive area in the backwater. The highest production rate of 245 mgC/m^3/hr was recorded at this station. The production rate is found to be the lowest at station II.

Post-monsoon months are characterised by high rates of primary production, the maximum value being 125 mgC/m^3/hr. The higher values may be due to the optimum light intensity and effective utilization of nutrients. In the estuary, since there is less mixing of the bottom waters with the surface waters, almost till the end of October, there is no effective utilization of the nutrients till that time. This accounts for the lower rates of production during the monsoon period and progressively increasing rates during the subsequent period (Nair *et al*, M. S.).

ZOOPLANKTON

The trend in the zooplankton biomass during the entire period of observations in all stations is given in Figure-2. Two peaks are observed, one in March-April and the other during October-January. The second peak was less prominent. The peaks were high at stations II, III and VI. During the monsoon season (July-September) the trend is completely changed showing very low values in the entire backwaters, both in numbers of groups present and in the abundance of the groups. Earlier observations of George (1958), Nair and Tranter (1971) and Haridas *et* al, (1973) and the present study also proved almost the same sequence of zooplankton distribution in the backwater system.

The zooplankton was represented by 16 groups of organisms in the plankton. They are the following: Copepods, Decapod larvae, Crab zoea, Lucifers, Jelly fishes, Hydromedusae, Amphipods, Cladocerans, Isopods, Cirripid nauplius, Oikopluera, Chaetognaths, Ctenophores, Mysids, Cumaceans and Copepodites. Invariably, copepods and decapod larvae were dominant in the plankton. Fish eggs and larvae were abundant during February, March and April.

Other than the general seasonal fluctuations in the zooplankton groups, one important feature was the occurrence of jelly fishes (*Acromytis* sp.) during February to April. This species appear regularly from the second half of February and slowly swims towards the upper reaches of the estuary. By March, they were abundant from Cochin to Alleppey indicating the presence of high saline water throughout the backwater.

Results and Discussion

The Vembanad Lake and the adjacent backwaters are more affected by the monsoons. This results in pronounced seasonal variations in the environmental parameters as well as in the primary and secondary productions. Changes in the environmental parameters and production are also caused by the fresh water influx, nutrients distribution, incident solar radiation, nature of the medium and species composition of the primary and secondary producers. As several rivers empty into the backwater in the southern and northern halves and the system is also connected to the sea at two locations it is quite natural to have a place to place variation in the nutrient concentration and the salt content of the medium. But the impact of the above features are reduced to a certain extent by water currents, tidal effect and also by the mixing processes.

To determine weather the variations in the production from station to station and from month to month were significant or not, the technique of analysis of variance was applied to the logarithm of primary production rates. Only four monthly observations could be used in this analysis as only during these months data were available for all the stations. The result is given in Table - I.

Table - I. *Analysis of variance of logarithm of Primary Production rates*

Source	S.S	D.F	M.S
Total	5.0785	27	
Between months	0.9366	3	0.3122*
Between stations	2.6587	6	0.4431**
Error	1.4832	18	0.0824

* Significant at 5% level

** Significant at 1% level

The spatial variation in primary production is highly significant and is more than the variation in time (months) which is significant at 5% level. The mean of the logarithm of production rates in the order of abundance are given below.

Station.	VI.	IV.	I.	V.	VII.	III.	II.
Mean.	1.9000	1.8496	1.7073	1.5648	1.4750	1.3923	0.9197

The means are based on the data used for the analysis of variance. To locate the stations which caused the significant difference, the difference 'D' of T. W. Turkey as given by G. W. Snedecor (1956) was calculated. From the D value of 0.6701, the production at station II was found to be significantly less than those at stations 1,4 and 6. If station 2 is set apart, there is no detected difference in the other stations.

The zooplankton data for six months (February, March, April, July, November and December) and representing fifteen groups were used for the analysis of variance which was applied to examine the difference in counts from place to place, from time to time and from group to group and also to see whether there were any significant interactions between any two of the three factors; space, time and groups. To stabilize the variance, the counts were converted to the logarithmic scale. To tackle 'O' counts '1' was added to each count before taking the logarithm. The results of this analysis are given in Table - II.

Table - II. *Analysis of variance of logarithm of Zooplankton counts*

Source	S.S	D.F	M.S
Total	1,519,2093	629	
Between stations	8.7704	6	1.4617+
Between months	57.4028	5	11.4806**
Between groups	798.9474	14	57.0677**
Station x month	34.3350	30	1.1445*
Station x group	58.8950	84	0.7011
Month x group	277.7680	70	3.9681**
Residual	283,0907	420	0.6740

* Significant at 5% level

** Significant at 1% level

+ More or less equal to the tabulated value of F at 5% level

The monthly variation in the counts is found to be highly significant (at 1 % level). So also is the variation between groups. Further observations are required to conclude whether the variation in the counts between stations is significant or not because the tabulated value of 'F' at 5 % level and the calculated value are more or less equal. However, compared with the monthly variation the spatial variation is low. As the interaction between stations and months is significant, it appears that the pattern of seasonal variation in the counts differs from place to place. The interaction between months and groups is found to be highly significant which shows that the different groups are abundant during different months. It appears that the groups do not have any particular preference for any particular station as the interaction between stations and groups is not significant. Thus the months, the groups and the interaction between these two appears to account for a good amount of variation in the counts. The group-wise mean monthly counts is given in Table - III. (The means of logarithmic counts are retransformed to the original scale. Thus the counts presented are the geometric means of the original counts).

From the results discussed above, it is evident that variation over time is significant in both zooplankton counts and primary production rates. But spatial variation is detected to be significant only in the primary production rates. However, significant spatial variation in the zooplankton counts cannot be ruled out.

To determine the extent of influence of the environmental factors of the estuary on the primary and secondary productions, the correlation coefficients were calculated.

Table - III. *Groupwise means of monthly counts of Zooplankton*

Zooplankton	1971 Feb.	Mar.	Apr.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1972 Jan.
Copepods	27869	3329	1097	48	490	1148	11359	646	2335	724	25029
Decapod larva	880	765	3052	9	200	197	344	396	963	231	12549
Crab zoea	31209	4165	18	2	0	0	0	0	0	0	0
Lucifers	334	845	2245	0	0	0	4	0	5	27	77
Jelly fishes	0	1	0	0	0	0	0	0	0	0	0
Hydromedusa	12	8	12	0	0	0	0	0	0	0	0
Amphipods	0	0	0	0	1	21	0	13	8	31	295
Cladocerans	0	0	0	0	0	0	84	13	45	0	0
Isopods	0	0	0	0	0	0	1	0	0	4	2
Cirripid nauplius	34	2	0	0	0	0	0	0	0	2	0
Oikopluera	32	2	14	0	0	0	0	0	2	2	0
Chaetognaths	0	0	0	0	0	0	0	0	0	9	2
Ctenophores	4	0	0	0	0	0	0	0	0	0	0
Mysids	0	0	2	0	0	0	0	0	0	0	0
Cumaceans	0	0	0	0	0	1	2	18	0	0	0
Copepodites	0	0	0	0	0	0	4	0	0	0	0

Table-IV. *Simple and Partial Correlation Coefficients*

r_{ZS}	r_{ZT}	r_{ZP}	r_{ST}	r_{SP}	r_{TP}	$r_{ZS.T}$	$r_{ZT.S}$	r_{PH}	r_{PN}	$r_{PH.N}$	$r_{PN.H}$
0.6552*	0·3456*	0.1056	0.4866**	0.1096	- 0.1039	0.5940**	0.0406	- 0.4858**	0.2161	- 0.4744**	0.1816

* Significant at 5% level ** Significant at 1% level T Temperature S Salinity H Phosphate N Nitrite
P Log of primary production Z Log of zooplankton counts

The correlation coefficients did not reveal any significant relationship between primary production and temperature or salinity, (both γSP and γTP being not significant). It is true that salinity has apparently no influence on primary production. But in an estuary, salinity is one of the important factors which determines the species composition and sucession of phytoplankton. However, the quantum of production is not much affected by the changes in salinity due to the replacement of suitable organisms along with the displacement of the medium and also due to the salinity tolerence of certain species constituting the phytoplankton. While the nitrite did not show any relationship with primary production rates, the phosphate showed a negative relationship (as evidenced by the highly significant negative partial correlation coefficient γPH. N). In the present study, since data on NO_3-N were not available it was not possible to calculate the N:P ratio. But the inorganic phosphate showed comparatively high values (the maximum value recorded was 32 μ g at/l) and also a trend of increase in primary production rates were observed with low inorganic phosphate contents especially during the post-monsoon period of September-November. Qasim *et al*, (1969) stated that while there is a close correlation between the cycles of phosphorus and organic production in the backwater, the nitrogen cycle is completely unconnected with productivity rhythm, for most of the year there is little or no Nitrite-N in the water. However, our data do not permit to arrive at any definite conclusion about the negative correlation observed. Sankaranarayanan and Qasim (1969) observed that there seems no firm basis, for believing that the instantaneous concentration of nutrients as inorganic salts in the estuary provide a significant source of phytoplankton bloom.

The influence of salinity on zooplankton production is evident from the highly significant value of the partial coefficient of correlation between Log zooplankton and Log salinity, γZS. T. Pillai *et al*, (1973) did not find any significant correlation between zooplankton biomass and salinity for the Cochin backwater. But they observed significant coefficients of correlation between copepod species (a major component of zooplankton in the area) and salinity. The significance of γZS. T in the present study suggests that the groups constituting the zooplankton population and predominent in the estuary prefer high salinity. It is thus possible that a large part of variation in zooplankton abundance in space and time is brought about by the variation in salinity. The significant relationship between zooplankton and temperature as evidenced by a significant γZT appears to be spurious, because the partial coefficient of correlation γZT. S is not significant. Salinity and temperature being highly correlated (γST significant at 1% level) high salinity will be associated with high temperature, which explains the spurious relationship between zooplankton counts and temperature. As the coefficient of correlation between Log zooplankton and Log primary production, γZP is not significant, it appears that primary production is not a limiting factor for secondary production in the estuary. In other words, the secondary producers are not proportionately converting the primary producers available in the estuary. The reason for not maintaining the conversion ratio between the primary and secondary trophic levels is possibly due to the interference of salinity.

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