A STUDY ON THE PRIMARY PRODUCTION IN THE VEMBANAD LAKE

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ABSTRACT

This paper forms part of a study on the phytoplankton standing crop, primary production and related properties in the Vembanad Lake and connected backwaters extending from Alleppey in the south to Azhicode in the north. A total area of 300 sq. km. has been covered by 28 stations for hydrographic properties and 7 stations for primary and secondary production. In the composition of phytoplankton, spatial heterogencity is observed with fresh water, estuarine and marine forms distributed at different regions. The standing crop does not always reflect the photosynthetic production which has regional and spatial variation in the magnitude. The annual gross production ranges from about 150 to 650 gC/m2/day maximum during pre-and post-monsoon period unlike in the adjacent marine environment. Total organic production in the Vembanad Lake has been estimated as 10,00,000 tonnes of carbon. The quantum of respiration by zooplankton and the surplus quantity left for alternate pathways in the food chain have been indicated.

INTRODUCTION

Considerable knowledge has been gained in recent years on the productivity parameters such as chlorophyll, solar radiation and nutrients of the Cochin backwaters (Qasim and Reddy, 1967, Qasim *et al.*, 1968 and 1967). The organic production was studied by Qasim *et al.*, (1969) using various techniques and they came to the conclusion that the gross production ranges from 272 to 293 gC/m^2/year with an average of 280 gC/m^2/year, while the net production for a day is 184 to 202 gC/m^2/year with an estimated annual consumption by zooplankton herbivores of 30 gC/m^2 leaving a large surplus basic food in the estuary. The above mentioned investigations cover only a rather limited area around Cochin and so far it has not been examined whether these observations hold good for the entire

Vembanad Lake system with the connected backwaters extending from Alleppey to Azhicode. The present study was commenced in 1971 to assess the magnitude of primary, secondary and tertiary production and also the available prawn resources of the Vembanad Lake and connected waters which forms an important nursery ground for the penaeid prawns on the south west coast of India. The aspects dealing with the higher trophic levels and prawn resources estimated from dry net collections have been dealt in another account by Pillai *et al.* (M. S. 1974). Besides, the hydrography and plankton have been earlier investigated by Ramamritham and Jayaraman (1963) and George and Kartha (1963); and the benthic fauna by Desai and Krishnan Kutty (1967).

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ENVIRONMENT

The area of investigation covers the extensive backwaters from Alleppey in the south to Azhicode in the north (90 km. S-N) including the Vembanad Lake. The depth varies from 1.5 to 10 m. and the total area is about 300 sq. km. On the northern half there are two permanent openings to the Arabian Sea, at Cochin and Azhicode respectively. There are five major rivers connected with the backwaters through their tributaries and branches. On the southern half the rivers Pamba and Muvattupuzha joins the Vembanad Lake. On the northern half the Periyar River joins the backwaters through its tributaries. All these rivers periodically enrich the area by flood waters bringing along with them nutrient-rich water and considerable quantity of silt. Seven stations were fixed for observations.

MATERIAL AND METHODS

Carbon production was measured by C^{14} technique. 5μ curie of $NaHC^{14}O_3$ 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%. CO_2 was determined separately for each stations. Chlorophyll *a* was determined by the method of Parsons and Strickland (1963) using a Unicam Spectrophotometer. Phytoplankton was collected using a 35 cm. bolting cloth net (mesh size 0.069 mm) and counted on Sedwick Rafter counting chamber.

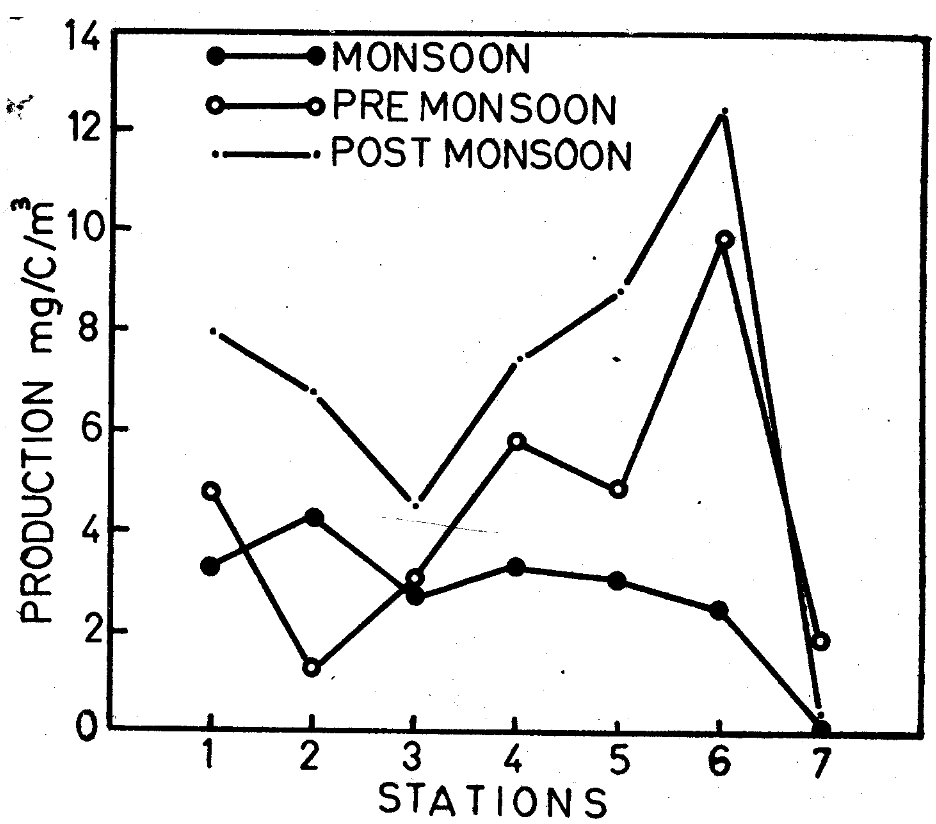

Fig. 1 Seasonal and spatial variation of primary production in Cochin backwaters.

FACTORS AFFECTING THE PRODUCTIVITY

The nutrient cycle governing the productivity of the area has been investigated by Sankaranarayanan and Qasim (1969). The distribution of nutrients is largely dependent on the marine influence and fresh water discharge. When the estuarine system remains predominently marine, the nutrient concentrations are low and homogeneous throughout the water column, while during the period of fresh water discharge high concentrations of nutrients occur.

Highest concentration of PO_4-P are observed in the southern region of the Lake either during the monsoon or during the post-monsoon period. Very high concentration of PO_4-P are observed only in the southern regions whereas in the lower reaches, PO_4-P values are low. The uneven distribution of phosphate has been attributed to external sources like land drainage and fresh water runoff.

In the Cochin backwater, Sankaranarayanan and Qasim (1969) observed three peaks, one towards May and June when the first pre-monsoon showers set in. Phosphate values decline sharply after the peak and another peak appears in August-September. A third peak appears in October in certain stations which do not coincide with the preponderence of rainfall. However, one characteristic difference observed in the present investigation is the unusually large amount of PO_4-P as compared to earlier study. The maximum value observed by Sankaranarayanan and Qasim (1969) has been around 2 to 2.5µg at/l while values exceeding 15µg at/l have been observed very commonly during monsoon and pre-monsoon period. On one occasion it attained a value of 32µg at PO_4-P/l indicating a level of eutrophication. The NO_2-N values do not seem to be affected by the fresh water discharge. Most of the values are within 1µg at/l except at one of the stations in the pre-monsoon period. When the value approached 6µg at/l bottom values are slightly higher. Sankaranarayanan and Qasim (1969) in their study of the Cochin backwaters have observed a trimodel cycle with a peak occurring during a period when the system remains fresh water dominated. They found that NO_3-N occurs in very high concentrations during the monsoon period especially in the surface waters. These authors have suggested that the NO_2-N may be formed as a result of decomposition of organic nitrogen and as it is a transitory stage in the nitrogen cycle and its progressive decrease from the surface to the bottom suggests its possible conversion into NO_3-N.

SALINITY

Though the salinity does not have a significant bearing on the primary production of Vembanad Lake, the constituent flora responsible for primary production differs forming different ecological zones due to its influence. During the pre-monsoon period when the salinity is very high in the Lake the southern-most stations are typically of estuarine nature. Towards the north there is a marked increase in the salinity approximating marine conditions. The surface salinity is generally low excepting at the nothern stations. During the monsoon period almost fresh water condition exists throughout the Lake at the surface. There is stratification because of the incursion of shelf waters which remains at the bottom. During the post-monsoon, brackish water condition exists along the greater part of the lake system. A pronounced gradient in the salinity continues for some period during the post-monsoon also.

PRODUCTIVITY

The standing crop as measured by chlorophyll *a* shows distinct spatial variation. The southern stations and the northern extremity shows the lowest standing crop whereas the two stations adjacent to the Cochin barmouth has the highest chlorophyll concentrations. From a little over 2 mg/m^3 at the stations which have got the highest influx of fresh water it varies to 21mg/m^3 at stn. 6, north of Cochin which has got the highest standing crop as well as the carbon production. The trend seems to persist both during premonsoon and post-monsoon period. But during the monsoon months the standing crop is of a lower magnitude almost throughout the lake compared to the other seasons.

Estimates of the total cell counts/m^3 as obtained by filtering through phytoplankton net do not tally with the chlorophyll values as may be seen from the figure (Fig. 2). This would perhaps be due to the combined effect of the loss of nannoplankters through the meshes of the bolting silk as well as the influence of the detrital chlorophyll in the measurements which will have opposing results. In terms of cell numbers, stations 2 and 3 are having the highest phytoplankton concentration during the pre-monsoon period and at station 5 during the post-monsoon period. Though these values do not suggest much on the composition and quantity of the standing crop it is indicative of the spatial variation in the nature of the constituent flora within the lake system.

Primary production measured by C^{14} shows wide fluctuations from station to station and season to season (Fig.1). Unlike in the inshore environment on the west coast when maximum production occurs during the monsoon period, in the Vembanad Lake relatively higher rates of production are observed during the other periods. The rate of production is uniformly high in almost all the stations exceeding 10mg/m^3/hr. In terms of chlorophyll as well as rate of production, station 6 is the most productive with an average daily rate of 1200 mgC/m^2/day which persists almost throught the year, highest single value being about 3000 mgC/m^2/day. It was not possible to measure the extinction coefficient and depth of the euphotic zone and conduct experiments throughout euphotic zone. However, assuming that the light penetration and depth of the euphotic zone is same as in Cochin backwater it may be taken as 3 m. in monsoon and 4 m. in pre and post-monsoon. The Seechi disc visibility readings (1 to 1.5 m) also confirms this. Hence the rate of production in the water column may be assumed to be 1.5 to 2 gC/m^2/day. This would amount almost twice the rate of annual production obtained in the Cochin backwater (Qasim *et al.*, 1969) The measurements by C^{14} further confirm the spatial variability in the

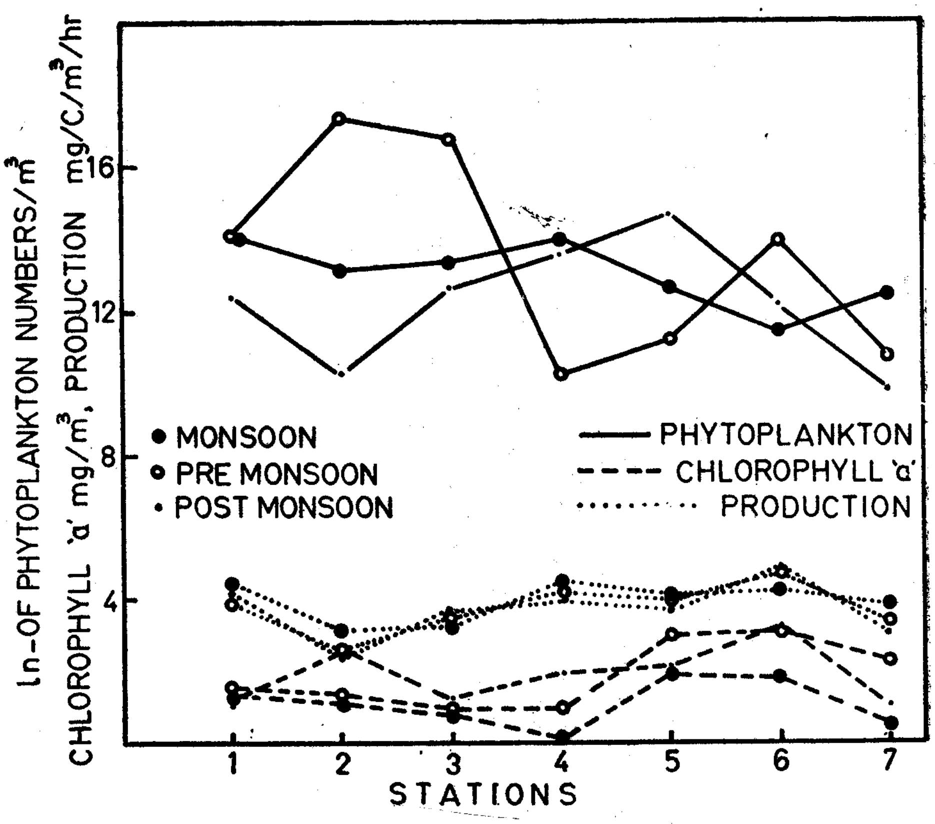

Fig. 2 Season-wise (Pre-monsoon, Monsoon and Post-monsoon) distribution of Phytoplankton, Chlorophyll and Primary production in Cochin backwaters.

Vembanad Lake as observed in the standing crop. For comparison, one of the least productive station on the southern side of the lake can be taken (stn. 2). The average rate of production amounts to 200 mg/m^3/day. The column production for euphotic zone is a little less than 0.5 gC/m^2/day. Hence an annual gross production of ca. 150 gC/m^2 seems to be the minimum rate of primary production in the Vembanad Lake.

Likewise at station 1 the annual gross production is a little over 500 gC/m^2. This amount of production is high but not unusual in such euphotic areas in marine environments (Strickland, 1965). It is likely that the enrichment of the waters may be from the adjacent paddy fields where artificial manuring is carried in large scale. Perhaps a suitable nitrogen-phosphorus ratio and a deeper euphotic zone would have resulted in still higher rates of production. Station no. 2 with an annual rate of 150 gC/m^2 is the least productive zone of the Vembanad Lake as pointed out earlier. The standing crop at this station does not imply a reduced rate of primary production compared to station 1. The average cell numbers are even higher due to the presence of *Cerataulina, Chaetoceros* and *Skeletonema*. The migration of euhaline sp. of *Chaetoceros* and *Skeletonema* to a weak estuarine condition could result in the physiological imbalance of the chloroplasts thereby reducing the rate photosynthesis. On the other hand, at station 1, typical fresh and brackish water forms are found to dominate which maintain physiological stability due to optimum environmental conditions.

Station 3 has 220 $gC/m^2/yr$ which is near about the typical average rate of production that is found in the backwater. Station 4 and 5 have almost the same magnitude of production and standing crop as in station 1. Here typical estuarine conditions and characteristic flora are predominant for most part of the year resulting in a sustained rate throughout.

The northern most station (stn. 7) is just about moderately productive. There is considerable admixture of inshore water through the barmouth into this area excepting during the monsoon floods. During this period the level of chlorophyll and rate of organic production drops to the lowest point. However, due to the moderately high rates during the rest of the season a gross annual production of nearly 220 gC/m^2 is recorded. This is considerably lower than the near shore values recorded by Nair *et al.* (1968). Inspite of seasonal and spatial variations the annual gross production for the entire Vembanad Lake comprising about 300 sq. km is about 1,00,000 tonnes of carbon which is a minimal estimate.

Discussion

In an earlier study on the seasonal and spatial variation of phytoplankton confined to a part of the lake by Gopinathan *et al.* (M. S. 1974) it was found by analysis of variance that the spatial variations in the magnitude of standing crop was as high as the seasonal variation. The observation on the pigment stocks (Qasim and Reddy, 1967) also indicates that it varies considerably from place to place and from time to time or with the state of tide. Primary production was significantly higher at the flood tide than at the ebb tide (Qasim and Gopinathan, 1969). The present observations on phytoplankton and primary production extending throughout the entire Vembanad lake system further confirm the seasonal and spatial variability.

During the pre-monsoon the phytoplankters were mostly marine in the lower reaches of the lake as the salinity was comparatively high reaching upto about 34 ‰. The flora was constituted by diatoms such as *Chaetoceros, Coscinodiscus, Skeletonema, Pleurosigma* and *Nitzschia* and dinoflagellates such as *Peridinium, Gymnodinium* and *Ceratium*. The highest rate of production of 98.8 mg $C/m^3/hr$ was observed near stn. 6 in the northern part of the backwaters. The maximum chlorophyll *a* concentration (206 mg/m^3) was also recorded in the same area. The cell counts were compatible. Thus more or less a direct relationship of the three parameters is found here. This may be attributed to the optimum nutrient concentration, salinity and temperature which render the organisms physiologically very active. The higher O_2 values in the area is a clear evidence of the considerably higher photosynthetic efficiency of the phytoplankters. The lowest organic production during this period (10.5 mg $C/m^3/hr$) was recorded near stn. 2 where the largest numbers of phytoplankters of all the three seasons was observed. Such anomaly may be due to the retardation in the physiological conditions of phytoplankters caused by high temperature, low salinity and nutrient concentration.

The advent of monsoon tilts the whole picture of the flora, it inactivates the marine species present, and goes upto the extent of replacing marine species by fresh water species in certain areas. During this season the southern most region turns out to be a typically fresh water environment recording the highest production of the season (84 mg $C/m^3/hr$). It was mainly the contribution of fresh water species such as *Pledorina, Pediastrum, Scenedesmus, Zygnema, Oscillatoria, Cosmarium, Desmidium* and *Staurastrum*. A switch over from a salinity of 11 ‰ in the pre-monsoon to less than 0.5‰ results in the disappearance of marine species. The optimum temperature with sufficiently high amount of nutrients enhance the photosynthetic efficiency of the fresh water species. At stn. 2 the picture is quite different. The production (23 mg $C/m^3/hr$) is the lowest recorded in the season with low chlorophyll contents but with considerably large numbers of phytoplankters. A slight increase in the salinity renders the fresh water species physiologically inactive resulting in very low production. On reaching the outlet of Ithypuzha River (stn. 3) no environmental factors seem to limit the photosynthetic rate and hence the production is comparatively high. Hence the flora comprises mostly of fresh water species of Chlorophyceae. Thereafter the production values show an increasing trend till there is decline in the values at the northern most station. This increasing trend of production is coupled with increasing salinity and gradual replacement of fresh water species with marine ones. The decline in the production values in the last station may be due to the reduction in the salinity and nutrient concentration.

The post-monsoon season is characterised by an increase in salinity. The average salinity varies from about 8‰ near station 3 to about 24‰ in the north at station 6. During the process of gradual tramsition from fresh water habitat, fresh water species to some extent succeed in acclimatising themselves in low salinity conditions. The presence of fresh water species in areas of low salinity (stn. 1 & 3) is an indication to their low salinity tolerance. But, these species completely disappear with the further increase in salinity as evidenced by their total absence in the pre-monsoon.

Of the main ecological factors which determine the rate of primary production in the estuary, the influence of nutrients has already been pointed out. During the monsoon and post-monsoon period although tidal influences bring in large volume of the sea water into the estuary, fresh water influx far surpasses that of the saline water and therefore surface salinity continues to be low whereas the sea water remains as a distinct bottom layer with sharp gradients. This bottom water of the estuary is considered as the same as the upwelled water of the Arabian Sea which has spread over the continental shelf (Ramamritham and Jayaraman. 1963). This nutrient-rich water when moves upto the euphotic zone triggers high rate of primary production in the inshore environment. But in the estuary, since there is considerable resistance to the mixing of the bottom waters with those of the surface almost till the end of October, effective utilization of the nutrients does not take place till that time. This accounts for the lower rate of primary production during the monsoon and progressive increase during the subsequent period.

With an annual average rate of gross production ranging from 150 to 550 g C/m^2 at different regions and the total annual gross production of 100,000 tonnes of carbon for the entire Vembanad Lake it can be considered as a very highly productive area almost comparable to the inshore area of the seas around India where there is constant replenishment of nutrients. However, certain problems in the food chain relationship have been raised by the earlier workers (Qasim *et al*, 1969 and Qasim, 1970). Of the gross production, 20 to 45% can be considered to be used for respiration and from the net production available to the next trophic level only a very small portion is supposed to be used up by the zooplankton (30 g C/m^2/year) leaving a large surplus of basic food (Qasim *et al*, 1970). Hence it has been suggested that there may be alternate pathways in the trophic chain and it is difficult to determine quantitatively how much from the surplus production would be utilized by these consumers. Qasim (1970) has suggested that one such pathway may be linked with herbivorous fishes which are found in the lake in appreciable numbers and another direct link from the basic food through detritus with prawn population which are omnivorous. As the euphotic zone is considerably less in the lake a good part of the phytoplankton production while sinking below the euphotic zone could form food of the benthic animal communities. Thus the magnitude of primary production of the Vembanad Lake could sustain a very rich biota of organisms feeding at different trophic levels.

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