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STUDIES ON PRIMARY AND SECONDARY PRODUCTION IN RELATION TO HYDROGRAPHY IN THE INSHORE WATERS OF TUTICORIN

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ABSTRACT

The results of hydrobiological investigations conducted in the inshore waters off Tuticorin during 1983-84 have been presented. The primary production estimated by oxygen technique indicated three distinct peak periods, the first during January-March, the second during June-August and the third during October-December. The trend of secondary production closely followed that of primary production. Zooplankters were found to be abundant during May-September and again a short secondary peak was noticed during November-January. The occurrence of different zooplankters showed a definite seasonal fluctuation. The physico-chemical properties of the seawater showed variations in space and time. A general picture of the environmental conditions of the inshore area, based on the earlier observations along with the present observations of primary and secondary production are discussed in this account.

INTRODUCTION

ATTEMPTS to correlate the rate of primary production and abundance of zooplankton with prevailing hydrological conditions are rare from this region. While relatively more information is available on the plankton and hydrography of the waters in other areas of the east coast (Chacko and Malu Pillay, 1957 ; Chacko and Rajendran, 1959 ; Chidambaram *et al.* 1951; Ganapati and Rao, 1953 ; Ganapati and Murty, 1954 ; Ganapati and Sarma, 1958 ; Prasad, 1954, 1956, 1958 ; Prasad and Nair, 1960, 1963 ; Prasad and Kartha, 1959), our knowledge of the plankton of the inshore area off Tuticorin is restricted to the accounts of Sambandamurty (1962) and recent work of Marichamy and Pon Siraimeetan (1979). An estimate of potential resources was made by Prasad and Nair (1963) from primary production in the Gulf of Mannar. In present account an attempt has been made to study the primary and secondary production of the inshore waters off Tuticorin in relation to the hydrological conditions based on the data collected during 1983-84.

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MATERIAL AND METHODS

Fortnightly collections were made on board the research vessels *Cadalmin IV* and *M.L. Chippy* of the Institute. Water samples were collected from surface and bottom regions (10-15 m) between 0600-0900 hours from the inshore area. Although 3 stations were samplep in the inshore area (Fig. 1), the data showed similar trend and hence only pooled values

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for these stations are presented here. Light and dark bottle oxygen technique (Gaarder and Gran, 1927) was employed for measuring the primary production on board the research vessel using neutral density filters in deck incubators. Uniform time was given for the samples and fixed by Winkler's method for the

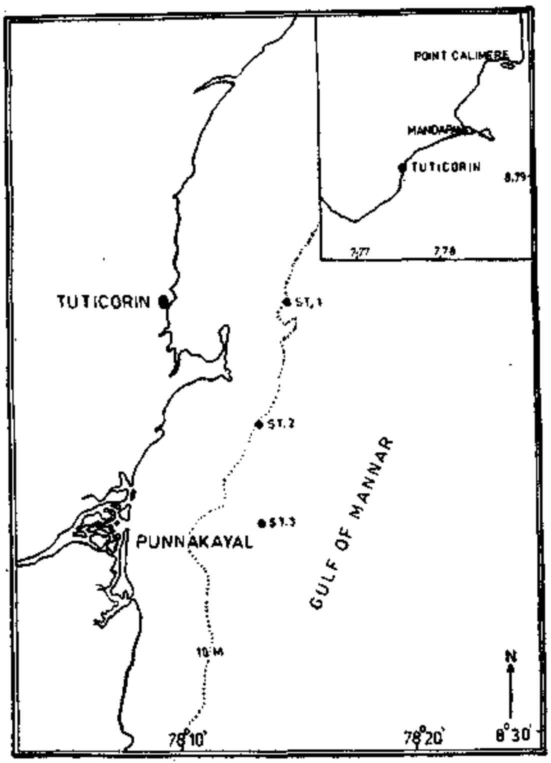

FIG. 1. Sampling stations in the inshore area off Tuticorin.

estimation of oxygen and converted the same for carbon equivalent using a PQ of 1.25 for obtaining the gross production.

The hydrological factors, studied simultaneously with the primary production and zooplankton abundance, were surface temperature, turbidity, salinity, oxygen, pH and nutrients such as inorganic phosphates and nitrite. The estimation of both physical and chemical parameters of the water followed was the same as by Strickland and Parsons (1968). The secchi disc was employed for the measurement of turbidity of the water.

The surface zooplankton was collected by a half-metre mouth diameter bolting nylon net (mesh size 0.33 mm) by towing the same in uniform speed (1 knot/hr) for ten minutes. The sample was immediately preserved in 5% formalin. The volume of plankton was measured by displacement method. Fish eggs and larvae were specially determined for the whole sample throughout the period while the other constituents of zooplaukton were observed in a subsample. The fluctuations in the primary and secondary producers and physico-chemical conditions are discussed in terms of monthly averages.

OBSERVATION AND RESULTS

Turbidity

The clarity of water as evidenced by secchi disc visibility of the inshore region ranged from 1.5 m to 7.5 m in different seasons (Fig. 2 a). Turbidity of the water was less during the months June-December '83 with slight fluctuations. However, during the year 1984, the clarity of the water column was moderate (5.5 m).

Temperature

The monthly average values of surface and bottom waters along with air temperature are shown in Fig. 2 b to indicate their relationship. The similarity in the curves reveal that the surface temperature is considerably influenced by the air temperature. This fact has been pointed out by Chacko *et al.* (1954) and Prasad (1958) for the Gulf of Mannar regions. It can be seen from the figure that air temperature was above the surface temperature continuously from March-August during 1983 and then January-March and August-September during 1984. The temperature of the surface water was well above the air temperature during

October-December '83 and April, July, October-November of '84. Similarly, the temperature of the bottom samples showed high values than the air temperature during January-February, September-December '83 and June-July, October-November of '84. Similar trend of high values were observed earlier by Prasad (1958) from the Gulf of Mannar. Both the air temperature and surface water temperature steadily increased from the winter low level upto April-May when it reaches the peak. The temperature gradually declined thereafter till August when the southwest wind is active. A secondary rise in surface temperature was noticed in September-October and afterward registered another fall during December-January when cooler weather prevailed. The general trend of temperatures exhibited a bimodal oscillation in 1984. Two maxima were noticed, one in March-April and the other in September-October, corresponding to the two dry seasons and the two minimum in June-July and December-January corresponding to the cool seasons prevailing in the Gulf of Mannar area.

Salinity

The monthly average values of salinity varied from 31.7 to 35.2‰ during the period of observations (Fig. 2 c). There was no much variations noticed from surface to bottom. The surface salinity steadily increased from January to March. From the peak of April-May, the salinity declined gradually in the following months. The decline continued from July coinciding with the southwest monsoon though not prominent. The salinity increased further to a secondary peak during September-October. With the onset of the northeast monsoon, a marked change in the salinity was observed during November-January. After the secondary fall, the salinity increased steadily until the commencement of southwest monsoon. Due to the failure of northeast monsoon in 1984, the monthly average values of salinity was well above 32‰ during November-December. The present observation clearly indicated a bimodal fluctuation in salinity with two maxima and two minima coinciding the temperatue fluctuations in the course of the year as has been pointed out earlier by Marichamy and Pon Siraimeetan (1979) from the Gulf of Mannar.

Oxygen

Both surface and bottom regions showed a high primary peak during February and a low secondary one during June 1983 (Fig. 2 d). However, the bottom regions showed a high value during September when the surface value was very low. Similarly during May, 1984 the values at surface was well above the bottom. These rises of oxygen values may be attributed to the production of oxygen liberated from the phytoplankton. The high values of primary production during following months also proved this fact clearly. Fall in dissolved oxygen content generally noticed with a rise in temperature and salinity.

pH

Similar to the variations of dissolved oxygen content, the pH of the water column also exhibited a bimodal variation (Fig. 2 e). The two maxima were recorded during May-June and September corresponding to the two dry seasons. The lowest value of pH was noted during April and October. In general the trend of fluctuation of pH at the surface and bottom regions did not show much difference.

Phosphate

The Fig. 2 f clearly shows wide fluctuations of phosphate at the surface and bottom. However, the surface phosphate values are always higher than the bottom. A unimodal variation in the values of phosphate was observed with a single peak during October to January and a minimum of negligible values during August-September. These low values

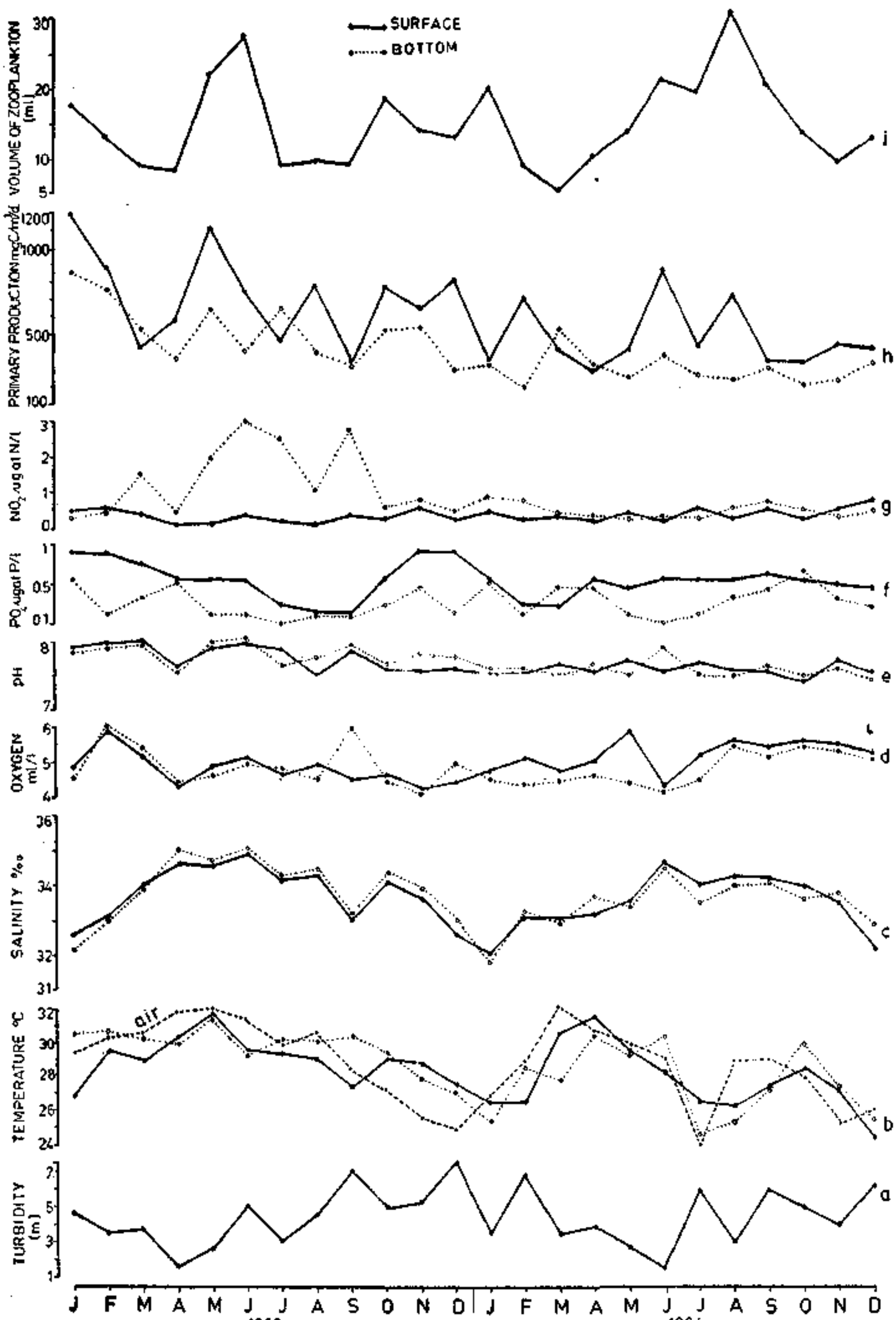

FIG. 2. Seasonal abundance and variation of different hydrological factors along with primary and secondary production.

of inorganic phosphate coincided with the peak periods of primary production suggesting higher utilisation by phytoplankoton.

Nitrite

The surface values showed wide fluctuations when compared to the bottom which was steady throughout the period of observations (Fig. 2 g). During May-July and September, the values at the surface showed slight increase while in other months negligible values were noticed indicating that nitrite-N has been utilised by the phytoplankton during the growth. Further, these low values coincided with the high values of primary and secondary production.

Primary Production

It is seen that wide range of fluctuations were noted between the values at the surface and bottom (Fig. 2 h). In comparison to the various hydrologicial parameters, the primary production indicated three seasonal peak periods ; one during January-February, the second during June-August and the third during October-December. However, the magnitude of production was very high during June-August compared to other periods. Also the surface production was found to be higher than the bottom. A fall in temperature and salinity in the corresponding peak periods may be seen from the figure. The peak periods of nutrients such as phosphates and nitrites studied during this investigation showed an inverse relationship with the primary production suggesting that the phytoplankton, the source of primary production might have utilized these nutrients for its rapid multiplication and thereby showing the higher rate of production.

Zooplankton

The zooplankton of the inshore area off Tuticorin is rich in quantity and variety, exhibiting regular seasonal variations (Fig. 2 i). The high rate of phytoplankton production, measured in terms of primary production has got an important bearing on the production of zooplankton also. The displacement volume of zooplankton indicated two peak periods, the primary one during May-June with high magnitude and a secondary one during January-February and sometimes an inter peak either in September or October. A reduction in the volume of zooplankton was noticed during March-April. After this decline in the summer, the volume of plankton steadily increased reaching a peak during June '83 as well as in August '84. The zooplankton population appeared to be steady and moderate during October-November.

The studies on the seasonal distribution of the various planktonic groups revealed a quick and marked change in the composition of the plankton with the onset of rains although the volume of plankton does not bear any direct relationship. The high standing crop during May to September was constituted largely by copepods, decapods and lamellibranchs. The seasons of occurrence of the dominant forms do not appreciably change, but the magnitude of production has been observed to vary in some grups.

The zooplankton consisted mainly of copepods, decapods, lucifer, chaetognaths, gastropods, lamellibranchs, appendicularians, amphipods, stomatopods, pteropods, polychaetes, siphonophores, cladocerans, foraminifers and fish eggs and larvae. Among the common forms, copepods, decapods, chaetognaths, gastropods, lucifers, lamellibranchs, appendicularians and fish eggs and larvae were the most dominant, present almost throughout the year. The seasonal variations of the common zooplankters which occur in the plankton almost round the year are presented in Fig. 3. Several other groups including the larval forms of molluscs, which were very rare in appearance were categorised as 'miscellaneous'. Foraminifera were observed in the sample during February-March

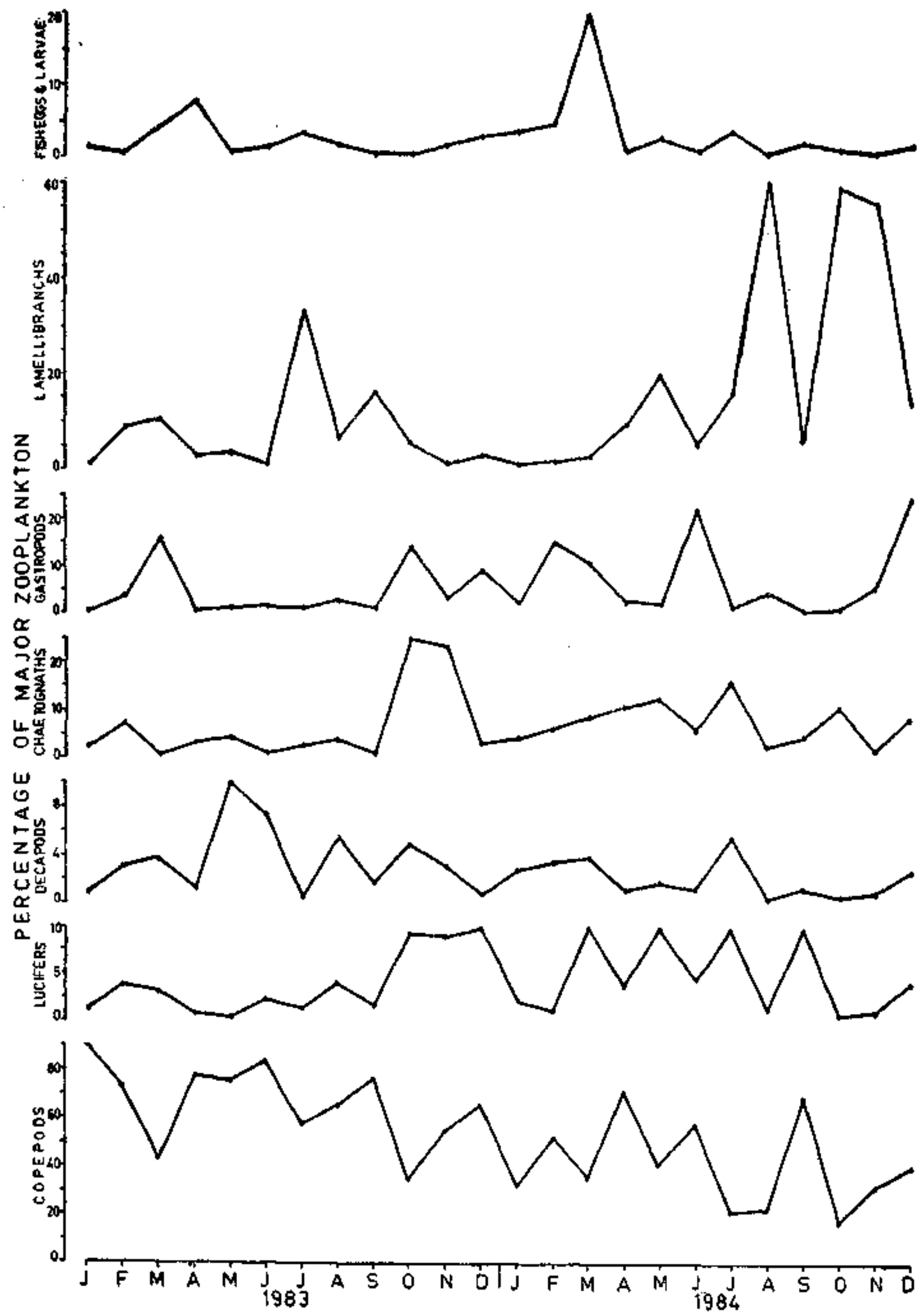

FIG. 3. Percentage composition of major zooplankton groups.

and November-December period of both the years. Siphonophores occurred during February, April, October and November. Polychaetes, amphipods, pteropods and cladocerans though negligible in proportions were noticed during March-June and October-November periods.

The distribution pattern of the common zooplankton groups and their relative percentage composition (Fig. 3) in the total volume of plankton revealed that copepods rank first among crustaceans and found to be present throughout the year. The total population and number of species vary widely. However, the bulk of the population constituted by calanoids. Followed by the copepods, decapod larvae, chaetognaths, gastropods, lamellibranchs, lucifers and appendicularians also found to be present in moderate numbers in all the samples.

A higher concentration of fish eggs and larvae observed during April '83 and March '84 indicate the possible spawning periods of various fishes of this area in post-monsoon season which may be attributed to the increase in surface temperature and salinity from January to April as seen in Fig. 2 b, c.

Discussion

It has been observed by earlier workers (Malu Pillay, 1962; Freda Chandrasekharan and Sudhakar, 1968) that a double oscillation in surface temperature and salinity has been found along the Tuticorin Coast. However, unlike the Mandapam area, a bimodal fluctuation in salinity has been observed by Marichamy and Pon Siraimeetan (1979). According to Jayaraman (1954) that the most important factor governing the seasonal distribution of salinity in these waters are the two monsoon-driven current system. Malu Pillay (1962) has correlated the declining salinity values recorded during June-July, to the effect of heavy rain the south and east Arabian Sea and in the catchment area of river Thambaraparani. According to Marichamy and Pon Siraimeetan (1979), since the southwest monsoon is negligible, the primary fall of salinity during June-August could be attributed to the effect of the coastal current from the southern part of the Arabian Sea around the penisula and flowing on the southeast coast to some extent.

Generally, the southwest monsoon was not active along the Tuticorin Coast and hence its influence on the general planktonological and hydrological conditions was negligible. The northeast monsoon which starts in late September or early October was observed to exert influence on the environmental conditions of the coastal waters. Prasad (1956) observed an inverse relationship with salinity and the zooplankton in general in Mandapam area and Ganapati and Rao (1958) observed an entirely different relationship of zooplankton with the hydrological conditions of Waltair Coast. Recently Marichamy and Pon Siraimeetan (1979) has pointed out that in certain respects there were similarities and distinct differences too between the occurrence of various zooplankton groups with prevailing hydrological conditions. The present observations further confirm this view.

It is well known that the rate at which the nutrients especially phosphates and nitrates are utilized by the phytoplankton and returned to the water and its utilization is taken as a measure of the productivity of the area. The seasonal variation of the phosphate and nitrite content of the water (Fig. 2 f, g) revealed that these two nutrients have been utilized by the phytoplankton during the peak periods of production. The seasonal variation of phospate content of the water showed three high values before the peak periods of primary production. While the nitrite content of the water indicated a single peak during May to September '83, coinciding the second peak of primary production. In other months, very low values were noted and this suggest that the nitrite nitrogen content of the water column of the inshore area is utilized and regenerated by the phytoplankton much faster than the inorganic phosphates. In addition to this, it is also probable that the denitrifying bacteria occur in the water column. It is already established by earlier workers (Subrahmanyan, 1959 ; Qasim *et al.*, 1972 ; Gopinathan *et al.*, 1974) in the Indian waters that whenever there is a fall in temperature and salinity and sudden increase of nutrient enrichment in the water column, a high rate of primary production can be expected.

It is generally agreed that high levels of primary production will be succeeded by that of the secondary production. A closer examination of the Fig. 2 h and i will reveal that a rise in primary production is immediately succeeded by a rise in the volume of zooplankton. Harvey *et al.* (1935) explained the inverse relationship observed in the English Channel as a grazing phenomenon, while Hardy and Gunther (1935) advanced the theory of animal exclusion, which postulated avoidance of phytoplankton patches by the zooplankton. Riley and Bumpus (1946) found out a significant inverse relationship between phytoplankton and zooplankton of the Georges Bank and pointed out that several species were involved in the grazing which caused this relationship. Further, they made a theoretical attempt to determine rates of grazing. According to Raymont (1980) that variations in the onset and intensity of grazing, in addition to other factors, may greatly influenced the pattern of seasonal phytoplankton change in a restricted area, especially in coastal waters. In the present study the two peak periods of zooplankton production recorded in May to September and November to January, occurred a little later than the primary production blooms in January-March and June-August respectively, revealed the grazing phenomenon. The two zooplkankton peaks differ in quantity and volume and the difference is attributed to the corresponding differences in the magnitude of primary production as suggested by Steemann Nielsen (1937). Such inverse relationship between the primary and secondary producers has been noticed by number of earlier workers in Indian waters. In the inshore environment of Mandapam, Prasad, (1956) studied the inverse relationship between quantities of phytoplankton and copepods and Prasad and Kartha (1959) studied the breeding behaviour of copepods and its relatin to diatom cycle. Further, Prasad and Nair (1963) has measured the organic production of the waters of the Gulf of Mannar to determine the magnitude of production, its seasonal variations and the yield in terms of carbon with a view to assess the fisheries potential. Later, Nair *et al.* (1968) has studied systematically the productivity of the inshore waters of the Gulf of Mannar and Palk Bay regions and the east coast as a whole, the magnitude of carbon production and the potential resources derived from it.

Earlier observations reveal the bimodality in the occurrence of copepods in the Gulf of Mannar (Prasad, 1954). However, the distribution and fluctuations of copepods in the present period of study has resulted in more than 2 peaks in a year. Moreover, it is seen in Fig. 3 that a gradual decrease in the percentage distribution of copepods from 1983 to 1984. Similarly, a difference in peak season of *Lucifer* was noticed in October-December '83 and March-September '84 as aginst the unimodal cycle described by earlier workers (Marichamy and Pon Siraimeetan, 1979).

Prasad and Nair (1963) has stated that the waters of the inshore area off Tuticorin is remarkably productive due to the extensive photosynthetic zone especially near Punnakayal area. Prasad (1954) also observed in the Gulf of Mannar, more than one maximum of phytoplankton production, a summer peak in May with others in February to March and August to November, more or less a similar trend of production observed in the present investigation.

REFERENCES

CHACKO, P. I. AND C. MALU PILLAY 1957. Importance of hydrological investigations in the Gulf of Mannar in relation to its fisheries. *Ind. Com. J.*, **12** : 194-197.

——— AND A. D. I. RAJENDRAN 1959. Maritime meteorology and hydrography of Tuticorin Bay, Gulf of Mannar, 1950-54. *Madras Fisheries Dept. Fish. St. Rep. Year Book.*, 1954-55, pp. 175-193.

———, H. P. VALSAN AND C. MALU PILLAY 1954. Meteorology and hydrography of the Kundugal Gut in the Gulf of Mannar. *Contrib. mar. Fish. biol. St. Krusadai, Gulf of Mannar*, **1** : 1-20.

CHIDAMBARAM, K., A. D. I. RAJENDRAN AND A. P. VALSAN 1951. Certain observations on the hydrography and biology of the pearl bank, Tholayiram Paar off Tuticorin in the Gulf of Mannar in April 1949. *J. Madras Univ.*, B **21** : 48-74.

FREDA CHANDRASEKHARAN AND K. SUDHAKAR 1968. Observations on the hydrography and planktology of pearl banks of Gulf of Mannar. *Madras J. Fish.*, **1** : 28-33.

GAARDER, T. AND H. H. GRAN 1927. Investigations of the production of plankton in the Oslo Fjord. *Rupp. Pro. Verb. Cons. Expl. Mer.*, **42** : 1-48.

GANAPATI, P. N. AND C. G. RAO 1953. Observations on the seasonal variation in the phytoplankton production on the Indian coast with special reference to Waltair Coast. *Ind. Sci. Congr.*, Part III, pp. 184.

——— AND D. V. S. RAO 1958. Quantitative study of plankton off Lawson's Bay, Waltair. *Proc. Indian Acad. Sci.* **58** B : 189-209.

——— AND V. S. R. MURTY 1954. Salinity and temperature variations of the surface waters off the Visakhapatnam Coast. *Mem. Oceanogr. Andhra Univ. Ser.*, **49** : 125-142.

——— AND D. V. R. SARMA 1958. Hydrography in relation to the production of plankton off Waltair Coast. *Andhra Univ. Mem. Oceanogr. Ser.*, **62** (2) : 168-192.

GOPINATHAN, C. P., P. V. R. NAIR AND A. K. K. NAIR 1974. Studies on the phytoplankton of the Cochin backwater, a tropical estuary. *Indian J. Fish.*, **21** (2) :501-513.

HARDY, A. C. AND E. R. GUNTHER 1935. The plankton of the south Georgia whaling grounds and adjacent waters, 1926-27. *Discovery Rep.*, **11** : 1-456.

HARVEY, H. W., L. H. N. COOPER, M. V. LEBOUR AND F. S. RUSSEL 1935. Planktor production and its control. *J. Mar. Biol. Ass. U. K.*, **20** : 407-441.

JAYARAMAN, R. 1954. Seasonal variations in salinity, dissolved oxygen and nutrient salts in the inshore waters of the Gulf of Mannar and Palk Bay near Mandapam (S. India). *Indian J. Fish.*, **1** : 345-364.

MALU PILLAY, C. 1962. A survey of the maritime meteorology and physico-chemical conditions of the Indian Pearl Banks off Tuticorin in the Gulf of Mannar from December 1958 to May 1959. *Madras J. Fish.*, **1** : 77-95.

MARICHAMY, R. AND PON SIRAIMEETAN 1979. Hydrological studies in the coastal waters of Tuticorin, Gulf of Mannar. *J. Mar. Biol. Ass. India.*, **21** (1 & 2) : 67-76 (1984).

NAIR, P. V. R., S. SAMUEL, K. J. JOSEPH AND V. K. BALACHANDRAN 1968. Primary production and potential fishery resources in the seas around India. *Proceed. Symp. Living Res. seas around India., Cochin, Sp. Publ.*, pp. 184-198.

PRASAD, R. R. 1954. The characteristics of plankton at an inshore station in the Gulf of Mannar near Mandapam. *Indian J. Fish.*, **1** : 1-36.

——— 1956. Further studies on the plankton of the inshore waters off Mandapam. *Ibid.*, **3** (1) : 1-42.

——— 1958. Plankton calendars of the inshore waters at Mandapam with note on the productivity of the area. *Ibid.*, **5** (1) : 170-188.

——— AND K. N. K. KARTHA 1959. A note on the breeding of copepocs and its relation to diatom cycle. *J. mar. biol. Ass. India.*, **1** (1) : 77-84.

——— AND P. V. R. NAIR 1960. Observations on the distribution and occurrence of diatoms in the inshore waters of the Gulf of Mannar and Palk Bay. *Indian J. Fish.*, **7** (1) : 49-68.

——— AND ——— 1963. Studies on organic production—I. Gulf of Mannar, *J. mar. biol. Ass. India.*, **5** (1) : 1-26.

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. *Mar. Biol.*, **12** : 200-206.

RAYMONT, J. E. G. 1980. *Plankton and productivity in the Oceans.* 1. *Phytoplankton*, 2nd Ed. pp. 489, Pergamon Press, Oxford.

RILEY, G. A. AND D. F. BUMPUS 1946. Phytoplankton-zooplankton relationship on Georges Bank. *J. Mar. Res.*, **6** (1) : 33-47.

SAMBANDAMURTHY, N. 1962. Surface plankton of the pearl bank, tholayiram paar off Tuticorin. *Madras J. Fish.*, **1** : 74-75.

STEEMANN NIELSEN, E. 1937. The annual amount of organic matter produced by the phytoplankton in the Sound off Helsingor. *Med. Kam. Danmarks Fisk. Havunders. Ser. Plankton.*, **3** (1) : 1-37.

STRICKLAND, J. D. H. AND T. R. PARSONS 1968. A practical handbook of seawater analysis. *Fish. Res. Bd. Canada.*, **167** : 1-311.

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