STUDIES ON PHYTOPLANKTON IN THE ESTUARINE AND MARINE ENVIRONMENTS

THESIS SUBMITTED
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF

DOCTOR OF PHILOSOPHY OF THE
UNIVERSITY OF COCHIN

By

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December 1981

To

M Y   P A R E N T S

C E R T I F I C A T E

This is to certify that the thesis entitled "Studies on phytoplankton of the estuarine and marine environments" is the bonafide record of the work carried out by Shri. C.P. Gopinathan under my guidance and supervision and that no part thereof has been presented for any other Degree.

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C O N T E N T S

P R E F A C E

The candidate's interest in phytoplankton investigations had started more than a decade ago when he joined the Central Marine Fisheries Research Institute in the Marine Biology & Oceanography Division in 1968. Since then he has been pursuing studies on the different aspects of phytoplankton in various ecosystems such as the estuarine, inshore and oceanic regions including the seas around the Andaman-Nicobar Islands. The extensive data collected all these years from different ecosystems have been brought under a unified scheme.

The first few years of the candidate's studies centered round the taxonomic aspects of estuarine and marine phytoplankton. During the course of these studies he had identified more than 500 species of phytoplankters occurring in various habitats. During the early part of these studies, he had received the guidance of Dr.R. Subrahmanyan, an eminent phytoplanktologist, whose publications are still considered to be the standard references in this field. But all the published accounts do not contain a comprehensive account of the littoral and epiphytic diatoms which contribute substantially to the estuarine and inshore production and hence it was felt desirable to include a taxonomic account of these forms comprising a total of 109 taxa, thereby fill up a major lacuna in the phytoplankton taxonomy, especially from the south west coast of India.

The candidate as part of his official duties, have taken part in several research cruises on board the Research Vessels of the Institute and allied sister Institutions. The coverage extends to a large part of the Arabian Sea, apart from the estuarine system of Cochin and adjacent areas. This has given him an opportunity to study the various parameters connected with phytoplankton research, such as standing stock, chlorophyll content, total cell counts and primary production measurements. In the project oriented research programmes of the Central Marine Fisheries Research Institute, the candidate has always shouldered a major responsibility in the implementation of the field programmes and subsequent analysis in the laboratory. The field collection involves collection of water and plankton samples, using the conventional techniques and the subsequent analysis involved with the familiarisation of methods connected with most of the biological and oceanographical researches in Fishery Science. This aspect of studies were entirely carried out under the able guidance and supervision of Dr.P.V.Ramachandran Nair, a pioneer worker in the field of primary productivity studies in India.

In fact, the greater part of the work has been around the spatial and seasonal variation of phytoplankton as manifested in the standing stock in terms of total cell counts, chlorophylls as well as primary production.

This study involved a great deal of data processing and statistical analysis. A mini Computor, model MICRO 2200 was used in the calculation of multiple regression analysis and analysis of co-variance.

The part dealing with the productivity parameters of the backwater ecosystem was taken up to study the influence of biological and environmental conditions in this ecosystem and connected prawn culture fields and mangrove areas mainly to determine the stocking potential of these fields. Though the findings were not conclusive, the same gave an idea on the stocking potential which has great significance in the culture practice of prawns in these fields.

The candidate had an opportunity to visit the Aquaculture Institute of South East Asian Fisheries Development Centre (SEAFDEC), Philippines, where he undertook intensive investigation on development of mass culture of phytoplankters and other fish food organisms. This gave him an insight into the development of large scale culture of micro-algae to meet the demands of a hatchery developed on modern lines. The facilities available at the SEAFDEC were utilized to undertake some fundamental aspects of phytoplankton culture which has been incorporated in Chapter IX.

During the field trips, the candidate had come across ecosystems where there has been heavy pollutional load from large quantities of petroleum hydrocarbons discharged from stranded tankers. In such ecosystems, the condition of stress starts with the first link in the food chain, viz. the primary producers on which data are very meagre. Hence a series of experiments were designed to underst and the behavioural pattern of phytoplankters under pollutional stress from hydrocarbons which has been evaluated in Chapter X.

Thus the coverage from taxonomy to toxicity have been brought under a unified scheme. In the section on standing stock measurements in oceanic regions, biomass estimation from plankton net collections have been made. The candidate is aware of the limitation in applying the data in deriving a composite picture of the basic productivity in view of the large quantity of nannoplankters which might escape through the meshes of the net. However, it was thought useful to include this data also in order to give a comparative picture of the net plankton alongside the more sophisticated method of productivity estimation by radioactive carbon (^{14}C). The several Expeditions that crossed the Indian Seas prior to the International Indian Ocean Expedition and the excellent coverage during the IIOE, especially by the U.S and USSR research vessels together with the collections made on board R.V. VARUNA manned by Central Marine Fisheries Research Institute scientists including the candidate have enabled him to compare the various aspects of biomass distribution of phytoplankton in different areas of the oceanic regions adjacent to Indian Seas, and also to derive a composite picture of the productivity of Exclusive Economic Zone of India.

The work had been carried out under different project programmes of the Central Marine Fisheries Research Institute, either as Project Leader or as associate, and he had received co-operation and help from a number of colleagues which has been duly acknowledged in the ensuing sections.

ACKNOWLEDGEMENTS

The candidate is deeply indebted to Dr. P.V.Ramachandran Nair, for suggesting the problem, valuable guidance, unfailing and constant encouragement and for critically correcting the manuscript, offering suggestions and advice, thus improving the quality of the work.

He is grateful to Dr. E.G. Silas, Director, for kind permission to carry out the present investigations in the laboratories of Central Marine Fisheries Research Institute, and for all facilities and encouragement. He is also grateful to Dr. S.Z. Qasim, former Director of the Institute; to Prof.Dr. C.V.Kurian, Dr. A.V.S.Murty and Dr. P.Vedavyasa Rao, for their many valuable suggestions. His special thanks are also due to his colleagues Dr.P.Parameswaran Pillai, for critically going through the typesript; to Shri.V.Kunjukrishna Pillai for correcting some of the chapters and to Shri. V.K. Balachandran, for the help rendered in the field as well as in the laboratory. His sincere thanks are also due to Shri. A.K.Kesavan Nair, for the help rendered in the statistical analysis of the data relating to the estuarine investigations.

The candidate takes this opportunity to thank the authorities of SEAFDEC, Philippines, especially to the scientists of the phycology laboratory, for facilities to conduct some of the enrichment experiments relating to phytoplankton culture.

Lastly, the co-operation and help received from other colleagues of the Institute, working in various research projects, are also greatfully acknowledged.

I. INTRODUCTION

The phytoplankters are the microscopic plant life of the aquatic environment which constitute the primary producers synthesising the basic food. It belongs to the Class Algae, which besides chlorophylls, possess other characteristic pigments. The important components of phytoplankton are: Diatoms (Bacillariophyceae), Dinoflagellates (Dinophyceae), blue-green algae (Cyanophyceae) and very minute forms belongs to the micro green algae (Chlorophyceae) called the nannoplankters. In addition to these, two other Classes, viz. Silicoflagellates and Coccolithophores also belong to the category of phytoplankton.

The word 'production' has been synonymously used for standing crop as well as for total phytoplankton production. But there is a distinction between the two, though in nature, there is rather a high correlation between the standing stock of phytoplankton and primary production. Primary production represents the quantum of organic matter produced by the planktonic algae and the benthic flora utilising the light energy from the sun and the nutrients in the environment. Since the phytoplankton initiates the whole food chain in any ecosystem, the study relates to their qualitative and quantitative aspects and the spatial and temporal distribution provide a significant knowledge about the aquatic environment.

Various methods, both direct and indirect are employed for estimating the production of an aquatic environment. Of the direct methods, the oxygen and ^{14}C techniques are the most reliable besides the standing crop by pigment analysis and total cell counts.

Although considerable information is available on standing stock measurements of the estuarine, inshore and marine environments, a comprehensive account of the organisms, especially the littoral, epiphytic and benthic diatoms and their various productivity parameters from an estuarine system to an inshore environment are lacking. This study thus providesa useful base for filling up this lacuna from this part of the Indian seas.

The results presented here in eleven Chapters are based on the work from 1968 onwards, from the estuarine and inshore environments of Cochin, as well as some of the prawn culture fields and associated mangrove areas, mud bank region of Alleppey, south west coast of India, coastal areas of Andaman-Nicobar Islands and also of the experiments conducted in the laboratory using cultures isolated from the samples collected from these regions. Besides, some work carried out in the oceanic regions have also been presented and commented upon in the light of available information.

Chapter I contains the introduction and historical resume of the phytoplankton productivity investigations in the Indian Ocean in general and Indian seas in particular. In Chapter II, dealing with the Environment, short descriptions of the estuarine system of Cochin, south west coast of India and the Andaman-Nicobar region where the investigations were mainly carried out, have been given together with the hydrological and the plankton characteristics of the area.

Chapter III, on material and methods, contains the details of sampling stations, methodology of collection and the techniques employed using different equipments. In Chapter IV, a taxonomic account is given relating to the littoral and epiphytic diatoms along with some of the planktonic dinoflagellates occurring in the estuarine and inshore waters since all these forms contribute substantially to the total production of the estuarine and inshore environments of our waters. In view of recent published accounts of planktonic diatoms of the Indian seas, this aspect has not been included.

Chapter V deals with the seasonal and quantitative variation of phytoplankton and other productivity parameters such as nutrients (nitrite, nitrate, phosphate and silicate) and co-relation of production with chlorophyll and total cell counts. A statistical analysis of the data collected from the estuarine environment of Cochin has also been included to interpret their significance and inter-relationships.

Chapter VI gives the phytoplankton investigation in the inshore area of Cochin upto 30 m depth contour. Seasonal variation in production especially in a fishing ground, standing crop in terms of total cells, qualitative studies with particular reference to geographical grouping and the effect of *Salvinia* deposit on the phytoplankton production are also included.

Chapter VII gives the phytoplankton investigations in the oceanic environment, from Cape Comorin to Karwar, based on R.V. VARUNA collections. Though the net samples will not give a true index of the standing stock, an attempt has been made to correlate the biomass with the primary production measurements obtained by ^{14}C technique, to evaluate the contribution of net plankton in the total productivity.

Chapter VIII deals with the phytoplankton productivity investigations in special ecosystems such as mud bank, prawn culture fields and associated mangrove areas and also in the waters around Andaman-Nicobar Islands.

Chapter IX deals with the culture techniques of phytoplankton, in the laboratory as well as in open system, including the preservation and harvest of the culture, for the purpose of feeding the crustacean larvae. Two sets of experiments conducted in the laboratory to study the growth rate and differentiation of each species with different culture solutions are also discussed.

Chapter X deals with the studies on toxic effects on phytoplankton by pollutants like hydrocarbons. Chapter XI gives a general discussion on phytoplankton ecology of the estuarine and marine environments in relation to physico-chemical factors, effect of monsoons and phenomena like upwelling. The results of various expeditions conducted in the Indian seas are also compared and discussed to derive a total picture of the phytoplankton distribution. The general level of primary production estimates from the world oceans, Indian Ocean and in the Exclusive Economic Zone of the Indian seas in particular, in relation to the potential resources available are also presented.

Historical resume

In the Indian Ocean, prior to the International Indian Ocean Expedition (IIOE) (1962-65), DANA (1928-30), JOHN MURRAY (1933-34), DISCOVERY (1934) and ALBATROSS (1947-48) Expeditions tried to evaluate the productivity from the nutrients and the standing crop of plankton. Gilson (1937) used the nitrate data of JOHN MURRAY Expedition to estimate the organic production in the Arabian Sea in wet weight of algae. During the GALATHEA Expedition, primary production was measured by ^{14}C technique in the western Indian Ocean along the coast of Africa, equatorial part of the Indian Ocean in a section from Mombassa to SriLanka, Bay of Bengal and the Indo-Malayan waters (Steemann Nielsen, 1952; 1954; Steemann Nielsen and Jensen, 1957). These studies revealed that, in general, the phytoplankton production in the shallow coastal regions of the tropics is high. It was also observed that in oligotrophic regions, where there was considerable addition of 'new water' with high nutrients in the photosynthetic zone, the daily production is very high.

During the last two decades there has been considerable progress in the study of primary production in the Indian Ocean and the environmental phenomena that regulate it. In connection with the IIOE, between 1959 and 1965, a large number of ships belonging to several countries carried out investigations in the Indian Ocean. The Arabian Sea and under the Australian programme, the 110°E longitude section were well studied (Ryther et al. 1966; Jitts, 1969). After extensive measurements of primary production on board the ANTON BRUUN, Ryther et al. (1966) showed that the western Indian Ocean is one of the most productive regions in the world. Some of the highest values ever recorded in the marine environment, excepting those from coral reefs and seagrass beds, were observed in the northern Arabian Sea off the Arabian peninsula. The observations in the western half of the Arabian Sea are summarised by Wooster et al. (1967).

A large number of phytoplankton productivity measurements were made on board R.V. VITYAZ which have been reported by Kabanova (1961, 1964, 1968), Zernova (1962), Sukhanova (1964) and Zernova and Ivanov (1964). In the eastern Indian Ocean, Wood (1966) found the horizontal distribution of phytoplankton related to land mass and upwelling. Besides, Burchall (1968) in the Agulhas Current region, Mitchell-Innes (1967) off South Africa, Jitts (1965) in the Australian waters and Humphrey (1966) from the eastern Indian Ocean have presented the results of their measurements. Krey (1973) have given an account of the distribution of chlorophyll and of potential assimilation in the Indian Ocean and Aruga (1973) has reviewed the relation of primary production in the Indian Ocean to chlorophyll and other environmental factors. As part of the U.S Antarctic Programme, El-Syed and Jitts (1973) studied the primary production and standing stock of plankton in the south-eastern Indian Ocean.

Estimates of primary production in the different ecological zones of the Indian Ocean were presented by Moiseev (1969). Prasad et al. (1970) made a quantitative assessment of the primary production in relation to the potential fishery resources of the Indian Ocean and Cushing (1971) for the upwelling areas. Recently Qasim (1976) reviewed the different aspects of the biological productivity of the Indian Ocean. In addition to such direct measurements of primary production, reports on phytoplankton pigments of the Indian Ocean by Ichimura and Fukushima (1963), Laird et al. (1964), McGill and Lawson (1966), Humphrey and Kerr (1969) provide a sound basis for the estimation of productivity in the Indian Ocean. Recently Krey and Babenerd (1976) compiled all the phytoplankton productivity informations from the Indian Ocean in the form of an Atlas.

Several studies have been made in the coastal and offshore regions of the Indian Seas. Subrahmanyan (1959 a,b) measured the standing crop of phytoplankton by various methods and came to the conclusion that the production on the west coast of India is of a high order comparable to some of the most productive areas in the temperate regions. Prasad and Nair (1960, 1963) made a study of the seasonal variation and magnitude of production in the Gulf of Mannar on the south east coast of India. The results of investigations carried out along the shelf regions of India and the Lakshadweep Sea were discussed in relation to the potential living resources by Nair et al. (1968) and Nair (1970, 1974). Radhakrishna (1969) made a study of the primary productivity in the shelf waters of Alleppey on the south west coast of India during the post monsoon period and Shah (1973) presented the seasonal variation of phytoplankton pigments in the Lakshadweep Sea off Cochin.

Further, Qasim *et al*. (1978) have discussed the biological productivity of the coastal waters of India upto 50 m depth and stated that the larger phytoplankton organisms (microplankton) contributed greater spatial variation in primary production than the smaller forms (nannoplankton). Radhakrishna (1978) and Radhakrishna *et al*. (1978a) recently studied quantitatively some aspects of phytoplankton productivity from the coastal areas of east coast including some stations in the Bay of Bengal. Similarly Radhakrishna *et al*. (1978b) studied primary productivity, chlorophyll *a* and related parameters from the shelf and oceanic regions in the north-eastern Arabian Sea and northern Arabian Sea (Radhakrishna *et al*. 1978c). Besides, the productivity of coral reefs (Nair and Pillai, 1972; Qasim *et al*. 1972), of seagrass beds (Qasim and Bhattathiri, 1971) and liberation of particulate organic matter by coral reefs on an atoll (Qasim and Sankaranarayanan, 1970) have also been investigated.

Studies on the biology and ecology of the phytoplankton of the various estuarine systems of India have not received as much attention as those from the marine environment. The pioneer work on the ecology and seasonal succession of the diatom flora of the estuarine waters of India was that of Iyengar and Venkataraman (1951) for the Cooum estuary in Madras. Since then biological investigations were carried out by various authors on the planktonic algae of Chilka Lake (Roy, 1954; Devasundaram and Roy, 1954; Patnaik, 1973) and in the Hooghly estuary (Dutta _et al_. 1954; Roy, 1949, 1955; Shetty _et al_. 1961; Gopalakrishnan, 1971). Seshadri (1957) studied the seasonal organic production in relation to environmental features in Zuari and Mandovi estuaries. Krishnamurty (1964) studied the nutrients in relation to plankton production in the inshore and estuarine waters of Porto Novo and Krishnamurty and Santhanam (1974) and Santhanam _et al_ (1975) gave a descriptive account of the species distribution and quantitative ecology of phytoplankton of the same region.

In recent years, the Cochin Backwaters have been studied intensively for plant pigments (Qasim and Reddy, 1967), light penetration (Qasim _et al_. 1968), tidal amplitude (Qasim and Gopinathan, 1969), organic production (Qasim _et al_. 1969), nutrient cycle (Sankaranarayanan and Qasim, 1969), salinity tolerance of phytoplankton (Qasim _et al_. 1972), seasonal abundance of phytoplankton (Gopinathan, 1972), spatial and temporal distribution of phytoplankton (Gopinathan _et al_. 1974; Joseph _et al_. 1975), contribution of nannoplankton (Qasim _et al_. 1974; Vijayaraghavan _et al_. 1974) and on primary productivity of the entire estuarine system (Nair _et al_. 1975). The results of the investigations discussed in the following pages form a useful adjunct to the existing knowledge on these ecosystems.

II. ENVIRONMENTS

The areas of investigation cover the estuarine system of Cochin, including the adjacent mangrove regions and prawn culture fields, the inshore area off Cochin upto 30 m depth, the mud bank region near Alleppey, the shelf and oceanic regions extending from Cape Comorin to Karwar on the south west coast of India and also the seas around the Andaman-Nicobar Islands.

1. Cochin estuarine system

The estuarine system of Cochin includes a system of inter-connected lagoons, bays and swamps, penetrating the mainland with innumerable prawn culture fields, both seasonal and perennial ones, and enclosing many islands in between and with a total area approximately amounting to 500 sq. km. The backwater around Cochin, where regular investigations were conducted is located along latitude $9^{\circ}58'$N and longitude $76^{\circ}15'$E. Actually this part of the estuary form more or less a northward extension of the Vembanad Lake. The upper reaches of this backwater are connected with the Arabian Sea by a channel, about 450 m wide. These regions are relatively deeper, with depth ranging from 5-15 m and are marked by constant flushing with flood and ebb tides with a maximum range of 1 m. The lower reaches of the estuary are shallower, with very little tidal influence and have low salinity.

The estuarine system has got two permanent openings to the Arabian Sea - one at Cochin and another at Azhikode. There are 5 major rivers connected with the backwaters through their tributories and branches. On the southern half, the rivers Pamba and Muvattupuzha join the Vembanad Lake. On the northern half, the river Periyar joins the backwater through its tributaries. All these rivers periodically enrich the area by run off bringing along with them nutrient-rich water and considerable quantity of particulate organic matter. The northern half of the estuary has high salinity and high tidal amplitude because of the two connections to the sea whereas in the lower reaches especially in the southern area, the tidal amplitude and salinity are lower. The various environmental parameters are greatly influenced by the tidal rhythm. In the backwater, the tides are of a mixed, semi-diurnal type with a maximum range of 1 m. The difference in almost all the parameters are more marked at the surface than at the bottom.

The chief characteristics of this estuary are that during the monsoon months, it receives a considerable amount of freshwater from the rivers and other sources and becomes highly turbid. The total annual rainfall of the Cochin area is about 3200 mm, of which nearly 75% occurs during the months May-September. The onset of south west monsoon and its duration may however, vary from year to year. The inflow of freshwater from various sources, particularly during the monsoon months, is considerable and it is in the backwater where mixing of salt and freshwater occurs, making it a highly dynamic environment.

2. Inshore area of Cochin

The inshore area upto 30 m depth contour is also subjected to the influence of river run off and highly changing conditions. The Cochin Harbour outer channel has been made navigable by cutting the sand bar present across the channel. Because of the high amount of siltation in the outer channel access to the harbour has been maintained through constant annual dredging. The depth of the main channel is more than 10 m and the sides have less than 6 m. The Fairway buoy is placed at 12 m depth about 2 km from the bar mouth. As this region is of intense fishing activity, it was studied in detail from various aspects. During low tide, large masses of brackish water flushing out through the bar mouth joins the inshore area. This area is characterised by a mixed type of predominantly semi-diurnal tides and tidal streams during ebb currents have longer duration and higher speed as compared with the flood current. During monsoon period, the low saline water reaches upto 50 m depth.

The benthic region is subjected to the influence of large masses of floating weeds, Salvinia molesta and *Eichhornia crassipes* which affect the benthic ecology as well as the nature of overlying water during the post monsoon and pre-monsoon seasons. Recent studies conducted in this area have revealed the variability in phytoplankton abundance as evinced by chlorophyll distribution, even within 50 m depth contour (CMFRI, Report on Remote Sensing - MS).

3. Mud Bank area

The calm, turbid regions in the coastal waters which form during the period June-August, along the south west coast of India, especially along the Kerala coast are called the mud banks. This takes place with cyclic regularity in the inshore areas during the south west monsoon reducing considerably the wave action in the sea on an otherwise surf ridden coast. The areas where such mud banks are formed facilitate fishing operations and are welcomed by the coastal people who depend on the sea for their livelihood. As the richest prawn fishing grounds in the west coast are located within the same region, mud banks are of great interest from the fishery point of view.

The most important and persistent mud banks are at Narakkal, north of Cochin and at Ambalapuzha-Purakkad-Thottappally region, near Alleppey. During the south west monsoon period, the bottom mud get churned up in these regions and is kept in suspension, thus making the water highly turbid. The muddy waters are free from wave action during the stormy season. Intensive investigations of all productivity parameters were conducted at Alleppey mud bank during 1971-72 period.

4. South west coast of India

The west coast of Peninsular India forms a narrow belt of low land lying between the sea and the Western Ghats which extend throughout the whole length of the peninsula varying in width from 30 to 150 km inland and running in a direction north-northwest and south-southwest. There are a number of short rivers, many of which drain into the backwaters of varying breadth parallel to the coast.

The outstanding feature of the wind system in the Indian Seas is a seasonal reversal of the direction associated with the two monsoons. During December to February, the north-east winds of the land origin prevail. The transition begins by about March and lasts through April. By the middle of May, the south west monsoon winds of the oceanic origin are established, which continue to increase gradually until June when there is sudden strengthening. During July and August, the wind force decreases in preparation for the transition which lasts through October and November. Of the two monsoons, the south-west monsoon endures over a longer period in the Arabian Sea and is stronger and steadier than the north east one. The onset of south west monsoon is associated with overcast skies, showers and strong winds, as a result of which the solar insolation vary from 750 ly on a bright day to 150 ly on a cloudy day in July (Qasim _et_ _al_. 1968). Despite the humid conditions evaporation in the Arabian Sea is maximum during south-west monsoon unlike the usual intense evaporation in winter (Venkateswaran, 1956; Jaganathan and Ramasastry, 1964).

From the vertical density structure, Sharma (1968) has inferred that the process of upwelling of the west coast of India in the deeper layers of about 90 m sets in by March and the upwelled water reaches the surface by May. The cessation of upwelling takes place in August and the reverse process of sinking begins by September. In a period of two months, the vertical movement is 80 m, giving rise to an average intensity of upwelling of 40 m per month, ie. 1.5×10^3 cm sec^{-1}. The earlier authors (Banse, 1959; Ramasastry and Myrland, 1959; Ramamirtham and Jayaraman, 1960) had inferred that upwelling of the south-west coast of India starts with the onset of the south-west monsoon. Regular upwelling is absent north of 15°N.

From July onwards cool water is present below 50 m, sometimes even at shallower depths which has a low oxygen content, 50% or less of saturation appear to be the rule at the inshore regions throughout the entire upwelling season (Banse, 1968). As is well known, all these hydrographic features exert a profound influence on the production and distribution of phytoplankton in this area.

Time series observations, during research cruises conducted by CMFRI on board the Indo-Norwegian Project research vessels, R.V.KALAVA, R.V.VARUNA and others provided data on the hydrology of the west coast (Banse, 1959; Ramasastry, 1959; Ramasastry and Myrland, 1960; Ramamirtham and Jayaraman, 1960; Patil and Ramamirtham, 1963; Ramamirtham and Patil, 1965; Sharma, 1966, 1968).

The surface temperature all along the coast exhibits a double oscillation during the year with the primary maximum in April and the secondary one in November. The corresponding minimum takes place in July/August and December/January. The low temperature is spread over a longer period in the north than in the south, The low temperature in the monsoon period is due to reduction in the insolation due to the cloudy conditions and the monsoon rains and run off waters.

Generally, the coastal surface current off the west coast of India sets towards the south from February until late October or November and are reversed during the rest of the year.

There is no prominent seasonal variation in the dissolved oxygen content of the surface waters all along the coast but it does vary considerably in the sub-surface layers. However, higher values of oxygen in the surface waters, in general, are noticed in June and September and lower values in January and July. The stratification of coastal waters during July and August in the depth range of 10 to 30 m results in the depletion of oxygen below the depth of stratification.

The depth of the mixed layer changes from a depth of more than 60 m in January-February to a depth less than 60 m by March-April. By May-June the mixed layer still moves to upper layers and the least depth of less than 20 m is observed in July-August. From then, it starts deepening to a depth of about 40 m by September-October.

Studies conducted for prolonged periods at different centres had indicated that phosphate, nitrate and silicate show a seasonal fluctuation, the peaks in their concentration being attained during the south west monsoon months. It is also found that when there is an abundant supply of these nutrients in the water, the ratio of N/P is 5:1, the same as has been found in the temperate waters (Subrahmanyan, 1959a).

5. Coastal areas of Andaman-Nicobar Islands

The Union Territory of Andaman-Nicobar Islands consists of several islands having an area of about 8290 sq. km between latitude 6-14^{o}N and longitude 92-94^{o}E forming a chain in the eastern boundary of the Bay of Bengal, and having 0.60 million sq. km area of Exclusive Economic Zone of India. These islands offer a vast coast line in which the flora and fauna thrive under typical tropical conditions. The ecosystem of these islands is a complex one and are unique since they are influenced by tropical rain, tidal interaction, winds and cyclones and other natural barriers such as rocky substratum and coral reefs. Many of these islands and banks have a fringing coral reef. Generally coral growth is less abundant on the eastern side. The distribution of coral is usually limited to high salinity and high temperature areas, having relatively clear water.

The Andaman group of islands rise from one continental shelf while the Nicobar group, including the outlying Car Nicobar rise from another continental shelf, the two being separated by the 10^{o} Channel, where a depth of about 1500 m is obtained. The continental shelf on the western side of the Andaman islands is relatively wide, while the eastern side of the Nicobar group of islands has extensive prolongations. The continental slope is very steep and great depths are encountered a little away from the edge of the continental shelf. The waters around these islands are relatively deep and the shelf areas are very narrow.

III. MATERIAL AND METHODS

Phytoplankters, mainly diatoms were dehydrated and mounted in styrax for qualitative studies. For quantitative investigations, one litre of water from the surface was collected every fortnight from fixed stations. The phytoplankton crop was estimated both qualitatively and quantitatively from a unit volume (100 ml) of sample settled in special settling chambers for 24 hrs period. One ml of the settled sample was counted after identification of the organisms upto species.

Duplicate samples (1 litre) were filtered using millipore filters (0.45 μ) and the filter paper was treated with 90% acetone and the pigments, chlorophyll a, b and c were measured by a Unicam SP 500 Spectrophotometer using the revised formula of Parsons and Strickland (1963).

Water samples were analysed for hydrological properties. Determination of salinity, oxygen and nutrients such as nitrite, nitrate, phosphate and silicate were made according to Strickland and Parsons (1968).

Light and dark bottle oxygen technique (Gaarder and Gran, 1927) has been used in all the prawn culture fields and associated mangrove areas to estimate the primary production. The difference in oxygen concentration between the light and dark bottles was converted into its carbon equivalents using a PQ of 1.25 for obtaining gross production values. The difference between the initial and dark bottle was taken as the respiration of the planktonic algae and that between the light bottle and initial bottle was taken as the 'net production' (Steemann Nielsen and Hansen, 1959).

In the brackish, inshore and marine environments, the estimation of primary production was carried out by ^{14}C technique (Steemann Nielsen, 1952). Sixty ml of the sample was collected in a reagent bottle and incubated with 5 μc of ^{14}C as $NaH^{14}Co_3$ under natural or artificial constant light (20 k lux) for 3-4 hrs. Dark uptake also was determined simultaneously. After incubation, the samples were filtered through a manifold filtration unit under suction. The filters were dried over silica gel and exposed to HCl fumes before counting. The activity of the filters were determined using a Geiger Counting System, the efficiency of which was 3.2%. The production rate per unit volume was calculated by the corrected counts of the filtered sample as a fraction of the added activity and multiplying with the total CO_2 content of the water. In oceanic water it was assumed as 90 mg/l and for the inshore waters estimated from the tables of Buch (1951) and Harvey (1957). For determination of added activity, the standardization procedure of Nair and Joseph (1975) was followed.

Column production was calculated by integration of the different rates at various depths using the formula of Dyson et al. (1965). In samples incubated under constant light, the empirical formula given by Steemann Nielsen and Jensen (1957) was applied to get the column production. In shallow waters, the values for the best depth (where maximum values are recorded) were multiplied by the actual depth, if it is less than the depth of the euphotic zone and half the product if it is more (Steemann Nielsen and Jensen, 1957).

From 1964, the erstwhile Indo-Norwegian Project placed a 28 m long research vessel, R.V.VARUNA at the disposal of CMFRI, for collecting hydro-biological data and to conduct exploratory fishing. All the observations on the west coast, especially the regions between Cape Comorin and Karwar, in the vicinity of Lakshadweep and in the equatorial region were made on board this research vessel during her research cruises.

For biomass or standing crop estimation, net samples were collected (both horizontal and vertical samples) during cruises. The horizontal haul was of 10 minutes duration, while vertical haul was from a maximum depth of 100 m to surface using half metre bolting nylon net (No. 21, mesh size 0.069 mm) attached with a Flow Meter (TSK 487). The relative abundance of different phytoplankters present in the net sample was noted from cursory examination of their composition. The total volume of the standing crop of phytoplankton was determined by the displacement method after filtering the sample through an organdy net (No. 3, mesh size 0.33 mm) to remove the zooplankton components from an aliquot of 1/5 of the sample. The conversion factor for the carbon equivalent of biomass was followed from Cushing *et al.* (1958).

Specific details as well as variations involved in special conditions have been dealt with in appropriate Chapters.

IV. TAXONOMY OF THE LITTORAL AND EPIPHYTIC DIATOMS AND PLANKTONIC DINOFLAGELLATES OCCURING IN THE ESTUARINE AND MARINE ENVIRONMENTS OF COCHIN

1. Diatomaceae (Bacillariophyceae)

Although some work has been done on the taxonomy of the plankton diatoms of the Indian Seas (Venkataraman, 1939; Menon, 1945; Subrahmanyan, 1946; Nair, 1959; Gopinathan, 1975), very little information is available on the littoral and epiphytic forms of our coastal waters. Gandhi (1965, 1967) reported on several species of fresh-water littoral forms from the North Indian waters. Apart from the studies by Misra (1956) on the littoral diatoms of the west coast of India, no systematic study has been made hitherto on the littoral marine forms from the Indian waters. In view of the fact that these forms also contribute substantially to the total production of the ecosystem, an attempt was made to enumerate the littoral diatoms of the south west coast of India, especially from the estuarine and inshore area of Cochin.

The present work forms a supplement to the available information regarding the diatom flora of the Indian seas particularly from the Kerala coast. The forms enumerated here were found to occur either as attached ones on seaweeds, rocks, dead shells and in the sediments of the estuarine area as well as from the inshore environment of Cochin.

The permanent slides were prepared by taking small bits of the plant material or sediments after ascertaining the presence of diatoms in a petri-dish and treated with concentrated HCl. After several washing and centrifuging it with distilled water, treated with concentrated sulphuric acid to which a few crystals of potassium dichromate were also added. After 30 minutes, repeated washing was done by centrifuging and the washed residue was evenly distributed on a clean slide already smeared with Mayer's albumen. The slide was then passed through 90%, 95% and 100% alcohol grades to xylol series and finally mounted in styrax. Nearly 300 slides were thus prepared. The figures represented here (Plate I - III) was drawn by 'Beck Cassal' mirror type camera-lucida. Identification of the forms are based on the keys provided by Van Heurck (1899), Hustedt (1930), Cupp (1943) and Hendey (1964).

Altogether 109 forms have been described including 10 varities and a new species, representing 40 genera. Out of these 8 genera and 17 species belong to the group Centrales and 32 genera and 92 species to the Pennales. The forms showed a good deal of resemblance to those of the British coast (Hendey, 1964). Many of the forms described here have been recorded previously from the east coast (Subrahmanyan, 1946) and a few forms from the Trivandrum coast (Nair, 1959), yet 49 species are found to be new distributional records from the Indian waters. The classification followed is that of Schütt (1896) as later modified by Hustedt (1930).

Order	CENTRALES
Sub Order	Discoideae
Family	Coscinodisceae
Sub Family	Melosirineae
Genus	*Podosira* Ehrenberg

1. *Podosira montagnei* Kützing
(Pl. I, fig. 1)

Kützing, 1844, p.52,pl. 29, fig. 85;
Smith, 1856, p.53, pl.59, fig.326;
Hustedt, 1930, p.281, fig.122;
Subrahmanyan, 1946, p.87, figs.5,6 & 10;
Misra, 1956, p.538, fig.4;
Hendey, 1964, p.90.

Podosira laevis Gregory, Greville, 1859,p.85,pl.6,figs.15-17.
Melosira montagnei Lagerstedt, 1876, p.9.

Cells round, cylindrical, united to form short chains, attached to higher algae. Cell wall areolated, areolae 22 in 10 µ. In valve view the areolae arranged in straight oblique lines. Girdle composed of intercalary bands. Length of valve 46 µ.

Occurrence: Found epiphytic on floating *Sargassum* in the inshore area of Cochin

Distribution: Atlantic coast, Caspian sea, coastal areas of Britain, west coast of India.

Genus *Cyclotella* Kutzing

2. *Cyclotella striata* (Kutzing) Grunow
(Pl. I, fig. 2)

Grunow, 1880,p.119;
Van Heurck, 1899,p.444, pl.22,fig.651;
Boyer, 1926, p.37;
Hustedt, 1930, p.744, fig.176;
Wood, 1963d, p.256, pl.6, fig.98;
Subrahmanyan, 1946,p.92,fig. 31;
Hendey, 1964, p.131, pl.1, fig.8;
Foged, 1975, p.20;
Huang, 1979, p.198, pl.1, fig.1.

Coscinodiscus striatus Kutzing, 1844, p.131, pl.1, fig.8.
Cyclotella dallasiana Smith, 1856, p.87.
Cyclotella radiata Brightwell, 1860, pl.6, fig.11.

Cells discoid, rectangular, valves with two distinct surface areas, the central portion coarsely punctate. Valve surface striate, striae 12 in 10 µ. Diameter of the valve 45 µ.

Occurrence: Found attached on dead shell in the estuarine area.

Distribution: Estuaries of Atlantic coast, North Sea coast and Indian coasts.

Family : Actinodisceae
Sub Family : Actinoptychineae
Genus Actynoptychus Ehrenberg

3. Actinoptychus senarius (Ehrenberg) Ehrenberg
(Pl. VI, fig. A)

Ehrenberg, 1843, p.6, pl.1, fig. 27;
Hendey, 1937, p.271; 1951, p.32, pl.8, fig. 11; 1964, p.95, pl.23, fig. 1-2;
Wood, 1963d, p.241, pl.1, fig.14;
Huang, 1979, p.196, pl.1, fig. 11.

Actinocyclus senarius Ehrenberg, 1838, p.172, pl.21, fig. 6.
Actinocyclus undulatus Kutzing, 1844, p.132, pl.1, fig. 24;
Bailey, 1842, pl.2, fig. 11;
Smith, 1853, p.25, pl.5, fig. 43.

Actinoptychus undulatus (Bailey) Ralfs, Hustedt, 1930, p.475;
Lebour, 1930, p.51, fig.27;
Allen and Cupp, 1935, p.121, fig. 20.

Cells discoid, valves divided into 6 sectors, alternately raised and depressed. Central area hexagonal, hyaline. The raised sectors possess a short blunt process in the middle near the margin. Valve surface strongly areolated, areolae 6 in 10 μ. Depressed sectors without processes, areolae not so prominent. Diameter of valve 56 μ.

Occurrence: Found attached on dead shell in the inshore area of Cochin

Distribution: European coastal waters, Atlantic and Pacific coasts, coastal regions of Australia and India.

4. *Actinoptychus splendens* (Shadbolt) Ralfs (Pl. VI, fig. B)

Ralfs in Pritchard, 1861, p.840;
Van Heurck, 1899, p.497, pl.22,fig.649;
Lebour, 1930, p.51, pl.1, fig. 6;
Nair, 1959, p.10, fig.25;
Hendey, 1964, p.95,pl.22, fig.1.

Actinosphenia splendens Shadbolt, 1854, p.116.
Actinoptychus quatuordenarius Ehrenberg, 1854, pl.18,fig.25.
Actinoptychus halionyx Grunow, 1870, p.25.

Valves circular, divided into 18 sectors that are alternately raised and depressed. Valve structure complex, alternate sectors differ in structure with coarse hexagonal areolae and are of fine areolae. Central space large, stellate, valve margin narrow. Diameter of valve 85 μ.

Occurrence: Found attached on dead shell in the inshore area of Cochin.

Distribution: Atlantic and Pacific coasts, coastal regions of Mediterranean, Java seas and west coast of India.

Sub Order Biddulphineae
Family : Chaetoceraceae
Sub Family : Anauleae
Genus Terpsinoë Ehrenberg

5. *Terpsinoe musica* Ehrenberg
(Pl. 1, fig.3)

Ehrenberg in De Toni, 1894, p.894;
Van Heurck, 1899, p.452, fig. 176;
Boyer, 1927, p.144;
Hustedt, 1930, p.898, fig. 540;
Venkataraman, 1939, p.301, fig.15, 18-21.

Valves quadrangular in girdle view, united to form zig-zag chains. The septa of the frustules thickened to form a structure resembling the musical notes. Valves linear, elliptical with undulating sides, slightly knobbed at the ends. The septa divides the inner side into 5-6 chambers. Surface of valve coarsely punctate. Length of valve 112 µ and breadth 64 µ.

Occurrence: Found epiphytic on *Cladophora* filaments in estuarine area of Cochin.

Distribution: Estuaries in Europe, British coastal waters, east coast of India.

Family : Eupodisceae
Sub Family : Eupodiscineae
Genus *Auliscus* Ehrenberg

6. *Auliscus sculptus* (W. Smith) Ralfs
(Pl. I, fig. 4)

Ralfs in Pritchard, 1861,p.845,pl.6,fig.3;
Schmidt, 1875,pl.32, figs.21-22;
Van Heurck, 1899, p.482, pl.21, fig.646;
Hustedt, 1930, p.516, fig.290;
Subrahmanyan, 1946, p.109, figs.93, 97;
Hendey, 1964, p.98, pl.23, fig.4.

Eupodiscus sculptus W. Smith, 1853, p.25, pl.4, fig.42.
Auliscus caelatus Bailey, 1854, p.6, pl.1, figs. 3-4.

Cells discoid, broadly elliptical, median area clear and distinct. Valves furnished with two large slightly produced ocelli which are situated near the margin, termed as 'eyes', facing opposite each other. Valves sculptured with strongly radial ribs, which are faint towards the centre. Valves radially striated, striae 26 in 10 μ. Diameter of the valve 62 μ in long axis and 56 in short axis.

Occurrence: Found attached on rock in the inshore area of Cochin.

Distribution: North Sea coast, West Indies, coastal waters of Australia and India.

Family : Biddulphieae
Sub Family Triceratineae
Genus <u>Triceratium</u> Ehrenberg

7. <u>Triceratium dubium</u> Brightwell
(Pl. I, fig. 5)

Brightwell, 1859, p.180, pl.9, fig.12;
Hustedt, 1930, p.806, fig.469;
Subrahmanyan, 1946, p.151, figs.274-276;
Misra, 1956, p.542, fig.14;
Huang, 1979, p.201, pl.2, fig.3.

<u>Triceratium bicorne</u> Cleve, 1878, p.17, pl.6, fig. 30.
<u>Amphitetras bicornis</u> De Toni, 1891, p.902.
<u>Biddulphia dubia</u> (Brightwell) Cleve in Boyer 1900, p.707; 1926, p.128;
Allen and Cupp, 1935, p.148, fig.84.

Cells rhomboid, lanceolate and four sided. In side view of the valve, two angles, each with a stout horn-like process, and the other angles with short blunt process. Valves strongly sculptured, irregularly areolated, valve margin striated. Length of apical axis, 65 μ.

<u>Occurrence</u>: Found attached on rock in the inshore area of Cochin.

<u>Distribution</u>: European coastal waters, Atlantic and Pacific coasts, coasts of Australia and India.

8. *Triceratium reticulatum* Ehrenberg

(Pl. I, fig. 6)

Ehrenberg, 1844, p.88, pl.18, fig.50;
Hustedt, 1930, p.823, figs. 485-486;
Subrahmanyan, 1946, p.151, figs.274,280;
Wood, 1963d, p.284, pl.12, fig. 250.

Triceratium sculptum Shadbolt, 1854, p.15, pl.1, fig.4.
Triceratium punctatum Brightwell, 1856, p.275, pl.9, fig.18;
Pritchard, 1861, p.856, pl.6, fig.20.
Biddulphia sculpta Van Heurck, 1899, p.476, pl.21, fig.645.
Biddulphia reticulum Boyer, 1926, p.138;
Gran, 1908, p.110, fig.146.

Cells with triangular valves and rounded corners. Valves punctate, small at the periferal region and larger at centre, scattered and of different sizes, groups of areolae seen separated by a hyaline ring. Length of valve 115 μ.

Occurrence: Found attached on dead shell in the estuarine area of Cochin.

Distribution: Coastal waters of Europe, Mediterranean and Scandinavian coasts, Texas Bay, coasts of India.

9. *Triceratium robertsianum* Greville
(Pl. I, fig. 7)

Greville, 1863, p.231, pl.9, fig.9;
Schmidt, 1881, pl.83, fig. 2-5;
Hustedt, 1830, p.803, fig. 466;
Subrahmanyan, 1946, p.150, figs.272-273.

Biddulphia robertsianum Boyer, 1927, p.134.

Valves triangular with convex sides, angles rounded, strongly sculptured. Valve corners with hollow cylindrical process. Length of valve 135 μ.

Occurrence: Found attached on dead shell in the Cochin estuarine area.

Distribution: Mediterranean coast, coastal areas of Australia, Texas Bay, east coast of Africa, coasts of India.

Sub Family : Biddulphineae
Genus *Biddulphia* Gray

10. *Biddulphia pulchella* Gray
(Pl. I, figs. 8-10)

Gray, 1821, p.1, fig.294;
Smith, 1856, pl.44, fig.321;
Schmidt, 1886, pl.118, figs.26-33;
Van Heurck, 1899, p.470, pl.20, fig.630;
Hustedt, 1930, p.832, fig.490;
Subrahmanyan, 1946,p.154, figs.283-284;
Misra, 1956, p.544, fig.17;
Wood, 1963d, p.248, pl.3, fig.52;
Hendey, 1964, p.101, pl.25, fig. 1;
Huang, 1979, p.196, pl.2, fig.1.

Biddulphia pulchella var. major Castracane, 1876, p.102, pl.23, fig.6.

Biddulphia biddulphiana (Smith) Boyer, 1900, p.694; 1926, p.121;
Gran, 1908, p.104, fig.135;
Lebour, 1930, p.172.

Cells colonial, united by their angles to form short chains, valves elliptical, swollen margins, strongly sculptured, divided into 3 sections by strong costae. Ends of the valve furnished with large globular process covered with fine pores, areolae arranged in longitudinal and transverse rows, girdle punctate in longitudinal lines. Length of valve 98 μ.

Occurrence: Found on rock as a short chain in the inshore area of Cochin.

Distribution: European coastal waters, coasts of Atlantic and Pacific, coasts of Australia and India.

11. Biddulphia alternans (Bailey) Van Heurck (Pl. I, fig. 11)

Van Heurck, 1895, p.208; 1899, p.475, pl.21, fig.644;
Boyer, 1923, p.137;
Lebour, 1930, p.181;
Hendey, 1951, p.34, pl.7, fig. 10;
1964, p.102, pl.25, fig. 5.

Triceratium alternans Bailey 1851, p.40; Smith, 1853, p.26, pl. 5, figs. 30,45;
Hustedt, 1930, p.825, fig.488;
Subrahmanyan, 1946, p.153, figs.277,282.

Cells box shaped, valves triangular with straight concave sides, corners rounded. Valve surface areolated, rows in the margin, but irregular at the centre, 9 in 10 u. Usually forms short chains by attaching at the angles of the cells by means of mucous. Length of valve 65 µ.

Occurrence: Found as a chain, attached to rock in the inshore area of Cochin.

Distribution: Coastal waters of Europe, British coast, coastal areas of North Sea, coasts of India.

12. <u>Biddulphia aurita</u> (Lyngbye) Brebisson
(Pl. I, fig. 12)

Brebisson, 1838, p.12;
Smith, 1856, p.49, pl.45, fig. 319;
Schmidt, 1886, pl.120, fig.5;
Van Heurck, 1899, p.471, pl.20, fig.631;
Hustedt, 1930, p.846, fig.501;
Lebour, 1930, p.173, fig.133;
Misra, 1956, p.544, fig.19;
Wood, 1963d, p.247, pl.3, fig.48;
Hendey, 1964, p.103, pl.24, fig.6.

<u>Diatoma auritum</u> Lyngbye, 1819, p.182, pl.62, fig. D.

Cells quandrangular, valves elliptical, with cornuate process, united by their processes to form short chains. Valve surface slightly swollen at the centre and furnished with radiating punctae. From the centre of the valve project a few long, slightly divergent spines. Length of valve 62 μ.

<u>Occurrence</u>: Found attached on rock in the inshore environment of Cochin.

<u>Distribution</u>: Atlantic and Pacific coasts, coastal area of North Sea, coasts of India.

13. <u>Biddulphia laevis</u> Ehrenberg

(Pl. I, fig. 13)

Ehrenberg, 1843, p.410;
Van Heurck, 1899, p.474, pl.20, figs. 506-507;
Misra, 1956, p.546, fig.20;
Wood, 1963d, p.247, pl.3, fig.49;
Hendey, 1964, p.105, pl.25, fig.7.

Cells sub-circular, valve surface flat, finely punctate. Valve mantle deep, occupying one third of the per-valvar length. On the major axis of the valve surface two large processes and on a line almost at right angles, two short spines present. In girdle view, the valves appear rectangular with straight sides. Diameter of valve 82 μ.

<u>Occurrence</u>: Found attached to rock in the estuarine area of Cochin.

<u>Distribution</u>: Estuarine areas of Atlantic, North Sea, coastal areas of Australia, west coast of India.

14. <u>Biddulphia granulata</u> Roper

(Pl. I, fig. 14)

Roper, 1859, p.13, pl.1, figs.10-11;
Van Heurck, 1899, p.473, pl.21, fig. 638;
Gran, 1905, p.107, fig.140;
Lebour, 1930, p.177, fig. 137;
Hendey, 1964, p.105.

Cells elliptic lanceolate, bearing two spines alternate with the terminal process, valve surface punctate, arranged oblique rows, girdle rectangular, punctate, arranged in decussate rows. Length of valve 74 μ.

__Occurrence__: Found attached on dead shell in the inshore area of Cochin.

__Distribution__: Coastal regions of Atlantic, North Sea, British coast, Australian coast and west coast of India.

Genus __Lithodesmium__ Ehrenberg

15. __Lithodesmium undulatum__ Ehrenberg
(Pl. I, figs. 15-16)

Ehrenberg, 1840, p.155, pl.4, fig.13;
Hustedt, 1927-30, p.789, fig.461;
Lebour, 1930, p.183, fig.145;
Subrahmanyan, 1946, p.149, figs.268-70;
Hendey, 1964, p.111, pl.6, fig.6.

Triceratium undulatum Brightwell, 1858, p.154.
Triceratium intricatum West, 1860, p.148, pl.7, fig.5.
Ditylum intricatum Grunow, Van Heurck, 1899, p.424, pl. 17, fig.607.
Lithodesmium victorioe Karsten, 1907, p.171,pl.28,fig.6.

Cells united to form a colony. Valves rectangular in girdle view, triangular in valve view with a median inflation, finely areolate. A small spine present from a conical base at the centre. Length of valve, 56 μ.

Occurrence: Found attached on dead shell in the inshore area of Cochin.

Distribution: Coastal areas of Europe, North Sea coast, coasts of Australia, east coast of India.

Family Isthemineae

Genus Isthmia Agardh

16. Isthmia enervis Ehrenberg
(Pl. I, fig. 18)

Ehrenberg, 1838, p.209,pl.16,fig.6;
Kutzing, 1844, p.137,pl.19, fig.4;
Smith, 1856,p.52,pl.48;
Hustedt, 1930, p.866, fig.516;
Subrahmanyan, 1946, p.157, fig.297,300;
Hendey, 1964, p.110, pl.25, fig.2.

<u>Isthmiella</u> <u>enervis</u> Cleve, 1873, p.10.

<u>Isthmiella</u> <u>obliquata</u> (Smith) Boyer, 1900, p.689.

Cells are united to form short chains, valves elongate, without costae, but well developed girdle with two distinct poles, one short and other slightly big. Valve surface and girdle areolated, 7 in 10 μ. Length 72 μ.

<u>Occurrence</u>: Found epiphytic on <u>Cladophora</u> sp. in the inshore area of Cochin.

<u>Distribution</u>: Atlantic and Pacific coasts, British coast, east coast of India.

17. <u>Isthmia</u> <u>nervosa</u> Kutzing
(Pl. I, fig.17)

Kutzing, 1844, p.137, pl.19, fig.5;
Smith, 1856, p.52, pl.47;
Schmidt, 1888, pl.135, figs.1-8;
Hustedt, 1927-30, p.865, fig.515;
Cupp, 1943, p.166, fig.116;
Hendey, 1964, p.110, pl.25, fig.3.

Cells trapizoidal in girdle view, 2-3 cells united to form short chains. The girdle is large, rectangular, valve mantle strongly costate, irregularly arranged. Cells showing two poles, somewhat equal and rounded, not elongate as in <u>I.</u> <u>enervis</u>. Valve surface and girdle areolated, the areolae on the border of the girdle longer than the others. Length of valve 120 μ.

<u>Occurrence</u>: Found attached to <u>Cladophora</u> sp. in the inshore area of Cochin.

<u>Distribution</u>: Europeal coastal waters and coasts of North Sea. New record to the Indian coasts.

Order : PENNALES
Sub Order Araphidineae
Family Fragilarioideae
Sub Family Tabellarieae

Genus Rhabdonema Kutzing

18. Rhabdonema mirificum Smith
(Pl. I, fig. 19)

Smith, 1856, p.35, pl.38, figs.305b;
Brightwell, 1859, p.180, pl.9, fig.11;
Subrahmanyan, 1946, p.161, figs.316, 318-319.

Climacosira mirifica (Smith) Grunow, De Toni, 1891-94, p.765;
Van Heurck, 1899, p.361, fig.112.

Rhabdonema punctatum Stoddar, Boyer, 1926, p.150.

Cells in girdle view ribbon-shaped with hyaline rounded corners forming more or less long bands. Valves linear with numerous intercalary bands, transversely striated, 15 in 10 μ. Length of one cell, 46 μ.

Occurrence: Found epiphytic on floating Sargassum, in the inshore area of Cochin.

Distribution: Coastal regions of Pacific, Red Sea, British coast, Ceylonese coast, east coast of India.

Genus <u>Striatella</u> Agardh

19. <u>Striatella unipunctata</u> (Lyngbye) Agardh
(Pl. I, fig. 20)

Agardh, 1832, p.61;
Van Heurck, 1899, p.363, pl.12, fig. 485a;
Lebour, 1930, p.200, fig.162;
Cupp, 1943, p.173, fig.122;
Hendey, 1964, p.161, pl.26, figs.17-18

<u>Fragilaria unipunctata</u> Lyngbye, 1819, p.183, pl.62, fig.6.

Cells colonial, united by their corners by small mucous pads, to form zig-zag chains, cell rectangular in girdle view, composed of numerous intercalary bands, alternate with short septa. Valve surface striate, undulating pseudoraphe, the striae crossing each other in curved oblique lines. Length of valve 118 μ, breadth 45 μ.

<u>Occurrence</u>: Found epiphytic on floating <u>Gracilaria</u> sp. in the inshore area of Cochin.

<u>Distribution</u>: Coastal waters of Europe, British coast, west coast of North America.

New record to the Indian coast.

Genus *Grammatophora* Ehrenberg

20. *Grammatophora undulata* Ehrenberg
(Pl. I, fig. 21)

Ehrenberg, in Kutzing 1849, p.121;
Boyer 1926, p.156;
Hustedt, 1931-32,p.48, fig.576;
Subrahmanyan, 1946, p.163, figs.
320, 324 and 326.

Cells united to form short colonies, valve quandrangular, rounded corners and undulate septa. Valves linear, oblong, broad, widened in the middle, ends capitulate. Striae not visible on the valve surface. Length of valve 52 μ, breadth 12 μ.

Occurrence: Found attached to decayed bamboo pole in the estuarine area of Cochin.

Distribution: European coastal waters, Mediterranean coast, West Indies, east coast of India.

Family : Licmophorineae
Genus *Licmophora* Agardh

21. *Licmophora abbreviata* Agardh
(Pl. I, fig. 22)

Agardh, 1831, p.42;
Hustedt, 1931-32, p.66, fig.590;
Cupp, 1943, p.177, fig.127;
Subrahmanyan, 1946, p.163, figs.330-32;
Misra, 1956, p.550, fig.31;
Nair, 1959, p.36, fig. 105.

Podosphenia lyngbyei Kutzing, 1849,p.110;
Smith, 1853, p.83, pl.24, fig.227;

Licmophora lyngbyei (Kutzing) Grunow in Van Heurck, 1899, p. 344, pl.11, fig.460; Lebour, 1930, p. 203, fig. 165; Hendey, 1964, p.167.

Licmophora lyngbyei var. abbreviata (Kutzing) Grunow, De Toni, 1891-94, p.735.

Cells colonial, united by means of short mucous stipes to form dense tufts, valves clavate, short with broad rounded bands. Cells in girdle view broadly cuneate, triangular septa projecting into the cell, pseudoraphe distinct. Numerous internal septa seen in girdle view as lines. Valve surface striate, 12 in 10 µ. Length of valve 65 µ.

Occurrence: Found epiphytic on Chaetomorpha filaments in the inshore area of Cochin.

Distribution: Atlantic and Pacific coasts, North Sea coast, English channel, coasts of India.

22. Licmophora ehrenbergii (Kutzing) Grunow
(Pl. I, fig. 23)

Grunow, 1867, p.36;
Van Heurck, 1899, p.344, pl.31, fig.853;
Cleve-Euler, 1953, p.18, fig.319 a,b;
Hendey, 1964, p.168.

Podosphenia ehrenbergii Kutzing, 1844,p.121,pl.9, fig.B.

Cells in girdle view cuneate, deep septa at the upper end, valves broadly clavate, with broad cuneate upper apex and rounded lower apex. Valve surface striate 8 in 10 µ, arranged in transverse lines upon either side of a well marked pseudoraphe. Length of valve 110 µ and breadth 22 µ.

Occurrence: Found epiphytic on Gracilaria, washed ashore in the inshore area of Cochin.

Distribution: Coastal waters of Europe, British coast, Australian coast.
New record for the Indian coast.

23. Licmophora flabellata (Greville) Agardh
(Pl. I, fig. 24)

Agardh, 1830-32, p.41;
Smith, 1853, p.86, pl.26, fig.234;

Van Heurck, 1899, p.342, pl.31,fig.852;
Boyer, 1927, p.165;
Hustedt, 1931-32, p.58, fig.581;
Misra, 1956, p.549, fig.28 a-c;
Hendey, 1964, p.168, pl.26, fig.5.

Exilaria flabellata Greville, 1823-28, pl.289.

Cells in girdle view, narrow, elongate and cuneate, valves join to form a 'fan' shaped appearance, supported upon a branching mucous stipe. Valves clavate, inflated at the base, faintly striated. Internal septa appear in girdle view as lines penetrating the cell from the broad end. Length of valve 86 μ.

Occurrence: Found attached on a tuft of Chaetomorpha filaments, attached to a rock in the inter-tidal area of the Cochin estuary.

Distribution: Coastal areas of Europe, British coast, Australian coast and west coast of India.

24. Licmophora gracilis (Ehrenberg) Grunow (Pl. I, fig. 25)

Grunow, 1867, p.34;
Van Heurck, 1899, p.343,pl.31,fig.851;
Hendey, 1964, p.167.

Podosphenia gracilis Ehrenberg, 1838, p.214,pl.17,fig.6.

Cells in fan shaped colonies, supported upon a simple stipe, valves cuneate, broadly rounded, tapering to a narrow slender lower end with a truncate base. Valves obovate, inflated with internal septa, appear in girdle view as lines, pseudoraphe present with faint transverse striation. Striae 18 in 10 µ. Length of valve 82 µ.

Occurrence: Found attached to a piece of *Wrangelia*, fixed to a rock in the inshore area of Cochin,

Distribution: Coastal waters of Europe, Mediterranean and North Sea coasts.
New record for the Indian coast.

25. *Licmophora juergensii* Agardh
(Pl. I, figs. 26-27)

Agardh, 1830-32, p.42;
Van Heurck, 1899, p.343,pl.31,fig.850;
Cleve-Euler, 1953,p.19,fig.325,b,d;
Hendey, 1964,p.168,pl.26,fig.14.

Podosphenia juergensii (Agardh) Kutzing, 1844,p.121,pl.9, fig.12.

Colonial form, attached to the substratum by means of stipes, form fan shaped appearance, being smaller than other species. Valves cuneate, truncate at the upper end, slightly rounded, clavate, sides straight, striated, striae 10 in 10 µ. Length of valve 58 µ.

<u>Occurrence</u>: Found epiphytic on <u>Cladophora</u>, which is attached to a rock in the estuarine area of Cochin.

<u>Distribution</u>: Coastal areas of North Sea, Mediterranean Sea, Atlantic coast, coastal areas of Australia.

New record for the Indian coast.

26. <u>Licmophora paradoxa</u> (Lyngbye) Agardh (Pl. I, fig. 30)

Agardh, 1825-35, p.32;
Van Heurck, 1899, p.344, pl.31, fig. 855;
Boyer, 1927, p.167;
Lebour, 1930, p.203, fig.165;
Hendey, 1951, p.40; 1964, p.168.

<u>Echinella paradoxa</u> Lyngbye, 1819, p.211.
<u>Licmophora paradoxa</u> (Lyngbye) Agardh var. <u>media</u> Misra, 1956, p.550, figs. 32-33.

Cells in fan shaped colonies, supported by a mucous stipe, valves obovate, rounded at both sides, broad at the posterior portion in girdle view, valve mantle faintly striate, well distinct pseudoraphe. Striae 22 in 10 μ. Length of valve 78 μ.

<u>Occurrence</u>: Found epiphytic on <u>Cladophora</u>, attached to a dead shell in the inshore area of Cochin.

<u>Distribution</u>: Coastal areas of North Sea, British coast, Atlantic coast, west coast of India.

Genus Climacosphenia Ehrenberg

27. Climacosphenia moniligera Ehrenberg

(Pl. I, figs. 31-32)

Ehrenberg, 1841, p.411, pl.2, fig. 6, i;
Boyer, 1926, p.171;
Hustedt, 1931-32, p.89, fig.625;
Cupp, 1943, p.178, fig.128;
Subrahmanyan, 1946, p.164, figs.322, 325, 333-334;
Nair, 1959, p.37, figs.106-108.

Climacosphenia australis Kützing, 1849, p.114.
Climacosphenia catena Shadbolt, 1854, p.17, pl.1, fig.15.
Climacosphenia monilifera Van Heurck, 1899, p.346, fig.100.

Epiphytic form, cells are borne on short stalked mucilage colonies, cells wedge shaped in girdle view, valves clavate, rounded at the apex, elongate below, traversed longitudinally by two parallel lines. Valves striated, 16 in 10 µ. Length of valve 268 µ and breadth at the tip 32 µ and 12 µ at the base.

Occurrence: Found epiphytic on Schizomeris sp., a green filamentous alga attached to a dead shell in the inshore area of Cochin.

Distribution: Widely distributed in the coasts of European countries, Atlantic coast, Gulf of Mexico, West Indies and coasts of India.

28. <u>Climacosphenia</u> <u>elongata</u> Bailey
(Pl. I, figs. 33-34)

Bailey in De Toni, 1891-94, p.739;
Boyer, 1926, p.172;
Hustedt, 1931-32, p.90, fig.626;
Subrahmanyan, 1946, p.164, figs. 323, 327-329 and 335.

Cells very slender and narrow, slightly rounded at angles with truncate bases, valves are more elongate than <u>C</u>. <u>moniligera</u>. Valves clavate, rounded at the apex and very much elongate below, traversed by two parallel longitudinal lines. Upper broader part short, 28 u broad, and rather suddenly diminishing in breadth lower down and becoming linear, lower part only 12 μ broad. Length of valve 820 μ, valve striated, 12 in 10 μ.

<u>Occurrence</u>: Found epiphytic on <u>Schizomeris</u> sp., attached to a rock in the inshore area of Cochin.

<u>Distribution</u>: Atlantic coast, coastal areas of Britain, Scotland, Florida coast, east coast of India.

Genus Rhaphoneis Ehrenberg

29. Rhaphoneis amphiceros Ehrenberg
(Pl. I, fig. 35)

Ehrenberg, 1844, p.87;
Boyer, 1926, p.190;
Hustedt, 1931-32, p.174, fig.680;
Allen and Cupp, 1935, p.153, fig.93;
Subrahmanyan, 1946, p.165, figs. 340-341;
Hendey, 1964, p.154, pl.26, figs.1-4.

Cocconeis amphiceros Ehrenberg, 1840, p.206.
Rhaphoneis lusitanica Rabenhorst, 1864, p.126.
Doryphora amphiceros Kutzing, 1849, p.50;
Smith, 1853, p.77, pl.24, fig.224.
Rhaphoneis amphiceros var. rhombica Grunow, Van Heurck, 1899, p.330, pl.10, fig.394.

Cells solitary, lanceolate or boat shaped, inflated at the centre, valve surface punctate, punctae in curved radiating lines, 6 in 10 μ. Length of valve 55 μ.

Occurrence: Found attached on a dead shell in the estuarine area of Cochin.

Distribution: European coastal waters, North Sea coast, British coast, west coast of North America, east coast of India.

Genus *Synedra* Ehrenberg

30. *Synedra superba* Kutsing
(Pl. I, fig. 36)

Kutsing, 1844, p.69, pl.15, fig. 13;
Smith, 1853, p.74, pl.12, fig.102;
Van Heurck, 1899, p.316, pl.30, fig.835;
Hendey, 1964, p.163.

Cells solitary, often in fan shaped clusters, supported on short mucous pads. Valves broadly linear, slightly rounded at the apices. Valve surface striate, crossed by three equidistant longitudinal lines, transverse except at the apices, 10 in 10 µ. Length of valve 360 µ, breadth 15 µ.

Occurrence: Found growing on rock in the estuarine region of Cochin.

Distribution: Coastal waters of Europe, North Sea coast. New record for the Indian coasts.

31. *Synedra pulchella* Kutsing
(Pl. I, figs. 37-38)

Kutzing, 1844, p.68, pl.29, fig.87;
Van Heurck, 1899, p.309, pl.10, fig.402;
Hendey, 1964, p.163.

Cells in fan shaped colonies, valves linear, lanceolate in girdle view with rounded apices. Valves with a distinct narrow pseudoraphe in the axial area, central area large. Valves striate, 15 in 10 μ. Length of valve 78 μ.

Occurrence: Found epiphytic on Cladophora, attached to a dead shell in the estuarine area of Cochin.

Distribution: Estuaries in Europe, North Sea coast, British coast.
New record for the Indian coasts.

32. Synedra crystallina (Agardh) Kutzing
(Pl. I, fig.28)

Kützing, 1844,p.69,pl.16,fig.1;
Smith, 1853,p.74,pl.12,fig.101;
Van Heurck,1899,p.315,pl.10, fig.435;
Boyer, 1927,p.208;
Hendey, 1964,p.164.

Diatoma crystallinum Agardh, 1824,p.3.

Valves very long, linear lanceolate, slightly tapering from the middle towards the weakly inflated rounded apices. Valve surface striate, 9 in 10 μ, finely punctate, arranged either side a thin, but distinct central pseudoraphe. Striae transverse, slightly radiate near the apices. Length of valve 760 μ and breadth 22 μ.

Occurrence: Found attached on rock in the inshore area of Cochin.

Distribution: Coastal areas of Europe, Atlantic and North Sea coasts.
New record for the Indian coasts.

33. *Synedra ulna* Ehrenberg
(Pl. I, fig.29)

Ehrenberg in De Toni, 1891, p.653;
Van Heurck, 1899,p.310,pl.10,fig.409;
Boyer, 1926,p.198;
Hustedt, 1930, p.151,figs.158,159;
1931-32,p.195,fig.691A, a-c;
Venkataraman,1939,p.105,figs.37,39,43.

Valves narrowly linear, somewhat broadened at the ends, rounded, pseudoraphe narrow, linear, central area rectangular, striae coarse, 12 in 10 µ. Length of valve 145 µ and breadth 8 µ.

Occurrence: Found in the sediment, in the estuarine area of Cochin.

Distribution: Estuaries, harbours and coastal areas of Atlantic, Pacific and North Sea and east coast of India.

Genus Podocystis Bailey ex Smith

34. Podocystis adriatica (Kutzing) Ralfs
(Pl. I, fig.39)

Ralfs in Pritchard,1861, p.772;
Smith, 1856,p.101;
Van Heurck, 1899,p.365, fig.117;
Hendey, 1964,p.169,pl.27,fig.4.

Surirella adriatica Kutzing, 1844,p.62,pl.30,fig. 80.
Podocystis americana Bailey, 1854,p.11 fig. 38.
Podocystis spathulata Foged, 1975,p.50,pl.8,fig.14.

Epiphytic form, attached to higher algae by means of short mucous stipe or pad. Valves broadly ovate or balloon-shaped, having the lower end slightly flattened. Valve surface with a median pseudoraphe and transverse costae, between which are two rows of areolae, alternately arranged. Striae 14 in 10 µ. Length of valve 105 µ and breadth 65 µ.

Occurrence: Found epiphytic on floating Sargassum in the inshore area of Cochin.

Distribution: North Sea coast, British coast, coastal areas of Australia, Ceylon.
New record for the Indian coasts.

Sub Order	Monoraphideae
Family	Achnanthoideae
Sub Family	Cocconeideae
Genus	Cocconeis Ehrenberg

35. Cocconeis scutellum Ehrenberg
(Pl. I, fig.40)

Ehrenberg, 1838, p.194;
Van Heurck, 1899, p.287, pl.8, fig.338;
Boyer, 1927, p.245;
Hustedt, 1930, p.191, fig.267;
1931, p.337, fig.790;
Wood, 1963d, p.252, pl.4, fig.73a;
Hendey, 1964, p.180, pl.27, fig.8.

Cells broadly elliptical, flat, upper valve with pseudoraphe, coarse punctae arranged in transverse lines, equidistant rows. The lower valve with a broad, marginal loculiferous rim and a small rounded central area, radiately striate, 9 in 10 µ, raphe straight. Length of valve 65 µ and breadth 38 µ.

Occurrence: Found epiphytic on Gracilaria corticata, in the inshore area of Cochin.

Distribution: European coastal waters, British coast, coasts of Sri Lanka.
New record for the Indian coasts.

36. Cocconeis placentula Ehrenberg
(Pl. I, figs. 41-42)

Ehrenberg, 1838, p.194;
Van Heurck, 1899, p.288, pl.8, fig.341;
Boyer, 1916, p.57, pl.16, fig.29;
1927, p.244;
Hustedt, 1930, p.189, fig.260;
1933, p.347, fig.802.

Valves elliptical, plain, disc striated, median hyaline zone of the upper valve enlarged at the centre and showing feeble traces of raphe and nodules, punctae distinct, separated by a hyaline zone. Striae 35 in 10 µ. Length of valve 65 µ and breadth 35 µ.

Occurrence: Found epiphytic on Gracilaria sp. in the inshore area of Cochin.

Distribution: British coast, mud flats in the North Sea, coastal areas of North America, Pacific coasts.
New record for the Indian coasts.

37. Cocconeis littoralis Subrahmanyan
(Pl. I, fig.43)

Subrahmanyan, 1946, p.171, figs. 368-70.

Epiphytic form, broadly elliptic valves, raphe-less, with three well defined hyaline areas, demarcated by striated bands, striae unequal in length, dot like thickening at the centre. Valve with raphe with somewhat radial punctae, alternating with those of the adjacent one, raphe sigmoid, axial area narrow, dilating into a very small central area. Striae 18 in 10 μ. Length of valve 55 μ and breadth 35 μ.

Occurrence: Found epiphytic on *Gracilaria* sp. in the inshore environment of Cochin.

Distribution: Coasts of India.

38. *Cocconeis pseudomarginata* Gregory (Pl.I, fig. 44)

Gregory, 1857,p.492,pl.9, fig.27;
Boyer, 1927,p.248;
Hustedt, 1931,p.359,fig.813;
Hendey, 1964,p.179,pl.28,fig.20.

Valves broadly elliptical, upper valve with a narrow lanceolate axial area and several longitudinal curved folds, lower valve with a narrow axial area, raphe terminating at a distance from the ends of the valve, central area small, valve surface striate, 18 in 10 μ. Length of valve 68 μ, breadth 45 μ.

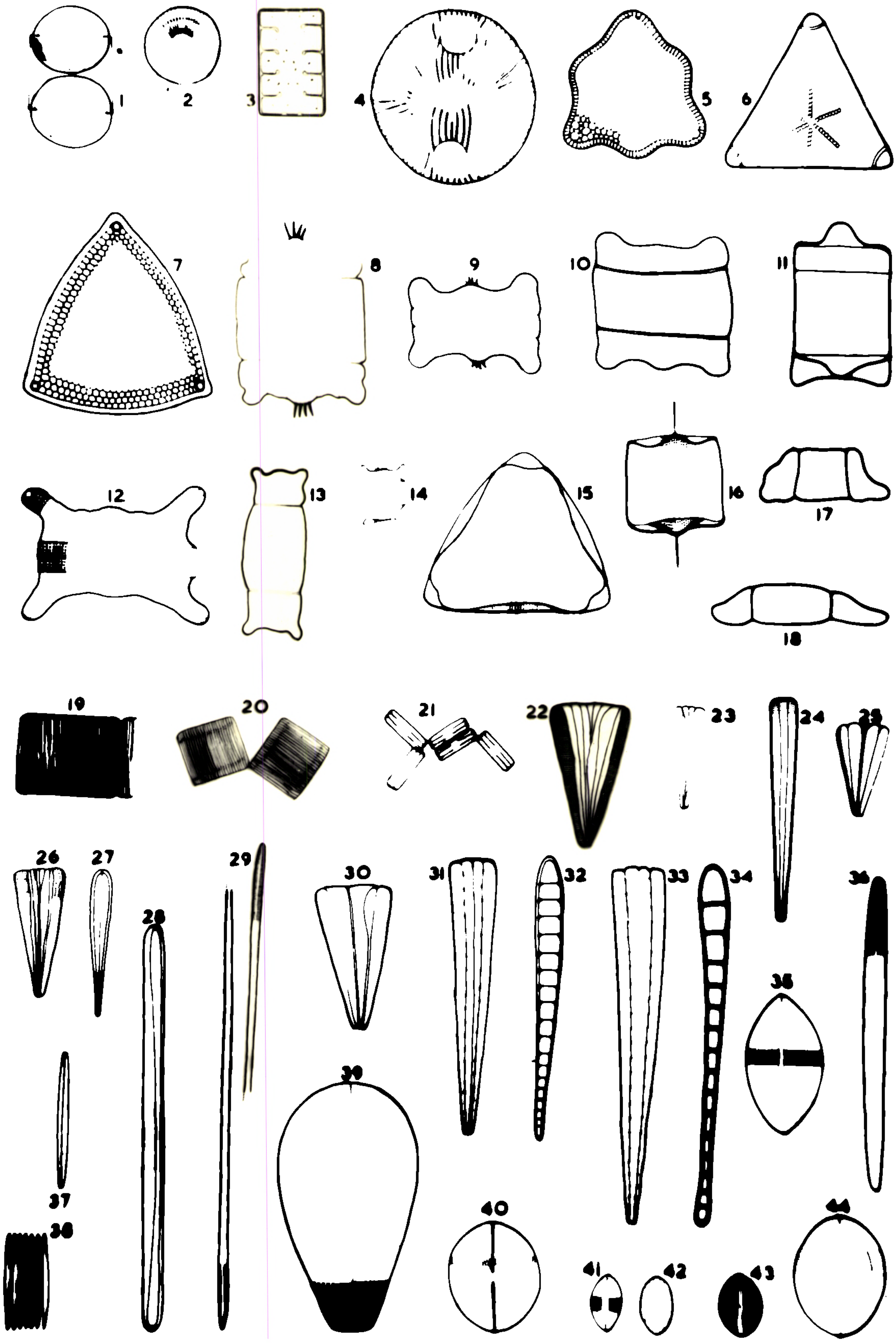
Occurrence: Found attached to rock in the estuarine area of Cochin.

Distribution: Atlantic and North Sea coasts, British coast. New record for the Indian coasts.

PLATE - I

Figs. 1 - 44. Fig. 1. Podosira montagnei, two cells in girdle view; Fig. 2. Cyclotella striata, valve view; Fig. 3. Terspinoe musica, girdle view; Fig. 4. Aulicus sculptus, valve view; Fig. 5. Triceratium dubium, valve view; Fig. 6. Triceratium reticulatum, valve view; Fig. 7. Triceratium roberstianum valve view; Figs. 8-10. Biddulphia pulchella, girdle views; Fig. 11. Biddulphia alternans, girdle view; Fig. 12. Biddulphia aurita girdle view; Fig. 13. Biddulphia laevis, girdle view; Fig. 14. Biddulphia granulata, girdle view; Figs. 15-16. Lithodesmium undulatum, valve and girdle views; Fig. 17. Isthmia nervosa, girdle view; Fig. 18. Isthmia enervis, girdle view; Figs. 1-18 x 980; Fig. 19. Rhabdonema mirificum valve view; Fig. 20. Striatella unipunctata, valve view of two cells; Fig. 21. Grammatophora undulata, chain of cells in girdle view; Figs. 19-21 x 720; Fig. 22. Licmophora abbreviata girdle view; Fig. 23. Licmophora ehrenbergii girdle view; Fig. 24. Licmophora flabellata girdle view; Fig. 25. Licmophora gracilis, girdle view; Figs. 26-27, Licmophora juergensii, girdle and valve views; Fig. 28. Synedra crystallina girdle view; Fig. 29. Synedra ulna, valve view; Fig. 30. Licmophora paradoxa, girdle view; Figs. 31-32. Climacosphenia moniligera, girdle and valve views; Figs. 33-34. Climacosphenia elongata, girdle and valve views; Fig. 35. Rhaphoneis amphiceros, valve view; Fig. 36. Synedra superba, valve view; Figs. 22-36 x 980; Figs. 37-38. Synedra pulchella, valve view of a cell and colonial habit; Fig. 37 x 840 and Fig. 38 x 720; Fig. 39. Podocystis adriatica, valve view; Fig. 40. Cocconeis scutelum, valve view; Figs. 41-42. Cocconeis placentula, ventral and dorsal valve views; Fig. 43. Cocconeis littoralis, valve view, ventral; Fig. 44. Cocconeis pseudomarginata, valve view, ventral; Figs. 39-44 x 980.

PLATE.I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Sub Family : Achnanthaceae

Genus Achnanthes Bory

39. *Achnanthes brevipes* Agardh

(Pl. II, fig.1)

Agardh, 1824, p.1;
Smith, 1856, p.27, pl.37, fig.301;
Van Heurck, 1899, p.279, pl.8, fig.324;
Hustedt, 1955, p.18;
Wood, 1963d, p.239, pl.1, fig.2;
Hendey, 1951, p.41, pl.16, figs.4-10;
1964, p.174, pl.28, figs.7-8.

Cells united to form short chains by mucous pads, valves linear elliptical, slightly constricted in the middle with broad obtuse ends. Valve structure punctate, 8 in 10 µ, rectangular. Valves dissimilar, lower one with a marked raphe enclosed in a stout rib, while the upper one bearing eccentric pseudoraphe. Girdle structure composed of annular segments. Length of valve 76 µ and breadth 27 µ.

Occurrence: Found epiphytic on *Cladophora* in the estuarine area of Cochin.

Distribution: Estuarine and coastal areas of Atlantic and Pacific, British coast.
New record for the Indian coasts.

40. <u>Achnanthes</u> <u>longipes</u> Agardh
(Pl. II, figs. 2-3)

Agardh, 1824, p.1;
Smith, 1856,p.26,pl.35, fig.300;
Van Heurck, 1899,p.279,pl.8,fig.323;
Boyer, 1927,p.231;
Lebour, 1930,p.205,fig.166;
Cupp, 1943,p.192, fig.141;
Hustedt, 1955,p.18;
Wood, 1963d,p.240,pl.1,fig.9;
Hendey, 1964,p.174,pl.28,fig.1-6, pl.42,fig.2.

Cells united by mucous pads to form short chains. Valves variable, elongate, elliptical, constricted in the middle, apices obtuse, valves punctate, in double rows, alternating with strong costae 6 in 10 µ, girdle with annular segments, upper valve with a narrow pseudoraphe, lower one a distinct raphe, dilated to form a narrow stauros. Length of valve 92 µ and breadth 28 µ.

<u>Occurrence</u>: Found epiphytic on <u>Cladophora</u> sp. in the estuarine area of Cochin.

<u>Distribution</u>: Coastal areas of Pacific and Atlantic, North Sea coast, west coast of North America, Texas Bay, Australian coast. New record for the Indian coasts.

Sub Order Biraphideae

Family : Naviculoideae

Sub Family : Naviculeae

Genus <u>Mastogloia</u> Thwaites

41. <u>Mastogloia pumula</u> (Grunow) Cleve
(Pl. II, fig.4)

Cleve, 1895, p.157;
Hustedt, 1931, p.553, fig.983;
Wood, 1963d, p.266, pl.8, fig.154a-c;
Hendey, 1964, p.238.

<u>Mastogloia braunii</u> var. <u>pumula</u> Grunow in Van Heurck, 1880, pl.4, fig.23.

Valves linear elliptic, broadly rounded apices, raphe straight, axial area very narrow, central area rectangular with longitudinal extensions on either side of the raphe in the form of an 'H', valve surface striate, radial, 22 in 10 µ. Septate plate marginal, composed of one or two large loculi and two or three smaller ones either side. Length of valve 77 µ, breadth 32 µ.

<u>Occurrence</u>: Found attached on a dead shell in the inshore area of Cochin.

<u>Distribution</u>: Coastal areas of Atlantic, North Sea, British coast, Texas Bay, west coast of North America.
New record for the Indian coasts.

42. Mastogloia braunii Grunow
(Pl. II, fig.5)

Grunow, 1863, p.156, pl.4, fig.2;
Van Heurck, 1899, p.156, pl.2, fig.66;
Hustedt, 1930, p.217, fig.320;
1931-33, p.551, fig.982;
Venkataraman, 1939, p.317, figs.57,62;
Hendey, 1964, p.239

Valves lanceolate, obtuse apices, raphe not straight but deviate at about middle, axial area narrow, central area large, rectangular and form two horns like 'H'. Valves striated, 16 in 10 µ, inner septate plate marginal composed of small numerous rectangular loculi, bigger in the middle than at the ends. Length of valve 76 µ and breadth 34 µ.

Occurrence: Found epiphytic on a dead shell in the inshore area of Cochin.

Distribution: Coastal areas of Europe, North Sea coast, Atlantic coast, Australian coast, east coast of India.

43. Mastogloia exigua Lewis
(Pl. II, fig. 6)

Lewis, 1861, pl.2, fig.5;
Van Heurck, 1899, p.155, pl.2, fig.63;
Hustedt, 1931-32, p.569, fig.1003;

Venkataraman, 1939, p.317, figs.44-45.

Valves elliptic, raphe straight, axial area narrow, central area square, striations radial, loculi 5 in number, bigger at the middle and smaller at the ends, striae 18 in 10 µ. Length of valve 45 µ and breadth 17 µ.

Occurrence: Found growing on a dead shell in the estuarine area of Cochin.

Distribution: Coastal waters of Europe, North Sea coast, east coast of India.

44. *Mastogloia lanceolata* Thwaites
(Pl. II, fig. 7)

Thwaites in Smith, 1856, p.64, pl.54, fig. 340;
Van Heurck, 1899, p.154, pl.2, fig.62;
Hustedt, 1931-33, p.493, fig.922;
Wood, 1963d, p.266, pl.8, fig.152 a-b.

Valves lanceolate with bluntly rounded ends, raphe curved slightly in the middle, axial area very narrow, central area small, circular in form. Valve surface with transverse and irregular striae, loculi numerous, but not reaching the ends. Striae 14 in 10 µ. Length of valve 74 µ and breadth 32 µ.

Occurrence: Found on a dead shell in the inshore area of Cochin.

Distribution: Coastal areas of North Sea, British coast, west coast of North America, Texas Bay. New record for the Indian coasts.

45. Mastogloia dolosa Vankataraman
(Pl. II, fig. 8)

Venkataraman, 1939,p.316,fig, 49.

Valves elliptical, lanceolate, sub-rostrate, axial area narrow, central area large, rectangular, widened to form a 'H' shape. The furrows on either side of raphe seem to meet at the tip. Striations radial, 24 in 10 μ, loculi 10 on either side, ending at a distance from the apices. Length of valve 52 μ and breadth 18 μ.

Occurrence: Found in the sediment, estuarine area of Cochin.
Distribution: Estuaries in the east coast of India.

46. Mastogloia exilis Hustedt
(Pl. II, fig. 9)

Hustedt, 1931-32, p.553,fig.985;
Subrahmanyan, 1946,p.172,fig.366,367.

Valves lanceolate, constricted, bluntly rounded ends, raphe straight, axial area narrow, central area widened and connected to two small half lanceolate areas forming and 'H' shape, loculi bigger 4 in number, bigger in the middle, and outermost smaller, transapical striae fine, 22 in 10 μ. Length of valve 36 μ and breadth 14 μ.

Occurrence: Found in the sediment, estuarine area of Cochin.
Distribution: Coastal areas of Indo-Malayan Archipelago, European coastal waters, Texas Bay, east coast of India.

47. Mastogloia cochinensis sp. nov.
(Pl. VI, fig. D)

Valves broadly elliptical, raphe striaght, axial area narrow, central area small, valve surface evenly areolated, forming radiate and concentric systems, areolae 16 in 10 µ, loculi marginal, big, striated, 6 in either side, reaching the apices. Length of cell 68 µ and breadth 52 µ.

This diatom shows a close resemblance to Mastogloia crucicula (Grunow) Cleve and M. hovarthiana Grunow in the broadly elliptical shape of the cell and in the arrangement of the areolae. However, the distinguishing characteristic feature of these two species are; in M. crucicula, the loculi are 4 in each side, uniform and not reaching the apex and in M. hovarthiana, numerous small loculi are present on either side.

Occurrence: Observed in the sediment, in the estuarine area of Cochin during November 1974.

Genus Navicula Bory

48. Navicula forcipata Greville

(Pl. II, fig.10)

Greville, 1859,p.83,pl.6,figs.10-11;
Schmidt, 1881,pl.70,figs. 30-34;
Van Heurck, 1899,p.203,pl.4,fig.163;
Boyer, 1927, p.416;
Subrahmanyan, 1946, p.182, fig.405;
Nair, 1959, p.44, fig.126;
Hendey, 1964, p.211,pl.33, figs.8-9.

Valves elliptical with broad, rounded ends, lateral areas narrow, constricted in the middle of the valve with convergent ends towards the pole, valve surface striated, 12 in 10 μ, transverse. Length of valve 78 μ and breadth 34 μ.

Occurrence: Found attached on a dead shell in the estuarine area of Cochin.

Distribution: Coasts of Britain, Belgium, Adriatic Sea, Atlantic and Pacific coasts, east and west coasts of India.

49. Navicula permagna Bailey

(Pl. II, fig. 11)

Bailey, 1850, p.40,pl.2,fig.28;
Van Heurck, 1899,p.218,pl.5,fig.202.

Cells solitary, broadly lanceolate, sub-acute apices, raphe distinct, surrounded by a broad hyaline zone, dilated into a round area, striae distinct, finely divided transversely and interrupted near the margin of the valve by a broad depression. Length of valve 82 µ and breadth 24 µ.

Occurrence: Found growing on a dead shell in the estuarine region of Cochin.

Distribution: Atlantic and Pacific coasts, coastal areas of Britain, west coast of North America. New record for the Indian coasts.

50. Navicula lyra Ehrenberg
(Pl. II, fig.12)

Ehrenberg, 1843, p.419;
Schmidt, 1875, pl.2, fig.16;
Van Heurck, 1899, p.202, pl.4, fig.161;
Hendey, 1964, p.209, pl.33, fig.2.

Navicula lyra var. ehrenbergii Cleve, 1895, p.63.

Valves elliptic lanceolate, with rostrate apices, striated, slightly radial, 12 in 10 µ, interrupted by lateral hyaline areas upon either side of the narrow axial area, formed as extensions of the strong central area. Some striae lie in between the lateral area and the valve margin, while others form a band between the bowl-shaped area and the raphe. Length of valve 85 µ.

<u>Occurrence</u>: Found growing on a dead shell in the estuarine area of Cochin.

<u>Distribution</u>: Coastal areas of Europe, Pacific and Atlantic coasts, British coast.
New record for the Indian coasts.

51. *Navicula gracilis* Kutzing
(Pl. II, fig. 13)

Kutzing, 1844, p.91,pl.3, fig.48;
Van Heurck, 1899,p.179,pl.3,fig.109.

Cells elongate, lanceolate, acute at the extremities. Valve surface striate, striac robust, central nodule short, the median ones scarcely radiant, all the striae are reaching to the raphe. Striae 12 in 10 μ. Length of valve 65 μ, breadth 15 μ.

<u>Occurrence</u>: Found epiphytic on *Cladophora* sp. in the estuarine area of Cochin.

<u>Distribution</u>: Atlantic and Pacific coasts, coastal waters of Europe.
New record for the Indian coasts.

52. *Navicula gracilis* var. *schizonemoides* Van Heurck
(Pl. II, fig.14; Pl.VI, fig.C)

Van Heurck, 1899,p.179,pl.3,fig.110.

Cells are endophytic, elongated and very narrow, striate, median striae longer and of unequal length, 9 in 10 μ. Length of valve 68 μ, breadth 15 μ. Cells usually embeded in mucilage tubes or in decayed algal pieces.

Occurrence: Found endophytic in a mucilage tube which was attached to rock in the estuarine area of Cochin.

Distribution: Coastal areas of Atlantic, North Sea. New record for the Indian coasts.

53. Navicula hasta Pantocsek
(Pl. II, fig.15)

Pantocsek in Cleve, 1895,p.25;
Boyer, 1923, p.399;
Hustedt, 1930,p.306,fig.541;
Venkataraman, 1939, p.331, fig.98.

Valves lanceolate, broad in the middle, tapering to sub acute ends. Axial area narrow, slightly widened in the middle, radial striae, coarse and slightly wide apart in the centre. Striae 9 in 10 μ. Length of valve 65 μ, breadth 17 μ.

Occurrence: Found in the sediment, estuarine region of Cochin.

Distribution: Estuaries and coastal areas of Europe, British coast and east coast of India.

54. Navicula pygmoea Kutzing
(Pl. II, fig.16)

Kutzing, 1849,p.77;
Cleve, 1895,p.65;
Van Heurck, 1899, p.203,pl.4,fig.164;
Boyer, 1927, p.416;
Hustedt, 1930, p.312, fig.561;
Venkataraman, 1939,p.333, fig.97.

Valves hyaline, elliptical, with broadly rounded ends. Axial area indistinct, lateral area constricted in the middle and converged at the ends, delicate striations, 22 in 10 μ. Length of valve 36 μ and breadth 14 μ.

Occurrence: Found in the sediment, estuarine area of Cochin.

Distribution: Estuaries, harbours of European countries, east coast of India.

55. Navicula bicapitata Lagerstedt
(Pl. II, fig. 17)

Lagerstedt in Van Heurck, 1899, p. 172, pl.2, fig. 90.

Valves narrow, linear with apices attenuated, rostrate, capitate. Valve surface costate, 8 in 10 μ, radiate in the middle of the valve, convergent at the apices, leaving round the raphe a narrow hyaline zone which expands into a sub-quandrangular area, round the central nodule. Length of valve 62 μ.

<u>Occurrence</u>: Found in the sediments collected from the estuarine area of Cochin.

<u>Distribution</u>: Coastal waters of Europe, North Sea coast, estuaries in Britain, Ireland.
New record for the Indian coasts.

56. <u>Navicula granulata</u> Baiely
(Pl. II, fig. 18)

Bailey, 1854, p.10, fig.16;
Cleve, 1895, p.48;
Van Heurck, 1899, p.211,pl.4,fig.183;
Hendey, 1951, p.48,pl.12; 1953, p.158, pl.1, fig.7-8; 1964,p.208, pl.31, fig.6.

Valves elliptical, rounded apices, axial area widened, central area round, surface striated, striae punctate, 16 in 10 μ, transverse at the centre, radiate at the poles. Length of valve 62 μ and breadth 26 μ.

<u>Occurrence</u>: Found in the sediments collected from the estuarine area of Cochin.

<u>Distribution</u>: Estuaries, harbours and coastal areas of Europe, North Sea, British coast.
New record for the Indian coasts.

57. __Navicula monilifera__ Cleve
(Pl. II, fig. 19)

Cleve, 1895, p.43;
Hendey, 1964,p.206,pl.31,figs.4-5.

Valves broadly elliptic, sides parallel with rostrate apices, axial area clear, narrow and central area orbicular, moderately large, raphe straight, valve surface coarsely striated, 8 in 10 μ. Length of valve 85 μ, breadth 25 μ.

__Occurrence__: Found in the sediments, in the estuarine area of Cochin.

__Distribution__: North Sea coast, coast of North America, coast of Britain and Wales.
New record for the Indian coasts.

58. __Navicula notabilis__ Greville
(Pl. II, fig. 20)

Greville, 1863,p.18,pl.1,fig.9;
Cleve, 1894,p.93;
Schmidt, 1875,pl.8,figs. 46-52;
Van Heurck, 1899, p.200,pl.26, fig. 750.

__Diploneis notabilis__ (Greville) Cleve, Hendey, 1964, p.224.

Valves elliptical, broadly rounded apices, central nodule moderately large, raphe narrow, straight, lying between strongly silicified parallel horns, lateral areas small, narrow, valve surface costate, transverse, between the costae are elongated alveoli of different lengths. Costae 7 in 10 μ, length of valve 82 μ and breadth 32 μ.

Occurrence: Found growing on rock in the estuarine area of Cochin.

Distribution: Coastal waters of Europe, British coast. New record for the Indian coasts.

59. *Navicula plicata* Donkin
(Pl. II, fig.21)

Donkin, 1870-73,p.59,pl.9,figs. 2a,b;
Cleve, 1894,p.154;
Van Heurck, 1899,p.235,pl.27,fig.787;
Hendey, 1964, p.193.

Valves in girdle view rectangular, rounded angles, girdle composed of numerous bands, valves linear, lanceolate, with tapering obtusely rounded ends in valve view, axial area narrow, central area small, valve surface more or less convex, fine parallel striae, 17 in 10 μ. Length of valve, 85 μ, breadth 16 μ.

Occurrence: Found growing on rock along with other *Navicula* species, in the estuarine area of Cochin.

Distribution: Coastal waters of Europe, British coast. New record for the Indian coasts.

60. <u>Navicula hennedyi</u> var. <u>neapolitana</u> Cleve
(Pl. II, fig. 22)

Cleve, 1895, p.58;
Mills, 1933, p.1060;
Reinhold, 1937,p.109,pl.13,fig.10.

Valve elliptical, middle region wide and broad, axial area narrow, raphe straight, surface of valve striate, striae in two bands, the axial striae forming a narrow band about 3-5 punctae, wide open either side of the raphe, and the lateral and marginal striae radiating from the centre towards the margin. Length of valve 110 μ, breadth 62 μ.

<u>Occurrence</u>: Found in the sediment, in the marine area of Cochin during September 1974.

<u>Distribution</u>: Coasts of Scotland, North Sea and Java Sea. New record for the Indian coasts.

61. <u>Navicula hennedyi</u> var. <u>nebulosa</u> (Gregory) Cleve
(Pl. II, fig. 23)

Cleve, 1895, p.58;
Van Heurck, 1899,p.204,pl.27,fig. 755;
Boyer, 1927, p.413;
Subrahmanyan, 1946,p.181, fig.404.

<u>Navicula nebulosa</u> Gregory, 1857,p.480,pl.9,fig.8;
Donkin, 1870-73,p.11,pl.2,fig.2;
Van Heurck, 1899,p.264,pl.27,fig.755;
Hendey, 1964, p.213.

Valves elliptical, angular margins, apices not fully rounded, axial area narrow, raphe well marked, straight, axial striae transverse, very short, marginal striae in a narrow band of approximately equal length, hyaline lateral area. Striae 18 in 10 μ. Length of valve 55 μ and breadth 26 μ.

<u>Occurrence</u>: Found growing on rock in the inshore area of Cochin.

<u>Distribution</u>: North Sea coast, English channel, Scotish coast, Belgium coast and east coast of India.

Genus <u>Dictyoneis</u> Cleve

62. <u>Dictyoneis marginata</u> Cleve
(Pl. II, fig. 24)

Cleve, 1890 in Van Heurck, 1899,
p. 157, fig. 29;
Wood, 1963a, p.108.

<u>Navicula strangulata</u> Leuduger-Fortmorel, 1878, p.41.
<u>Navicula spectatissima</u> Leuduger-Fortmorel, 1878, p.42.

Valve elongated, broad and round apex, median part of valve constricted, raphe straight, surrounded by a narrow hyaline zone, surface of valve striated, marginal striae broad and large, resembling the loculi of the genus Mastogloia. Length of valve 68 µ.

Occurrence: Found in the sediments, in the marine environment of Cochin.

Distribution: Coasts of Atlantic, Mediterranean, East Indies, Tasmania, Madagascar and Sri Lanka. New record for the Indian coasts.

Genus Caloneis Cleve

63. Caloneis liber (Smith) Cleve
(Pl. II, fig.25)

Cleve, 1894, p.54;
Boyer, 1927, p.310;
Hendey, 1951, p.57, pl.9, fig.8;
1964, p.229, pl.29, fig.2.

Navicula liber Smith, 1853, p.48, pl.16, fig.133;
Van Heurck, 1899, p.222, fig.219.

Valves elliptical, oblong, with rounded apices. Axial area very narrow, developing into a small, orbicular central area, valve surface striate, striae parallel, 8 in 10 µ. Longitudinal lines median, about half way between the raphe and the valve margin. Length of valve 65 µ and breadth 16 µ.

Occurrence: Observed in the sediments, estuarine area of Cochin.

Distribution: North Sea coast, British coast, coasts of Australia.
New record for the Indian coasts.

Genus Diploneis Ehrenberg

64. *Diploneis smithii* (Brebisson) Cleve
(Pl. II, fig. 29)

Cleve, 1894, p.96;
Boyer, 1927, p.354;
Hustedt, 1930, p.253, fig.402;
Subrahmanyan, 1946, p.180, fig.399;
Wood, 1963d, p.259, pl.6, fig.112;
Hendey, 1964, p.225, pl.32, fig.10.

Navicula elliptica Brebisson, Smith, 1853, p.48, pl.17, fig.152a.
Navicula smithii Van Heurck, 1899, p.192, pl.4, fig.151 a,b.

Cells small, elliptical, oval, central nodule small, produce two horns, enclosing the raphe, furrows narrow, punctate, close to the horns. Surface of valve costate, alternating with double rows of areolae. Length of cell 72 µ and breadth 38 µ.

Occurrence: Found in the sediment, in the estuarine area of Cochin.

Distribution: Coasts of Atlantic, North Sea, Mediterranean Sea, Texas Bay, Australian waters and Indian Seas.

65. *Diploneis dydima* (Ehrenberg) Cleve
(Pl. II, fig. 26)

Cleve, 1894, p.90;
Hustedt, 1931-34, p.685, fig.1075;
Smith, 1853, p.53, pl.17, fig.154;

Boyer, 1927, p.352;
Hendey, 1951, p.58, pl.8, figs. 5-6;
1964, p.226, pl.32, fig.12.

<u>Navicula</u> (<u>Pinnularia</u>) <u>dydima</u>, Ehrenberg, 1840, p.155;
Kutzing, 1844, p.100;
Schmidt, 1875, pl.13, fig.13;
Van Heurck, 1899, p.193, pl.3, fig.147.

Cells slightly constricted in the middle, valves divided into two tongue-shaped segments. The central nodule is subquadrate or almost circular. Valve surface costate, transverse in the middle, slightly curving, radiating lines towards the apices and crossed by numerous undulating longitudinal lines. Costae 6 in 10 µ. Length of valve 85 µ and breadth 35 µ.

<u>Occurrence</u>: Found growing on rock in the inter-tidal zone of the inshore area of Cochin.

<u>Distribution</u>: Coastal areas of North Sea countries,
European coastal waters.
New record for the Indian coasts.

66. <u>Diploneis</u> <u>subovalis</u> Cleve
(Pl. II, fig.27)

Cleve, 1894, p.96, pl.1, fig.27;
Rick, 1936, p.211, pl.10, fig.1;
Venkataraman, 1939, p.322.

Cells oval, valves elliptical, central nodule large, rounded, furrows narrow, closely following the central nodule and its horns. Costae strong, far apart, alternating with double rows of alveoli, costae 12 in 10 µ.

Length of valve 62 μ and breadth 36 μ.

Occurrence: Found on rock in the inter-tidal area of Cochin.

Distribution: Coastal waters of Europe, North Sea coast, east coast of India.

67. Diploneis splendida (Gregory) Cleve
(Pl. II, fig. 28)

Cleve, 1894, p.87;
Hustedt, 1931-34, p.712, fig, 1089;
Hendey, 1964, p.227.

Navicula splendida Gregory, 1856, p.44, pl.5, fig.14;
Van Heurck, 1899, p.193, pl.26, fig.729;
Schmidt, 1875, pl.13, figs.31-34;
Peragallo, 1897-1908, p.18, figs.15-18.

Navicula entomon sensu Donkin, 1870-73, pl.7, fig. 5.

Valves linear elliptic, constricted in the middle, dividing the valve into two tongue-shaped broadly cuneate segments, furrows somewhat wide and linear, inner margin straight, horns strong, linear and parallel. Beyond the furrows, the valve surface costate, 8 in 10 μ. Length of valve 110 μ and breadth 45 μ.

Occurrence: Found epiphytic on a dead shell in the inshore area of Cochin.

Distribution: Coastal waters of Europe, British coast. New record for the Indian coasts.

68. Diploneis elliptica (Kutzing) Cleve
(Pl. II, fig. 30)

Cleve, 1894, p.92;
Boyer, 1927, p.355;
Wood, 1963a, p.175;
Hendey, 1951, p.59, pl.8, fig.3;
1964, p.226.

Navicula elliptica Kutzing, 1844, p.98, pl.30, fig, 55;
Schmidt, 1875, pl.7, fig.27-28;
Van Heurck, 1899, p.201, pl.4, fig.156.

Cells elliptical, valves with broad and rounded apices, central nodule medium in size, produced to two slender horns, furrows narrow, close to the horn, uniform breadth throughout. Valve structure punctate, 12 in 10 μ, transverse in the middle, slightly radiate towards the apices. Length of valve 45 μ and breadth 18 μ.

Occurrence: Found on a dead shell in the estuarine area of Cochin.

Distribution: Estuaries in North Sea coast, British coast, Australian coasts.
New record for the Indian coasts.

69. Diploneis chersonensis (Grunow) Cleve
(Pl. II, fig. 31)

Cleve, 1894, p.91;
Hustedt, 1931-34, p.709, fig.1088;
Hendey, 1964, p.227, pl.32, figs.7-8.

Navicula chersonensis Grunow in Schmidt, 1875, pl.12, fig.40;
Peragallo, 1897-1908, pl.19, fig.9;
Venkataraman, 1939, p.196, pl.26, fig. 738.

Navicula opis Schmidt, 1874, pl.1, fig. 9.

Valves linear, elliptic, with a deep trans-apical constriction, opposite the central nodule to form panduriform outline, with two tongue shaped segments having round apices. Central nodule small, horns narrow, linear, flanked by narrow linear furrows, having longitudinal lines of punctae and transverse striae 12 in 10 µ. Length of valve 88 µ and breadth 24 µ.

Occurrence: Found growing on rock in the inshore area of Cochin.

Distribution: Atlantic coast, North Sea coast, west coast of Britain, Wales and Australian coast. New record for the Indian coasts.

Genus *Anomoeoneis* Ehrenberg

70. *Anomoeoneis sculpta* (Ehrenberg) Cleve
(Pl. II, fig. 32)

Cleve, 1895, p.6;
Boyer, 1927, p.324;
Hendey, 1951, p.56, pl.17, fig.16;
1964, p.218, pl.37, fig.12.

Navicula sculpta Ehrenberg, 1854, pl.10, figs.1, 5;
Schmidt, 1877, pl.49, fig.46,48;
Van Heurck, 1899, p.216, pl.4, fig.194.

Cells lanceolate, obtuse apices, axial area narrow, linear, bordered upon each side with a single row of puncta, valve surface striate, 15 in 10 µ, radiate, irregular towards the lateral sides, closely packed near the margin. Length of valve 95 µ and breadth 28 µ.

Occurrence: Found attached to rock in the estuarine area of Cochin.

Distribution: Coastal areas of Britain, France, English channel, Australian coast.

New record for the Indian coasts.

Genus *Trachyneis* Cleve

71. *Trachyneis aspera* (Ehrenberg) Cleve
(Pl. II, fig. 33)

Cleve, 1894, p. 191;
Boyer, 1927, p. 428;
Subrahmanyan, 1946, p. 183, fig. 408;
Hendey, 1964, p. 236, pl. 29, fig. 13.

Navicula aspera Ehrenberg, 1840, p. 213;
De Toni, 1891-94, p. 109;
Van Heurck, 1899, pl. 10, fig. 13.

Stauroneis pulchella Smith, 1853, p. 61, pl. 19, fig. 194.

Trachyneis aspera var. *pulchella* (Smith) Cleve, 1894, p. 191.

Valves linear-lanceolate, obtuse ends, axial are narrow, central area chilated to form a transverse staurose slightly widening towards the margin, transapical striae 9 in 10 µ, longitudinal striae 22 in 10 µ. Length of valve 145 µ and breadth 35 µ.

Occurrence: Found attached to rock in the estuarine area of Cochin.

Distribution: North Atlantic coast, Mediterranean coast, British coast, east coast of India.

72. Trachyneis antillarum Cleve

(Pl. II, fig.34)

Cleve, 1894, p.193;
Boyer, 1927, p.429;
Subrahmanyan, 1946, p.183, fig.409.

Alloneis antillarum Cleve and Grunow, Cleve, 1878, p.8, pl.2, fig. 11.

Scoliopleura antillarum De Toni, 1891-94, p.265.

Valves linear, elliptical, with obtuse ends, raphe eccentric, axial area broad, irregularly linear, transverse striae in radial rows, alveolate, alveolae 9 rows in 10 µ. Length of valve 118 µ and breadth 45 µ. The main difference between T. aspera is the broad nature of the cell and the alveolar arrangement on the surface of the valve.

Occurrence: Found attached to rock in the estuarine area of Cochin.

Distribution: Coastal areas of Britain, Belgium, Mediterranean sea, West Indies, Sri Lanka coast and east coast of India.

Sub Family : Amphiproroideae

Genus <u>Amphiprora</u> Ehrenberg

73. <u>Amphiprora gigantea</u> Grunow var. <u>sulcata</u> (O'Meara) Cleve

(Pl. II, fig. 42)

Cleve, 1894, p.18;
Allen and Cupp, 1935, p.160;
Cupp, 1943, p.198, fig. 151;
Subrahmanyan, 1946, p.184, figs. 410-413.

<u>Amphiprora sulcata</u> O'Meara 1871, p.22, pl.3, fig.3;
De Toni, 1891-94, p.334.

Cells strongly constricted and sides resembles 'bow' like appearance. Keel with hyaline margin, keel punctae forming obliquely decussating rows, 15 rows in 10 μ, striae curved, connecting zone with numerous longitudinal divisions, striae on the connecting zone 16 in 10 μ. Length of valve 86 μ and breadth 38 μ.

<u>Occurrence</u>: Found attached to rock in the inshore area of Cochin.

<u>Distribution</u>: North Sea coast, coasts of Java Sea, west coast of North America, Australian coast and east coast of India.

Genus <u>Pleurosigma</u> Smith

74. <u>Pleurosigma formosum</u> Smith

(Pl. II, fig. 43)

Smith 1852,p.5,pl.1,fig.1;
1853,p.63,pl.20,fig.195;
Boyer, 1916,p.73,pl.22,fig.5;
1927,p.467;
Wood, 1963d,p.277,pl.11,fig.220;
Hendey, 1964,p.242.

Valves elongated, sigmoid and linear with sub-acute apices. Raphe strongly sigmoid, sweeping across the valve at about middle distance and becoming almost coincident with the convex margin as it approaches the apices. Valve surface striate, arranged in oblique lines, 14 in 10 µ and in transverse lines 16 in 10 µ. Length of valve 380 µ and breadth 45 µ.

This species is often confused with *P. decorum* Smith, but it is less lanceolate and the apices are a little more obtuse. The striations are more coarse than in *P. decorum*.

Occurrence: Found growing on rock in the inshore area of Cochin.

Distribution: European coastal waters, North Sea coast, Australian coast.
New record for the Indian coasts.

Genus *Gyrosigma* Hassel

75. *Gyrosigma balticum* (Ehrenberg) Cleve
(Pl. II, fig. 45)

Cleve, 1894,p.118;
Boyer, 1927,p.456;
Hustedt,1930,p.318,fig.71-72;

Venkataraman, 1939, p.318, figs.71-72;
Subrahmanyan, 1946, p.173, figs.373-375;
Hendey, 1964, p.248, pl.35, fig.9.

<u>Navicula</u> <u>baltica</u> Ehrenberg, 1838, p.180, pl.13, fig.10

<u>Pleurosigma</u> <u>balticum</u> (Ehrenberg) Smith, 1853, p.66, pl.22, fig. 207;
Hendey, 1951, p.61, pl.11, fig. 9.

Valves linear, sides parallel, sigmoid towards the ends with obtuse apices. Raphe slightly eccentric, sigmoid, having the same sigmoid curvature as the valve margin, central area small, oblique, transverse and longitudinal striae equidistant, 14 in 10 µ. Length of valve 310 µ, breadth 42 µ.

<u>Occurrence</u>: Found growing on a dead shell in the estuarine area of Cochin.

<u>Distribution</u>: North Atlantic coast, North Sea coast, European coastal waters, Sri Lanka coast, east coast of India.

76. <u>Gyrosigma</u> <u>scalproides</u> var. <u>eximia</u> (Thwaites) Cleve
(Pl. II, fig.44)

Cleve, 1894, p.118;
Hustedt, 1930, p.226, fig.339;
Venkataraman, 1939, p.319, fig.76.

<u>Colletonema</u> <u>eximium</u> Thwaites 1848, pl.12, fig.F

<u>Pleurosigma</u> <u>eximium</u> (Thwaites) Van Heurck, 1899, p.259, pl.7, fig.283.

Valves short, linear, parallel sides and obliquely rounded ends. Raphe slightly sigmoid at the ends, rarely central, transverse striae finely punctate, longitudinal striae very faint. Transverse striae 22 in 10 µ. Length of valve 55 µ and breadth 12 µ.

Occurrence: Found in the sediment, estuarine area of Cochin.

Distribution: West coast of North America, Atlantic coast, British coast, east coast of India.

Sub Order : Raphidiodineae
Family : Eunotiaceae
Sub Family Eunotioideae
Genus *Eunotia* Ehrenberg

77. *Eunotia monodon* Ehrenberg
(Pl. II, fig. 36)

Ehrenberg in Smith, 1853, p. 16, pl. 11, fig. 16;
Boyer, -1927, p. 221;
Hustedt, 1930, p. 185, fig. 254;
Venkataraman, 1939, p. 310, fig, 40.

Valves arcuate with the dorsal side well bent, narrow towards the ends, rounded, structures coarse, narrower near ends. Striae 9 in 10 µ. Length of valve 65 µ and breadth 12 µ.

Occurrence: Found in the sediment, estuarine area of Cochin.

Distribution: Estuaries, coastal areas of Europe, North Sea coast, east coast of India.

78. Eunotia diodon Ehrenberg
(Pl. II, fig.37)

Ehrenberg, 1856,p.192,pl.21,fig.23;
Van Heurck, 1899,p.303,pl.30,fig. 829-830;
Hustedt, 1930,p.173,fig.207.

Valves with ventral margin concave, dorsal margin showing two slight rounded ridges, apices obtuse, rounded subcapitate, valves finely punctate, punctae 5 in 10 μ. Length of valve 26 μ and breadth 9 μ.

Occurrence: Found in the sediment, estuarine area of Cochin.

Distribution: Estuaries of European coast, North Sea coast, British coast, Swedish and Ireland coasts.
New record for the Indian coasts.

Family : Epithemiaceae
Sub Family : Epithemoideae
Genus Epithemia Brebisson

79. Epithemia turgida Kutzing
(Pl. II, fig.38)

Kutzing, 1856,pl.5,fig.14;
Van-Heurck,1899,pl.294,fig.346;
Hustedt,1930,p.387,fig.733.

Valves arcuate, apices more or less rostrate, capitate, dorsal margin rather flexed, costae radient, 4 in 10 μ., about 8 radiant rows of coarse elongated beads in the same space, girdle view more or less strongly inflated in the median portion. Length of valve 77 μ and breadth 14 μ.

Occurrence: Found attached to rock in the estuarine area of Cochin.

Distribution: Coastal and estuarine waters of Europe, North Sea coast, Japanese waters and Sri Lanka coast.
New record for the Indian coasts.

80. *Epithemia musculus* Kutzing
(Pl. II, fig.40)

Kutzing, 1844,p.33,pl.30, fig.6;
Smith, 1853,p.14,pl.1,fig.10;
Van Heurck, 1899,p.297,pl.9,fig.359;
Boyer, 1927,p.490;
Hendey, 1964,p.271.

Cells broadly elliptical, sub-orbicular, with dorsal margin strongly arcuate and ventral margin concave, apices acute, valve complex, consisting of an inner plate or septate system, costae radiant, variable in number, moniliform striae, 15 in 10 μ. Length of valve 45 μ, breadth 16 μ.

Occurrence: Found growing on rock in the estuarine area of Cochin.

Distribution: Estuarine waters of Europe, North Sea coast, British coast.
New record for the Indian coasts.

Genus Encyonema Kutzing

81. Encyonema prostratum Ralfs

(Pl. II, fig. 39)

Ralfs, 1845, pl.3, fig.3;
Schmidt, 1881, pl.71, figs.6-7;
Van Heurck, 1899, p.149, pl.1, fig.44.

Valves large, dorsal side considerably inflated, ventral side with slight curvature, apices abruptly produced, obtuse and rounded, raphe straight with its median ends slightly arcuate towards the dorsal margin, surrounded by a hyaline zone. Valve surface striated, 7 in 10 µ. Length of valve 75 µ and breadth 18 µ.

Occurrence: Found growing on rock in the estuarine area of Cochin.

Distribution: Estuaries and coastal areas of North Sea, British coast.
New record for the Indian coasts.

82. Sub Family : Gomphocymbelloideae

Genus Amphora Ehrenberg

Amphora ovalis Kutzing

(Pl. II, fig.35; Pl.III, fig.3)

Kutzing, 1844, p.107, pl.5, fig.35,39;
Schmidt, 1875, pl.26, figs. 106-111;
Van-Heurck, 1899, p.127, pl.1, fig.15;
Hustedt, 1930, p.342, figs.628.

Cells oval, inflated at the median portion, then slightly attenuate, apices broadly truncate, valves arcuate, at dorsal margin, concave at internal margin, raphe inflexed, striae strongly marked with coarse punctae, 12 in 10 µ. Length of valve 62 µ and breadth 28 µ.

Occurrence: Found on a dead shell in the estuarine area of Cochin.

Distribution: Coastal waters of Atlantic and Pacific, North Sea coast, coast of Sri Lanka. New record for the Indian coasts.

83. Amphora laevissima Gregory (Pl. II, fig.41)

Gregory, 1857,p.41,pl.4,fig.72;
Schmidt, 1874,pl.26,fig.3,13-14;
Van Heurck, 1899,p.139,pl.24,fig. 694.

Valves linear, oblong, extremities hyaline, raphe abruptly inflexed towards the median portion, with a broad stauros, striae invisible. Length of valve 62 µ and breadth 28 µ.

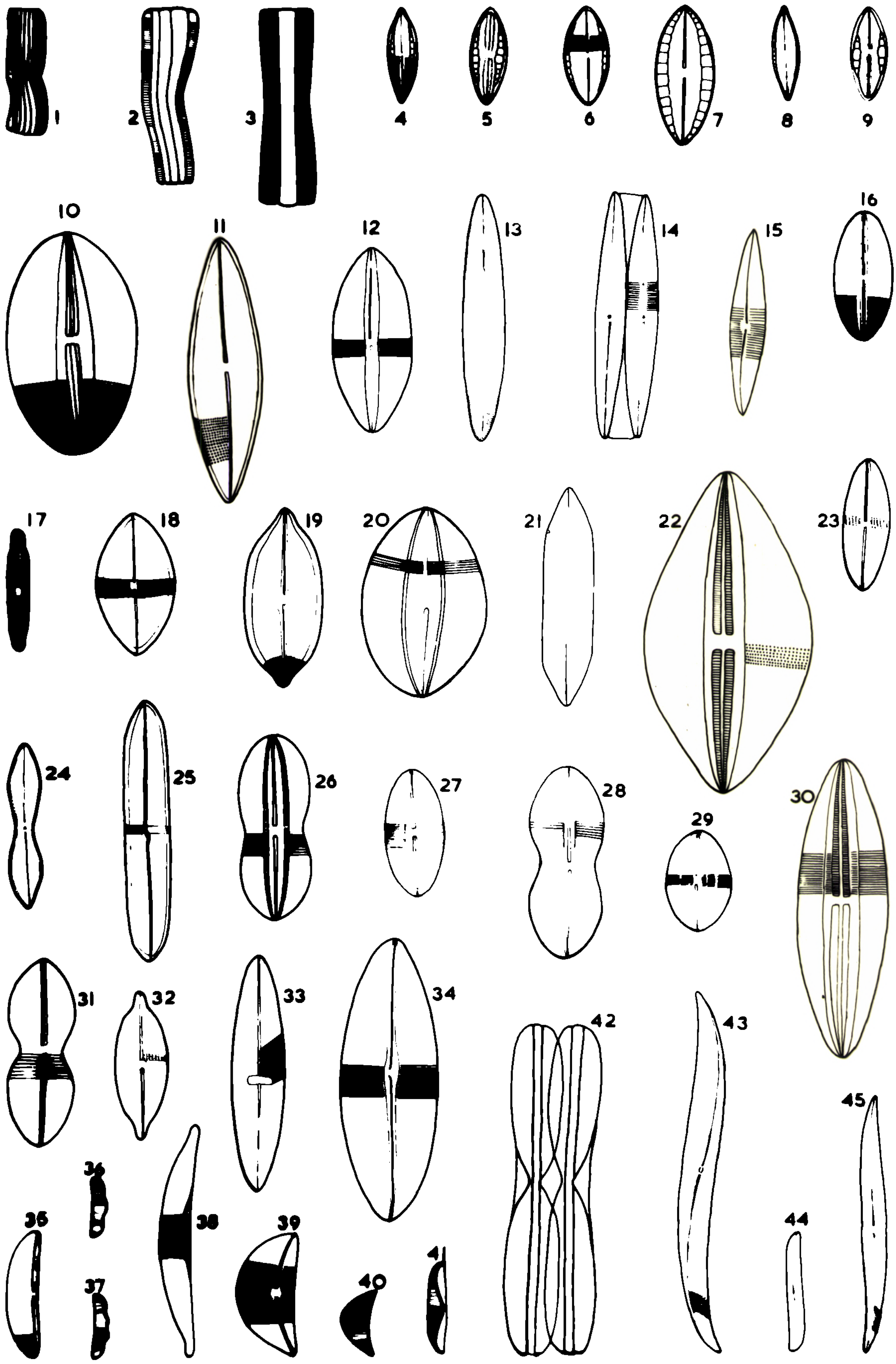
Occurrence: Epiphytic on dead shell in the inshore area of Cochin.

Distribution: European coastal waters, North Sea coast. New record for the Indian coasts.

PLATE - II

Figs. 1-45. Fig. 1. Achnanthes brevipes, girdle view; Figs. 2-3. Achnanthes longipes, girdle view and side view; Figs. 1-3 x 980; Fig. 4. Mastogloia pumula, valve view; Fig. 5. Mastogloia braunii, valve view; Fig. 6. Mastogloia exigua, valve view; Fig. 7. Mastogloia lanceolata, valve view; Fig. 8. Mastogloia dolosa, valve view; Fig. 9. Mastogloia exilis, valve view; Figs. 4-9 x 720; Fig. 10. Navicula forcipata, valve view; Fig. 11. Navicula permagna, valve view; Fig. 12. Navicula lyra, valve view; Fig. 13. Navicula gracilis, valve view; Fig. 14. Navicula gracilis var. schizonemoides, valve view shows division; Fig. 15. Navicula hasta, valve view; Fig. 16. Navicula pygmoea, valve view; Fig. 17. Navicula bicapitata, valve view; Fig. 18. Navicula granulata, valve view; Fig. 19. Navicula monilifera, valve view; Fig. 20. Navicula notabilis, valve view; Fig. 21. Navicula plicata, valve view; Fig. 22. Navicula hennedyei var. neapolitana, valve view; Fig. 23. Navicula hennedyei var. nebulosa, valve view; Fig. 24. Dictyoneis marginata, valve view; Fig. 25. Caloneis liber, valve view; Fig. 26. Diploneis dydima, valve view; Fig. 27. Diploneis sub-ovalis, valve view; Fig. 28. Diploneis splendida, valve view; Fig. 29. Diploneis smithii, valve view; Fig. 30. Diploneis elliptica, valve view; Fig. 31. Diploneis chersonensis, valve view; Fig. 32. Anomoeneis sculpta, valve view; Fig. 33. Trachyneis aspera, valve view; Fig. 34. Trachyneis antillarum, valve view; Fig. 35. Amphora ovalis, valve view; Figs. 10-34 x 980, Fig. 35 x 720; Fig. 36. Eunotia monodon, valve view; Fig. 37. Eunotia diodon, valve view; Fig. 38. Epithemia turgida valve view; Fig. 39. Encyonema prostratum, valve view; Fig. 40. Epithemia musculus, valve view; Fig. 41. Amphora laevissima, girdle view; Figs. 36-40 x 980, Fig. 41 x 720; Fig. 42. Amphiprora gigantea var. sulcata, girdle view, cell undergoing division; Fig. 43. Pleurosigma formosum, valve view; Fig. 44. Gyrosigma scalproides, valve view; Fig. 45. Gyrosigma balticum, valve view; Figs. 42-43 x 980, Fig. 44 x 720 and fig. 45 x 980.

PLATE II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84. <u>Amphora lineolata</u> Ehrenberg

(Pl. III, fig.1)

Ehrenberg, 1856,p.188,pl.14,fig.4;
Pritchard, 1861,p.883;
Schmidt, 1875,pl.26,fig.51;
Cleve, 1895,p.126;
Van-Heurck, 1899,p.138,pl.1,fig.10;
Hustedt, 1930,p.346,fig.636;
Subrahmanyan, 1946,p.184,fig.407;
Wood, 1963a, p.22.

<u>Amphora tenera</u> Smith, 1853, p.20,pl.30, fig.252.

<u>Amphora plicata</u> Gregory, 1857, p.70,pl.1, fig.31.

Valves weakly silicified, hyaline, in girdle view rectangular, elliptical, with slightly convex sides. Inter-calary bands numerous, central area absent, trans-apical striae slightly radial, finely punctate, 18 in 10 μ. Length of valve 92 μ and breadth 44 μ.

<u>Occurrence</u>: Found growing on a dead shell in the inshore area of Cochin.

<u>Distribution</u>: West coast of North America, North Sea coast, coastal areas of European waters, east coast of India.

85. <u>Amphora decussata</u> Grunow

(Pl. III, fig, 2)

Grunow 1877, p.178;
Cleve, 1895,p.128,pl.4,fig.10;
Peragallo, 1897-1908,pl.49,fig.24;
Boyer, 1927,p.267;
Allen and Cupp,1935,p.161,fig.116;

Subrahmanyan, 1946,p.185,fig.414-415;
Hendey, 1964,p.266,pl.37,fig.9.

Cells elliptical, valves flat with straight ventral margin and truncate ends, arcuate dorsal margin with somewhat flattened side from the sub-acute apices, giving the valve the appearance of an equilateral triangle. Raphe along the ventral margin, central nodule dilated to form a narrow staurose, striated, 16 in 10 µ. Length of valve 98 µ and breadth 46 µ.

Occurrence: Found growing on a shell in the inshore area of Cochin.

Distribution: West coast of North America, North Sea coast, European coastal waters, east coast of India.

86. Amphora ostrearia (Brebisson) Kutzing
(Pl. III, fig.4)

Kutzing, 1849,p.94;
Pritchard, 1861,p.881;
De Toni, 1891-94,p.376;
Cleve, 1895,p.129;
Schmidt, 1875,pl.26,fig.23;
Van Heurck, 1899,p.139,pl.1,fig.1;
Subrahmanyan, 1946,p.185,fig.418-419;
Hendey, 1964,p.266,pl.38,fig.5.

Amphora quadrata Brebisson, Kutzing, 1849,p.95.
Amphora ostrearia var. quadrata (Brebisson) Rabenhorst, 1864,p.88.
Amphora membranaceae Smith, 1853,p.20,pl.11,fig.29.
Amphora littoralis Donkin, 1858,p.30,pl.111, fig.15.

Valves elliptic-oblong, extremities narrow, rounded ends, arcuate dorsal margin and straight ventral margin, striae well-marked on the dorsal side, central nodule dilated transversely to produce a staurose, girdle composed of numerous longitudinal narrow bands which appear as lines, striae 14 in 10 µ. Length of valve 82 µ and breadth 22 µ.

Occurrence: Found attached to a dead shell in the intertidal area of Cochin.

Distribution: West coast of North America, Pacific coast, North sea coast, British coast, east coast of India.

87. Amphora laevis Gregory
(Pl. III, fig.8)

Gregory, 1857,p.42,pl.4,fig.74;
Schmidt, 1874,pl.26,figs.9-10;
Van Heurck, 1899,p.139,pl.24,fig.693;
Boyer, 1927,p.268;
Wood, 1963a, p.22; 1963d,p.244,pl.2, fig.33a,b;
Hendey, 1964,p.267.

Cells rectangular, slightly constricted in the middle, rounded or truncate ends, weakly siliceous, membranaceous. Valves narrow, straight ventral margin, surface striated, 22 in 10 µ, crossed by a well-defined staurose, girdle composed of numerous segments and marked with parallel lines. Length of valve 87 µ and breadth 45 µ.

<u>Occurrence</u>: Found on rock in the inter-tidal area of Cochin bar mouth.

<u>Distribution</u>: Atlantic and Pacific coasts, west coast of North America, Texas Bay, Australian coast. New record for the Indian coasts.

88. <u>Amphora</u> <u>proteus</u> Gregory
(Pl. III, fig. 5)

Gregory, 1857,p.518,pl.13,fig.81;
Van Heurck, 1899,p.129,pl.24,fig. 671;
Boyer, 1927,p.254;
Wood, 1963d,p.245,pl.2,fig.36 a-c;
Hendey, 1964,p.262.

Cells in girdle view elliptic to oblong, parallel sides and rounded ends, valves lunate, surface striate, raphe biarcuate, central area variable. Length 82 µ and breadth 36 µ.

<u>Occurrence</u>: Observed in the sediments collected from the marine environment of Cochin.

<u>Distribution</u>: Coasts of Atlantic, North Sea, English channel, Texas and Galvastone Bays, western Indian Ocean.
New record for the Indian Seas.

Genus <u>Tropidoneis</u> Cleve

89. <u>Tropidoneis</u> <u>lepidoptera</u> (Gregory) Cleve
(Pl. III, fig.6)

Cleve, 1894, p.25;
Boyer, 1916,p.69,pl.4,figs.8-9;
Cupp, 1943, p.197, fig.149;
Venkataraman, 1939,p.340,figs.101,106;
Wood, 1963d, p.284,pl.12,fig.251a,b;
Hendey, 1964,p.256,pl.36,figs.2-4.

Amphiprora lepidoptera Gregory, 1857a,p.505,pl.12,fig.59b.
Tropidoneis lepidoptera var. mediterranea Peragallo,1897-1908,p.188,pl.39, figs. 8-9.
Orthotropis lepidoptera Van Heurck, 1899,p.263,pl.5,fig.287.

Cells rectangular, linear oblong, constricted in the middle, valves lanceolate, acute central area small, transversely lanceolate, wing unilateral, projecting above the median line, striae transverse, 18 in 10 µ. Length of valve 245 µ and breadth 35 µ.

Occurrence: Found attached to a dead shell in the intertidal area near bar mouth of Cochin.

Distribution: North Sea coast, British coast, west coast of North America, Texas Bay, Australian coast, east coast of India.

90. Tropidoneis semistriata Grunow
(Pl. III, fig.9)

Grunow in Cleve, 1894,p.27,pl.111, figs. 9-11;

Subrahmanyan, 1946,p.184,figs.411-412.

Valves membranaceous, lanceolate, acute and in girdle view slightly constricted in the middle. Keel somewhat eccentric, surface striated, 16 in 10 µ, not reaching the margin of the valve. Length of valve 128 µ and breadth 22 µ.

Occurrence: Found attached to a dead shell in the inter-tidal area, near bar mouth of Cochin.

Distribution: North Sea coast, Java Sea coast, coasts of North America, east coast of India.

91. Tropidoneis antarctica var. polyplasta Gran and Angst
(Pl. III, fig.7)

Gran and Angst, 1931,p.501,fig.90;
Cupp, 1943,p.198, fig.150.

In girdle view, cells elliptical, slightly constricted at the central nodule, in valve view lanceolate, with broad ends. Keel median, long, valves with two transverse rod-like thickenings at both sides of the central nodule. Cell wall thin, weakly siliceous, both transverse and longitudinal striae present, striae 22 in 10 µ.

Occurrence: Found attached to rock in the inter-tidal area, near bar mouth of Cochin.

Distribution: West coast of North America, North Sea coast. New record for the Indian coasts.

Genus Cymbella Agardh

92. Cymbella marina Castracane
(Pl. III, fig.11)

Castracane, 1886, p.21, pl.27, fig.13;
De Toni, 1891-94, p.359;
Subrahmanyan, 1946, p.187, fig.416.

Valves linear, elliptical, convex sides and obtuse ends, raphe straight, somewhat broad, axial area narrow, central area slightly dilated, striae radiate 9 in 10 µ. Length of valve 74 µ and breadth 21 µ.

Occurrence: Found attached to a dead shell in the intertidal area of the estuarine region of Cochin.

Distribution: West coast of North America, Japanese coastal waters, Australian coast, east coast of India.

93. *Cymbella cistula* (Hemprich) Van Heurck (Pl.III, fig.10)

Van Heurck, 1899, p.147, pl.1, fig.41;
Boyer, -1927, p.280;
Hustedt, 1930, p.363, fig.676b;
Venkataraman, 1939, p.344, fig.136;
Wood, 1963d, p.256, pl.6, fig.100a.

Valves asymetrical, ventral margin swollen, ends rounded, central area dilated on dorsal side, distinct row or punctae on ventral side, striae radial. Length 82 µ.

Occurrence: Found in the sediment in the estuarine area of Cochin.

Distribution: Estuarine regions of North Sea, Texas Bay, Australian and Indian coasts.

Family Nitzschiaceae

Sub Family : Nitzschioideae

Genus *Nitzschia* Hassal

94. *Nitzschia panduriformis* Gregory
(Pl. III, fig. 12)

Gregory, 1857, p.529, pl.14, fig.102;
Grunow, 1880, p.71,
Van Heurck, 1899, p.386, pl.15, fig.500;
Boyer, 1927, p.497;
Subrahmanyan, 1946, p.188, fig.425;
Cleve-Euler, 1952, p.54;
Hendey, 1964, p.279.

Cells elliptical, slightly constricted in the middle, with pointed extremities. Margin with strongly marked keel, punctae 8 in 10 µ; valve finely punctate, 24 in 10 µ, arranged in transverse and oblique lines. Length of valve 85 µ and breadth 24 µ.

Occurrence: Found in the sediment of the estuarine area of Cochin.

Distribution: North European coast, North Sea coast, British coast, east coast of India.

95. *Nitzschia sigma* (Kutzing) Smith var. *indica* Karsten
(Pl. III, figs. 15-16)

Karsten, 1907, p.400, pl.44, figs. 11 a,b;
Allen and Cupp, 1935, p.163, fig.120;
Subrahmanyan, 1946, p.189, figs. 423-24, 430-431.

Synedra sigma Kutzing, 1844,p.67,pl.30,fig.14;

Nitzschia sigma (Kutzing) Smith var. *sigma*, Hendey, 1964, pl.42, fig.1.

Valves linear, with weakly truncate endsm slightly sigmoid in girdle view, in valve view almost straight, considerably diminish in size at the extremities, elongated, keel distinct, punctae 8 in 10 µ, valve surface striate, striae transverse 16 in 10 µ. Length of valve 285 µ, breadth at the middle 18 µ.

Occurrence: Found on rock in the estuarine area of Cochin.

Distribution: North Sea coast, estuaries in European countries, Java Sea coast, North American coast, east coast of India.

96. *Nitzschia acuminata* (Smith) Grunow
(Pl. III, fig. 14)

Grunow in Cleve and Grunow, 1880, p.73;
Van Heurck, 1899, p.388, pl.15, fig. 506;
Hendey, 1964, p.280, pl.39, fig.10.

Trybilionella acuminata Smith, 1853, p.36, pl.10, fig.77.

Valves broad and linear, with apiculate apices, valve margin straight, slightly concave, keel marginal, valve surface striate, striae transverse, 7 in 10 µ, interrupted by a longitudinal fold which is hyaline. Length of valve 76 µ and breadth 16 µ.

Occurrence: Found in the sediment of the estuarine area of Cochin.

Distribution: European coastal waters, North Sea coast, British coast.

New record for the Indian coasts.

97. Nitzschia longissima (Brebisson) Ralfs
(Pl. III, fig.18)

Ralfs in Pritchard, 1861,p.783;
Van Heurck, 1899,p.404,pl.17,fig.568;
Boyer, 1927,p.526;
Subrahmanyan, 1946,p.191,figs.435-437;
Hendey, 1964,p.283.

Ceratoneis longissima Brebisson, Kutzing 1849, p.891.
Nitzschia birostrata Smith, 1853,p.42,pl.14,fig.119.
Nitzschiella longissima Rabenhorst, 1864,p.164.

Valves linear lanceolate, tapering to very long apical extremities, valves straight over the whole length, extremities not curved, marginal keel strong, keel punctae definite, valves fainly striate, keel punctae 12 in 10 µ. Length of cell 322 µ.

Occurrence: Found in the sediment, estuarine area of Cochin.

Distribution: Coastal and estuarine regions of Britain, France, Denmark, North Sea coast, west coast of North America, east coast of India.

98. Nitzschia obtusa Smith
(Pl. III, fig.17)

Smith, 1853, p.39, pl.13, fig. 109;
Van Heurck, 1899, p.397, pl.16, fig.539;
Boyer, 1916, p.121, pl.39, fig.16;
Schmidt, 1921, p.336, pl.20, fig.21;
Wood, 1963d, p.273, pl.10, fig.200a,b;
Hendey, 1964, p.282.

Cells linear, slightly sigmoid at the ends, valves with obtuse apices, keel central, slightly turned in at the margin, keel punctae 6 in 10 μ, the 3 median ones more distant, giving the impression of a central nodule, valve surface striate, 22 in 10 μ. Length of valve, 182 μ and breadth 16 μ.

<u>Occurrence</u>: Found in the sediment, estuarine area of Cochin.

<u>Distribution</u>: North American coast, North Sea coast, British coastal waters, Texas Bay and Australian coast.
New record for the Indian coasts.

Genus <u>Bacillaria</u> Gmelin

99. <u>Bacillaria paradoxa</u> Gmelin
(Pl. III, figs. 19-21)

Gmelin, 1788, p.390;
Smith, 1856, p.10, pl.32, fig.279;
Pritchard, 1861, p.784, pl.9, figs.166-67;
Karsten, 1928, p.294;
Lebour, 1930, p.211, fig.175;
Hustedt, 1930, p.396;
Venkataraman, 1939, p.351, figs.144-45;
Subrahmanyan, 1946, p.187, figs.417, 421, 427.

<u>Vibrio paxillifer</u> Muller, 1786, p.54.
<u>Nitzschia paxillifer</u> Huberg, 1863, p.113; Boyer, 1927, p.509.

Nitzschia paradoxa Grunow in Cleve and Grunow, 1880, p.85.
Van Heurck, 1899, p.392, pl.16, fig.518.

Bacillaria paxillifer Hendey, 1964, pl. 21, fig.5.

Cells united by their valves to form a mat-like colony, valves linear, lanceolate with squarish apices, spindle shaped in appearance, keel punctae strong, central, valve striate, transverse, 18 in 10 µ. Length of valve 115 µ and breadth 8 µ.

Occurrence: Found growing on Schizomeris sp., a filamentous green alga, in the estuarine area of Cochin.

Distribution: European coastal waters, west coast of North America, Japanese coast, coasts of Australia and India.

Genus Hantzschia Grunow

100. Hantzschia amphioxys (Ehrenberg) Grunow
(Pl. III, fig. 22)

Grunow, 1863, p.103;
Van Heurck, 1899, p.381, pl.15, fig.438b;
Schmidt, 1930, p.329;
Hustedt, 1930, p.345, fig.11.

Eunotia amphioxys Ehrenberg, 1841, p.25, pl.1, fig.26.

Nitzschia amphioxys Smith, 1853, p.41, pl.13, fig.105.

Cells narrowly rectangular, in girdle view, elongated, narrow and slightly bent in valve view, sides almost straight, keel punctate irregular, striated, transverse, 16 in 10 µ. Length of valve 72 µ, breadth 18 µ.

Occurrence: Found in the sediment, estuarine area of Cochin.

Distribution: Atlantic coast, west coast of North America, Texas Bay, Australian coast.

New record for the Indian coasts.

101. *Hantzschia amphioxys* var. *major* Van Heurck (Pl. III, fig. 23)

Van Heurck, 1899, p.381, pl.15, fig.484b.

Cells rectangular, much linear and longer than the type species, with 6 carinal dots, valve striate, 12 in 10 µ. Length of valve, 120 µ and breadth 18 µ.

102. *Hantzschia amphioxys* var. *intermedia* Van Heurck (Pl. III, fig. 24)

Van Heurck, 1899, p.381, pl.15, fig.485b.

Cells rectangular in girdle view, linear and longer, slightly constricted in the middle, with 4 carinal dots, striated valve with 11 in 10 µ. Cells similar to the type except its slightly bigger size and shape. Length of valve 85 µ and breadth 16 µ in the middle.

103. *Hantzschia amphioxys* var. *vivax* Van Heurck (Pl. III, fig. 25)

Van Heurck, 1899, p.381, pl.15, fig.486b.

Valves slender, long, rostrate, 5 carinal dots and 13 striae in 10 µ, slightly squarish at the apices in girdle view, much bigger than the type species. Length of valve 92 µ and breadth 14 µ.

Occurrence: Found in the sediment, estuarine area of Cochin.

Distribution: Estuaries in Britain, coastal areas of North Sea.

New record for the Indian coasts.

Family Surirellaceae

Sub Family Surirelloideae

Genus *Surirella* Turpin

104. *Surirella neumeyeri* Janish

(Pl. III, fig. 26)

Janish, 1862, pl.31, fig.33;
Schmidt, 1886, pl.56, fig.1;
Wood, 1963a, p.210, pl.4, fig.100.

Surirella nervatus Grunow, Lefe'bre, 1947, pl.31, fig.6.

Valves reniform, radiating septa, reniform axial area, surface of valve hyaline, striae indistinct. Length of valve 62 µ and breadth 28 µ.

Occurrence: Found epiphytic on *Sargassum*, washed ashore in the inter-tidal area of Cochin bar mouth.

Distribution: Coastal waters of North Sea, British coast, Australian coast.

New record for the Indian coasts.

105. *Surirella fastuosa* (Ehrenberg) Kutzing

(Pl. III, fig.27)

Kutzing, 1844, p.62, pl.28, fig.19;
Smith, 1853, p.32, pl.9, fig.66;

Van Heurck, 1899, p.372, pl.13, fig.583;
Boyer, 1929, p.544;
Hendey, 1964, p.288, pl.40, fig.4.
Huang, 1979, p.201, pl.6, fig.5.

Navicula fastuosa Ehrenberg, 1840, p.214.

Valves broadly oval, costae robust, directed towards the margin, become narrow to the central space, lanceolate and hyaline. Valve surface striate, delicate, 20 in 10 µ. Length of valve 65 µ and breadth 42 µ.

Occurrence: Found in the sediment, estuarine area of Cochin.

Distribution: Estuaries and harbours of North Sea coasts, British coast, west coast of North America. New record for the Indian coasts.

106. Surirella fluminensis Grunow
(Pl. III, fig. 28)

Grunow, 1862, p.463;
Schmidt, 1875, pl.5, fig.6;
Peragallo, 1908, p.249, pl.60, fig.1-2;
Allen and Cupp, 1935, p.164, fig.126;
Subrahmanyan, 1946, p.102, fig.438.

Suriraya fluminensis Grunow in Rabenhorst, 1864, p.58;
De Toni, 1891-94, p.589.

Valves ovate, broad, ribs or canaliculi few on the valve surface, inflated towards the margin, except 2 pairs at the ends. Central region linear and large, marginal striae 18 in 10 µ. Length of valve 55 µ, breadth 35 µ.

Occurrence: Found in the sediment, in the estuarine area of Cochin.

Distribution: North sea coast, Java Sea, coast of North America, Adriatic sea, coasts of India.

107. Surirella eximia Greville
(Pl. III, fig.29)

Greville, 1857, p.10, pl.3, fig.6;
Subrahmanyan, 1946, p.192, fig.439;
Nair, 1959, p.48.

Suriraya eximia (Greville) De Toni, 1891-94, p.585.

Valves linear oblong, rounded ends, slightly constricted in the middle, canaliculi delicate, 18 in each side, reaching the narrow linear median space and attenuate from ring-like space near the margin. Length of valve: 92 µ, breadth 43 µ.

Occurrence: Found on a dead shell in the estuarine area of Cochin.

Distribution: West Indies, North Sea coast, British coast, coasts of India.

Sub Family : Campylodiscoideae

Genus Campylodiscus Ehrenberg

108. Campylodiscus hodgsonii Smith
(Pl. III, fig. 30)

Smith, -1853, p.29, pl.6, fig.63;
Schmidt, 1877, pl.53, fig.5;
Van Heurck, 1899, p.376, pl.32, fig.868;

Boyer, 1927, p.549;
Hendey, 1964, p.291.

Valves sub-orbicular, nearly circular, canaliculi numerous, 3 in 10 µ, equal in length, about one third of the radius of the valve, central area punctate, arranged in radiating lines, interrupted by a linear median space. Length of valve 85 µ and breadth 78 µ.

Occurrence: Found in the sediments, estuarine area of Cochin.

Distribution: Estuaries in west coast of North America, British coastal waters.
New record for the Indian coasts.

109. Campylodiscus biangulatus Greville
(Pl. III, fig.31)

Greville, 1863, p.4, fig.2;
Schmidt, 1895, pl.14, figs.18-22;
Wood, 1963d, p.249, pl.4, fig.60.

Valve heart-shaped, strongly convolute, costae strong, bifurcate near margin, reaching linear ovate median space, costae strong in valve view, 3 in 10 µ. Length of valve 65 µ and breadth 35 µ.

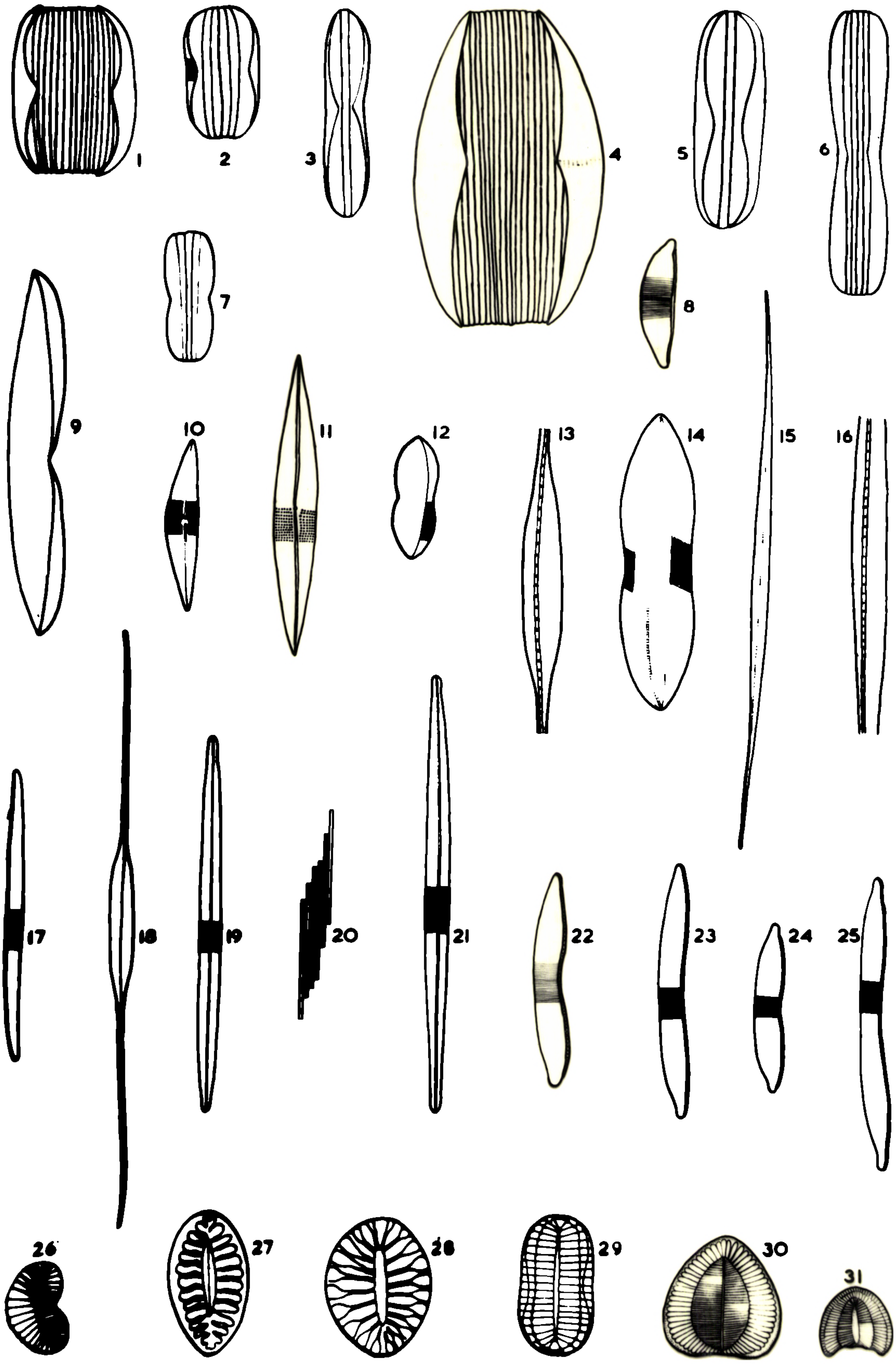
Occurrence: Found in the sediments, estuarine area of Cochin.

Distribution: Coastal and estuarine waters of Europe, west coast of North America, Texas Bay.
New record for the Indian coasts.

PLATE - III

Figs. 1-31. Fig. 1. *Amphora lineolata*, girdle view; Fig. 2. *Amphora decussata*, girdle view; Fig. 3. *Amphora ovalis*, girdle view; Fig. 4. *Amphora ostrearia*, girdle view; Fig. 5. *Amphora proteus*, girdle view; Fig.6. *Tropidoneis lepidopetera*, girdle view; Fig. 7. *Tropidoneis antarctica* var. *polyplasta* girdle view; Fig. 8. *Amphora laevis*, valve view; Figs.1-7 x 980, fig. 8 x 720; Fig. 9. *Tropidoneis semistriata*, valve view; Fig. 10. *Cymbella cystula*, valve view; Fig. 11. *Cymbella marina* valve view; Figs. 9-11 x 980; Fig.12. *Nitzschia panduriformis*, valve view x 720; Fig. 13. *Nitzschia sigma*, middle portion enlarged x 1200; Fig. 14. *Nitzschia acuminata*, valve view; Figs. 15-16. *Nitzschia sigma* var. *indica*, entire cell x 720 and middle portion enlarged x 1200; Fig. 17. *Nitzschia obtusa*, valve view x 980; Fig. 18. *Nitzschia longissima*, valve view x 720; Figs. 19-21. *Bacillaria paradoxa*, two cells in girdle view and the colonial habit; Figs. 19,21 x 980 and fig. 20 x 380; Fig. 22. *Hantzschia amphioxys*, valve view; Fig. 23. *Hantzschia amphioxys* var. *major*, valve view; Fig. 24. *Hantzschia amphioxys* var. *intermedia*, valve view; Fig. 25. *Hantzschia amphioxys* var. *vivax*, valve view; Fig. 26. *Surirella neumeyeri*, valve view; Fig. 27. *Surirella fastuosa*, valve view; Fig.28. *Surirella fluminensis*, valve view; Fig. 29. *Surirella eximia*, valve view; Fig. 30. *Campylodiscus hodgsonii*, valve view; Fig.31. *Campylodiscus biangulatus*, valve view; Figs. 22-31 x 980.

PLATE III



2. Dinophyceae (Dinoflagellates)

Dinophyceae forms an important constituent of phytoplankton next to Diatomaceae. While the plankton diatoms of Indian Seas are well documented, very little information is available on the planktonic Dinophyceae. Several species from the Indian Ocean region are illustrated in the 'VALDIVIA' Expedition Reports (Karsten, 1907), but a systematic account is lacking. A list of species recorded from the south western Indian Ocean is given by Taylor (1966) and from Madagascar region by Sournia (1967, 1968). Wood (1954, 1963 a,b,c) has given accounts of Dinophyceae recorded from the Australian waters and south-eastern Indian Ocean.

The only detailed information on the Dinophyceae of the Indian Seas was that of a list by Subrahmanyan (1958) and 2 monographs, one on the genera *Ceratium* Schrank (Subrahmanyan, 1968) and the other on the family Peridiniaceae (Subrahmanyan, 1971). Recently Gopinathan and Pillai (1974, 1975) gave an account of 27 species of Dinophyceae as new distributional records from the Indian Seas.

A systematic study of the Dinophyceae, consisting of 67 species, represented by 16 genera, observed from the estuarine and marine environments of Cochin has been included as a supplement to the available information. Of these 8 species are found to be new distributional records from the Indian waters.

The classification followed here is essentially based on Pascher (1927), Lindemann (1928) and Schiller (1933-37) given in Fritsch (1935).

Division		PYRROPHYTA
Class	:	DINOPHYCEAE
Sub Class		DESMOKONTAE
Order	:	Prorocentrales
Family		Prorocentraceae
Genus		Prorocentrum Ehrenberg

1. Prorocentrum micans Ehrenberg
(Pl. IV, fig. 1)

Ehrenberg, 1833, p.12;
Schutt, 1896, p.6;
Bohm, 1936, p.13;
Wood, 1954, p.179, fig.5;
Steidinger and Williams, 1970, p. 36, pl.38, figs. 136 a-b.

Cells very small, strongly compressed laterally, somewhat heart shaped, broad at the middle, dorsal side more convex than the ventral, bearing a solid tooth or spine at the anterior region. Length 38 μ.

Occurrence: Observed in the estuarine and inshore environments of Cochin during June-August, 1974.

Distribution: Estuarine and inshore waters of all warmer seas.

Sub Class	DINOKONTAE
Order	Gymnodiniales
Family	Gymnodiniaceae
Genus	<u>Gymnodinium</u> Stein

2. <u>Gymnodinium splendens</u> Lebour
(Pl. IV, fig.2)

Lebour, 1925,p.43,pl.5, fig.1;
Subrahmanyan, 1958,p.439;
Wood, 1963a,p.29,fig.102;
Steidinger and Williams, 1970,
p. 52,pl.22, figs.69 a-d.

Body ovate, flattened, dorsoventrally, epicone and hypocone somewhat equal, epicone sub-hemispherical, hypocone constricted at the apex, girdle median, sulcus large, wide posteriorly. Length 42 μ.

<u>Occurrence</u>: Observed in the inshore area of Cochin during June 1974.

<u>Distribution</u>: Coasts of North Sea, Coral sea, Australian waters and west coast of India.

3. <u>Gymnodinium gelbum</u> Kofoid
(Pl. IV, fig.3)

Kofoid, 1931,p.13,pl, 1,fig.1;
Schiller, 1933,p.363,fig.368;
Subrahmanyan, 1958,p.439;
Wood, 1963a, p.26,fig.85.

Body oval, epicone and hypocone somewhat equal, epicone hemispherical, hypocone slightly depressed antapically, girdle median, sulcus from girdle to antapex, chromatophores large. Length 42 µ.

Occurrence: Observed in the inshore plankton of Cochin during June 1974.

Distribution: Coasts of Atlantic, North Sea, Australian waters and west coast of India.

Family Noctilucaceae

Genus *Noctiluca* Suriray

4. *Noctiluca miliaris* Suriray

(Pl. VII, fig.A)

Suriray in Lamarck, 1816, p.470;
Wood, 1954,p.220, fig.83 a,b;
Subrahmanyan, 1958,p.439.

Medusa scintillans Macartney, 1810, p.264,pl.15,fig.9-12.

Mammaria scintillans Ehrenberg, 1834, p.559.

Noctiluca punctata Busch, 1851,p.199, fig.1.

Noctiluca pacifica Giglioli, 1870, p.491.

Noctiluca scintillans (Macartney) Lindemann, 1928, p.48, fig. 32, 33;
Kofoid and Swezy,1974,p.407,fig.1-6.

The body is inflated, spherical, girdle reduced to proximal remnant, sulcus rudimentary, deeply placed, longitudinal flagellum short, transverse one reduced to a mobile tooth, tentacle at posterior end of sulcus, yellow tinge in the central area with hyaline surface. Diameter of the cell 215 - 245 µ.

Occurrence: Blooming in the inshore area of Cochin, with pinkish colouration during September-October 1974.

Distribution: Widely distributed in the coasts of all warm water seas, causing 'red tide' phenomena.

Order : Dinophysiales
Family Dinophysiaceae

Genus Dinophysis Ehrenberg

5. Dinophysis caudata Kent
(Pl. IV, figs. 4-5)

Kent, 1882, p.460;
Jorgensen, 1923, p.24, figs.30-34;
Bohm, 1936, p.20, figs. 7-8;
Wood, 1954, p.201, figs. 49 a-c;
Subrahmanyan, 1958, p.439;
Sournia, 1968, p.554.

Dinophysis homunculus Stein, 1883, pl.21, figs.1,2,5,7.
Dinophysis allieri Gourret, 1883, p.79, pl.3, figs. 54,54a.
Dinophysis inaequalis Gourret, 1883, p.80, pl.1, fig.21.

Body variable in shape, elongated, 1½ times as long as wide, anterior portion irregularly obovate in lateral view, posterior portion slender. In dorsal view, strongly flattened, anterior girdle list 1½ times as wide as girdle, left sulcal list extends to base of peduncle. Theca finely areolated. Length 82 µ.

Occurrence: Found in the inshore area of Cochin during July-August 1974.

Distribution: Widely distributed in all warm water seas.

6. *Dinophysis miles* Cleve
(Pl. IV, fig. 6)

Cleve, 1900 in Karsten, 1907,
p. 421, pl.47,fig.8 a,b;
Wood, 1954,p.203, fig.52;
Subrahmanyan, 1958,p.439;
Sournia, 1968,p.554.

Body of variable form, epitheca flat, hypotheca almost straight, slightly wavy from which the long antapical process emerged, dorsal contour from girdle convex, then running into a short extension which is concave ventrally, posterior process shorten than the dorsal process, seldom bent with a rounded apex, anterior sulcal list and posterior girdle lists broad and ribbed. Sometimes 8 daughter cells remain together to form a whirl or circular body.
Length of cell 115 μ.

Occurrence: Found in the inshore plankton of Cochin during September-October 1974.

Distribution: Widely distributed in the coastal areas of Indian Ocean, Mediterranean Sea, Red Sea, Australian and Indian Seas.

7. *Dinophysis sphaerica* Stein
(Pl. IV, fig. 7)

Stein, 1883, pl.20, figs.3,4;
Schutt, 1895, pl.1, fig.7;
Pavillard, 1916, p.60;
Jorgensen, 1923, p.23, fig.29;
Wood, 1954, p.195, fig.36 a-c.

Cell ovate, round and slightly assymmetrical, somewhat resembling Phalacroma rotundatum, but can be distinguished by the presence of distinctly striated 'funnel' and a distinct longitudinal fin. Hypotheca symmetrical, left sulcal list about half of the body, anterior girdle list 1½ times wider than girdle, ribbed. Differs from Dinophysis ovum in ribbed anterior girdle list and less developed posterior portion of left sulcal list. Length 72 μ.

Occurrence: Found in the inshore plankton of Cochin during October 1974.

Distribution: Widely distributed in all the warm seas and also in the adjacent coastal areas and estuaries.

New record for the Indian waters.

8. Dinophysis hastata Stein

(Pl. IV, fig. 8)

Stein, 1883,pl.19,fig.12;

Jorgensen, 1925,p.31,figs. 40-41;

Wood, 1954,p.199,figs.47 a,b;

Sournia, 1968, p.554;

Steidinger and Williams, 1970,p.29, pl. 17, fig. 48.

Phalacroma hastatum Pavillard, 1909,p.283, fig. A,B.

Dinophysis hastata f. phalacromoides Jorgensen, 1923,p.31, fig. 41.

Dinophysis hastata f. uracanthoides Jorgensen, 1923,p.31, fig. 40.

Body sub-ovate, rounded posteriorly, compressed laterally with cingular lists, anterior funnel shaped process extending beyond the epitheca, hypotheca much bigger with prominent sulcal list, resembling wings, supported by ribs, hypotheca with prominent posterior sail. Length 82 μ.

Occurrence: Observed in the inshore plankton of Cochin during May 1974.

Distribution: Widely distributed in the tropical, sub-tropical and warm-temperate seas. Coasts of Atlantic, Pacific, Mediterranean Sea, Red Sea, Australian waters and Gulf of Mexico.

New record for the Indian Seas.

Genus _Phalacroma_ Stein

9. _Phalacroma_ _rotundatum_ Kofoid and Michener
(Pl. IV, fig.9)

Kofoid and Michener, 1911,p.290;
Jorgensen, 1923,p.5,fig.2;
Lebour, 1925,p.78,pl.11,fig.3;
Schiller, 1933,p.67,fig.60;
Subrahmanyan, 1958,p.438.

Dinophysis _rotundata_ Claparade and Lachman, 1859 ,p.16.
Phalacroma _rudgei_ Murray and Whitting, 1899,p.331,pl.31, figs. 6 a,b.
Wood, 1954,p.185, fig.13 a,b.

Body in the form of a ball, contour of hypotheca continuous with that of epitheca, girdle and sulcal list narrow, list with two ribs. In ventral view, body is rotund, base and apex flattened. Length 68 μ.

Occurrence: Found in the inshore plankton of Cochin during October 1974.

Distribution: Widely distributed in the coastal areas of Atlantic, Mediterranean sea, North sea, Australia and west coast of India.

10. _Phalacroma_ _dolichopterygium_ Murray and Whitting
(Pl. IV, fig. 10)

Murray and Whitting, 1899, p.330, pl.31, figs. 8 a,b;
Jorgensen, 1923, p.15, fig.15;
Wood, 1954, p.191, fig.28 a-c;
Subrahmanyan, 1958, p.438.

Phalacroma mitra Schutt, 1895, pl.4, figs. 18, 1-4.
Pavillard, 1916, p.53, fig. 13 B.

Body small, epitheca dome-shaped, projecting slightly above the girdle, hypotheca much bigger and smoothly curved in the lower part, left longitudinal furrow list broader below, ribbed. Length 64 µ.

Occurrence: Observed in the inshore plankton of Cochin during May 1974.

Distribution: Widely distributed in tropical, sub-tropical and warm-temperate waters.

11. Phalacroma operculatum Stein
(Pl. IV, fig. 11)

Stein, 1883, p.43, pl.18, fig.8;
Schutt, 1895, pl.2, fig.10;
Jorgensen, 1923, p.9, fig.7;
Wood, 1954, p.185, fig.14.

Body somewhat rounded, biconical, epitheca much smaller than the hypotheca, form a lid or operculum, almost straight along the sulcal list, then tapering into the blunt conical antapex. Girdle list, 3 ribbed, theca finely areolated. Length 78 µ.

Occurrence: Observed in the inshore plankton of Cochin during August 1974.

Distribution: Coasts of Atlantic, Adriatic, North Sea, western Indian Ocean and Australian waters. New record for the Indian Seas.

Genus *Ornithocercus* Stein

12. *Ornithocercus magnificus* Stein

(Pl. IV, fig. 12)

Stein, 1883, p.26, pl.23, figs. 1,2;
Schutt, 1900, p.262, figs. 8-10;
Jorgensen, 1923, p.35, fig.48;
Lindemann, 1928, p.75, fig.60;
Wood, 1954, p.208, fig.60a,b;
Seurnia, 1967, p.424;
Steidinger and Williams, 1970, p.33, pl.25, fig.79 a,b.

Cells sub-circular in lateral view, girdle lists anterior and posterior with some incomplete ribs, left sulcal list ends on dorsal side of body with narrowly rounded 3 lobes, reticulation in each lobe. Length 65 μ.

Occurrence: Observed in the plankton of the inshore area of Cochin during June 1974.

Distribution: Widely distributed in tropical, sub-tropical and warm-temperate seas.

Family Amphisoleniaceae

Genus *Amphisolenia* Stein

13. *Amphisolenia bidentata* Schröder

(Pl. IV, fig. 13)

Schroder, 1900,p.20,pl.1,figs.16a-c;
Jorgensen, 1923,p.39,fig.56;
Wood, 1954,p.205,fig.55;
Subrahmanyan, 1958,p.439;
Sournia, 1967,p.420;
Steidinger and Williams, 1970,p.26, pl.2, fig.5 a-c.

Body very long and narrow, slightly sigmoid, head 2-3 times wider than long, epitheca convex, mid body fusiform, merging with anterior process and apical, antapical foot with 2 spinules (bidentate). Length 722 μ.

Occurrence: Found in the inshore plankton of Cochin during May 1974.

Distribution: Widely distributed in tropical, sub-tropical and warm-temperate waters.

14. *Amphisolenia palmata* Stein
(Pl. IV, fig.14)

Stein, 1883,pl.21, figs.11-15;
Jorgensen, 1923,p.40,fig.57;
Wood, 1954,p.205,fig.56;
Sournia, 1967,p.422.

Body much like *A. bidentata*, but slightly smaller, moderately sigmoid, epitheca gently convex, apart from two teeth in the dilated antapical end, also a smaller one. Length 580 μ.

Occurrence: Observed in the inshore plankton during May 1974.

Distribution: Widely distributed in tropical, sub-tropical and temperate regions.
New record for the Indian waters.

Order Peridiniales
Family Goniaulacaceae
Genus Goniaulax Diesing

15. Goniaulax polyedra Stein

(Pl. IV, fig.15)

Stein, 1883,p.76;
Wood, 1954,p.261,fig.171 a,b;
Stedinger and Williams, 1970, p. 51,pl.21, fig.63.

Body small, angular, polyhedral with ridges along sutures, girdle equatorial, displaced 1-2 widths, surface of the body pitted. Length 42 μ.

Occurrence: Observed in the inshore plankton, causing 'red tide' phenomena along with Noctiluca miliaris, during September 1974.

Distribution: Widely distributed in all warm waters. New record for the Indian Seas.

Family Peridiniaceae
Genus Diplopsalis Bergh

16. Diplopsalis lenticula Bergh

(Pl. IV, figs 16-17)

Bergh, 1881,p.244,figs.60-62;
Lebour, 1922,p.795, fig.1-5;
1925, p.99,pl.15,figs.a-c;
Lindemann, 1928,p.93,fig.77;
Wood, 1954,p.222,fig.86 a-c;

Steidinger and Williams, 1970, p.29, pl.18, fig. 51;
Subrahmanyan, 1971, p.3-4, pl.1, figs.1-3, 5, 7-9; pl.3, figs.1-3, 8, 10.

Glenodinium lenticula (Bergh) Schiller, 1937, p.103, fig. 95 a-h.
Diplopsalis sphaerica Meunier, 1909, p.41.

Cells globular, epitheca and hypotheca equal, epitheca with a short apical horn, girdle circular, sulcus at the posterior end forms a small cavity where a small process projected. Length 68 µ.

Occurrence: Found both in the estuarine and inshore environments of Cochin during the period July-August 1974.

Distribution: Coastal waters of Europe, Red Sea, Western Indian Ocean, Australian waters and west coast of India.

Genus *Peridinium* Ehrenberg

17. *Peridinium quarnerense* Schroder
(Pl. IV, fig. 18)

Schroder, 1910 in Dangeard, 1927, p.14, fig.9;
Matzenauer, 1933, p.476, fig.64;
Wood, 1954, p.236, fig.111 a,b;
Subrahmanyan, 1971, p.36, pl.13, fig.10-11; pl.14, figs.1-3, 5, 8-9, 12; pl.15, figs.1-2, 5-6, 8, 10-12.

Peridinium globulus Stein, 1883, pl.9, fig.8.

P. globulus var. *quarnerense* Schiller, 1937, p.184, fig.186.

P. spitzbergense Broch, 1913,p.49,fig.24.

P. globulus Meunier, 1919, pl.16, figs.24-26.

Cells are very variable, rounded and compressed, apical horn button shaped, antapical horn two, needle like without wings, continuous with the sulcal list. Length 65 µ.

Occurrence: Observed in the inshore plankton of Cochin during March-April 1974.

Distribution: Red Sea, Mediterranean Sea, Indian Ocean, Australian and Indian Seas.

18. Peridinium brevipes Paulsen
(Pl. IV, fig.19)

Paulsen,1908,p.108,fig.151;
1911,p.313,fig.13;
Lebour, 1925,p.131,pl.27,fig.2a-d;
Schiller, 1937,p.200,fig.195a-m;
Wood, 1954,p.241,fig.122;
Subrahmanyan, 1971,p.38,pl.20,
figs. 1-12,pl.21, fig.1.

Peridinium varicans Paulsen, 1911,p.312,fig.12.

Peridinium incurvum Lindemann, 1924c, p.2,pl.1,fig.7-9.

Cells rhomboid, rounded sides with conical apex, girdle right handed with narrow lists, sulcus wide at the posterior, ending in two small spines. Length 45 µ.

Occurrence: Observed in the inshore area of Cochin during September-October 1974.

Distribution: European coastal waters, coasts of Australia and India.

19. *Peridinium cerasus* Paulsen
(Pl. IV, fig.20)

Paulsen, 1907,p.12,fig.12;
1908,p.43,fig.52;
Lebour, 1925,p.130,pl.27,fig.1a-c;
Wood, 1954,p.112,fig. 113 a-b;
Subrahmanyan, 1971,p.39,pl.13, figs.12,pl.14,figs.4,6; pl.15, fig.9.

Cells spherical, apical horn long, girdle dextral with narrow lists, sulcus narrow, antapical spines well developed, left one is strong than the right. Length 62 µ.

Occurrence: Observed in the estuarine area of Cochin during September-August 1974.

Distribution: Coasts of North Sea, Mediterranean Sea, European coastal waters, coasts of Australia and India.

20. *Peridinium pyriforme* Paulsen
(Pl. IV, fig. 21)

Paulsen, 1907,p.13,fig.15;
1908,p.46,fig.57;
Lebour, 1925,p.126,fig.38;
Schiller, 1937,p.194,fig.191 a-n;
Wood, 1954,p.239,fig.118;
Subrahmanyan, 1971,p.42,pl.22, figs. 1-15.

P. steinii f. pyriformis Paulsen, 1905,p.4,fig. d,e.
P. castaneiforme Mangin, 1922,p.79,fig.200.
P. steinii var. africanum Dangeard, 1927,p.3,fig. i D,F.
P. oviform Schiller, 1929,p.403, fig.17;
P. sylvanae Dangeard, 1927,p.2, fig.1 A-C.
P. rectum Kofoid, 1907b, p.311,pl.32,figs.48,49.
P. rectiforme Schiller, 1929,p.402,fig.15.

Cells pear-shaped, slender, hypotheca semi-circular, epitheca conical, girdle broad, sulcus straight, right side winged, posterior side ends in two broadly winged processes. Length 52 μ.

Occurrence: Observed in the inshore area of Cochin during March 1974.

Distribution: Coasts of Atlantic, Australian and Indian Seas.

21. Peridinium sinaicum Matzenauer
(Pl. IV, fig. 22)

Matzenauer, 1933,p.459,fig.37a,b;
Schiller, 1937,p.272,fig.279a,b;
Subrahmanyan, 1958,p.438; 1971, p. 45,pl.24,figs. 9,10.

Cells small, rounded, epitheca conical, with a well developed apical horn, sulcus narrow, sulcal wing connected with the left process, right process free, separated away from the sulcus. Length 36 μ.

Occurrence: Observed in the estuarine area during July 1974.

Distribution: Red Sea, western Indian Ocean, coasts of India.

22. <u>Peridinium</u> <u>steinii</u> Jorgensen

(Pl. IV, fig.23)

Jorgensen, 1899,p.38;
Lebour, 1925,p.125,pl.25,fig.4;
Schiller, 1937,p.196,fig.192 a-h;
Wood, 1954,p.240,fig.120a;
Taylor, 1966,p.462;
Steidinger and Williams, 1970,p.58;
Subrahmanyan, 1971,p.45,pl.23,figs. 1-13.

<u>Peridinium</u> <u>michaelis</u> Stein, 1883,pl.9,figs. 9-14;
Shutt, 1895,pl.14,fig.46.

<u>P.</u> <u>pellucidum</u> Ramsay-Wright, 1907,pl.1,fig.17.

<u>P.</u> <u>steinii</u> sub sp. <u>paulsenii</u> Kofoid, 1909,p.40.

<u>P.</u> <u>micrapium</u> Meunier, 1919,pl.16,figs.37-40.

<u>Protoperidinium</u> <u>pellucidum</u> Pouchet, 1883,p.431,pl.1.

Cells rounded, epitheca form a long horn, hypotheca semicircular, girdle broad and dextral, sulcus narrow, towards posterior widened, two strong processes surrounded by more or less broad fins arise near the widened sulcal region. Length 62 μ.

<u>Occurrence</u>: Observed in the estuarine area during August-September 1974.

<u>Distribution</u>: Coasts of Pacific and Atlantic, western Indian Ocean, Australian and Indian Seas.

23. <u>Peridinium</u> <u>pallidum</u> Ostenfeld

(Pl. IV, figs. 24-25)

Ostenfeld, 1899,p.60; 1903,p.581, figs. 130-131.
Lebour, 1925,p.134,pl.28,fig.1a,d;
Schiller, 1937,p.209,fig.206 a-m;
Wood, 1954, p.244,fig.129 a,b;
Subrahmanyan, 1971,p.54,pl.31, figs. 1-8; pl.32, figs.1-5.

Peridinium pseudopallidum Peters, 1930,p.73,fig.39E.

Cells broad, pear shaped, dorsoventrally flattened, with well developed apical horn, girdle with winged lists, sulcal region narrow, with two broadly winged processes. Length 78 µ.

Occurrence: Observed in the estuarine area of Cochin during October-November 1974.

Distribution: Widely distributed in the coasts of Atlantic, Arctic and Antarctic waters, western Indian Ocean, Australian and Indian Seas.

24. Peridinium pedunculatum Schutt
(Pl. IV, fig. 26)

Schutt, 1895,pl.14,fig.47;
Schiller, 1937,p.211,fig.208 a-c;
Wood, 1954,p.244,fig.130;
Taylor, 1962,p.462;
Subrahmanyan, 1958,p.439; 1971,p.55, pl.32, figs. 6-11.

Cells with both epitheca and hypotheca broadly conical, apical horn cylindrical, in side view hypotheca rounded, posterior horns two, broad with wings, girdle winged with radial lists. Length 54 μ.

Occurrence: Observed in the estuarine area of Cochin during the period September-October 1974.

Distribution: Coasts of Atlantic, Pacific, Mediterranean Sea, Australian and Indian Seas.

25. Peridinium pellucidum (Bergh) Schutt
(Pl. IV, fig. 27)

Schutt, 1895,pl.14,fig.45;
Lebour, 1925,p.134,pl.28,fig.2 a-d;
Schiller, 1937,p.212,fig.209;
Wood, 1954,p.245,fig.131 a,b;
Balech, 1964,p.191,pl.3,figs.56-66;
Steidinger and Williams, 1970,p.57, pl. 33, fig.111;
Subrahmanyan, 1971,p.55-56,pl.33, fig.1-11;pl.34,fig.1-12;pl.35, fig. 1-11.

Protoperidinium pellucidum Bergh 1881,p.227,figs.46-48.
Peridinium cavispinum Mangin, 1922,p.79,fig.20.
P. huberi Schiller, 1929,p.408, fig.25 a-c.
P. meunieri Peters, 1930,p.73,fig.3a.

Cells small, pyriform, without a well developed antapical horn, but 2 spines developed diverging each other, also a false spine on the left side of the sulcus, slightly dilated. Length 56 μ.

Occurrence: Observed in the estuarine area during the period March-April 1974.

Distribution: Warm water form, widely distributed in all the coasts.

26. <u>Peridinium</u> <u>heteracanthum</u> Dangeard
(Pl. IV, fig. 28)

Dangeard, 1927a,p.7,fig.4;
1932,p.348;
Schiller, 1937,p.206,fig.199a,b;
Taylor, 1966,p.461;
Subrahmanyan, 1971,p.60,pl.19,
figs.8-10,pl.29,fig.11,
pl. 36, figs.5-6.

Cells spherical, distinguished from other species by the presence of a well-developed wing on the left side which extends through the right spine, left spine small, apical horn straight, girdle flat. Length 58 μ.

<u>Occurrence</u>: Observed in the inshore plankton of Cochin during March-April 1974.

<u>Distribution</u>: Coasts of Atlantic, western Indian Ocean, west coast of India.

27. <u>Peridinium</u> <u>conicoides</u> Paulsen
(Pl. IV, fig.29)

Paulsen, 1905,p.3,fig.2;
1908,p.58, fig.75;
Lebour, 1925,p.112,pl.20,fig.2 a-d;
Schiller, 1937,p.231,fig.228 a-d;
Wood, 1954,p.250,fig.145;
Subrahmanyan, 1958,p.439;
1971,p.66,pl.41,
figs. 1-8.

Cells rhombic in ventral view, girdle circular, hypotheca ends in two horns, epitheca and hypotheca somewhat equal, sulcus broad. Length 56 μ.

Occurrence: Observed in the inshore waters of Cochin during October-November 1974.

Distribution: Coasts of Atlantic, Australian waters, western Indian Ocean and Indian Seas.

28. Peridinium conicum (Gran) Ostenfeld and Schmidt (Pl. IV, fig.30)

Ostenfeld and Schmidt, 1901,p.174;
Gran, 1902,p.185,fig.14;
Lebour, 1925,p.111,pl.19,fig.1;
Schiller, 1937,p.233,fig.229 a-j;
Wood, 1954,p.250;
Steidinger and Williams,1970,p.55, pl.29, fig.94 a,b;
Subrahmanyan, 1971,p.66-67,pl.42, fig.1-9,pl.44,fig.1.

Peridinium acutangulum Jorgensen, 1912, p.37.
P. conicum var. bilobata (Meunier) Schiller,1929,p.399,fig.11.
P. conicum f.ceylonica Matzenauer, 1933,p.455,fig.28c.

Cells dorso-ventrally flattened, symmetrical, epitheca triangular, epitheca and hypotheca sub-equal, girdle circular, sulcus broad, reaching beyond hypotheca. Length 74 µ.

Occurrence: Observed in the inshore plankton of Cochin during March-April 1974.

Distribution: Coasts of Red Sea, Mediterranean Sea, Gulf of Aden, Australian and Indian Seas.

29. Peridinium leonis Pavillard
(Pl. IV, fig.31)

Pavillard, 1916a,p.32,fig.6;
Lebour, 1925,p.112,pl.21,fig.1 a-d;
Schiller, 1937,p.236,figs.236 a-m;
Wood, 1954,p.251,fig.148 a-c;
Steidinger and Williams, 1970,p.56, pl.32, fig.105;
Subrahmanyan, 1958, p.439; 1971,p.68, pl.43,figs.1-13; pl.44,fig.10-14.

Cells are rhomboid in ventral view, epitheca trigonal, tapering to a point, hypotheca project out into two wedge shaped horns, between which lies 2 spines. Length 72 μ.

Occurrence: Found in the inshore plankton of Cochin during July-August 1974.

Distribution: Coasts of Atlantic, Mediterranean Sea, North Sea, Australian and Indian Seas.

30. Peridinium leonis f. matzenauri (Matzenauer) Schiller
(Pl. IV, fig.32)

Schiller, 1937,p.239,fig.238 a,b;
Steidinger and Williams, 1970,p.57;
Subrahmanyan, 1971,p.69,pl.43,fig.10; pl.44, figs.15-19; pl.45, fig.1,2, 12, 13; pl.46, fig.1.

Peridinium leonis Pavillard in Matzenauer 1933,p.456,fig.29.

P. divergens obtusum Karsten, 1906,p.149,pl.23,fig.12; Subrahmanyan, 1958,p.439.

The distinguishing feature of this species is that the epitheca spherical when compared to the type species. The plates are sculptured with undulating ribs. Length 72 µ.

Occurrence: Observed in the inshore plankton of Cochin during March-April 1974.

Distribution: Coasts of Atlantic, Gulf of Mexico and west coast of India.

31. *Peridinium marielebourae* Paulsen
(Pl. IV, fig. 33)

Paulsen, 1930,p.230,fig.40;
Schiller, 1937,p.239,fig.239a;
Wood, 1954,p.253,fig.149;
Taylor, 1966,p.461;
Subrahmanyan, 1971,p.69-70,pl.45, figs.3-11,pl.46, figs.2-12.

Peridinium obtusum Lebour, 1925,p.121,pl.24,fig.2.
P. divergens obtusum Karsten, 1906,p.149,pl.23,fig.12.

Cells flattened dorso-ventrally, sulcus reaches well into posterior end, hypotheca with two hollow horns, each with terminal spines. Length 58 µ.

Occurrence: Observed in the inshore plankton of Cochin during March-April 1974.

Distribution: Coasts of Europe, Mediterranean Sea, western Indian Ocean, Australian and Indian Seas.

32. <u>Peridinium pentagonum</u> Gran
(Pl. IV, fig.34)

Gran, 1902,p.185,fig.15;
Lebour, 1925,p.112,pl.20,figs.1a-e;
Schiller, 1937,p.241,fig.242;
Wood, 1954,p.253,fig.150a;
Steidinger and Williams, 1970,p.57, pl.33,figs.112 a,b;
Subrahmanyan, 1958,p.439; 1971,p.71, pl.47,fig.4-9.

<u>Peridinium divergense</u> var. <u>senuosa</u> Lemmermann 1897,p.368.
<u>P. senuosum</u> Lemmermann 1905,p.32.
<u>P. divergens</u> pentagonum Karsten, 1906,pl.23,fig.11 a,b.

Cells asymmetrical, pentagonal, right side smaller than the left, compressed dorso-ventrally, girdle median, sulcus short rounded towards posterior, not reaching upto the lower end, posterior horn less developed. Length 88 µ.

<u>Occurrence</u>: Observed both in the estuarine and marine environments of Cochin during June-August 1974.

<u>Distribution</u>: Widely distributed in the coasts of Atlantic, Pacific, Gulf of Mexico, North Sea, Australian and Indian Seas.

33. <u>Peridinium pentagonum</u> var. <u>latissimum</u> (Kofoid) Schiller
(Pl. IV, fig.35)

Schiller, 1937,p.242,fig.243 a-j;
Wood, 1954,p.253,fig.150 b,c;
Subrahmanyan, 1971,p.72,pl.48, figs.4-11; pl.49,fig.1-10.

Peridinium latissimum Kofoid, 1907,p.175,pl.5,fig.31-32.
P. pentagonum var. depressum Abe, 1927,p.409,fig.29.

Body dorso-ventrally compressed, asymmetrical, middle region is deeply furrowed, dorsal side arched, Length 76 µ.

Occurrence: Found in the estuarine and inshore environment of Cochin during July-August 1974.

Distribution: Pacific coast, Gulf of Mexico, coasts of Japan, western Indian Ocean, coasts of Australia and India.

34. Peridinium subinerme Paulsen
(Pl. IV, fig.36)

Paulsen, 1904,p.24,fig.10; 1930, p. 71, fig.42;
Lebour, 1925,p.114,pl.22,fig.2;
Schiller, 1929,p.402,fig.16; 1937,p.243,fig.244 a-o;
Wood, 1954,p.254,fig.151;
Subrahmanyan, 1958,p.439; 1971,p.75, pl.50, figs.8-14;pl.51,figs.2-15;
Steidinger and Williams, 1970,p.58, pl.34, fig.115.

Peridinium subinerme f. asymmetrica Matzenauer 1933,p.458;
P. punctulatum Paulsen, 1907,p.19,fig.28.
P. punctulatum f. asymmetrica Matzenauer 1933,p.458,fig.32.

Cells bilaterally symmetrical, epitheca and hypotheca are equal, sulcus broad, lower part of sulcus lies in a depression, posterior horns not well developed. Length 72 µ.

Occurrence: Observed in the inshore waters of Cochin during March-April 1974.

Distribution: Coasts of North Sea, Atlantic, Antarctic, Gulf of Mexico, western Indian Ocean, Australian and Indian Seas.

35. *Peridinium depressum* Bailey
(Pl. IV, fig.37)

Bailey, 1855,p.12,fig.33,34;
Jorgensen,1899,p.36;1905,p.109;
Pavillard,1916,p.31;1931,p.55;
Lebour, 1925,p.119,pl.23,figs.6A-E;
Schiller, 1937,p.250,figs.251a-t;
Wood, 1954,p.255,fig.155a,b;
Taylor, 1964,p.461;
Subrahmanyan, 1958,p.439; 1971,p.80-82,pl.53,figs.8-10;pl.55,figs.1-10.

Peridinium divergens var. *reniforme* Ehrenberg 1834a,p.240.

Ceratium divergens Claparède et Lachmann 1861,p.71,pl.13, fig.23.

P. divergens var. *depressa* (Bailey) Aurivillius 1898,p.55.

P. elegans Cleve 1900a, pl.7,fig.16.

P. parallelum Broch 1906,p.153-57,fig.2.

P. antarcticum Schimper in Karsten 1905,p.37,pl.19,fig.1-4.

P. divergens antarctica Karsten 1907,p.225.

P. (*divergens*) *pustulatum* Karsten 1907,p.417,pl.52,fig.5a,b.

P. marinum Lindemann, 1925a,p.98-99,figs.7-11.

P. depressum var. *travectum* Lindemann 1925,p.99,fig.12.

P. depressum var. *parallelum* (Broch) Graham 1942,p.21,figs. 21,22.

P. depressum var. *rectius* Graham 1942,p.23,fig.26.

P. depressum f. *bisintercalares* Graham, 1942,p.23,fig.27.

P. depressum f. multitabulatum Graham, 1942, p.23, fig.28.

Cells variable in shape, broad and flattened obliquely, with conspicuous apical horn, girdle slightly left sided, hypotheca broad with hollow antapical horns, somewhat pointed, theca reticulated. Length 120-185 µ.

Occurrence: Observed both in the estuarine and marine environments of Cochin during August 1974.

Distribution: Widely distributed in all the coasts of tropical, sub-tropical and temperate seas.

36. Peridinium claudicans Paulsen
(Pl. IV, fig.38)

Paulsen, 1907, p.16, fig.22;
Lebour, 1925, p.123, pl.25, fig.1;
Schiller, 1937, p.249, fig.250 a-g;
Wood, 1954, p.255, fig.154;
Steidinger and Williams, 1970, p.55, pl.28, fig.93 a,b;
Subrahmanyan, 1958, p.439; 1971, p.83, pl.57, figs. 1-11.

Peridinium obliquum Dangeard 1927, p.353, fig.19.

P. oceanicum f. claudicans Meunier 1919, p.17, pl.15, fig. 22-23.

Cells broad, antapical horn long, posterior horns diverge, unequal, right one longer than the left, girdle with conspicuous lists, closely resemble P. oceanicum. Length 68 µ.

Occurrence: Observed in the estuarine area of Cochin during March-April 1974.

Distribution: Coastal waters of Atlantic, Pacific, North

Sea, Gulf of Mexico, Australian and Indian Seas.

37. Peridinium oceanicum Vanhoffen
(Pl. IV, fig.39)

Vanhoffen, 1897a,pl.5,fig.2;
Cleve, 1900a,p.17,pl.7,fig.17-18;
Lebour, 1925,p.120,fig.36b;
Schiller, 1937,p.260,fig.257a-k;
Wood, 1954,p.256,fig.157a,b;
Taylor, 1966,p.462;
Subrahmanyan, 1958,p.439; 1971,
p.84-85,pl.57,fig.12-15;pl.60,
fig.1;pl.61,fig.1-3,pl.79,fig.
1-3.

Peridinium divergens Bergh 1881,fig.39,40;
Schutt, 1895,pl.13,fig.44;
Stein, 1883,pl.10,fig.7.
P. divergens var. oceanicum Ostenfeld, 1899,p.60.
P. divergens var. oblongum Aurivillius 1898,p.96.
P. depressa var. oceanica Ostenfeld 1900,p.57.
P. oblongum Cleve 1900b,p.20; Dangeard 1927,p.353,fig.18a,b.
P. divergens var. elegans Karsten 1907,p.416.
P. oceanicum f. arupinensis Broch 1910,p.190,fig.7.
P. elegans Karsten 1905,p.179.
P. oceanicum f. typica Broch 1909, p.154,fig.3.
P. divergens oceanicum Karsten 1907,p.224.
P. oceanicum var. typica Lebour 1925,p.121.
P. oceanicum var. oblongum (Aurivillius) Paulsen,1908,p.56.
P. oceanicum var. inaequipes Mangin, Matzenauer 1933,p.376,
fig.1.
P. oceanicum var. parvulum Mangin, Matzenauer, 1933,p.463.

Cells dorsi-ventrally flattened, all processes are long and slender, some are having short antapical horn and small posterior horn, sulcus with winged lists, girdle oblique to sulcus, surface plates invisible. Length 132-185 µ.

Occurrence: Observed in the inshore plankton of Cochin during March-April 1974.

Distribution: Widely distributed in all the warmer seas.

38. *Peridinium crassipes* Kofoid

(Pl. IV, fig. 40)

Kofoid, 1907, p.309, pl.31, fig.46,47;
Schiller, 1937, p.223, fig.220a,b;
Wood, 1954, p.247, fig.137a-d;
Subrahmanyan, 1958, p.439; 1971, p.87-88, pl.58, fig.6-12, pl.61, fig.5.

Peridinium (*divergens*) *asymmetricum* Karsten 1907, p.418, pl.53, fig.2.
P. crassipes f. *assymmetrica* Matzenauer 1933, p.467, fig.50c-d.
P. curtipes Jorgensen, 1912, p.8; Lebour 1925, p.128, fig.3.
P. magnum Schiller 1929, p.406, fig.22.

Cells rhomboid, hypotheca with two thick horns, right longer than the left, horns blunt or pointed, girdle concave, plate sculpture net like. Length 85 µ.

Occurrence: Observed in the inshore plankton of Cochin during February-March 1974.

Distribution: Pacific coast, western Indian Ocean, Australian waters, Gulf of Mexico, west coast of India.

39. *Peridinium divergens* Ehrenberg

(Pl. IV, fig. 41)

Ehrenberg, 1840b, p.204;
Lebour, 1925, p.127, pl.26, fig.2;
Schiller, 1937, p.226, fig.22a-g;
Wood, 1954, p.248, fig.139;
Subrahmanyan, 1958, p.439; 1971, p.88-89, pl.59, fig.1, 2; pl.61, fig.6.

Peridinium divergens var. lenticulare Ehrenberg, 1854, p.240.
P. lenticulare (Ehrenberg) Jorgensen, 1899, p.400.
P. divergens var. adriaticum Schiller, 1929, p.407, fig.23.
P. (divergens) remotum Karsten, 1907, p.417, pl.57, fig.5 a,b.
P. (divergens) pulchellum Karsten, 1907, p.418, pl.53, fig.1.

Cells are very variable, sides of epitheca more or less concave, the horns slender, posterior horns divergent, sides of hypotheca concave, girdle circular. Length 82 μ.

Occurrence: Observed in the inshore plankton during September-October 1974.

Distribution: Coasts of Atlantic, Pacific, North Sea, Gulf of Mexico, Australian and Indian Seas.

40. Peridinium remotum Karsten
(Pl. IV, fig. 42)

Karsten, 1907, p.417, pl.53, figs.5a,b;
Matzenauer, 1933, p.473, fig.61 a,b;
Schiller, 1937, p.262, fig, 258 a,b;
Wood, 1954, p.249, fig.140;
Taylor, 1966, p.462;
Subrahmanyan, 1971, p.92, pl.52, figs. 3,4; pl.53, fig.2.

Peridinium (*divergens*) *remotum* Karsten, 1907,p.417,pl.53, fig. 5 a,b.

Epitheca conical, hypotheca cuneiform, posterior horns robust, carrying an outwardly projected process. Sulcus small, margin ending in projecting edges of both horns. Length 134 µ.

Occurrence: Observed in the inshore area of Cochin during September-October 1974.

Distribution: Coasts of Atlantic, western Indian Ocean, Australian and Indian Seas.

41. *Peridinium brochii* Kofoid and Swezy (Pl. IV, fig.43)

Kofoid and Swezy,1921,p.183;
Schiller, 1937,p.221,fig.218a-i;
Wood, 1954,p.247,fig.136;
Subrahmanyan, 1971,p.93,pl.52, fig.7-12;pl.53,figs.7,12.

Peridinium adriaticum Lebour, 1925,p.128.
P. divergens Lindemann, 1929,p.229,fig.78.
P. divergens var. *adriaticum* (Broch) Schiller, 1929,p.407, fig, 23,24.

Cells with concave epitheca and hypotheca, posterior horns divergent, girdle region rounded, shows close resemblence to *P. divergens*. Length 82 µ.

Occurrence: Observed in the estuarine region of Cochin during July 1974.

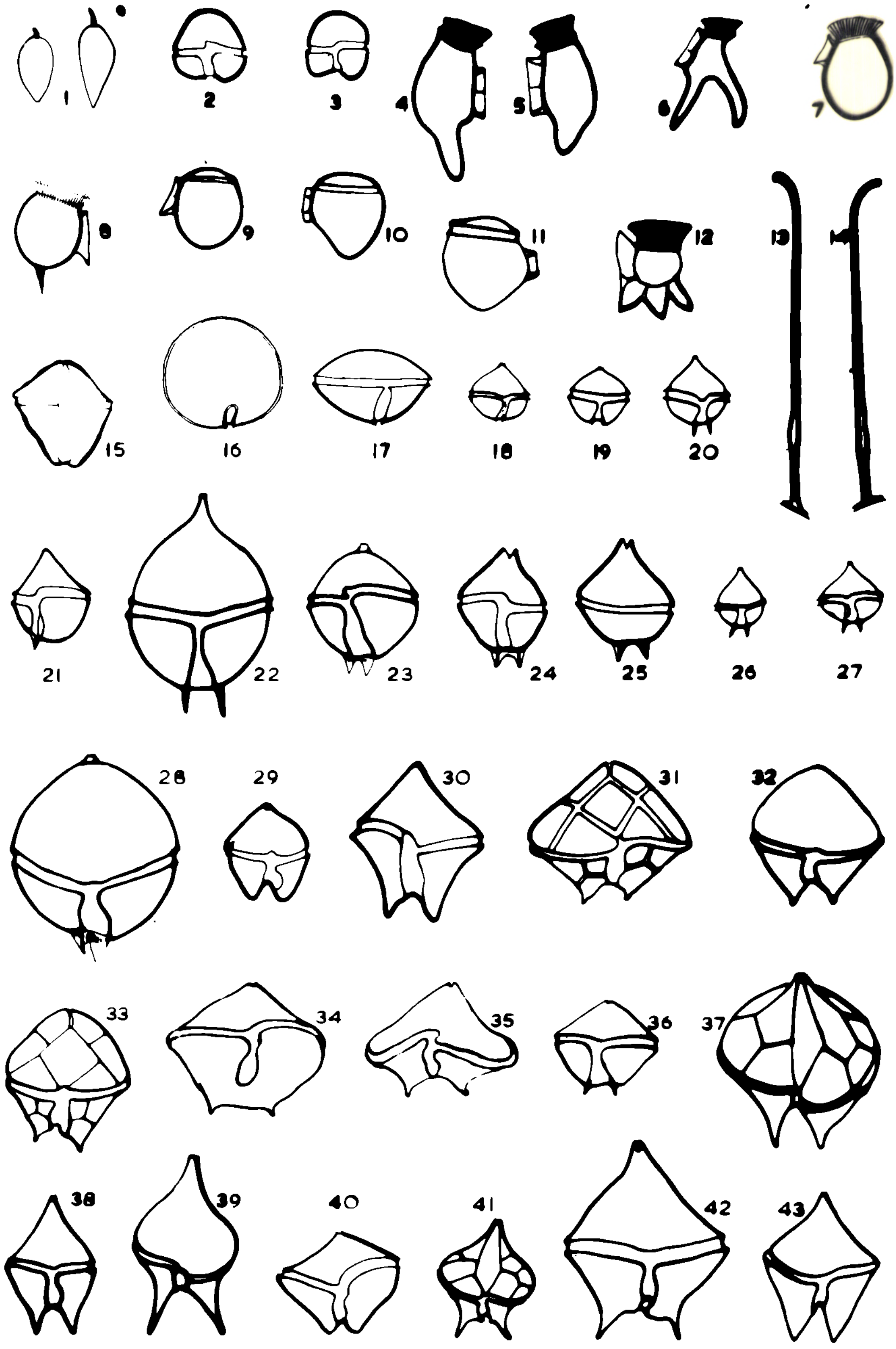
Distribution: Coasts of Atlantic, Mediterranean Sea, western Indian Ocean, Australian and Indian Seas.

PLATE - IV

Figs. 1-43. Fig. 1, Prorocentrum micans, two cells showing morphological variations;
Fig. 2, Gymnodinium splendens, ventral view;
Fig. 3, Gymnodinium gelbum, ventral view;
Figs. 4-5, Dinophysis caudata, two cells showing morphological variations;
Fig. 6, Dinophysis miles, side view;
Fig. 7, Dinophysis sphaerica, side view;
Fig. 8, Dinophysis hastata, side view;
Fig. 9, Phalacroma rotundatum, side view;
Fig.10, Phalacroma dolichopterigium, side view;
Fig.11, Phalacroma operculatum, side view;
Fig.12, Ornithocercus magnificus, side view;
Fig.13, Amphisolenia bidentata, showing 2 dentate processes at the tip;
Fig.14, Amphisolenia palmata, side view;
Fig.15, Goniaulax polyhedra, ventral view;
Figs.16-17, Diplopsalis lenticula, antapical and ventral views;
Fig.18, Peridinium quarnerense, ventral view;
Fig.19, Peridinium brevipes, ventral view;
Fig.20, Peridinium cerasus, ventral view;
Fig.21, Peridinium pyreforme, ventral view;
Fig.22, Peridinium sinaicum, ventral view;
Fig.23, Peridinium steinii, ventral view;
Fig.24,25, Peridinium pallidum, ventral and dorsal views;
Fig.26, Peridinium pedunculatum, ventral view;
Fig.27, Peridinium pellucidum, ventral view;
Fig.28, Peridinium heteracanthum, ventral view;
Fig.29, Peridinium conicoides, ventral view;
Fig.30, Peridinium conicum, ventral view;
Fig.31, Peridinium leonis, ventral view;
Fig.32, Peridinium leonis f. matzenauri, ventral view;
Fig.33, Peridinium marielebourae, ventral view;
Fig.34, Peridinium pentagonum, ventral view;
Fig.35, Peridinium pentagonum var. latissimum ventral view;
Fig.36, Peridinium subinerme, ventral view;
Fig.37, Peridinium depressum, ventral view;
Fig.38, Peridinium claudicans, ventral view;
Fig.39, Peridinium oceanicum, ventral view;
Fig.40, Peridinium crassipes, ventral view;
Fig.41, Peridinium divergens, ventral view;
Fig.42, Peridinium remotum, ventral view;
Fig.43, Peridinium brochii, ventral view;

All the figures x 1200

PLATE. IV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Family Ceratiaceae

Genus Ceratium Schrank

42. Ceratium hirundinella (Muller) Bergh

(Pl. V, fig. 1)

Bergh in Jorgensen, 1911, p.14, figs. 19, 20 a,b;
Lindemann, 1928, p.92, fig. 78;
Schiller, 1937, p.359, fig.396a;
Wood, 1954, p.273, fig.188;
Subrahmanyan, 1968, p.17, pl.1, fig.2.

Bursaria hirundinella Muller, 1786, p.117, pl.17, figs.9, 12.
Ceratium tetraceros Schrank, Kisselev, 1950, p.225.

Cells flattened, easily distinguished from other species by the presence of 3 posterior horns, one small and other 2 well developed, long apical horn, posterior portion low and broad, cell surface sculptured. Length 93 μ.

Occurrence: Observed in the estuarine plankton of Cochin during July-August 1974.

Distribution: Coasts of Atlantic, Mediterranean Sea, Australian and Indian Seas.

43. Ceratium candelabrum (Ehrenberg) Stein

(Pl. V, fig.2)

Stein, 1883, pl.15, figs. 15, 16;
Schutt, 1895, pl.9, fig.78;
Cleve, 1901, p.14; 1903, p.340;
Lebour, 1925, p.143, figs.45 b,c;
Steemann Nielsen, 1934, p.8, fig.6, 7;

Schiller, 1937,p.364,fig.401;
Wood, 1954,p.272;
Sournia, 1967,p.390,fig.14-17;
Subrahmanyan, 1968,p.17-18,figs.16-20.

<u>Peridinium candelabrum</u> Ehrenberg, 1860,p.792;

<u>Ceratium candelabrum</u> Stein f. <u>commune</u> Bohm, 1931a, p.351, fig.1-2.

<u>C. candelabrum</u> Stein f. <u>curvatulum</u> Jorgensen,1920,p.15, fig.6.

<u>C. candelabrum</u> Stein f. <u>depressum</u> Pouchet, Bohm, 1931b, p.8, fig.3a,c-d.

<u>C. candelabrum</u> var. <u>dilatum</u> (Gourret) Jorgensen, 1911,p.16, figs. 4,5.

<u>C. candelabrum</u> var. <u>depressum</u> (Pouchet) Jorgensen, 1920, p.13,fig.5.

<u>C. candelabrum</u> var. <u>algerence</u> Schiller, 1928,p.410,fig.28.

<u>C. candelabrum</u> Stein var. <u>candelabrum</u> Sournia, 1967, p. 393, fig.14.

Cells of variable form, body as wide as long, anterior portion short, conical, suddenly tapering to apical horn, apical horn short and straight, posterior portion obliquely diagonal, posterior horns short and parellel. Length 260 µ.

<u>Occurrence</u>: Observed in the inshore plankton of Cochin during August-September 1974.

<u>Distribution</u>: Coasts of all warmer Seas.

44. <u>Ceratium furca</u> (Ehrenberg) Claparade et Lachman
(Pl. V, figs.3-4)

Claparade et Lachman, 1859, p.390, pl.19, fig.5;
Schutt, 1895, pl.9, fig.37;
Cleve, 1901, p.13; 1903, p.341;
Paulsen, 1908, p.90, fig.122;
Lebour, 1925, p.145, pl.30, fig.3;
Bohm, 1931b, p.8, figs.4-8;
Schiller, 1937, p.367, figs.404, 405;
Wood, 1954, p.274, figs.189 a-c;
Sournia, 1967, p.395, figs.18-20;
Subrahmanyan, 1968, p.20, pl.2, figs.7-12;
Steidinger and Williams, 1970, p.45, pl.7, figs. 20 a,b.

Peridinium furca Ehrenberg 1836, p.574, pl.2, fig.2; 1838, p.256, pl.22, fig.21.

Ceratium hircus Taylor, 1966, p.463.

Ceratium furca var. *berghii* (Jorgensen) Schiller, 1937, p.367.

Ceratium furca var. *eugrammum* Jorgensen, 1911, p.17, figs.24-26.

Epitheca tapering to form a short apical horn, posterior horns parallel to slightly divergent, one will be slightly bigger, both have pointed ends, girdle distinct. Length 65-85 µ.

Occurrence: Found to be abundant during March-May 1974 in the estuarine and marine environments of Cochin.

Distribution: Warm water neritic form distinguished in all tropical areas, widely distributed in all the coasts.

45. Ceratium incisum (Karsten) Jorgensen

(Pl. V, fig.5)

Jorgensen, 1911,p.19,figs.29,30;
Bohm, 1931b, p.12,fig.9a;
Peters, 1934,p.29;
Steemann Nielsen, 1934,p.10,fig,11;
Schiller, 1937,p.370,fig.407b;
Graham and Broniskovsky, 1944,p.19, fig. 9 a-c;
Wood, 1954,p.275,fig.190;
Silva, 1955,p.50,pl.7,fig.2;
Sournia, 1967,p.400,fig.21;
Subrahmanyan, 1968,p.21,fig.31.

Ceratium furca incisum Karsten, 1906,pl.28,figs. 6a,b.
C. furca var. incisa Karsten, 1907,p.227.
C. brunellii Rampi, 1942,p.222, fig.1.

Epitheca long and lancet-shaped, slightly bent dorsally, tapering to form a horn, hypotheca broad, posterior horns unequal, almost parellel, the left one twice bigger than the right and laterally bent. Cell wall on the dorsal side thickened. Length 180 μ.

Occurrence: Observed in the inshore plankton of Cochin during March-April 1974.

Distribution: Coasts of Atlantic, Pacific, Mediterranean, Red Sea, Japanese and Australian waters, Mozambique channel and west coast of India.

46. <u>Ceratium</u> <u>pentagonum</u> Gourret

(Pl. V, fig. 6)

Gourret, 1883, p.45, pl.4, fig.58;
Jorgensen, 1911, p.20, figs.31,32;
Bohm, 1931b, p.12, fig.9b;
Steemann Nielsen, 1934, p.11, fig.12;
Schiller, 1937, p.370;
Wood, 1954, p.276, fig.191 a-f;
Sournia, 1967, p.40, figs.23,24;
Subrahmanyan, 1968, p.23, figs.32,33.

<u>Ceratium</u>-<u>furca</u> var. baltica Schutt, 1895, pl.9, fig.36.
<u>C</u>. <u>lineatum</u> var. <u>robustum</u> Cleve 1900, p.925, fig.6.
<u>C</u>. <u>furca</u> var. <u>pentagonum</u> Lemmermann, 1899, p.368;
Karsten, 1906, pl.23, fig.7.
<u>C</u>. <u>pentagonum</u> f. <u>robustum</u> (Cleve) Jorgensen, 1911, p.20, pl.2, fig.32.
<u>C</u>. <u>pentagonum</u> var. <u>turgida</u> Jorgensen, 1911, p.21, pl.2, fig.33.
<u>C</u>. <u>pentagonum</u> var. <u>subrobustum</u> Jorgensen, 1920, p.26, fig.16.
<u>C</u>. <u>subrobustum</u> Steemann Nielsen, 1934, p.11, fig.13;
<u>C</u>. <u>pentagonum</u> f. <u>tenerum</u> Jorgensen, Gaarder 1954, p.15, fig.14;
Steidinger and Williams, 1970, p.47, pl.12, fig.31.

Epitheca conical, with a slender apical horn, hypotheca flatly trapezoidal with convex and concave sides, posterior horns short, unequal, slightly diverging. Length 160 µ.

<u>Occurrence</u>: Observed in the inshore plankton of Cochin during March-April 1974.

<u>Distribution</u>: Coasts of North Sea, Red Sea, Mediterranean Sea, Mozambique channel, Gulf of Aden, Australian and Indian seas.

47. <u>Ceratium inflatum</u> (Kofoid) Jorgensen

(Pl. V, fig.7)

Jorgensen, 1911,p.25,figs.45,46,48a;
1920,p.35,fig.25;
Forti, 1922,p.39,pl.1,fig.24;
Bohm, 1931,p.14,fig.10a,b;
Steemann Nielsen, 1934,p.13,fig.20;
Schiller, 1937,p.376,fig.415;
Rampi, 1939,p.303,fig.15;
Wood, 1954,p.281,fig.198;
Sournia, 1967,p.412,fig.36;
Subrahmanyan, 1968,p.29,figs,48,49;
Steidinger and Williams, 1970,p.46,
pl.10, fig.25.

<u>Ceratium pentagonum</u> f. <u>inflatum</u> Kofoid, 1907d,p.172,pl.2,fig.13.
<u>C. fusus</u> var. <u>concavum</u> Gourret, 1883,pl.4, fig.64;
Karsten, 1907,p.230.

Epitheca and hypotheca somewhat equal, epitheca broad at the lower region tapering to uniform level to the apex and form the apical horn, hypotheca also broad, narrow towards posterior region, left horn very long distal portion arched, right horn very small, pointed. Length 820 μ.

<u>Occurrence</u>: Observed in the inshore plankton of Cochin during November-December 1974.

<u>Distribution</u>: Coasts of Atlantic, Red Sea, Japan, China, Australia, Mozambique channel and Indian Seas.

48. <u>Ceratium</u> <u>fuses</u> (Ehrenberg) Du Jardin

(Pl. V, fig.8)

Du Jardin, 1841,p.378;
Cleve, 1901,p.14;
Paulsen, 1908,p.90,fig.123;
Lebour, 1925,p.146,pl.31,fig.1;
Bohm, 1931,p.14,figs.10 ef;
Schiller, 1937,p.378,figs.418 a,b;
Wood, 1954,p.282, fig.202;
Subrahmanyan, 1958,p.439; 1968,p.31, fig.55,pl.1,figs.3-6;
Sournia, 1967,p.408,figs.32-34;
Steidinger and Williams, 1970,p.45, pl.8, figs.21 a,b.

<u>Cercaria</u> <u>fusus</u> Michaelis, 1830 in Schiller 1937,p.379.
<u>Peridinium</u> <u>fusus</u> Ehrenberg, 1833,p.271; 1834,p.25,pl.2,fig.3.
<u>Ceratium</u> <u>pellucidum</u> Gourret 1883,pl.1,fig.20;pl.4,fig.66.
<u>C.</u> <u>seta</u> Kofoid, 1908,p.387.
<u>C.</u> <u>fusus</u> var. <u>seta</u> (Ehrenberg) Jorgensen, 1911,p.29,fig.55; Sournia,1967,p.409,fig.33.

Epitheca very long, tapered into a narrow horn, hypotheca suddenly narrowed, longer than broad, left posterior horn pointed and bent, right rudimentary.

Length 110 µ.

<u>Occurrence</u>: Observed in the inshore plankton of Cochin during March-April 1974.

<u>Distribution</u>: Widely distributed in all the warm waters.

49. <u>Ceratium</u> <u>dens</u> Ostenfeld and Schmidt

(Pl. V, fig.9)

Ostenfeld and Schmidt,1901,p.165, fig.16;
Cleve, 1903,p.340;

Karsten, 1907,p.414,pl.48,fig.8 a,b;
Jorgensen, 1911,p.31,fig.58;
Bohm, 1931b,p.15,fig.11;
Steemann Nielsen, 1934,p.15,fig.27;
Schiller, 1937,p.381,figs.420 a,b;
Wood, 1954,p.284,fig.204;
Sournia, 1967,p.457,fig.80;
Subrahmanyan, 1958,p.439; 1968,p.34, fig.58,pl.3,fig.16.

C. dens var. reflexa Schmidt, 1901,p.131,fig.2.

Large and robust form, body broader than long, epitheca small, apical horn well-developed, broadened at base, hypotheca low, double as broad as long, left horn short and blunt, right horn bent round uniformly from base, divergent towards the apical horn. Length 180 µ.

Occurrence: Found in the inshore plankton of Cochin during March-April 1974.

Distribution: Coasts of Pacific, Red Sea, Gulf of Aden, Mozambique channel, western Indian Ocean, Australian waters and Indian Seas.

50. Ceratium tripos (Muller) Nitzsch
(Pl. V, fig.10)

Nitzsch, 1817,p.4;
Cleve, 1901a,p.14; 1903,p.342;
Paulsen, 1908,p.77,figs.102-107;
Lebour, 1925,p.148,figs.32,33;
Schiller, 1937,p.382,figs.383,385;
Wood, 1954,p.284;
Sournia, 1967,p.416,figs.40-43;
Subrahmanyan, 1968,p.35,fig.59; pl.3,figs.17,18.

Cercaria tripos Muller, 1786,p.136,pl.19,fig.22.
Peridinium tripos Ehrenberg 1833,p.272; 1836,p.573,pl.2, fig.1 a-e.
Ceratium tripos f. balticum Schutt, 1892,p.266,fig.49; Wood, 1954,p.286,fig.205b.
Ceratium arcuatum Vanhoffen, 1897,pl.5,fig.14.
C. neglectum Ostenfeld, 1903,p.584,fig.135.
C. pulchellum var. indicum Bohm 1931b,p.45,fig.38.
C. tripodioides Steemann Nielsen, 1934,p, 15,fig.28.
C. tripos f. tripodioides Paulsen, Wood, 1954,p.285,fig.205a; Steidinger and Williams, 1970,p.47, pl.14, fig.37 a,b.
C. tripos var. pulchellum (Schroder) Lopez 1955, Sournia,1967, p. 420, fig.40.

Cells large, structure variable, body broad, epitheca low, left side concave, right side convex, hypotheca as long as the anterior body, horns robust, right posterior horn weakly developed than the left, diverge little towards apical horn, apical horn very large. Length 220 µ.

Occurrence: Observed in the inshore plankton of Cochin during August-September 1974.

Distribution: Widely distributed in all the tropical, sub-tropical and temperate seas.

51. Ceratium pulchellum Schroder

(Pl. V, figs. 11-12)

Schroder, 1906,p.358,fig.27;
Jorgensen, 1911,p.33,figs.59-62;
Bohm, 1931b,p.15;

Steemann Nielsen, 1934,p.16,fig.31;
Schiller, 1937,p.386,figs.422 a,b;
Wood, 1954,p.286,fig.206a;
Subrahmanyan, 1968,p.36,fig.60;
Steidinger and Williams, 1970,p.47, pl.13, fig.32.

Ceratium tripos var. *gracile* Schroder, 1900,pl.1,fig.17e.
C. pulchellum f. *postico juvenile* Jorgensen, 1911,p.33,fig.61.
C. pulchellum f. *semipulchellum* Jorgensen, 1920,p.55,figs.43-4
C. tripos f. *dalmaticum* Bohm, 1931c,p.379,figs.33-35.
C. tripos pulchellum Peters, 1932,p.34,pl.4,fig,20.
C. semipulchellum Steemann Nielsen, 1934,p.16,figs.29,30.
C. pulchellum f. *dalmaticum* Schiller, 1937,p.387,figs.424-426.
C. tripos subsp. *semipulchellum* Graham and Broniskovsky, 1944, p. 26,figs.L-N.

Body longer than broad, posterior contour convex, antapical horn strong and robust, uniform upto apex, hypotheca slightly concave, posterior horns short, left one arched, ends of horns parallel with the apical horn.
Length 280 μ.

Occurrence: Found in the inshore plankton of Cochin during March-April 1974.

Distribution: Coasts of Atlantic, Pacific, Mediterranean Sea, western Indian Ocean, Mozambique channel, Gulf of Mexico, Australian and Indian Seas.

52. *Ceratium breve* (Ostenfeld and Schmidt) Schroder
(Pl. V,fig. 13)

Schroder, 1906,p.358;
Jorgensen,1911,p.40,fig.84.
Steemann Nielsen,1934,p.18,figs. 35-36;

Schiller, 1937,p.391,figs.429a,b;
Wood, 1954,p.288,figs.209a,b;
Subrahmanyan, 1958,p.439; 1968,p.40,
figs.62,63, pl.3,figs.13-15;
Sournia, 1967,p.426,figs.47-50.

<u>Ceratium tripos</u> var. <u>breve</u> Ostenfeld et Schmidt, 1901,p.164, fig.13.
<u>C. tripos azoricum</u> Karsten, 1906,pl.20,figs.3 a,b;
<u>C. tripos azoricum</u> var. <u>breve</u> Ostenfeld et Schmidt, Karsten, 1907,pl.48,figs. 1 a,b.
<u>C. tripos</u> var. <u>parallelum</u> Schmidt, 1901,p.213,fig.1.

Short-horned medium-sized species, epitheca broad and long, apical horn short, hypotheca clearly longer than epitheca, posterior horns robust, left one is stronger than the right, somewhat equal in length, bent to form an arch, runs parallel with the apical horn. Length 184 µ.

<u>Occurrence</u>: Observed in the inshore plankton of Cochin during August-September 1974.

<u>Distribution</u>: Coasts of Atlantic, North Sea, Red Sea, western Indian Ocean, Australian waters and west coast of India.

53. <u>Ceratium contortum</u> (Gourret) Cleve
(Pl. V, fig. 14)

Cleve, 1900a,p.14,pl.7,fig.10;
Jorgensen, 1911,p.55,fig.120;
Bohm, 1931b,p.23,fig.20;
Steemann Nielsen, 1934,p.23,fig.52,53;
Schiller, 1937,p.395,fig.433;

Wood, 1954,p.289,fig.212 a-c;
Sournia, 1967,p.441,fig.67-72;
Subrahmanyan, 1968,p.44,45,fig.69-71;
Steidinger and Williams, 1970,p.44,
pl. 6, fig.16 a,b.

<u>Ceratium gibberum</u> var. <u>contortum</u> Gourret, 1883,pl.2,fig.33.
<u>C</u>. <u>sub contortum</u> Schroder, 1906,p.358,figs.28a,b.
<u>C</u>. <u>saltans</u> Schroder, 1906,p.359,figs. 29 a-c.
<u>C</u>. <u>contortum</u> var. <u>saltans</u> Jorgensen, 1911,p.56,figs.121 a,b.
<u>C</u>. <u>contortum</u> f. <u>sub contortum</u> (Schroder) Steemann Nielsen,
Schiller, 1937,p.396,fig.434.
<u>C</u>. <u>contortum</u> var. <u>robustum</u> Sournia, 1967,p.442,fig. 72.
<u>C</u>. <u>contortum</u> var. <u>karstenii</u> (Pavillard) Sournia, 1967,p.442,
fig. 71,pl.3,fig.10.
<u>C</u>. <u>contortum</u> var. <u>longinum</u> Sournia, 1967,p.444,fig.68.
<u>C</u>. <u>contortum</u> var. <u>contortum</u> Sournia, 1967,p.444,fig.67.

Epitheca oblique, left side contour convex, apical horn bent to the left and twisted, posterior contour convex and swollen, posterior horns unequal, the right longer than the left and twisted dorsally towards the apical horn. Length 520 µ.

<u>Occurrence</u>: Found in the inshore plankton of Cochin during March-April 1974.

<u>Distribution</u>: Coasts of Atlantic, Pacific, Red Sea, Mozambique channel, Gulf of Mexico, Australian and Japanese waters, west coast of India.

54. <u>Ceratium gibberum</u> Gourret
(Pl. V, figs. 15-16)

Gourret, 1883,p.34,pl.2,figs.33-35;
Paulsen, 1905,p.75,fig.98;
Jorgensen, 1911,p.49,figs.106,107,109;

Lebour, 1925,p.152,fig.49;
Steemann Nielsen, 1934,p.22,fig.48;
Schiller, 1937,p.397,figs.436 a,b;
Wood, 1954,p.290,figs. 214 a,b;
Subrahmanyan, 1958,p.439; 1968,p.46, figs.76-78;
Sournia, 1967,p.446.

C. gibberum f. *semistrum* Gourret, 1883,p.36,pl.2,fig.34.
C. tripos var. *megaceros* Pouchet, Schiller, 1937,p.397.
C. tripos var. *curvicornis* Daday, Cleve 1900,pl.17,fig.2.
C. curvicorne Daday, Cleve 1901,p.14.
C. tripos gibberum Karsten, 1907,p.249.
C. gibberum f. *dispar* (Pouchet) Jorgensen, 1920,p.70,fig.67.
C. gibberum f. *subequale* Jorgensen, 1920,p.70-72,fig.68.
C. concilians f. *dispar* Bohm, 1931b,p.24,fig.21.
C. gibberum var. *dispar* Sournia, 1967,p.447,fig.73.

Body thick and flattened, epitheca low, angle of side contour blunt, left side straight, right side convex, anterior horn bent at the base than straight. Hypotheca longer than epitheca with very oblique left side contour. Basal contour strongly convex, left antapical horn strong, evenly bent, right variable in manner, directed from base sharply forward. Length 245 µ.

Occurrence: Observed in the inshore plankton of Cochin during May 1974.

Distribution: Coasts of Atlantic, Pacific, Red Sea, North America, North Sea, Japan, Australian and Indian Seas.

55. *Ceratium schmidtii* Jorgensen
(Pl. V, fig.17)

Jorgensen, 1911,p.50,fig.110,111;
Bohm, 1931b, p.24,fig.22;
Steemann Nielsen, 1934,p.18,fig.37;
Schiller, 1937,p.400,fig.440;
Wood, 1954,p.291,fig.216 a,b;
Halim, 1963,p.498,fig.20,21;
Subrahmanyan, 1968,p.49,51, fig.88.

C. curvicorne Schmidt, 1901,p.215, figs.3,4.

C. breve var. schmidtii (Jorgensen) Sournia, 1967,p.427, fig.49.

Large cell with short antapicals, epitheca high, hypotheca longer than epitheca and continuous with both antapicals. Apical horn long, bent left side and broadened, with short winged dentate ridges. Posterior horns broad at the base, sharply bent forward, shorter than body, the right one bent dorsally at the tip, showed a close resemblence to C. gibberum, but differs by the regular body contour, short horns and less concave posterior contour. Length 280 µ.

Occurrence: Observed in the inshore plankton of Cochin during March-April 1974.

Distribution: Coasts of Pacific, western Indian Ocean, south China Sea, Malacca straight, Mozambique channel, Australian and Indian Seas.

56. Ceratium symmetricum Pavillard
(Pl. V, fig. 19)

Pavillard, 1905,p.52,pl.1,fig.4;
Steemann Nielsen, 1934,p.19,figs.40,41;

Schiller, 1937, p. 401, figs. 441 a-d;
Wood, 1954, p. 292, figs. 217 a-c;
Sournia, 1967, p. 432;
Subrahmanyan, 1968, p. 51, 52, figs. 89-92.

C. tripos var. gracile Gourret, 1883, p. 24, pl. 1, fig. 1.

C. tripos coarctatum Karsten, 1907, p. 229.

C. gracile Jorgensen, 1911, p. 44, figs. 92, 93.

C. coarctatum Pavilard, 1923, p. 917.

C. aultii Graham and Broniskovsky, 1944, p. 30, fig. 15F.

C. symmetricum var. coarctatum Graham and Broniskovsky, 1944, p. 30; Sournia, 1967, p. 433, fig. 56.

C. symmetricum var. symmetricum Sournia, 1967, p. 432, fig. 57.

C. symmetricum var. orthoceros Graham and Broniskovsky, Sournia, 1967, p. 434, fig. 55.

Cells medium, robust form, body much longer than broad, flattened, left side strongly convex, rather steep towards apical horn, apical horn slightly bent, hypotheca same length as epitheca, with strongly convex posterior contour gradually merges into 2 posterior parallel horns. Length 190 μ.

Occurrence: Observed in the inshore plankton of Cochin during March-April 1974.

Distribution: Coasts of Atlantic, Pacific, Mediterranean Sea, western Indian Ocean, Japan and Australian waters and west coast of India.

57. Ceratium vulture var. sumatranum (Karsten) Steemann Nielsen

(Pl. V, fig. 18; Pl. VII, fig. B)

Steemann Nielsen, 1934, p.27, figs.65-66;
Schiller, 1937, p.419, figs.460 a-c;
Wood, 1954, p.305, fig.233 d;
Subrahmanyan, 1958, p.439; 1968, p.69, figs.132, 133; pl.5, figs.27, 28; pl.6, fig.31;
Sournia, 1967, p.482.

Ceratium tripos var. *neglecta* Karsten, p.1905, pl.19, fig.12a.

C. tripos vulture Karsten, 1907, pl.48, fig.15; pl.51, figs.14.

C. tripos buceros Karsten, 1907, pl.51, fig.8.

C. sumatranum Jorgensen, 1911, p.74, fig.155.

C. sumatranum var. *recurvum* Jorgensen, 1911, p.74, fig.156.

Cells robust, medium sized, form chains by attaching the apical horn to the hypotheca of the adjacent cell, characteristic of the species. Epitheca low, hypotheca double as long as epitheca, apical horn broad, posterior horns unequal, the left horn with short, posteriorly directed basal piece and right horn with a corresponding basal portion towards right and oriented backward. Length excluding the horns 86 μ.

Occurrence: Observed in the inshore waters of Cochin during March-April 1974.

Distribution: Rare warm water form, coasts of Atlantic, Pacific, western Indian Ocean, Australian waters and west coast of India.

58. *Ceratium massiliense* (Gourret) Jorgensen

(Pl. V, fig.21)

Jorgensen,1911,p.66,figs.140-142;
Bohm,1931a,p.362,figs.16-18;
Steemann Nielsen,1934,p.25,figs.60-62;
Schiller, 1937,p.422,figs.463a-d;
Wood, 1954,p.306,figs.235 a-c;
Sournia, 1967,p.465;
Subrahmanyan, 1968,p.74,pl.4,fig.23;
pl.7,fig.34,35;
Steidinger and Williams,1970,p.46,
pl.11,fig.30 a-c.

C. tripos var. massiliense Gourret, 1883,p.27,pl.1,fig.2.

C. volans Ostenfeld et Schmidt, 1901,Schiller,1937,p.424.

C. aequatoriale Schroder, 1906,p.361,fig.32.

C. undulatum Schroder, 1906,p.326.

C. tripos macroceroides Karsten, 1906,p.22,fig.29a.

C. tripos intermedium f. aequatorialis Schroder, Karsten, 1907,p.49,figs.21 a,b.

C. tripos robustum Karsten, 1907,pl.51,fig.7.

C. massiliense f. macroceroides Jorgensen, 1911,p.66, figs. 140-142.

C. massiliense f. ornatum Jorgensen, 1911,p.67,fig.146.

C. tripos tergestinum Karsten, 1906,pl.21,fig.24.

C. tripos longipes Karsten, 1907,pl.48,fig.11b.

C. protuberans (Karsten) Paulsen, 1931,p.89,fig.56.

C. massiliens f. ellipticum Bohm 1931a,fig.17 a,b.

Large, of variable form, long-horned body, epitheca oblique, hypotheca a little longer than epitheca, apical horn long and slender, antapical horns arising almost at right angles to each other, becoming straight and then diverging or curved with slender ends. Length 580 μ.

<u>Occurrence</u>: Observed in the inshore area of Cochin during May 1974.

<u>Distribution</u>: Widely distributed in all the warm waters.

59. <u>Ceratium deflexum</u> (Kofoid) Jorgensen (Pl. V, fig.22)

Jorgensen, 1911,p.64,pl.7,fig.138;
Bohm, 1931b,p.37,figs.33;
Steemann Nielsen, 1934,p.25,fig.63;
Schiller, 1937,p.310,fig.237;
Wood, 1954,p.310,fig,237;
Sournia, 1967,p.464,fig.86;
Subrahmanyan, 1968,p.78,figs.145-46.

<u>C. macroceros deflexum</u> Kofoid, 1907b,p.304,pl.24,figs. 13-15.

<u>C. tripos macroceros</u> Karsten, 1907,pl.49,figs.26 a,b.

<u>C. californiense</u> Karsten, 1907,pl.51,fig.15.

<u>C. recurvatum</u> Schroder, 1906,p.367,fig.40.

Large, long horned species, with less apread distally straight antapicals, epitheca slightly oblique, hypotheca longer than epitheca, apical horn long, straight, This species shows close resemblance to <u>C. macroceros</u>. Length 360 µ.

<u>Occurrence</u>: Observed in the inshore plankton of Cochin, during May 1974.

<u>Distribution</u>: Coasts of Pacific, North America, Red Sea, western Indian Ocean, Mozambique channel, east coast of Australia and west coast of India.

60. <u>Ceratium macroceros</u> (Ehrenberg) Vanhoffen (Pl. V, fig.20)

Vanhoffen, 1897, p.310, pl.5, fig.10;
Cleve, 1900, p.227; 1901, p.14;
Paulsen, 1908, p.81, fig.109;
Lebour, 1925, p.155, pl.35;
Schiller, 1937, p.428, fig.468;
Wood, 1954, p.310, fig.238 a;
Subrahmanyan, 1958, p.440; 1968, p.79-80, figs.149-150; pl.4, fig.24; pl.5, figs.25, 26; pl.6, figs.29, 30;
Sournia, 1967, p.460, fig.83, 84.

<u>Peridinium macroceros</u> Ehrenberg, 1840, p.201;
<u>Ceratium tripos</u> var. <u>macroceros</u> Gourret, 1882, p.26-27, pl.2, fig.41.
<u>C. tripos</u> var. <u>scotica</u> Schutt, 1892, Schiller, 1937, p.429.
<u>C. californiense</u> Kofoid, 1907b, p.302, pl.23, figs.8, 9; Karsten, 1907, p.312.

Long horned cells, body thick and concave, epitheca broad and depressed with convex sides, hypotheca longer than epitheca, anterior horn somewhat straight, posterior horns diverging more or less from one another. Theca sculptured. Length 285 μ.

<u>Occurrence</u>: Observed in the inshore area of Cochin during the period July-August 1974.

<u>Distribution</u>: Coasts of Atlantic, Pacific, North Sea, Red Sea, Madagascar region, Australian waters and west coast of India.

Family Pyrophacaceae

Genus _Pyrophacus_ Stein

61. _Pyrophacus horologicum_ Stein

(Pl. V, fig.23)

Stein, 1883, p.28, pl.24, fig.1-13;
Lindemann, 1928, p.96, fig.83;
Wood, 1954, p.221, fig.84 a;
Subrahmanyan, 1958, p.439;
Sournia, 1967, p.426;
Steidinger and Williams, 1970, p.38, pl.39, fig, 146 a,b.

Pyrophacus horologium var. _steinii_ Schiller, 1937, p.87, fig. 74.

Cells lens shaped, biconvex, epitheca and hypotheca equal, longitudinal furrow showed a few small plates. Breadth of the cell 82 μ.

Occurrence: Observed in the inshore plankton of Cochin during June 1974.

Distribution: Widely distributed in the coastal areas of Atlantic, Pacific, western Indian Ocean, Australian waters and west coast of India.

Family Ceratocoryaceae

Genus _Ceratocorys_ Stein

62. _Ceratocorys horrida_ Stein

(Pl. VII, figs. C,D)

Stein, 1883, p.20, pl.6, figs.4-11;
Karsten, 1907, p.419, pl.52, fig.1-3;
Lindemann, 1928, p.98, fig, 85;
Wood, 1954, p.313, fig.242 a,b;

Subrahmanyan, 1958,p.440;
Sournia, 1967,p.428;
Steidinger and Williams, 1970,p.28,
pl.16, fig.42 a,b.

Ceratocorys horrida var. africana Karsten, 1907,p.419,
pl.52, fig. 1-3.
C. horrida var. extensa Pavillard, 1931,p.101,pl.3,fig.17b.
C. horrida var. longicornis Lemmermann, 1899,p.350.

Body angular, pyramidal apical region, girdle lists very wide, hypotheca with 5 long spines, 4 arising from the corners of the antapical plates, one in the ventral region. The spines are winged, small ribs project from all sides. Length 62 µ.

Occurrence: Observed in the inshore area of Cochin during August 1974.

Distribution: Widely distributed in all the warmer seas.

Family Cladopyxiaceae

Genus Cladopyxis Stein

63. Cladopyxis caryophyllum (Kofoid) Pavillard
(Pl. V, fig. 24)

Pavillard, 1931,p.102;
Wood, 1963a,p.51,fig.190.

Acanthodinium caryophyllum Kofoid, 1907,p.193,pl.11,fig.67;
Lindemann, 1928,p.99,fig.86.

Body sub-globose, epitheca smaller than hypotheca, girdle anterior, from the middle 4 epithecal and 6 hypothecal plates arise, equal number of spines or branched process projected out. Length 45 μ.

Occurrence: Observed in the estuarine area of Cochin during September 1974.

Distribution: Coasts of Pacific, eastern Indian Ocean, Australian waters.

New record for the Indian Seas.

Family Podolampaceae

Genus *Podolampas* Stein

64. *Podolampas bipes* Stein

(Pl. V, fig.25)

Stein, 1883,p.22,pl.8,fig.6;
Schutt,1896,p.23;
Lindemann, 1928,p.100,fig.87;
Wood, 1954,p.316,fig.251a;
Subrahmanyan, 1958,p.440;
Sournia, 1967,p.429;
Steidinger and Williams, 1970, p.60,pl.36,fig.125.

Cells broad and pear shaped, tapering to apical horn, flattened dorso-ventrally, girdle not clear, two strong equal antapical spines supporting transverse wings, the left being a continuation of the wing of the ventral area. Length 65 u.

Occurrence: Observed in the inshore plankton of Cochin during July 1974.

Distribution: Coasts of Atlantic, Pacific, Boeton straight, English channel, east coast of Australia and west coast of India.

65. <u>Podolampas palmipes</u> Stein

(Pl. V, fig.26)

Stein, 1883,p.22,pl.18,fig.9-11;
Wood, 1954,p.317,fig.252 a,b;
Subrahmanyan, 1958,p.440;
Sournia, 1967,p.429;
Steidinger and Williams, 1970,
p. 60,pl.36,fig.128 a,b.

Cells elongated, pear shaped, narrow frontal portion and tapering to a slender apical horn, two unequal spines, left antapical spine longer, wings fused with the spine. Length 82 μ.

<u>Occurrence</u>: Observed in the inshore plankton of Cochin during April 1974.

<u>Distribution</u>: Coasts of Atlantic, Pacific, North Sea, Madagascar region, east coast of Australia and west coast of India.

Order Dinococcales

Family Dissodiniaceae

Genus <u>Pyrocystis</u> Murray

66. <u>Pyrocystis fusiformis</u> Murray

(Pl. V, fig.28)

Murray, 1876,p.553,pl.21;
Wood, 1954,p.318,fig.256 a;
Subrahmanyan, 1958,p.440;
Sournia, 1967,p.430,fig.4;
Steidinger and Williams, 1970,
p.38,pl.39,fig.142.

Cells rescent shaped, hyaline, thin walls with blunt ends. The protoplasm of the cell found divided into two 'spores' which act as resting spores. Length 280 µ.

Occurrence: Observed in the inshore plankton of Cochin during September-October 1974.

Distribution: Widely distributed in all the warm seas.

67. Pyrocystis robusta Kofoid
(Pl. V, fig.27)

Kofoid, 1907,p.167,pl.1,fig.5;
Wood, 1954,p.320,fig.260 a,b;
Ballantine, 1961,fig.64;
Sournia, 1967,p.431,fig.8;
1968,p.556.

Pyrocystis lunula var. robusta Apstein, 1909,p.9.
Pyrocystis elegans Schiller, 1937,p.492,fig.569.

Cells deeply crescentic, fusiform, convex margin, hyaline body, bent into a deep crescent, tips nearly face each other. Differs from P. fusiformis in its greater curvature, stouter body and broad middle portion. Length 240 µ.

Occurrence: Observed in the inshore plankton of Cochin during September-October 1974.

Distribution: Coasts of Pacific, western Indian Ocean, Madagascar region, Australian waters. New record for the Indian Seas.

PLATE - V

Figs. 1-28. Fig. 1, Ceratium hirundinella, ventral view;
Fig. 2, Ceratium candelabrum, dorsal view;
Fig. 3,4, Ceratium furca, morphological variations of two cells;
Fig. 5, Ceratium incisum, ventral view;
Fig. 6, Ceratium pentagonum, dorsal view;
Fig. 7, Ceratium inflatum, ventral view;
Fig. 8, Ceratium fusus, dorsal view;
Fig. 9, Ceratium dens, ventral view;
Fig. 10, Ceratium tripos, dorsal view;
Figs. 11-12, Ceratium pulchellum, two cells shows structural variations, dorsal and ventral views;
Fig. 13, Ceratium breve, ventral view;
Fig. 14, Ceratium contortum, dorsal view;
Figs. 15-16, Ceratium gibberum, two cells in ventral view showing morphological variations;
Fig. 17, Ceratium schmidtii, ventral view;
Fig. 18, Ceratium vulture var. sumatranum, dorsal view, two cells adhere to form part of the chain;
Fig. 19, Ceratium symmetricum, ventral view;
Fig. 20, Ceratium macroceros, dorsal view;
Fig. 21, Ceratium massiliense, dorsal view;
Fig. 22, Ceratium deflexum, ventral view of two cells;
Fig. 23, Pyrophacus horologicum, antapical view showing plate arrangements;
Fig. 24, Cladopyxis caryophyllum, body showing nine processes;
Fig. 25, Podolampas bipes, dorsal view;
Fig. 26, Podolampas palmipes, dorsal view;
Fig. 27, Pyrocystis robusta, side view;
Fig. 28, Pyrocystis fusiformis, body cavity shows Gymnodinium like structures.

All the figures x 1200

PLATE. V

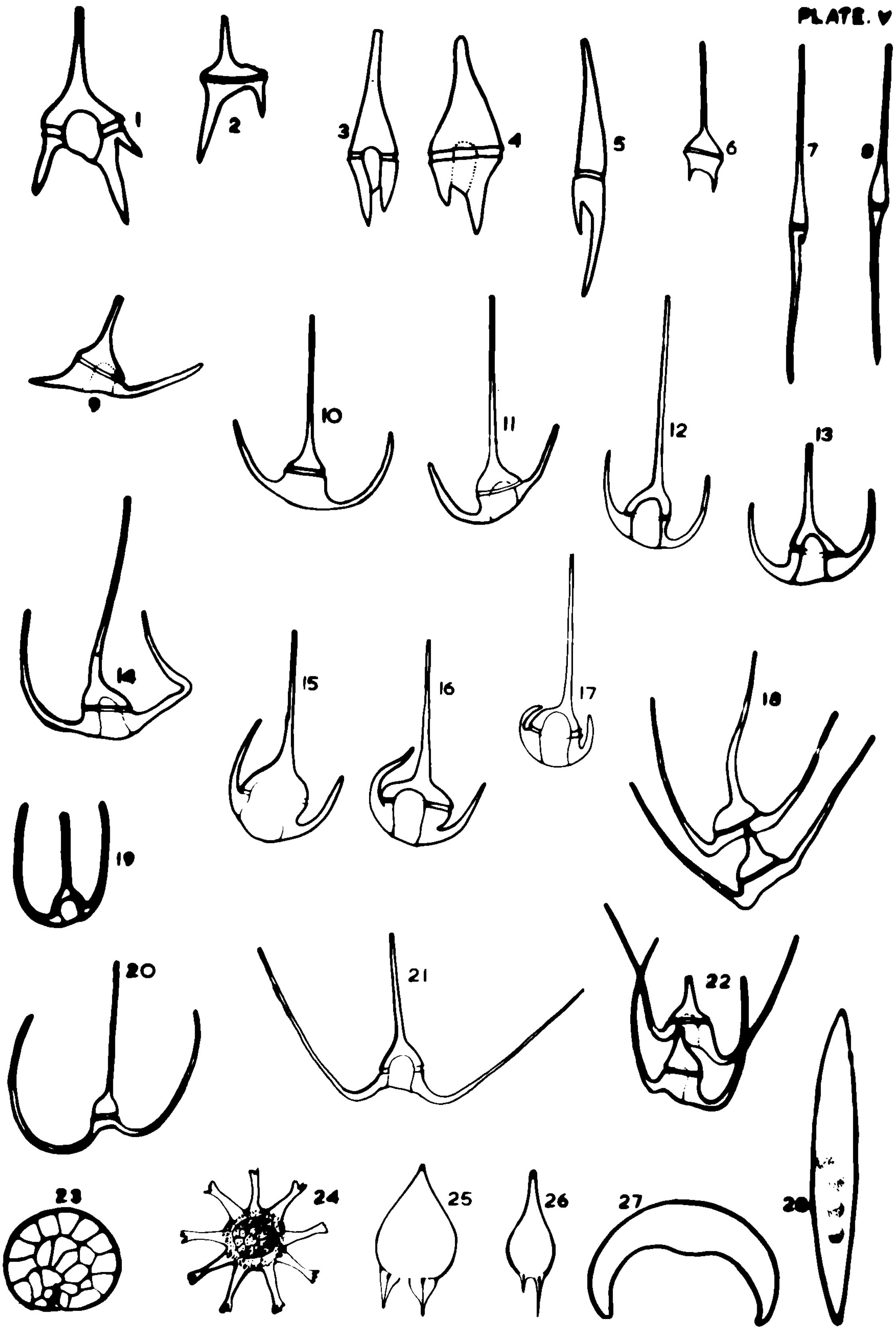


PLATE - VI

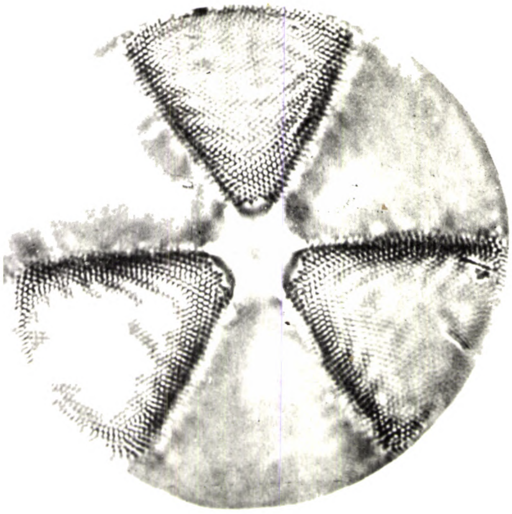
Figs. A-D. Fig. A, Actinoptychus senarius,
valve view.

Fig. B, Actinoptychus splendens,
valve view.

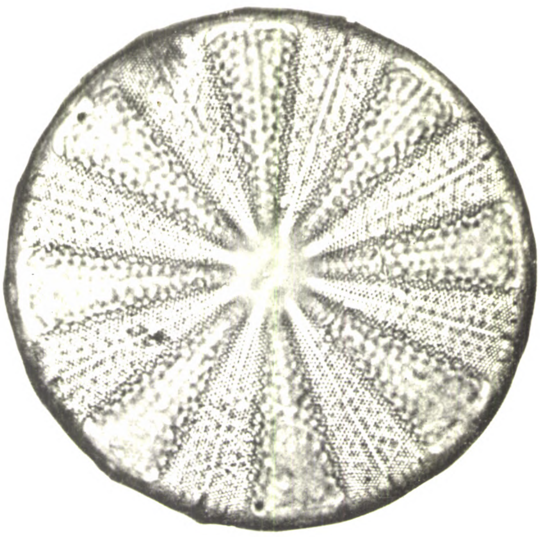
Fig. C, Navicula gracilis var.
schizonemoides, (endophytic)
colony in mucilage tube.

Fig. D, Mastogloia cochinensis sp. nov.
valve view.

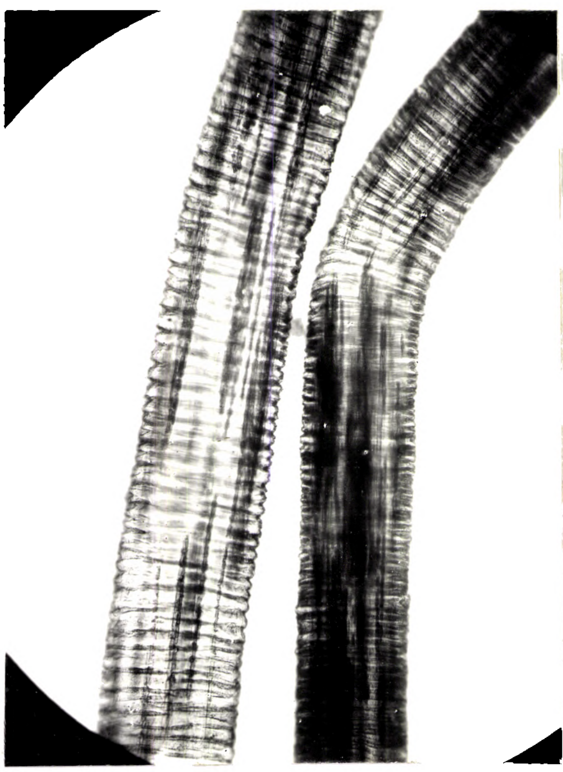
PLATE VI



A



B



C

D

PLATE - VII

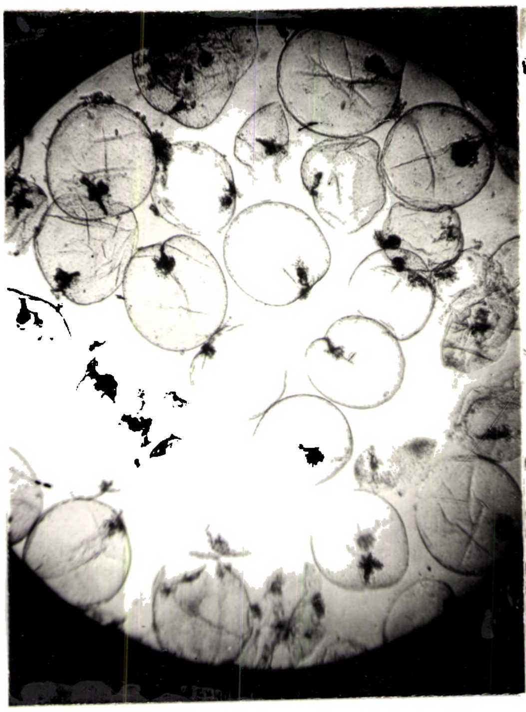
Figs. A-D. Fig. A, Noctiluca miliaris, a group of cells with flagellae.

Fig. B, Ceratium vulture var. sumatranum, a chain of cells.

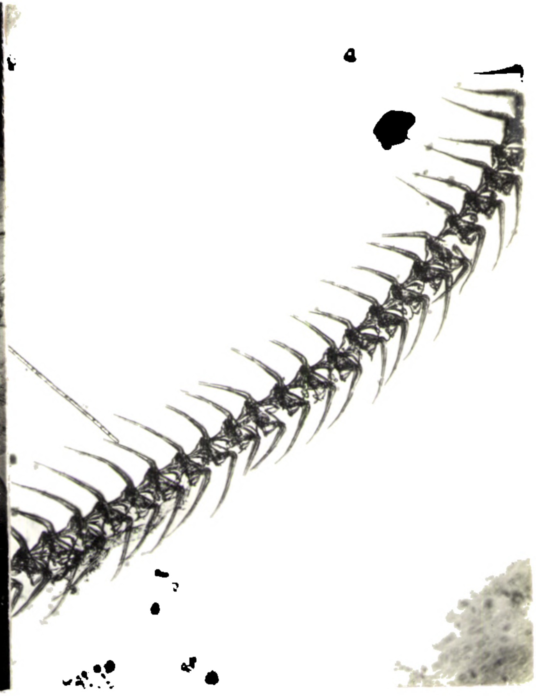
Fig. C, Ceratocorys horrida, side view of the cell with horns and funnel like antapical process.

Fig. D, Ceratocorys horrida, antapical view.

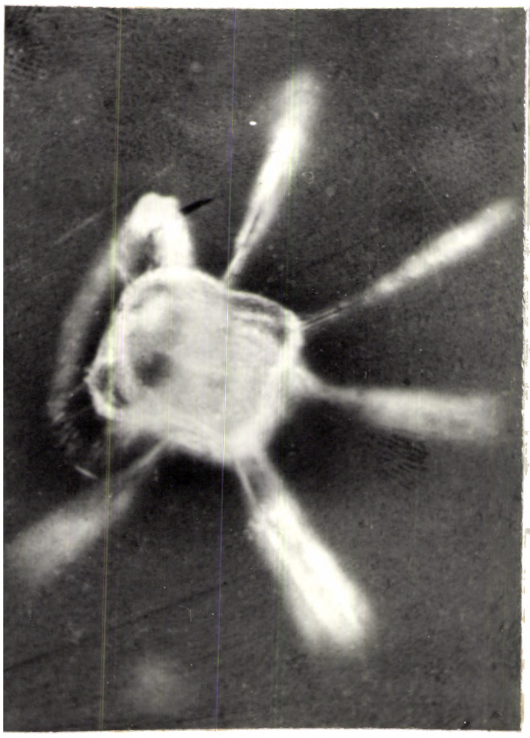
PLATE VII



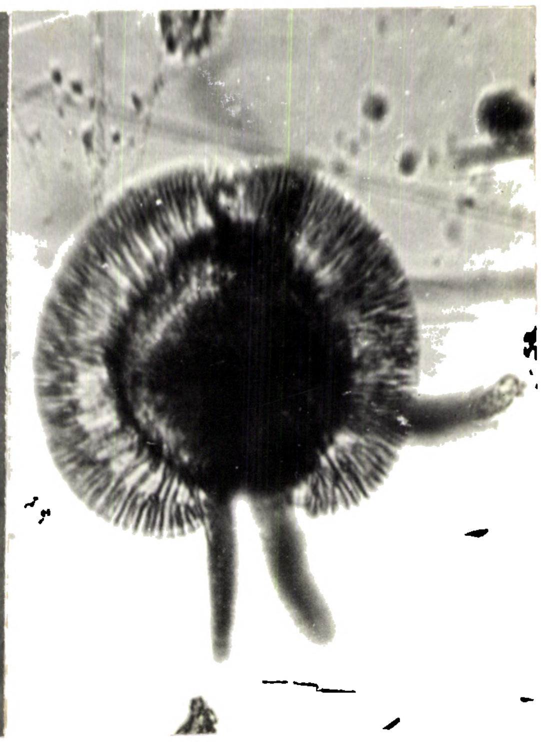
A



B



C



D

V. PHYTOPLANKTON INVESTIGATIONS IN THE ESTUARINE AREA OF COCHIN

In recent years, the estuarine system of Cochin and connected backwaters has been a subject of study for various hydro-biological and productivity parameters due to its unique dynamic environmental conditions as well as due to its resource potential. A comprehensive account on the organic production of the Cochin backwaters by Qasim *et al.* (1969) showed that the estuarine system is one of the most productive in the tropical environment with an estimated annual gross production of 295 gC/m^2. Subsequent studies on the variation and distribution of the phytoplankton and the factors affecting its production has revealed that the standing crop in terms of chlorophylls (Qasim and Reddy, 1967), biomass (Gopinathan, 1972), total cell counts (Gopinathan *et al.* 1974; Joseph *et al.* 1975) and primary production (Nair *et al.* 1975), vary from place to place and time to time as a result of the water masses being constantly renewed by an inflow of freshwater from the rivers and seawater from the inshore areas of the Arabian Sea.

In an earlier investigation Gopinathan *et al.* (1974) studied the usefulness of chlorophyll *a* in relation to the phytoplankton counts as a measure of the phytoplankton abundance by using the correlation coefficients and found from an analysis of co-variance that a common relationship exists between phytoplankton and chlorophyll a for the estuary.

Studies on the phytoplankton of different enviroments have shown that none of the productivity indices such as chlorophyll, biomass and total cell counts can independently give a true picture of the standing crop because of the inherent drawbacks in each method. Moreover, the hydrological and productivity parameters also differ according to the change of environment and place of sampling. Hence, in this account an attempt has been made to determine the relationship of different variables responsible for the phytoplankton production by means of multiple regression analysis.

Area of study:

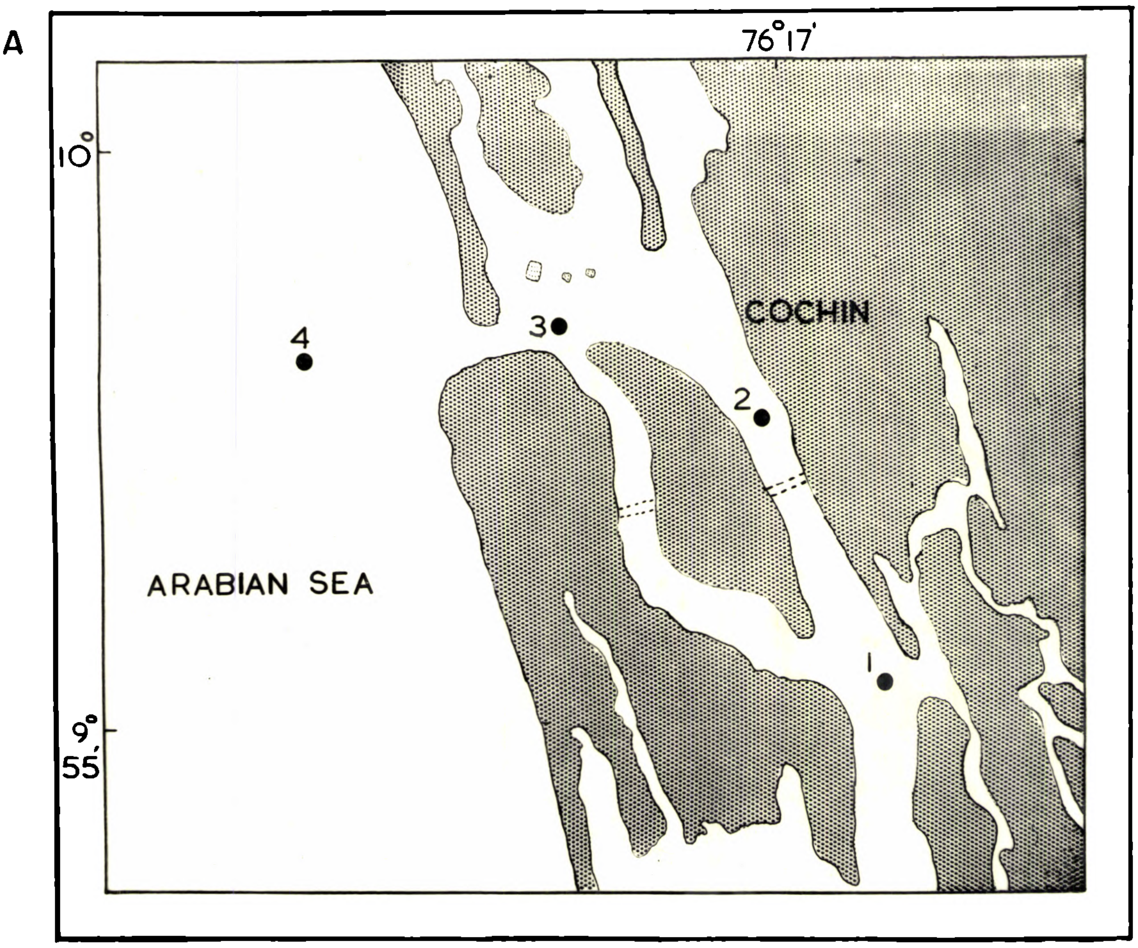
In the central part of the estuarine system of Cochin, 4 stations were sampled fortnightly during the year 1974 for collecting the data related to hydrological and productivity parameters (Pl. VIII, fig.A). The phytoplankton crop was estimated by total cell counts, chlorophylls and by primary productivity measurements using radioactive isotope of carbon (^{14}C). For calculating the concentrations of chlorophylls, revised equation of Parsons and Strickland (1963) were employed. Duplicate samples were analysed for hydrological properties like salinity, oxygen and nutrients.

PLATE - VIII

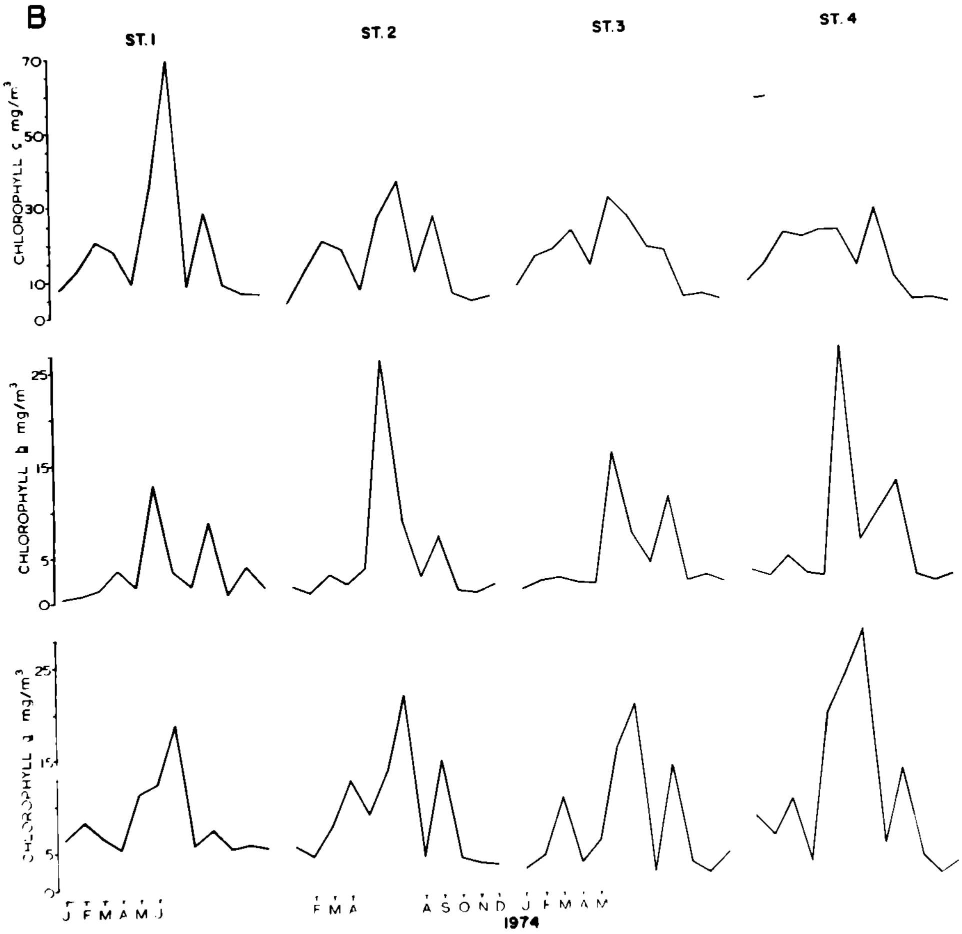
Figs. A-B. Fig. A, Location of the stations in the Cochin Backwater.

Fig. B, Seasonal variation of chlorophyll a, b, and c at 4 stations in the Cochin Backwater.

A


76°17'
10°
9°
55'
COCHIN
ARABIAN SEA
1
2
3
4

B


ST. 1
ST. 2
ST. 3
ST. 4
CHLOROPHYLL c mg/m³
CHLOROPHYLL b mg/m³
CHLOROPHYLL a mg/m³
J F M A M J
F M A
A S O N D J F M A M
1974

Results:

Primary Production

In the present investigation, two seasonal peaks of primary production were noticed in all the four stations - the primary peak during the pre-monsoon season, and the secondary peak during the post-monsoon months of September-December. The range of production for the first station being 432-3900 $mgC/m^3/day$; for the 2nd, 360-3400 $mgC/m^3/day$; for the 3rd, 261-1750 $mgC/m^3/day$ and for the 4th, a production range of 438-2035 $mgC/m^3/day$. Though the monsoon months are said to be the most productive season for the phytoplankton in the coastal waters, in the estuarine system, it is not the case as was observed in the present investigation (Table - 1).

Generally there was a high rate of production noticed in the backwater area than the inshore. The observations of Qasim _et al_. (1969) indicated 3 small peaks, in April, July and October, but these authors suggested that the fluctuations may not be consistent from year to year due to the prevailing environmental conditions.

Chlorophylls

In the present observation, chlorophyll _a_, _b_ and _c_ were measured at all the stations. Since chlorophyll _a_ is one of the major indices of the standing crop of phytoplankton, the estimation of this pigment along with

Table - 1

Primary productivity measurements

	Production mgC/m^3/day (surface)			
	St. 1	St. 2	St. 3	St. 4
1974				
January	1825	3124	1615	2035
February	538	432	462	612
March	899	2012	261	716
April	1375	773	360	644
May	719	1200	564	789
June	448	360	494	503
July	432	1010	338	438
August	561	911	262	486
September	2548	1134	330	715
October	3900	3400	1750	1452
November	1850	1130	461	1034
December	2880	1740	735	965

primary production will give a general idea of the variation in the magnitude of production. Tables 2, 3 and 4 gives the average values of these pigments in the surface waters. The most dominant pigment was chlorophyll c followed by a and b.

Table - 2

Monthly average values of Chlorophyll a

(mg/m^3)

	St. 1	St. 2	St. 3	St. 4
1974				
January	6.45	5.01	2.68	7.96
February	8.10	4.20	4.0	5.86
March	6.63	7.68	10.13	9.61
April	4.32	12.05	3.36	2.88
May	11.79	8.61	5.75	18.52
June	12.05	13.35	15.25	22.95
July	18.95	21.25	20.15	27.75
August	5.57	4.0	2.60	4.32
September	7.27	14.62	13.80	12.25
October	5.12	4.05	3.10	3.39
November	5.30	3.55	2.60	1.28
December	5.11	3.52	4.22	2.39

Like primary production, chlorophyll a values also showed distinct seasonal and spatial variation. In contrast to primary production, chlorophyll a values showed a single peak during monsoon season in all the stations, indicating an inverse relationship with production. Chlorophyll b also showed a single peak during monsoon and a secondary abundance of less magnitude during September.

Table - 3

Monthly average values of Chlorophyll b

(mg/m^3)

1974	St. 1	St. 2	St. 3	St. 4
January	0.36	1.31	0.73	2.05
February	0.65	0.73	1.60	1.64
March	1.02	2.50	1.92	3.56
April	3.55	1.46	1.42	1.92
May	1.89	3.18	1.10	1.65
June	12.90	25.85	15.10	26.45
July	3.10	7.20	6.65	5.21
August	1.55	2.22	3.25	8.50
September	8.20	6.60	11.65	11.05
October	0.55	0.75	1.20	1.40
November	3.60	0.65	1.95	0.90
December	1.10	1.20	1.10	1.15

A comparison of chlorophyll a, b and c (Pl. VIII, fig. B) is of interest in view of the generally accepted status of chlorophyll a as the most predominant pigment of the phytoplankton and chlorophyll b as an accessory pigment (Strickland, 1960). Chlorophyll c showed exceptionally high values during pre-monsoon and monsoon months (Table-4).

Table - 4

Monthly average values of Chlorophyll *c*

(mg/m^3)

	St. 1	St. 2	St. 3	St. 4
1974				
January	7.45	2.45	6.60	6.65
February	12.35	10.65	14.75	14.20
March	20.43	18.67	15.25	19.23
April	18.76	16.65	21.45	18.62
May	8.25	5.50	11.50	19.50
June	34.75	26.30	29.40	19.62
July	69.40	35.70	24.40	9.50
August	8.05	10.75	16.65	25.60
September	28.12	25.80	15.50	7.15
October	7.75	4.60	2.15	3.00
November	5.75	2.75	2.25	3.30
December	5.55	3.24	1.84	2.75

With regard to the status of chlorophyll *c*, it is doubtful whether it can be accepted as an accessory pigment (Spencer, 1964). Parsons (1961) while dealing with phytoplankton culture, stated that in some algal cells chlorophyll *c* can markedly increase under certain environmental conditions. Earlier accounts on chlorophyll *c* (Currie, 1958; Humphrey, 1960, 1963; McAllister *et al*. 1960) have also pointed out the possible errors involved in its determination.

The inter-relationship of chlorophylls is expressed in terms of their ratio with each other by chlorophyll c/a, and chlorophyll b/a (Tables 5 and 6).

Table - 5

Chlorophyll c/a Ratio

	St. 1	St. 2	St. 3	St. 4
1974				
January	1.15	0.48	2.46	0.83
February	1.52	2.53	3.68	2.42
March	3.08	2.43	1.50	2.0
April	4.34	1.38	6.38	6.46
May	0.69	0.45	2.0	1.05
June	2.88	1.97	1.92	0.85
July	3.66	1.68	1.21	0.34
August	1.44	2.68	6.25	5.92
September	3.86	1.76	1.12	0.58
October	1.51	1.13	0.69	0.88
November	1.08	0.77	0.86	2.75
December	1.08	0.92	0.43	1.15

It is seen that high values noted in the ratio of c/a than b/a revealing the dominance of chlorophyll c in the magnitude of total pigments in the water column.

Table - 6

Chlorophyll b/a Ratio

	St. 1	St. 2	St. 3	St. 4
1974				
January	0.05	0.26	0.27	0.25
February	0.07	0.17	0.40	0.27
March	0.15	0.32	0.18	0.37
April	0.82	0.12	0.42	0.65
May	0.16	0.36	0.19	0.08
June	1.07	1.93	0.99	1.15
July	0.16	0.33	0.33	0.18
August	0.27	0.55	1.25	1.96
September	1.12	0.45	0.84	0.90
October	0.10	0.16	0.38	0.41
November	0.67	0.18	0.75	0.70
December	0.21	0.34	0.26	0.48

The probable explanation for the high values of chlorophyll c, evident in the ratios, may have resulted from pigments coming from stirred up mud from the bottom which contained more of chlorophyll degradation products. Vallentyne (1957) and Krey (1958) have indicated the role which the dead chlorophyll plays in the estimation of phytoplankton pigments of coastal waters.

Thus the results on plant pigment analysis clearly indicate that the backwater is characterised by a large quantity of organic and inorganic particulate matter. It is not possible to estimate how much pigment came from living organisms alone, since the water masses are constantly renewed by an inflow of seawater on one side and freshwater from the rivers. The pigment stock has been found to vary considerably from place to place and from time to time with the state of tidal rhythm.

<u>Total cells of phytoplankton</u>

Corresponding to primary production and chlorophylls, the total cell counts also showed evidence of seasonal and spatial variations. Similar to primary production, the total number of cells also indicated a primary peak during the pre-monsoon months and a secondary peak of less magnitude during the post-monsoon months. Low values were observed in the months of July-August and November-December (Table - 7). Generally, the trend in cell numbers are more or less homogenous between stations than the trends in primary production and chlorophylls.

Thus the different indices of standing crop of phytoplankton showed different trends in the fluctuation with no direct relationship with each other. The observations of Qasim *et al.* (1969), based on the primary

Table - 7

Standing crop of phytoplankton in terms of total cell counts/litre

	St. 1	St. 2	St. 3	St. 4
1974				
January	$227x10^3$	$213x10^3$	$238x10^3$	$244x10^3$
February	362 "	285 "	316 "	372 "
March	347 "	382 "	371 "	316 "
April	396 "	367 "	383 "	357 "
May	247 "	221 "	237 "	307 "
June	261 "	234 "	185 "	196 "
July	174 "	148 "	167 "	177 "
August	165 "	237 "	118 "	136 "
September	276 "	209 "	262 "	332 "
October	289 "	237 "	254 "	338 "
November	192 "	207 "	176 "	265 "
December	145 "	186 "	191 "	234 "

production values and Gopinathan et al. (1974) and Joseph et al. (1975) based on the total cell counts indicate that the fluctuations of the standing crop of phytoplankton in the Cochin backwater vary from year to year and more often may depend on metereological conditions and other environmental parameters.

Qualitative studies:

Since the sampling stations were so chosen to represent the varying environmental features between the backwater and marine environments, ie. the stretch of varying influence of tide and other relevant factors, the species composition also varied from station to station. The backwater station (st. 1) showed a dominance of both freshwater and brackishwater species, while the 2nd and 3rd stations showed the preponderence of brackish water forms only. At the marine station (st. 4), a high dominance of oceanic species was evident and the fresh water forms were completely absent.

During the peak periods, the phytoplankton was largely constituted by diatoms and the nannoplankters formed the next important component. During the pre-monsoon months, the diatoms and dinoflagellates were present in equal numbers and in the post-monsoon period, dinoflage-llates dominated. The primary peak during the pre-monsoon months was due to diatoms such as Skeletonema costatum, Thalassiosira subtilis and Chaetoceros socialis. During the second peak, the dinoflagellates such as Ceratium furca, Peridinium depressum and Prorocentrum micans formed the major components along with diatoms Skeletonema costatum and Fragilaria oceanica. Silicoflagellates such as species of Distephanus and Dictyocha were present in lesser numbers during the pre-monsoon months along with the diatoms. The Coccolithophore, _Coccolithus huxley_ and members of blue-green algae such as species of _Oscillatoria_, _Trichodesmium_, _Meresmopedia_ and _Synechocystis_ were found in lesser numbers during the post-monsoon season. Freshwater desmids such as species of _Euastrum_, _Cosmarium_, _Micrasterias_ and _Desmidium_ and filamentous green algae such as _Spirogyra_, _Oedogonium_ and _Cladophora_ species also were seen during the monsoon season at the first station.

Environmental factors affecting phytoplankton production

It is an established fact that the environmental factors, both physical and chemical, may influence the production and distribution of phytoplankton in any ecosystem. In the present investigation, hydrological factors like temperature, salinity, dissolved oxygen and nutrients such as nitrite, nitrate, phosphate and silicate were estimated at the surface waters of all the stations in order to make an assessment of their relative role in the quantitative and seasonal variations of phytoplankton. The station-wise hydrographic features are given in Tables 8, 9, 10 and 11.

Temperature:

The fluctuations in the surface temperature during different seasons were very low ranging from 27-31°C in all the stations. The temperature was at its maximum during the pre-monsoon months, extending upto May and with the onset of monsoon, the temperature values begin to decrease at surface. During monsoon and in the early post-monsoon periods, the surface temperature showed low values. Further increase in temperature observed during November-December continued upto the pre-monsoon months and reached the maximum during March-April period.

In the estuary, with typical tropical conditions, the temperature by itself seemed to have no direct influence on the phytoplankton production unlike in temperate waters. The increase in temperature will definitely enhance the rate of respiration of the planktonic algae and thereby the energy stored during photosynthesis will be used up thus reducing the multiplication activity of the phytoplankton. According to Roy (1955) in the Hooghly estuarine system, the low winter temperature never acts as a limiting factor for the phytoplankton production. Shetty _et al_. (1961) have shown that the secondary peak of phytoplankton in the Hooghly area during June-August was due to the relatively high temperature ($30^{o}C$) and this peak was the highest during that year. However, as pointed out by Steemann Nielsen and Jensen (1957) that in shallow regions where the bottom is in direct contact with over-lying water, the indirect influence of temperature causes an enhancement in the regeneration process to some extent which reflects in the rate of primary production.

<u>Salinity</u>:

Among the hydrological parameters in an estuary, salinity is the most important one since it regulates the entire biological activities of the ecosystem. The salinity fluctuations are very wide in the Cochin estuarine system because of the influence of monsoon and consequent run off from land. During the pre-monsoon season, especially March-April, the surface salinity at all the stations exhibited considerable increase, and may be interpreted as the season of highest salinity when the influence of the seawater was at its maximum throughout the estuary. During monsoon, large quantities of freshwater enter the estuary from the nearby rivers and from the rainfall, resulting in very low saline water at the surface even at the marine station (st. 4) and dense saline water at the bottom. By August nearly freshwater condition prevail in the estuary. Subsequently, the salinity values begin to increase gradually in the late post-monsoon months and reach the peak period in the pre-monsoon months.

A horizontal gradient in salinity was observed from station 1 to 4; the former being more brackish while the latter is an inshore one and more akin to marine environment. The salinity in general, decreases from the mouth of the estuary towards the head. The extent of intrusion of saline water depends on the strength of the tidal influx and the freshwater mixing which differ with seasons.

Studies of Qasim et al. (1972) indicated that many phytoplankters 'bloom' in exceptionally low salinities in the Cochin backwater, revealing that waters of low salinity support a greater abundance of phytoplankton provided other environmental factors are favourable. Such a dependence of the phytoplankton on low salinity serves as an adaptation to utilise the enrichment of water to a maximum degree. As has already been stated by Subrahmanyan (1959 a) on the Calicut coast that when there is a sudden fall in temperature and salinity with high nutrient enrichment in the water column, a 'bloom' of phytoplankton could be expected.

Oxygen:

The dissolved oxygen content of the surface waters does not show much fluctuations. An analysis of the surface oxygen values at all the stations for the whole year showed that the higher oxygen values are found during the monsoon period. However, the dissolved oxygen content of the water, considered as an index of production seems to have no direct relationship with the phytoplankton production.

Nutrients:

In the present investigation, nutrients such as nitrite, nitrate, phosphate and silicate were studied. The nitrite-N values showed a single peak at the 1st and 2nd stations, while the 3rd and 4th stations showed two peaks, a primary one during the monsoon and the secondary one in post-monsoon season. But nitrate-N showed wide fluctuations in different seasons in different stations. The inorganic phosphorus (PO_4) showed distinct primary and secondary peaks, during pre and post-monsoon periods in the first and second stations, while 3rd and 4th stations indicated a third peak during the monsoon with less magnitude. Contrary to this, the silicate values were found to be high during the monsoon months, coinciding with the chlorophyll peaks and inverse relationship with the diatom abundance.

According to Sankaranarayanan and Qasim (1969), the instantaneous concentration of nutrients in the Cochin backwater as inorganic salts does not seem to have any significant influence on the production of phytoplankton. Recent studies by Gopinathan et al. (1974) also revealed this fact clearly. But in several ecosystems the nutrient-phytoplankton relationship is an important one in which the cause and effect could not be found out as available nutrients which stimulate the growth of phytoplankton, resulting in the reduction of the quantity

Table - 8

Hydrographic features at station 1

	Temp. °C	Salinity ‰	Oxygen ml/l	Nitrite µg at N/l	Nitrate µg at N/l	Phosph. µg at P/l	Silicate µg at S/l
1974							
January	28.6	22.8	3.4	0.84	6.31	1.02	28.35
February	29.4	24.7	3.8	0.72	3.68	0.84	17.92
March	30.5	26.5	2.9	1.07	2.72	1.61	33.25
April	30.6	28.7	3.1	0.96	1.94	1.32	16.52
May	30.0	28.3	2.6	0.24	1.83	0.84	37.50
June	28.5	12.4	4.4	0.86	4.85	0.92	42.80
July	28.7	2.5	4.1	2.35	5.92	1.23	47.12
August	28.2	0.79	4.8	1.89	3.53	0.57	36.75
September	27.5	1.2	3.9	0.02	4.06	0.78	31.34
October	27.8	2.8	3.9	0.04	3.92	1.27	17.86
November	29.4	4.1	2.3	0.92	5.63	1.87	11.45
December	28.6	8.8	2.2	1.85	1.02	2.35	23.50

of nutrients, thereby showing an inverse relationship. Such a negative relationship could be seen in the Pl. IX, where all the productivity parameters have been plotted along with nutrients.

Table - 9

Hydrographic features at station 2

	Temp. °C	Salinity ‰	Oxygen ml/l	Nitrite µg at N/l	Nitrate µg at N/l	Phosphate µg at P/l	Silicate µg at S/l
1974							
January	28.8	24.4	3.8	0.68	6.32	2.31	27.50
February	29.8	25.6	2.5	0.62	4.36	1.61	17.43
March	30.7	26.8	2.9	0.78	3.25	1.92	26.45
April	29.8	26.7	2.6	0.54	3.20	2.06	32.24
May	30.2	28.3	3.4	0.82	2.85	0.65	29.65
June	29.4	14.0	3.8	0.69	3.56	0.87	37.20
July	28.2	2.8	4.5	1.02	4.14	0.52	33.45
August	28.0	1.0	4.8	1.61	3.50	0.78	47.14
September	27.8	1.9	5.1	0.64	2.56	0.47	26.25
October	27.0	4.2	4.6	0.47	4.52	1.76	23.05
November	28.5	15.6	2.0	0.61	5.67	2.15	19.65
December	29.2	19.3	3.1	0.38	3.32	1.87	22.15

Table - 10

Hydrographic features at station 3

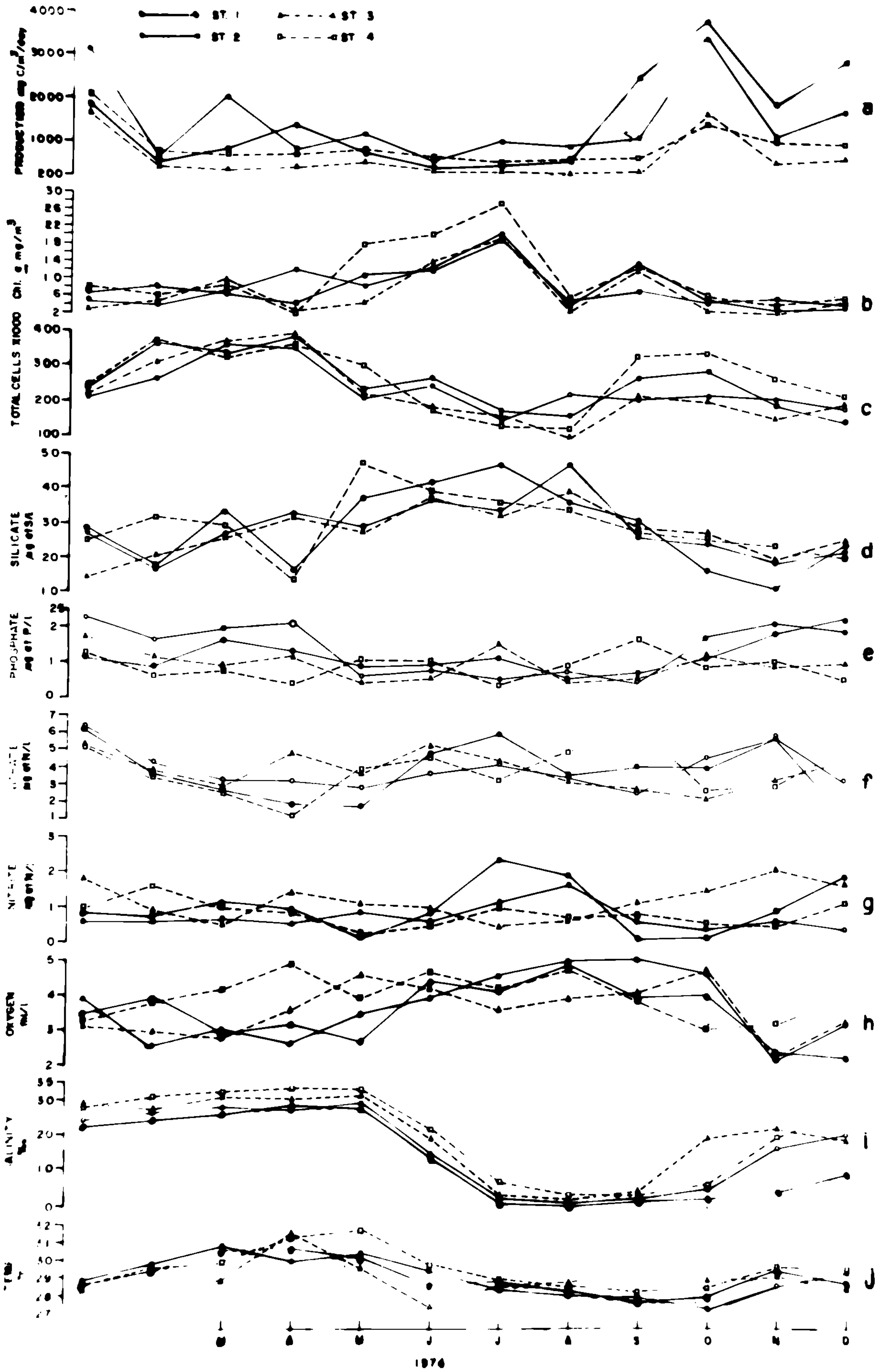
	Temp. °C	Sali- ‰	Oxygen ml/1	Nitrite µg at	Nitra- te N/1	Phos- phate µg at P/1	Sili- cate µg at S/1
1974							
January	28.5	29.6	3.1	1.74	5.27	1.79	13.90
February	27.8	28.8	2.9	0.82	3.62	1.17	21.25
March	28.9	30.2	2.8	0.59	2.96	0.86	26.75
April	31.5	30.0	3.6	1.40	4.88	1.26	33.25
May	29.5	32.1	4.6	1.26	3.66	0.45	28.72
June	27.2	18.6	4.3	0.92	5.14	0.58	37.65
July	28.4	2.1	3.5	0.45	4.22	1.45	34.26
August	28.6	1.6	3.9	0.64	3.06	0.59	39.20
September	29.4	4.4	4.0	1.17	2.62	0.68	28.25
October	28.8	18.2	4.6	1.46	2.09	1.35	27.65
November	29.0	21.2	2.2	2.0	3.14	0.82	19.75
December	28.2	18.6	3.1	1.7	4.2	0.96	25.42

Table - 11

Hydrographic features at station 4

	Temp. °C	Salinity ‰	Oxygen ml/l	Nitrite µg at N/l	Nitrate µg at N/l	Phosphate µg at P/l	Silicate µg atS/l
1974							
January	28.5	28.7	3.2	0.92	5.25	1.22	26.80
February	29.2	30.2	3.8	1.62	3.50	0.65	32.20
March	29.8	31.3	4.2	1.07	2.76	0.78	28.80
April	31.2	32.8	4.9	0.84	1.20	0.42	12.75
May	31.6	32.6	3.8	0.26	3.80	1.04	47.82
June	29.6	20.4	4.6	0.47	4.56	0.82	38.45
July	28.8	6.4	4.2	0.82	3.20	0.36	36.62
August	28.4	2.7	4.8	0.65	4.85	0.92	33.46
September	28.0	2.0	3.9	0.73	6.20	1.68	34.80
October	28.3	5.8	2.9	0.56	2.64	0.89	27.26
November	29.4	17.18	3.2	0.45	2.76	1.02	23.75
December	29.2	26.15	3.8	1.08	4.85	0.56	22.64

PLATE IX



ST. 1
ST. 2
ST. 3
ST. 4
a
b
c
d
e
f
g
h
i
j
TOTAL CELLS X1000
SILICATE
PHOSPHATE
OXYGEN
M A M J J A S O N D
1976

The nitrate-N does not indicate any relationship with any of the productivity indices which would suggest that major part of the nitrogen is supplied in the form of nitrite and other nitrogenous compounds. The N/P ratio at different stations also supports this assumption (Table - 12). The highest ratio for all the stations has been found to be only 8.8, instead of the expected 16:1 by atom observed in highly productive ecosystems. The very low values suggest that the inorganic phosphate present in the surface waters is utilised and regenerated much faster than the nitrates. Under the conditions of depleted nitrogen concentration, production of phytoplankton can occur with lower assimilation ratios (McAllister _et al_. 1960; Stefanson and Richards, 1963).

Discussion

It is well known that a combination of different parameters are responsible for the nature and distribution of phytoplankton in an estuary. Hence, in order to study the influence of various hydrological and productivity parameters, a statistical analysis was done using the data from all the four stations investigated. A multiple regression relationship was set up with all the parameters studied using a Micro Computor (MICRO 2200); the hydrological factors such as temperature, salinity, oxygen and

Table - 12

N/P Ratio

1974	St. 1	St. 2	St. 3	St. 4
January	6.18	2.73	2.94	4.30
February	4.38	2.70	3.09	5.38
March	1.68	1.69	3.44	3.53
April	1.46	1.55	3.87	2.85
May	2.17	4.38	8.13	3.65
June	5.27	4.09	8.86	5.56
July	4.81	7.96	2.91	8.88
August	6.19	4.48	5.18	5.27
September	5.20	5.44	3.85	3.69
October	3.08	2.56	1.54	2.96
November	3.01	2.63	3.82	2.70
December	0.43	1.77	4.37	8.66

nutrients such as nitrite, nitrate, phosphate and silicate as the independent variables and primary production as the dependent variable. The correlation coefficient between the independent variable and production and the standard regression coefficients for the four stations are represented in Table - 13.

From the standard regression coefficients, it can be seen that the contributing variables are different

Table - 13

St. No.		Temp.	Salinity	Oxygen	Nitrite	Nitrate	Phosphate	Silicate
1	Corr. coeff.	-0.4535	-0.3619	-0.2551	-0.3884	-0.1139	0.4251	-0.5419
	Std. reg. coeff.	-0.7148	0.0688	0.0514	-0.5708	-0.0957	0.6114	-0.2597
2	Corr. coeff.	-0.3523	-0.0118	0.2198	-0.2722	0.4410	0.4730	-0.2838
	Std. reg. coeff.	-0.0979	0.4898	1.2774	0.1623	0.0467	0.9061	-0.4086
3	Corr. coeff.	-0.1366	0.2395	0.2047	0.5167	0.0123	0.5934	-0.4911
	Std. reg. coeff.	-0.4295	0.2440	0.5593	0.5619	-0.3070	0.7325	0.0205
4	Corr. coeff.	-0.2670	0.1400	-0.7647	0.0371	0.1367	0.3594	-0.2842
	Std. reg. coeff.	-0.9877	1.0361	-0.4461	-0.6295	-0.0028	0.0305	-0.2702

at the different stations, showing that they stand independently from each other. Taking the first 4 important variables, multiple regression equations were worked out for the four stations. These equations along with the coefficient of determination (R^2) and standard error of estimate (SEE) are given in Table - 14.

For station 1, temperature, nitrite, phosphate and silicate gave a significant (1% level) multiple correlation coefficient. According to the order of importance, the variables are: temperature, phosphate, nitrite and silicate. While temperature, nitrite and silicate show an inverse relationship, phosphate shows a positive relationship. About 84% of the variations in production is explained by all these parameters.

For station 2, the important variables were found to be oxygen, phosphate, salinity and silicate in that order. These variables gave a coefficient of determination of 0.814 which is significant at 5% level. Here salinity, oxygen and phosphate show a positive relationship and silicate show an inverse relationship.

For station 3, the important variables in the order of significance are: phosphate, nitrite, oxygen and temperature. Of these, phosphate, nitrite and oxygen show a positive relationship, while temperature show a negative relationship. These variables together contribute to 85% of the variation in production. The multiple

Table - 14

St. No.	Regression equation	S E E	R^2	F	d.f.
1	$P = 21452.27 - 696.55\ (T) - 685.97\ (NO_2) + 1325.13\ (PO_4) - 24.67\ (SiO_3)$	557.94	0.8447	9.52^{**}	4, 7
2	$P = -4317.81 + 31.35\ (S‰) + 1231.93\ (O_2) + 1328.67\ (PO_4) - 36.76\ (SiO_3)$	526.52	0.8140	7.65^{*}	4, 7
3	$P = 2773.0 - 170.42\ (T) + 355.01\ (O_2) + 606.44\ (NO_2) + 801.42\ (PO_4)$	246.20	0.8503	9.94^{**}	4, 7
4	$P = 14677.55 - 434.54\ (T) + 41.46\ (S‰) - 327.98\ (O_2) - 745.58\ (NO_2)$	261.07	0.7988	6.95^{*}	4, 7

* significant at 5% level, ** significant at 1% level

correlation coefficient was found to be significant at 1% level.

For station 4, the important variables in their order of significance are: salinity, temperature, nitrite and oxygen. Of these, salinity showed a direct relationship, as the station is situated in the inshore area. The rest of the variables showed an inverse relationship. The coefficient of determination of 0.7988, revealed 5% level of significance.

Thus the multiple regression analysis proved that all the four stations are independent of each other and the contributing parameters also vary from station to station. The probable reason for these variations is the effect of the dynamic nature of backwaters and also due to the sampling method. It may be that the instantaneous concentration of the various environmental factors is reflected in the computor analysis for each station thereby showing variation from station to station. Another reason for these variations is the influence of marine conditions and the freshwater discharge which result in the process of mixing brought about by the semi-diurnal tidal rhythm which may not be constant all over the estuary. During the period when the system showed more of marine conditions, the nutrient concentrations are low and remain homogeneous throughout the water column, but during the time of freshwater discharge, high concentrations of nutrients occur with gradient zones within the system. As seen from the regression equation, for the 1st station, all the nutrients particularly phosphate showed highly significant level with temperature in the production of phytoplankton. This station receive the maximum discharge of freshwater, rich in nutrients from the adjacent river. In the 2nd station, besides oxygen, salinity, silicate and phosphate also plays a significant role. This station is situated in the brackish water area and had frequent blooming of the diatom Skeletonema costatum. The silicate has been used proportionately for building up of the diatom cells and hence an inverse relationship is evident between this factor and production. The 3rd station, being more close to the bar-mouth where mixing process is relatively high, the nutrients, oxygen and temperature were found to be highly significant for the production of phytoplankton. Similarly, in the 4th station, which is situated in the marine environment, salinity showed a direct relationship with phytoplankton production besides temperature, oxygen and nitrite in their order of significance.

VI. PHYTOPLANKTON INVESTIGATIONS IN THE INSHORE AREA OF COCHIN

Phytoplankton productivity investigations were carried out in the inshore environment off Cochin upto 30 m depth during the period 1976-78 on board CADALMIN-I of the Central Marine Fisheries Research Institute. During the period 1976-77, 3 stations were sampled at 10, 15 and 20 m depths in the southern side of the main channel near Manassery fishing ground and data collected relating to primary production by ^{14}C technique and total cell counts of phytoplankton by settling method from surface and bottom. During the year 1978, the inshore area of Cochin has been surveyed and samples taken from 3 stations (10, 20 and 30m) (Pl. X) for productivity measurements.

The phytoplankton production and total standing crop in terms of total cells showed distinct seasonal and spatial variations.

Primary Production:

Table - 15 shows the surface and bottom values of primary production of the 3 stations sampled during 1976-77. The rate of production at the surface in the inshore area during the period indicated 3 peaks, first peak during April-June, second during August-September and third during November-December. However, the bottom region showed only

PLATE - X

Location of the sampling stations at different depth contours in the inshore area off Cochin. Open circles denote the stations of sampling during 1976-77 and closed circles represent the sampling stations during 1978.

PLATE X

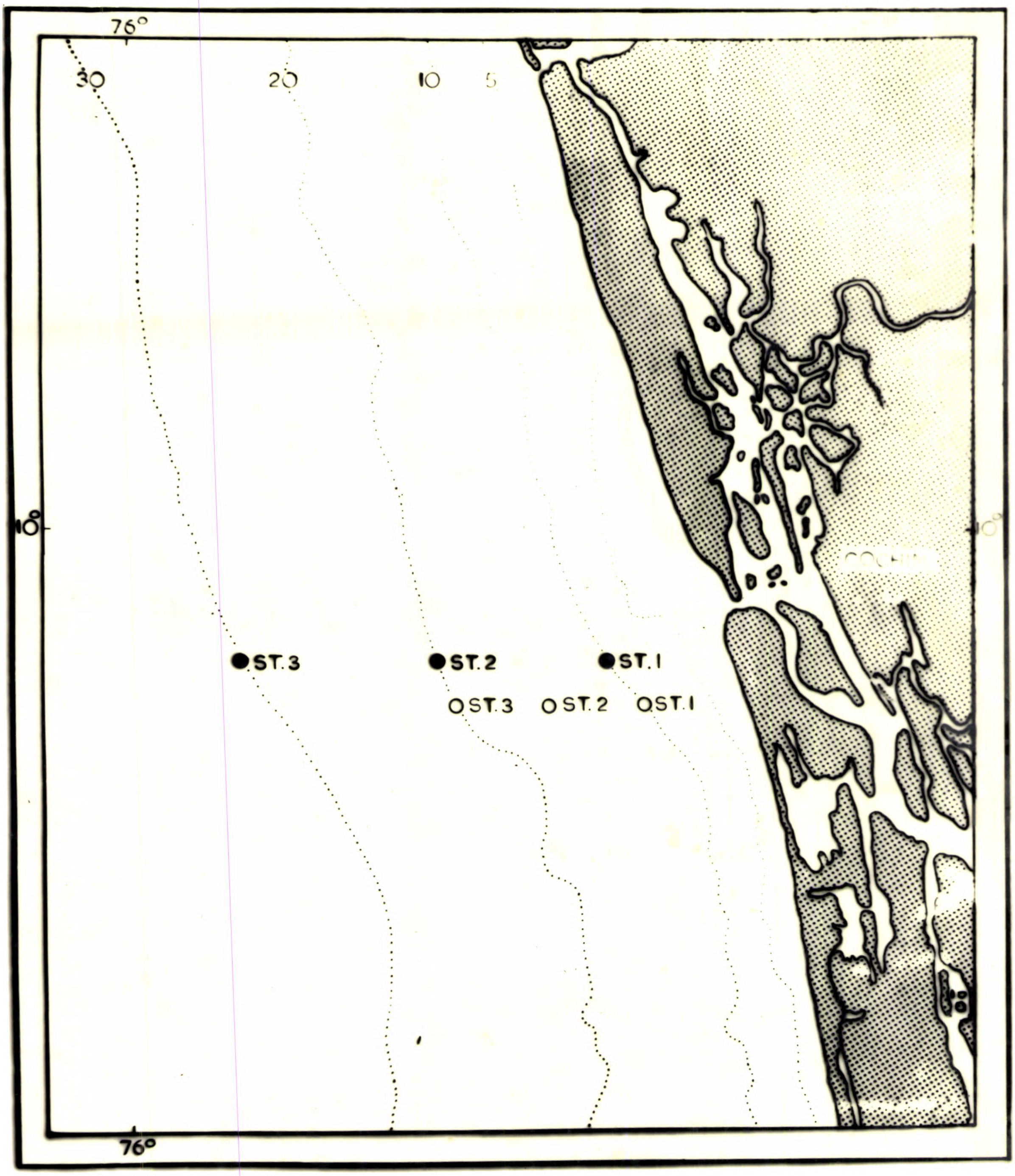


Table - 15

Productivity measurements in the inshore area of Cochin

		Production mgC/m³/day		
		St. 1	St. 2	St. 3
1976				
September	S*	668	552	584
	B**	471	496	243
October	S	534	512	488
	B	438	404	214
November	S	867	842	697
	B	532	375	272
December	S	726	837	698
	B	331	126	135
1977				
January	S	556	1081	1144
	B	256	503	305
February	S	278	256	250
	B	251	233	240
March	S	580	430	420
	B	260	360	290
April	S	668	552	584
	B	571	491	243
May	S	695	470	1330
	B	218	153	159
June	S	859	687	584
	B	812	422	293
July	S	445	523	378
	B	272	252	103
August	S	791	872	807
	B	318	391	168

S* - surface B** - bottom

two peaks, the primary one during April-June and secondary peak during the post monsoon months of September-November.

The seasonal variation of primary production at all the stations show a unimodel nature, though the 3rd station 30? (20 m) indicated two peak values during January and May. A seaward decrease in the magnitude of production was noticed from 10 m to 20 m depths of the inshore area.

Investigations carried out in a fishing ground off Cochin, during 1978 indicated varying nates of production (Table - 16). This area showed a primary peak of lesser magnitude during January-March at the surface and a secondary peak of higher magnitude during the monsoon and post monsoon periods of June-November. During August-October, at 10 m and 20 m depths, there is no variation in the rate of production at the surface and bottom, probably due to mixing and uniform light penetration. The lower values seen at the bottom in the fishing ground during the post monsoon period has a profound influence on the benthos and can be attributed to the decayed deposits of the weed Salvinia molesta, which are brought to the inshore waters from the backwater system during low tide.

Total cells of phytoplankton

The phytoplankton standing crop in terms of total cells/l collected during 1976-77 is presented in Table - 17. Two peaks were noticed, the primary one at the surface during the monsoon season, July-September and a

Table - 16

Productivity measurements at the fishing ground off Cochin

		Production mgC/m^3/day		
		St. 1	St. 2	St. 3
1978				
January	S*	712	736	692
	B**	364	218	112
February	S	592	514	403
	B	231	215	132
March	S	641	623	567
	B	284	297	117
April	S	416	584	434
	B	292	386	147
May	S	384	391	387
	B	265	292	234
June	S	1236	1062	915
	B	508	386	487
July	S	1006	464	1250
	B	399	293	287
August	S	2195	1228	916
	B	2156	870	751
September	S	1537	1251	942
	B	1041	269	254
October	S	2750	1167	720
	B	2177	917	419
November	S	1473	559	222
	B	419	301	86
December	S	264	331	757
	B	124	192	104

* surface ** bottom

Table - 11

Phytoplankton standing crop in terms of total cell counts/litre

		St. 1	St. 2	St. 3
1976 September	S*	426x10^3	406x10^3	318x10^3
	B**	384 "	216 "	195 "
October	S	226 "	264 "	186 "
	B	164 "	169 "	95 "
November	S	336 "	293 "	219 "
	B	212 "	186 "	114 "
December	S	571 "	480 "	520 "
	B	430 "	341 "	240 "
1977 January	S	658 "	580 "	520 "
	B	392 "	433 "	218 "
February	S	518 "	492 "	473 "
	B	320 "	212 "	173 "
March	S	387 "	289 "	308 "
	B	231 "	194 "	119 "
April	S	275 "	203 "	268 "
	B	192 "	168 "	109 "
May	S	386 "	468 "	318 "
	B	290 "	220 "	143 "
June	S	284 "	238 "	304 "
	B	172 "	196 "	138 "
July	S	388 "	410 "	418 "
	B	273 "	220 "	184 "
August	S	463 "	392 "	289 "
	B	217x10^3	238x10^3	104x10^3

* surface ** bottom

secondary peak during December-February. The primary peak was due to the abundance of the diatom Chaetoceros socialis along with Fragilaria oceanica and dinoflagellate Ceratium furca while the secondary peak was the result of a monospecific bloom of the diatom Skeletonema costatum. The bottom samples also showed a similar trend of abundance with less magnitude of cell numbers. Like primary production, the total cells also showed a decrease in trend from lower depths to higher depths. In almost all the samples, nannoplankters such as species of Chlorella, Synechocystis and Tetraselmis formed the bulk of the standing crop when compared to the diatoms and dinoflagellates.

Qualitative studies:

It is an established fact that from year to year qualitative and quantitative variations, fluctuations and the regularity in presence or absence of certain species may occur in an ecosystem. From the inshore area of Cochin altogether 74 species of phytoplankters (excluding the nannoplankters) were identified from the samples collected. Of these 45 species were diatoms, 24 species were dinoflagellates, one Coccolithophore and two species each of Silicoflagellates and blue-green algae. Among these 24 species of phytoplankters were found to be well represented, most of which exhibit some kind of periodicity and seasonal fluctuations. Though the nannoplankters contribute about

60% of the total cells of phytoplankters, the microplankton formed 'bloom' conditions at the time of two peak periods.

The principal constituent of the diatom population that occur in plankton are the pelagic species of neritic and oceanic provinces. The littoral and benthic forms were found to be present in lesser numbers. Based on the available information regarding the bio-geographical types, species usually found in the plankton of the inshore area are grouped as follows:

LITTORAL - <u>Melosira</u> <u>sulcata</u> (Ehrenberg) Kützing
<u>Cyclotella</u> <u>striata</u> (Kützing) Grunow
<u>Nitzschia</u> <u>closterium</u> (Ehrenberg) Smith
<u>N.</u> <u>longissima</u> (Brebison) Ralfs
<u>Pleurosigma</u> <u>elongatum</u> Smith
<u>P.</u> <u>normanii</u> Ralfs

NERITIC -

Artic: <u>Fragilaria</u> <u>oceanica</u> Cleve
<u>Nitzschia</u> <u>seriata</u> Cleve

Temperate: <u>Chaetoceros</u> <u>affinis</u> Lauder
<u>C.</u> <u>lorenzianus</u> Grunow
<u>Bacteriastrum</u> <u>hyalinum</u> Lauder
<u>Biddulphia</u> <u>mobiliensis</u> Bailey
<u>Ditylum</u> <u>brightwellii</u> (West) Grunow
<u>Eucampia</u> <u>zoodiacus</u> Ehrenberg

Guinardia flaccida (Castracane) Peragallo

Hemiaulus sinensis Greville

Asterionella japonica Cleve

Rhizosolenia stolterfothii Peragallo

R. imbricata Brightwell

Thalassionema nitzschioides Grunow

Tropical

Skeletonema costatum (Greville) Cleve

Stephanopyxis palmariana (Greville) Cleve

Thalassiosira subtilis (Ostenfeld) Gran

Triceratium favus Ehrenberg

Coscinodiscus excentricus Ehrenberg

C. granii Gough

C. gigas Ehrenberg

C. marginatus Ehrenberg

C. radiatus Ehrenberg

Bellerochea malleus (Brightwell) Van Heurck

Chaetoceros socialis Lauder

C. decipiens Cleve

C. indicus Subrahmanyan

Bacteriastrum varians Lauder

OCEANIC -

Temperate: Chaetoceros peruvianus Brightwell

Rhizosolenia alata Brightwell

R. styliformis Brightwell

Thalassiothrix longissima Cleve and Grunow
T. frauenfeldii Grunow

Tropical : *Planktoniella sol* (Wallich) Schütt
Chaetoceros coarctatus Lauder
Rhizosolenia castracanei Peragallo
R. robusta Norman
Biddulphia sinensis Greville
Hemidiscus hardmannianus (Greville) Mann

The Dinophyceae, Silicoflagellatae, Coccolithophoridae and Cyanophyceae, represented in the inshore waters of Cochin immediately after the diatom maxima during the monsoon months are listed below:

DINOPHYCEAE *Prorocentrum micans* Ehrenberg
Gymnodinium breve Davis
Ceratium hirundinella (Muller) Bergh
C. furca (Ehrenberg) Claparade et Lachman
C. fusus (Ehrenberg) Du Jardin
C. pulchellum B.Schroeder
C. breve (Ostenfeld et Schmidt) Schroeder
C. symmetricum Pavillard
C. dens Ostenfeld et Schmidt
Peridinium depressum Bailey
P. oceanicum Van Hoffen
P. elegans Cleve

Peridinium fatulipes Kofoid

P. steinii Jorgensen

P. claudicans Paulsen

P. divergens Ehrenberg

Diplopsalis lenticula Bergh

Goniaulax polyhedra Stein

Ornithocercus magnificus Stein

Dinophysis miles Cleve

D. caudata Saville Kent

Noctiluca miliaris Suriray

Pyrophacus horologium Stein

Podolampas spinifer Okamura

SILICOFLAGELLATAE

Dictyocha fibula Ehrenberg

Distephanus speculum (Ehrenberg) Haeckel

COCCOLITHOPHORIDAE

Coccolithus huxley (Wallich) Schiller

CYANOPHYCEAE

Oscillatoria salina Biswas

Trichodesmium theibautii Gormont

Discussion :

As in the estuarine waters of Cochin, in the inshore environment also, the indices of standing crop indicate that the primary production and total cells are independent variables and no strong co-relation exists in the inshore area. This is totally at variance with the accepted norms of phytoplankton productivity and this abberation may be indicative of the high contribution of nannoplankters in the inshore area. In the adjacent areas, Qasim et al. (1974) and Vijayaraghavan et al. (1974) have observed that 45% to 96% of the production is due to nannoplankters and rest to microplankters. Numerous investigations from neritic and oceanic environments of temperate and tropical regions have also shown that 80-90% of the total production is contributed by the nannoplankters (Teixeira, 1963; Anderson, 1965; Malone, 1971; Bhargava et al. 1977). However, a positive correlation was observed between primary production and total cells during different months in the post monsoon period (Table - 17).

From the observations made on the distribution and abundance of phytoplankton in the inshore waters and oceanic areas of the Indian seas, it is seen that the 'biological spring' falls during the monsoon months with a primary maxima during July-September and a secondary maxima during December-February. Ganapati and Rao (1953) observed that there is a regular sequence in a north to south direction in the commencement of the primary maximum of phytoplankton on the east coast of India. At Waltair, it commences in February (Ganapati and Murty, 1955), at Madras in March (Menon, 1931) and at Krusadai (Chacko, 1950), it is from June. Prasad (1954) observed in the Gulf of Mannar and Palk Bay regions more than one maxima of diatom population, a summer peak in February-May and an 'autumn' peak during August-November. The same sequence in the phytoplankton production was noticed in the west coast of India also which, however, moves in a south to north direction. At Trivandrum, the peak period is from January to May (Menon, 1945), at Cochin it is from May to August (Gopinathan, 1972), at Calicut it is from May to September (Subrahmanyan, 1959a) and at Bombay, it is from September to February (Gonzalves, 1947).

As was observed at Calicut Coast, (Subrahmanyan, 1959a) the diatom peak was followed by a dinoflagellate peak in the inshore area of Cochin. The July-August maximum of diatoms was found to be closely associated with the dinoflagellate maximum. Though they are far less in numbers than the diatoms, they occur in swarms during their peak periods.

It is clear from the observations of the various workers cited above that while the phytoplankton production on the coastal waters is fairly continuous throughout the year, there are periods of intense production which are subjected to variations from year to year depending on the hydrological and other environmental conditions.

It is evident from the Table - 15 that the rate of primary production per unit volume does not exhibit very marked seasonal fluctuations as observed in temperate waters or in regions where there is high fluctuations in the governing parameters. The values at the surface region fluctuate from a minimal rate of 278-866 mgC/m^3/day at station 1, 256-1081 mgC/m^3/day at station 2 and 250-1330 mgC/m^3/day in station 3. While June and November are the peak periods at station 1, November to January are the peak periods at station 2 and June-May at station 3. However, if we integrate values for the euphotic zone in the inshore area, where 1% light depth lies between 10-15 m, we get a value over 2 gC/m^2/day uniformly. In these regions, due to constant mixing of the surface and bottom waters, there is no distinct gradient with regard to the nutrients, temperature or any other parameter except perhaps the turbidity which affected the penetration of light that regulates the photosynthetic rate.

It can be seen that though there is no definite seasonal variation, the period between November and January and April-May period are comparatively more congenial from the point of view of light penetration, and the slightly higher rate of production noted in August could perhaps be the result of enhanced nutrient supply consequent on the land run off during the monsoon months and as well as spill-over of the upwelled water from the deeper regions moving over the shelf. These conditions in the production cycle is typical of a tropical production cycle as has been indicated by Cushing (1975). According to him, the production cycle in any region, excluding upwelling areas and areas of divergence, is controlled by the critical depth, compensation depth and depth of mixing. Each of these factors is indirectly affected by the depths of the sea and extinction coefficient of water. In shallow areas, the depth of mixing is limited by the depth of the water. In tropical cycles, it is continuous through the year.

One of the contributing factor affecting the nature of benthos and productivity of the benthic region and overlying water is the effect of floating weeds, *Salvinia molesta* and *Eichhornia crassipes* disengaged from the innumerable water ways and canals of the Vembanad Lake and which are carried into the inshore environment. When it reaches the saline waters, they perish and settle at the bottom. The decaying *Salvinia* change the nature of the benthic fauna as well as the microbial flora which can fix up carbon in the dark. Hence the benthic production as a result of the microbial activity has been the subject of more intensive study during 1978.

The seasonal variations and magnitude of production in the fishing ground indicated a higher potential fishery in the inshore area. The reason for this cannot be completely attributed to the magnitude of primary production because the demersal fishery and the bottom fauna depend on the photosynthetic activity below the euphotic zone which cannot be measured by the ^{14}C technique. The composition of the phytoplankton of the north and southern banks of the main channel are almost similar, with tropical neritic forms predominating. The endemic population characteristic of the brackish water and oceanic regions may release more of extracellular products of photosynthesis under stress in changed environmental conditions and in different densities of occurrence (Fogg, 1963). This factor also will affect the measurement of production as only the particulate fraction is sampled.

VII. PHYTOPLANKTON INVESTIGATIONS IN THE OCEANIC ENVIRONMENTS

Investigations on primary production using ^{14}C technique on the west coast of India between Cape Comorin and Karwar and in the Lakshadweep Sea have indicated that there is regional as well as seasonal variation in the daily rates of production. The inshore regions within 50 m depth are on the whole highly productive especially during the south west monsoon period. In addition, there is a reduction in the rate of primary production seaward, the availability of nutrients and the depth of mixed layer mainly determining the magnitude of production. The present study on the distribution of phytoplankton biomass in the same area during 1966 is envisaged to assess the qualitative and quantitative variability of phytoplankton during different seasons for various regions and to examine the same in the light of data on organic production measured by ^{14}C. Earlier coverage on the distribution of phytoplankton for this area was primarily based on data from isolated zones (Subrahmanyan, 1959 a,b) or on biomass estimated from displacement volume and dry-weight of plankton (Chennubhotla, 1969).

Area of study and methods:

The area dealt with is between Cape Comorin and Karwar, between 11-14°N and 72-75°E. The hydrographic features of the eastern Arabian Sea along the Indian coast show distinct seasonal variations. Time series observations during the cruises of R.V.VARUNA off the west coast of India have indicated that arbitrarily four seasons can be distinguished: monsoon (June-August), post monsoon (September-November), inter-monsoon (December-January) and summer (March-May). From all accounts, it has been reported that the monsoon season is the most productive for phytoplankton.

Quantitative and qualitative studies on the phytoplankton were made for a period of 10 months during 1966, based on the samples obtained during the cruises of R.V. VARUNA between Cape Comorin in the south and Karwar in the north. The location of the stations of sampling varied from month to month. The data related to 14 cruises covering 183 stations, consisting of 214 samples, obtained by vertical hauls using a half metre bolting nylon net from a maximum depth of 100 m to surface.

The displacement volume was taken for a 50 ml aliquot of the sample and multiplied by five to get the value for the standard sample of 250 ml. For qualitative studies, one ml of the sample was transferred to a 'Sedwick-Rafter' counting cell and counted upto species. The standing crop expressed in terms of carbon using the phytoplankton equivalent (Cushing _et al_. 1958) along with the values of primary production and total cell counts (Tables 18 and 19). The species-wise composition of different phytoplankters present seasonally in the area of observation is presented in Appendix - I.

<u>Seasonal variation in the phytoplankton biomass and primary production</u>

Table - 18 shows the seasonal variations in the phytoplankton abundance, based on biomass values for the different depth zones. During January and February, the phytoplankton biomass shows moderately high values over the shelf in contrast to oceanic areas. Values increase from May till August in both the depth zones (50-100 m). During the post-monsoon months of September to November, values decrease considerably and lowest values are recorded in November-December. This trend is reflected in the total counts of cells also with numerical augmentation during the monsoon periods, (in view of the loss of nannoplankters through meshes of the bolting cloth and also due to the presence of minute forms of zooplankters, the values could at best be considered only as approximations).

A perusal of the total cell counts showed that the maximum cell concentrations exceeding one million cells/m^2 was observed during May-July period. The abundance in June-July has been the result of a monospecific bloom of the dinoflagellate, *Pyrocystis fusiformis*. The lower values obtained in September could perhaps be on account of the reduction due to grazing, consequent on the dominance of zooplankters. In general, the phytoplankton abundance has been a characteristic phenomenon associated with monsoon conditions. This has earlier been reported by Subrahmanyan (1959a) in his extended studies off Calicut.

Table - 18

Seasonal variation in the phytoplankton biomass based on the values of displacement volume of phytoplankton (ml/m^2) for the different depth zones and its carbon equivalents (gC/m^2/day)

	Area covered		50 m		50-100 m		100 m	
	Latitude	Longitude	Biomass	Carb. eq.	Biomass	Carb. eq.	Biomass	Carb. eq.
1966								
January	13-14°N	73-74°E	-	-	27	0.64	16.5	0.39
February	08-11°N	72-76°E	-	-	17	0.40	14.0	0.33
April	11-13°N	73-75°E	13	0.31	26	0.61	14.0	0.33
May	07-08°N	75-77°E	-	-	21	0.50	25.0	0.59
June	11-13°N	73-74°E	-	-	23	0.54	17.0	0.40
July	07-13°N	72-77°E	-	-	25	0.59	60.0	1.42
August	12-14°N	72-75°E	65	1.54	31.5	0.75	55.0	1.30
September	08-09°N	75-77°E	16	0.38	13.5	0.32	28.0	0.66
November	16-17°N	71-72°E	22	0.52	26.0	0.61	18.0	0.42
December	09-12°N	71-75°E	-	-	-	-	22.0	0.52

Table - 19

Seasonal variation of the standing crop of phytoplankton in terms of primary production/ total cell counts

	Latitude	Longitude	Production gC/m^2/day	Total cells counts/m^2
1966				
January	14°N	72-74°E	0.28	3,34000
February	12-13°N	75-76°E	0.19	4,27000
April	9-11°N	75-76°E	0.25	7,70000
May	12-13°N	73-74°E	0.13	11,20000
June	9-13°N	74-76°E	0.35	26,40000[a]
July	13°N	73-74°E	0.60	17,20000[a]
August	12-13°N	73-74°E	0.90	6,90000[b]
September	8-9°N	75-76°E	2.89	12,28000
November	16-17°N	71-74°E	0.12	5,04000[c]
December	11-12°N	74-75°E	0.09	1,85000

a - bloom of *Pyrocystis fusiformis*

b - bloom of *Rhizosolenia* sp,

c - bloom of *Planktoniella sol*

From the ^{14}C values, it is found that the level of organic production becomes less towards the edge of the continental shelf and least outside the shelf. Rates exceeding 2.0 gC/m^2/day are obtained within 50 m depth. The seasonal trend in the shallow inshore regions indicates that there is progressive increase through the winter months to the maximum production during September. The high rate sets in on the west coast with moderate temporal variations from south to north. This can be correlated with the shift of the upwelling region along with the advancement of the monsoon. Because of the inadequacy in sampling in the nearshore regions, it cannot be conclusively established that the periods of high rates of primary production and phytoplankton biomass are synchronising. However, the carbon equivalents of the phytoplankton biomass and the organic production measurements show a positive co-relation, especially during the monsoon months. The observations suggest that high rates of organic production and phytoplankton biomass can occur in the inshore regions at sometime between June to September. During this period, the average rate for the inshore regions is over 1.0 gC/m^2/day and for the offshore regions 0.5 gC/m^2/day.

Qualitative studies

The qualitative studies reveal the presence of altogether 161 species of phytoplankters (excluding nannoplankters), major groups being diatoms and dinoflagellates (Appendix - 1). The diatoms, considered to be the major component of phytoplankton appears to be about 50% or less when compared to the dinoflagellates. Out of the 161 species, 74 are diatoms, 79 dinoflagellates, 2 Silicoflagellates, 5 blue-green algae and one Coccolithophore. Thus diatoms constitute 46%, dinoflagellates 49% and others constitute only 5% of the total standing crop during the period of observation.

Only a few species of phytoplankters occur throughout the year. They are diatoms such as Planktoniella sol, Rhizosolenia alata, Chaetoceros coarctatus, Climacodium frauenfeldianum, Ditylum brightwellii, and Biddulphia sinensis and dinoflagellates such as Phalacroma rotendatus, Dinophysis miles, Ornithocercus magnificus, Peridinium depressum, Diplopsalis lenticula, Ceratium furca, Ceratocorys horrida and Pyrocystis fusiformis. June-July period is characterised by a monospecific bloom of the dinoflagellate Pyrocystis fusiformis, ranging from 1.2 to 2.6 million cells/m^2. Pyrocystis is a typical oceanic form (Fritsch, 1935) and its presence indicates the incursion of oceanic waters (Nair et al. 1965) unlike some other dinoflagellates occurring in swarms in the coastal waters, such as Goniaulax, Noctiluca and Gymnodinium, causing discolouration of water. Subrahmanyan (1960) suggests that the incursion of low salinity water favours 'bloom' of certain species of dinoflagellates. However, Prakash and Sharma (1964) remark that while certain dinoflagellates are known to require a discrete mass of water of relatively low salinity for their growth, it does not imply that salinity difference is the sole requirement for the development of a monospecific bloom.

During August and November, species of *Rhizosolenia* and *Planktoniella* were found to dominate the collections, with the former approximating 'bloom' conditions, (600,000 cells/m^2). These bloom conditions of phytoplankters are clearly reflected in the biomass distribution (Table - 19) and also to some extend in the total organic production.

Thus, this study also confirms the view put forward by earlier workers (Prasad, 1966; Nair *et al*. 1968; Ryther *et al*. 1966) that along the south west coast of India, the coastal waters as well as the waters over the continental shelf regions have high rate of standing crop, which could be compared to any other productive regions elsewhere.

Appendix - I

	J	F	A	M	J	J	A	S	N	D
DIATOMACEAE										
1. Melosira sulcata	-	F	R	C	-	-	-	C	-	R
2. Stephanopyxis palmariana	-	-	-	-	O	O	R	-	-	-
3. S. turris	-	F	O	R	O	F	F	-	-	-
4. S. nipponica	-	-	-	-	O	R	R	-	-	-
5. Skeletonema costatum	-	O	O	-	R	-	-	-	-	-
6. Thalassiosira decipiens	-	-	-	R	F	O	-	-	O	-
7. T. subtilis	-	C	F	R	O	A	-	-	-	-
8. Coscinodiscus excentricus	-	C	F	-	F	F	A	O	-	-
9. C. marginatus	-	-	-	-	R	O	O	O	-	-
10. C. radiatus	R	F	-	-	F	R	R	O	O	-
11. C. granii	-	O	-	O	-	O	R	O	-	-
12. C. jonesianus	F	R	-	O	-	-	-	-	-	-
13. C. concinnus	R	C	-	O	F	-	-	O	R	-
14. C. centralis	C	O	F	R	O	F	C	O	-	-
15. C. asteromphalus	-	R	O	-	-	-	R	O	-	-
16. C. oculus-iridis	-	R	-	-	O	O	R	-	-	-
17. C. gigas	O	-	R	-	-	-	R	-	O	-
18. C. gigas var. praetexta	O	F	F	-	-	R	F	-	-	-
19. C. reniformis	-	R	R	-	R	-	-	R	O	R
20. C. nitidus	-	-	-	O	-	-	-	R	-	-
21. C. curvatulus	-	F	-	-	F	-	-	O	-	-
22. Planktoniella sol	F	C	R	F	F	R	A	A	B	F
23. Actinoptychus undulatus	-	-	-	O	-	-	-	R	-	-
24. Asteromphalus flabellatus	R	F	-	-	-	-	O	-	-	-

	J	F	A	M	J	J	A	S	N	D
25. *Asteromphalus wyvellei*	-	R	-	-	O	-	O	R	-	-
26. *A. hepactis*	R	O	-	-	-	-	-	R	-	R
27. *A. arachne*	R	-	-	R	-	-	-	-	-	-
28. *Asterolampra marylandica*	R	-	-	R	-	-	-	-	-	-
29. *A. marylandica* var. *major*	-	-	-	R	-	-	-	-	-	-
30. *A. dallasiana*	-	-	-	R	-	-	-	-	-	-
31. *Gossleriella tropica*	-	R	C	O	F	-	-	O	-	-
32. *Schroederella delicatula*	-	-	R	A	O	-	-	-	-	-
33. *Lauderia borealis*	-	-	O	R	-	-	O	-	-	O
34. *Bellerochea malleus*	-	-	-	F	R	R	O	-	-	-
35. *Guinardia flaccida*	-	A	-	F	O	R	O	-	-	-
36. *Rhizosolenia robusta*	R	O	-	-	-	-	O	-	-	-
37. *R. stolterfothii*	-	-	-	-	O	-	O	-	-	-
38. *R. calcar-avis*	R	F	-	R	F	O	C	F	-	R
39. *R. imbricata*	F	F	A	F	R	O	C	R	-	-
40. *R. styliformis*	R	F	C	F	F	O	C	R	-	-
41. *R. alata*	R	F	C	F	O	O	A	C	R	O
42. *R. castracanei*	F	-	-	-	O	O	F	-	-	R
43. *Bacteriastrum hyalinum*	R	C	O	F	R	-	-	-	R	R
44. *B. varians*	-	R	-	F	-	-	F	-	-	-
45. *Chaetoceros coarctatus*	C	C	R	O	F	O	A	O	F	R
46. *C. curvisetus*	-	-	-	F	-	-	O	-	-	-
47. *C. denticulatum*	F	O	-	-	-	R	O	R	-	-
48. *C. peruvianus*	-	F	-	-	R	O	R	-	-	-
49. *C. decipiens*	-	R	F	R	O	-	O	-	O	R
50. *C. didymus*	-	O	-	O	-	R	-	-	-	-

	J	F	A	M	J	J	A	S	N	D
51. Chaetoceros messanensis	-	-	-	F	-	-	-	O	F	R
52. C. affinis	-	O	F	R	O	-	-	-	O	R
53. Climacodium frauenfeldianum	R	O	F	F	C	O	O	F	O	C
54. Streptotheca indica	-	O	-	R	O	-	R	O	-	O
55. S. thamensis	-	-	O	-	-	R	F	-	R	R
56. Ditylum brightwellii	F	F	R	A	O	F	R	O	O	O
57. Triceratium favus	-	-	O	F	R	O	R	-	O	-
58. T. reticulatum	-	-	R	O	O	-	O	-	R	-
59. Biddulphia mobiliensis	-	C	-	O	-	-	R	F	-	-
60. B. sinensis	F	F.	O	F	O	O	O	R	O	O
61. Hemiaulus sinensis	R	-	-	R	-	O	F	-	-	R
62. H. hauckii	-	-	-	R	-	-	-	-	R	O
63. Hemidiscus hardmannianus	-	R	-	O	-	-	C	-	-	-
64. H. cuneiformis	-	R	F	-	F	O	O	R	-	-
65. Fragilaria oceanica	-	-	-	O	R	-	C	-	-	-
66. Pseudoeunotia doliolus	-	R	O	-	-	-	-	-	-	R
67. Thalassionema nitzschioides	-	-	-	C	C	R	F	-	-	-
68. Thalassiothrix frauenfeldii	-	O	-	R	R	F	F	F	F	R
69. Asterionella joponica	-	-	R	R	F	F	F	C	R	O
70. Pleurosigma normanii	O	-	-	O	R	O	R	R	-	O
71. P. elongatum	-	O	R	O	O	O	O	R	-	R
72. P. directum	-	-	O	O	-	R	O	-	O	-
73. Nitzschia longissima	-	-	-	O	-	O	O	-	-	R
74. N. seriata	F	-	O	R	-	R	R	-	O	-

DINOPHYCEAE	J	F	A	M	J	J	A	S	N	D
1. *Prorocentrum micans*	-	F	-	O	R	O	R	F	R	-
2. *P. maximum*	-	R	-	-	R	O	-	-	R	-
3. *Phalacroma rotundatus*	O	R	R	O	R	O	R	R	R	O
4. *P. rapa*	-	-	-	-	-	O	-	R	-	R
5. *P. apicatum*	-	-	-	-	R	R	O	R	-	R
6. *Dinophysis caudata*	O	R	R	-	O	-	R	F	R	O
7. *D. caudata* var. *pedunculata*	-	R	-	-	-	O	-	-	R	-
8. *D. miles*	R	R	F	R	R	O	R	R	R	O
9. *D. hastata*	-	R	-	-	R	-	-	-	-	-
10. *Amphisolenia bidentata*	R	F	R	-	R	A	F	-	O	O
11. *A. thrinax*	-	R	-	-	R	O	-	-	-	-
12. *Triposolenia bicornis*	-	-	-	R	R	R	-	-	-	-
13. *Ornithocercus magnificus*	O	F	O	R	R	C	F	O	R	R
14. *O. steinii*	O	-	-	-	-	R	O	O	R	-
15. *O. splendens*	O	-	-	R	O	R	F	R	-	R
16. *O. thumii*	-	-	-	-	O	R	-	-	-	-
17. *O. quadratus*	O	-	-	-	-	R	-	-	-	-
18. *Cladopyxis* sp.	-	-	-	O	R	R	-	-	-	-
19. *Oxytoxum scolopax*	-	-	O	R	R	O	-	-	-	-
20. *O. tesselatum*	-	-	-	-	O	R	-	-	-	-
21. *Noctiluca miliaris*	-	-	O	R	O	F	F	O	-	-
22. *Pyrophacus horologium*	O	R	F	F	F	-	F	O	-	R
23. *Peridinium globulus*	-	-	-	-	-	-	R	O	-	-
24. *P. divergens*	-	-	R	F	R	-	R	O	-	-
25. *P. humile*	-	-	-	-	-	-	R	C	O	-

	J	F	A	M	J	J	A	S	N	D
26. Peridinium pentagonum	-	-	-	-	-	F	R	O	-	-
27. P. claudicans	F	F	F	O	F	-	R	-	-	-
28. P. depressum	R	F	C	R	R	C	F	R	F	C
29. P. murrayi	R	-	R	R	-	-	R	-	-	-
30. P. oceanicum	O	R	F	O	F	R	O	O	-	-
31. P. elegans	R	R	R	F	F	R	O	O	-	-
32. P. elegans f. granulata	-	-	O	F	F	C	C	C	O	-
33. P. steinii	O	R	R	O	F	-	O	-	-	O
34. P. fatulipes	-	R	-	R	-	-	-	O	-	-
35. Heterodinium sp.	-	-	R	-	-	-	-	R	-	-
36. Diplopsalis lenticula	R	R	F	F	C	O	F	R	O	O
37. Goniaulax polyhedra	-	-	O	R	-	-	-	-	-	-
38. G. pacifica	-	-	O	-	-	-	-	R	-	-
39. Ceratium furca	O	C	F	R	R	O	F	C	O	F
40. C. candelabrum	R	R	F	-	R	-	-	-	-	R
41. C. praelongum	-	R	O	-	R	F	-	-	-	-
42. C. cephalotum	-	R	O	-	-	O	-	-	-	-
43. C. gravidum	-	-	-	O	R	R	-	O	-	-
44. C. gravidum var. elongata	-	-	-	-	O	R	-	-	-	-
45. C. pentagonum	R	R	-	-	R	-	-	-	-	-
46. C. schmidti	R	R	-	R	O	R	F	-	-	-
47. C. contortum	R	R	F	-	R	-	F	-	-	-
48. C. breve	O	-	-	F	F	-	R	R	O	F
49. C. vulture	O	F	-	-	-	-	O	-	O	-
50. C. vulture var. sumatranum	-	-	-	-	F	-	O	-	-	-
51. C. paradoxides	-	F	-	-	R	O	C	R	-	-

	J	F	A	M	J	J	A	S	N	D
52. C. karstenii	-	F	-	-	R	O	C	R	-	R
53. C. geniculata	O	R	-	-	-	-	-	-	-	-
54. C. longissima	-	R	-	-	R	-	-	O	-	-
55. C. symmetricum	-	R	O	-	-	-	-	O	-	-
56. C. ranipes	-	R	-	-	R	-	-	O	-	-
57. C. hexacanthum	-	-	-	-	R	O	F	O	-	-
58. C. pulchellum	-	R	-	C	F	F	O	R	R	R
59. C. massiliense	O	R	O	F	F	R	-	-	-	-
60. C. euarcatum	-	-	-	O	F	R	-	-	-	-
61. C. declinatum	-	-	-	O	R	O	-	O	-	O
62. C. macroceros	-	-	-	R	R	R	O	-	O	-
63. C. horridum	-	C	-	-	R	R	-	-	-	R
64. C. humile	O	R	O	-	O	R	-	-	-	-
65. C. longinum	-	-	O	-	R	O	-	-	R	O
66. C. fusus	O	R	-	F	R	O	-	R	-	R
67. C. dens	-	-	-	F	C	R	-	F	-	R
68. C. conciliense	-	-	F	-	R	-	-	-	-	-
69. C. digitatum	-	-	R	O	R	-	-	-	-	-
70. C. tripos	-	-	O	R	R	-	F	F	R	-
71. C. platycorne	F	-	-	-	O	R	-	O	O	-
72. Ceratocorys horrida	O	R	O	F	F	C	F	O	R	O
73. C. bipes	-	R	-	-	-	O	R	-	R	O
74. Podolampas bipes	-	R	F	-	-	-	-	-	F	O
75. P. palmipes	-	-	R	-	R	O	-	R	-	-
76. P. elegans	R	-	O	-	-	-	R	R	-	-
77. P. spinifera	-	O	-	-	-	-	-	-	O	R

	J	F	A	M	J	J	A	S	N	D
78. *Pyrocystis fusiformis*	R	O	F	F	B	B	A	C	F	O
79. *P. fusiformis* f.*biconica*	-	R	R	-	R	-	-	-	-	-
SILICOFLAGELLATAE										
1. *Dictyocha fibula*	-	-	-	R	R	R	-	-	-	R
2. *Destephanus speculum*	-	O	R	R	-	O	O	R	-	R
COCCOLITHOPHORIDAE										
1. *Coccolithus pelagicus*	R	O	O	-	-	-	-	-	-	-
CYANOPHYCEAE										
1. *Lyngbya aestuarii*	O	-	O	R	-	-	-	-	-	-
2. *Trichodesmium erythreum*	R	R	C	F	R	C	O	-	-	-
3. *T. theibautii*	F	R	A	F	R	O	O	O	-	-
4. *Katagneme spiralis*	-	R	-	R	O	-	-	-	-	-
5. *Oscillatoria* sp.	-	O	C	R	O	-	-	-	-	-

B	=	Bloom	10,00,000	cells/m^2
A	=	Abundant	1,00,000	"
C	=	Common	50,000	"
F	=	Few	25,000	"
O	=	Occasional	10,000	"
R	=	Rare	5,000	"
-	=	absent		

VIII. PHYTOPLANKTON INVESTIGATIONS IN SPECIAL ECOSYSTEMS

1. Prawn Culture Fields and associated Mangroves

The dynamic environment of the estuarine system of Cochin and the connected backwater plays a significant role in the fishery of the area in general and the prawn fishery in particular. In recent years, due to the high demand for prawns, efforts are being made to augment their production through prawn/shrimp farming. In Kerala, about 5120 ha of fields are utilized for prawn culture, of which about 3500 ha are situated in and around the Cochin estuarine system. Although several publications (Qasim *et al*. 1969; Qasim and Gopinathan, 1969; Qasim and Sankaranarayanan, 1972; Sankaranarayanan and Qasim, 1969; Gopinathan *et al*. 1974; Nair *et al*. 1975; Pillai *et al*. 1975; Madhupratap *et al*. 1977) provide information on the hydro-biology and ecology of the Cochin Backwater and adjacent areas, detailed account dealing with the productivity parameters of the prawn culture fields situated in the estuarine system is lacking. The main objective of this study is to assess the productivity of the seasonal and perennial fields through a baseline survey with productivity data and related hydrological parameters in assessing the biogenic capacity of the water in the fields, a pre-requisite in determining the stocking strategies and in the evaluation of the production in the culture system. Also this study covers 4 stations in the mangrove area situated in the southern part of the estuarine system of Cochin near Perumbalam in the Vembanad Lake which are usually the nursery grounds of prawns.

(i) PRAWN CULTURE FIELDS:

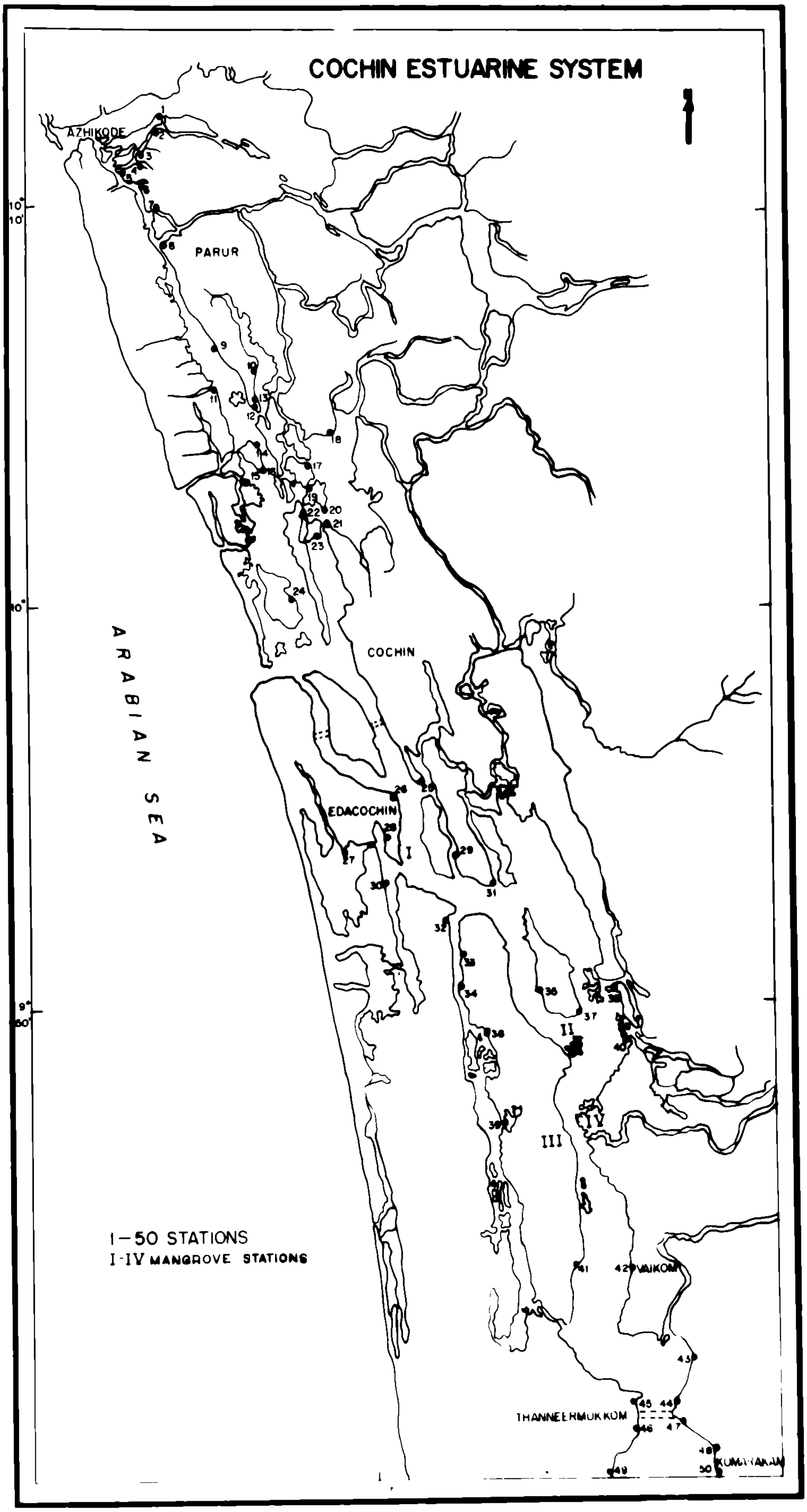
Area of study and methods

The area of investigation cover the extensive backwater from Azhikode in the north to Kumarakam in the south including the Vembanad Lake enclosing a large number of prawn culture fields, both seasonal and perennial ones. Fifty stations (32 seasonal fields and 18 perennial fields) were covered during the prawn culture period of December 1977 to May 1978 (Pl. XI). Although culture practice is extensively carried out in the entire system, at Thanneermukkom region of the Vembanad Lake, virtually no prawn culture fields are in operation in the zones south of the Bund since the commissioning of the same in 1976. In the seasonal fields, paddy is cultivated from May to August and after making the harvest, juvenile prawns brought in by the tidal currents are allowed to enter and grow in the fields and are periodically harvested. Since the perennial fields are deeper than the seasonal ones, only prawn culture is possible which is carried out throughout the year. The average depth of the seasonal fields is about one metre whereas the perennial fields are 2-3 metres deep.

PLATE - XI

Sampling positions in prawn culture fields (1-50 stations) and associated mangrove areas (I-IV) in the estuarine system of Cochin. The backwater station is near to the mangrove station - IV.

PLATE XI


COCHIN ESTUARINE SYSTEM
AZHIKODE
PARUR
COCHIN
EDACOCHIN
ARABIAN SEA
VAIKOM
THANNEERMUKKOM
1-50 STATIONS
I-IV MANGROVE STATIONS
10°
10'
10°
9°
50'

Light and dark bottle oxygen technique has been used at all the stations to estimate the primary production with occasional cross checks by ^{14}C technique. The production per unit volume has been computed using PQ 1.25. The sampling has been done only at the surface and the incubation has been carried out under identical conditions of light and temperature. In view of the limited depth range of the water bodies, it was not felt necessary to conduct sampling at various depths. As the light penetration takes place upto the bottom, there is not much limitation regarding the available energy for photosynthetic activity. Hydrological properties such as salinity, oxygen and nutrients (nitrite, nitrate and phosphate) were determined by standard methods (Strickland and Parsons, 1968).

Results:

The data on the various physico-chemical properties of the water along with that on the primary production is presented in Pl. XII.

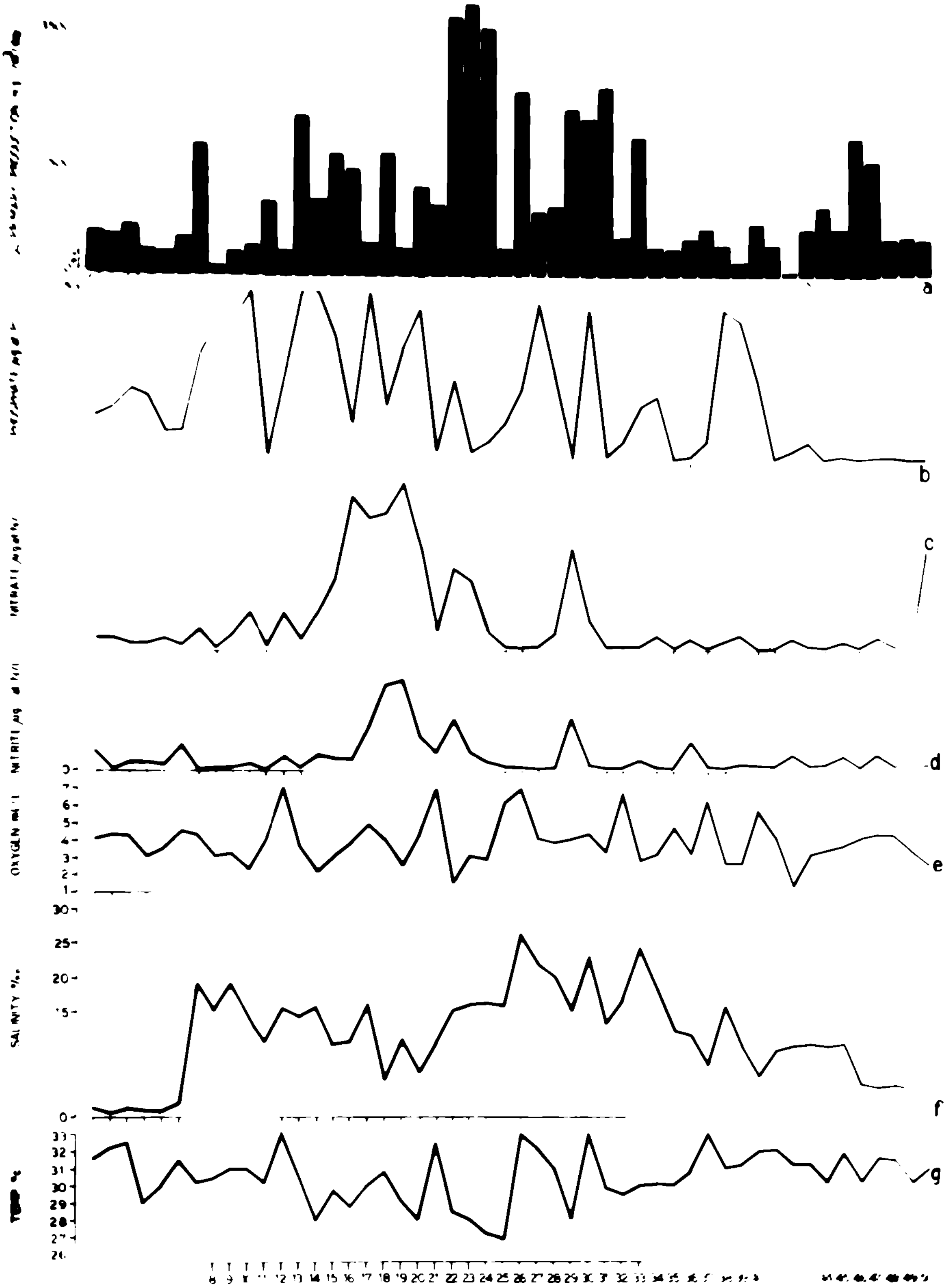
Hydrology

Temperature: The temperature of the ambient water of the fields recorded a difference of 7.5°C ranging from 27 to 34.5°C during the period of survey (Pl. XII, fig. g). It has already been established that in the Cochin backwater and adjacent areas, temperature has little significance in the production of organic matter (Qasim *et al.* 1969).

PLATE - XII

Primary production values and hydrographic properties in the prawn culture fields during the culture season

PLATE XII



<u>Salinity</u>: In contrast to temperature, wide ranges of salinity variations were observed, ie. from 1 to 27‰ in the different fields investigated (Pl. XII, fig.f). Since the northern region of the estuary has two openings with the sea, relatively high salinity values were recorded in the fields of this zone. Similarly, low values were recorded in the fields adjacent to the Vembanad Lake. The effect of salinity is a known aspect in the entire Cochin estuarine system and dealt with in various publications (Josanto, 1971; Qasim <u>et</u> <u>al</u>. 1972; Gopinathan <u>et</u> <u>al</u>. 1974; Pillai <u>et</u> <u>al</u>. 1975).

<u>Dissolved oxygen</u>: The dissolved oxygen content of the water showed distinct variation from north to south (Pl. XII, fig.e). The northern stations have high or optimum values as compared to southern regions of the estuary. The dissolved oxygen content, though has no direct role in the production of organic matter in the estuary, it is an index of the metabolic activities of the entire community comprising producers as well as consumers.

<u>Nutrients</u>: During the present investigation, nutrients such as nitrite, nitrate and phosphate were estimated from the water samples. The nitrite content of the water was very low (< 1 μg at N/l) in almost all the stations and ranged from 0.2 to 1.10 μg at N/l (Pl. XII, fig.d). However, wide variations was noted in the nitrate values,

ranging from 0.24 to 4.94 μg at N/l in the fields investigated (Pl. XII, fig.c). Both nitrite and nitrate showed moderate to high values in the fields located in the middle region of the estuary. The fields situated in the northern and southern regions had very low values of nitrogenous compounds. The phosphate values ranged from 0.06 to 5.80 μg at P/l (Pl. XII, fig.b). As in the case of the nitrate values, the phosphate also showed high values in the fields of the middle zone as well as in a few stations of the northern zone.

The observed values of nutrients showed an increasing trend in the fields located in the middle and northern regions as compared to the fields located in and around the Vembanad Lake. The lowest production rate of 57 mgC/m^3/day, observed at a station in the Vembanad Lake coincides with the lowest quantity of nitrates and phosphates. The NP ratio is also significant in phytoplankton production. This could perhaps account for the low production at the stations (stations 8 and 9) where there is high phosphate with nitrates almost absent. In such cases, to sustain a balanced production, it is necessary to have additional inputs so as to develop a proper balance in the NP ratio.

Primary Production : The productivity values obtained during the survey period of December-May of all the stations were plotted in Pl. XII, fig.a. The measurements indicate that the entire area covered during the investigation can be classified into 3 categories; viz. highly productive (>1500 mgC/m^3/day), moderate productive (500–1500 mgC/m^3/day) and low productive (<500 mgC/m^3/day) zones. The prawn fields in the middle region of the estuary which showed high rate of production as compared to the extreme northern and southern regions (Pl. XI, stations: 7, 13–16, 18, 22–24 in the northern half and stations: 26, 29–31, 34 in the southern half). Moderate values were observed in the northern and southern extremities of the estuary especially at stations: 1, 3, 6, 11, 20, 21, 27–28, 33, 37–38, 44–45. Low values were observed in the prawn fields where there is direct connection with the main land, such as the stations: 4–5, 8–10, 12, 17, 19 of the northern region and stations 25, 32, 35–36, 39–40, 42–43 in the southern region. However, the fields near Thanneermukkom Bund showed rather high values when compared to other fields located in the interior regions of the northern half of the estuary.

Among the prawn fields, the seasonal fields are found to be more productive than the perennial ones. This is reflected in the occurrence of more seasonal fields in the northern regions of the estuary where the productivity parameters showed an increasing trend. Based on the data on primary production, it has been possible to classify the different regions of the prawn culture fields as follows:

1. A highly productive area north and south of Cochin bar mouth where there is constant incursion of seawater and influx of river water. In such a dynamic environment, due to high replenishment rate, the water is never 'old'. Similarly, a belt of high productive area is found in the prawn fields lying adjacent to Azhikode bar mouth where there is freshwater discharge from the Chalakudy river. During the period of freshwater discharge, high concentration of nutrients occur with great variations within the system. Large quantity of organic matter are brought into the estuary through the land run off. These are probably decomposed at the bottom and as a consequence seem to have a marked influence on the nutrient distribution.
2. The waters in between the highly productive zones, ie. between station 7 and station 24, on the northern half of the estuary and the waters in the region of Vembanad Lake are found to be moderately productive. The effect of Thanneermukkom Bund, on the basic productivity of the water on either side seem to be insignificant, though in the overall population structure, there has been significant variation.
3. The water bodies on the hinter-land around Vaikom in the south form a low productive area as

observed earlier by Nair et al. (1975). This is probably because the incursion of nutrient-laden water is highly restricted in this zone which may be limiting the primary production. In such areas, it would be necessary to provide artificial feeds or additional inputs to supplement the basic productivity.

(ii) MANGROVES:

For the mangrove areas, the investigation extended from the vicinity of Cochin harbour in the north to Perumbalam in the south, covering 4 stations in the southern half of the estuarine system of Cochin and a backwater station adjacent to station 4 (Pl. XI). Station 1, is located about 5 km south of Cochin in the backwater system and is a shallow muddy bay which extends to about 7000 sq. m during low tide. Station 2 is a small island near Perumbalam in the Vembanad Lake, and station 3 is also a small island, part of which has been utilised for paddy cum prawn culture by the local people. Station 4 is fairly a vast area in the main land, opposite to st.3, is backed by more terestrial habitat due to man-made cahnges. A great variety of mangrove vegetation could be seen intermingled with terestrial plants in almost all the stations.

Physico-chemical features:

Average monthly surface temperature varied from 26.3 to 36.8°C for all the stations; surface salinity varied from 0.64 to 29.26‰; dissolved oxygen content showed seasonal changes and varied from 2.02 to 5.6 ml/l and the nutrients such as nitrate and phosphate values did not show much fluctuations in all the stations. The monthly average values of all these parameters studied are presented in Table - 20.

Table - 20

Hydrological features of the mangroves

(pooled values of 4 stations)

	Temp. °C	Salinity ‰	Oxygen ml/l	Phosphate µg at P/l	Nitrate µg at N/l
1976					
January	28.2	27.52	3.2	1.68	0.74
February	29.4	28.44	3.7	1.83	0.85
March	33.4	29.26	4.1	0.52	1.35
April	36.8	28.72	4.3	0.68	1.40
May	34.2	18.48	5.2	2.27	1.59
June	29.6	1.22	4.8	2.59	0.43
July	26.3	0.64	5.4	1.52	0.82
August	26.4	5.72	4.9	0.79	1.43
September	28.1	14.15	5.6	0.54	0.47
October	28.5	17.32	4.3	0.72	1.03
November	29.2	21.46	3.8	1.02	0.63
December	30.4	24.48	2.0	0.88	0.96

The productivity values estimated by oxygen technique for the four stations along with the values for backwater are presented in Table - 21. It could be observed from the Table that the mangrove areas generally exhibit moderate to high productivity which of course show some amount of seasonal variations. The rate of production for the year ranged from 490-2150 $mgC/m^3/day$ in station 1; 240-960 $mgC/m^3/day$ in station 2; 320-1460 $mgC/m^3/day$ in station 3 and 260-1560 $mgC/m^3/day$ for the 4th station, while the backwater station showed a range of 340-980 $mgC/m^3/day$. The monsoon period indicates a higher rate, followed by post monsoon months.

The backwaters indicated a lower trend in production during most part of the year as compared to the mangrove areas. However, during the monsoon months, the rates tend to become higher reaching comparable values to those in the mangrove areas. Briefly, it may be stated that the mangrove areas are more productive than the open backwaters. Among the 4 stations studied, the first one was found to be highly productive probably due to high detrital components from large amount of litter fall, enriching the bottom with high particulate organic matter. Since other stations are somewhat open, all the three stations showed a similar trend of production and organic load.

Table - 21

Productivity measurements from the mangrove areas in the Cochin backwater

(Production $mgC/m^3/day$)

		St. I	St. II	St. III	St. IV	Back-water st.
1976	January	670	780	1460	430	450
	February	1010	490	320	370	480
	March	490	350	320	1560	540
	April	1430	240	360	320	620
	May	2150	660	680	320	980
	June	1280	960	640	560	540
	July	1350	840	460	670	470
	August	600	360	520	410	420
	September	580	340	680	260	360
	October	1090	530	580	610	590
	November	820	610	430	280	430
	December	780	420	360	310	340

Discussion:

The difference in the productivity of the prawn culture fields has been recognised in a classification scheme in which the range is from a relatively low productive, oligotrophic type to a highly productive eutrophic type. Primary productivity is an index of nutrients and energy supply. None of the factors such as temperature or nutrients seems to be of limiting nature in the estuary and the prawn culture fields connected with it. Monthly variations in the total solar radiation are not sufficiently large to affect seasonal changes in production but the light penetration and reduced euphotic zone of the fields limit to some extent column production. During the monsoon months, the estuary becomes highly turbid as a result of the inflow of a considerable amount of freshwater. But in the prawn fields which are less than 1 m depth, this is of little consequence except on very cloudy days.

Eutrophic fields are having comparatively a high tidal influx and the nutrients are constantly replenished. In such situations of eutrophication, large phyto and zooplankton populations are produced. A highly anomalous situation in such cases is the deoxygenation of water in the lower regions especially during the predawn period. As the water bodies are comparatively shallow, there is no marked stratification and due to high wind speeds, there is uniform mixing leading to the establishment of a well-aerated water body colonised by benthic invertebrates and other aquatic organisms. But in low productive regions, the nutrient levels and consequent production of plankton and benthic animals will be of a lower order making the system inadequate for maintaining a reasonably high level of cultivable organisms. Such fields require more elaborate investigation regarding the inputs required by way of chemical fertilizers to maintain the NP ratio and organic manure to increase the particulate fraction.

It is observed that the seasonal fields are more productive than the perennial ones. Due to paddy cultivation and also by the regeneration process of nutrients in the mud, the organic compounds increase considerably at the bottom. The nutrient content of the waters in majority of the seasonal fields located in the northern sector of the estuary, showed high values compared to the fields in the southern region. It is also seen that in the middle region of the estuary where there is direct connection with the sea, the fields showed higher rate of production. The relative variations of productivity in the seasonal and perennial fields are reflected in the presence of more seasonal fields abounding in the northern sector of the estuary.

In regions south and north of Cochin bar mouth as well as the Azhikode bar mouth, the prawn fields showed high rate of production. So also where there is the influx of freshwater from river discharge, the rates are comparatively higher. In some areas in the estuarine system, where there is least influence of either 'new water' or freshwater, the rate of production showed a decreasing trend. This type of phenomenon is characteristic of oligotrophic environment where 'new' surface water with a higher proportion of both the soluble organic phosphate and the phosphorus in the detritus besides the 'adsorbed phosphate' may be rapidly regenerated into inorganic form. Whereas in the older water accumulation of materials takes place which is more difficult to decompose (Steemann Nielsen and Jensen, 1957).

While considering the productivity in relation to developing culture practices, it has also to be stressed that high production is sometimes undesirable. Situations which can tend to become eutrophic require constant watch and cleansing with tidal water. It has been pointed out that the estuarine water is being tidally influenced, rises and falls in a predictable way and as such different biota colonise the area of land according to time of immersion or exposure (Qasim, 1970). The wide variation of salinity and associated physical parameters and phases of immersion and exposure in the adjoining banks of the fields also will have its reflection on the type of food organisms that will be generated by the natural process.

In order to have a critical appraisal of the productivity in these areas, various other parameters having a direct bearing on the sustenance and growth of culture organisms such as the nature of epifauna and infauna and the general pattern of zooplankton distribution in the water column have also been studied. In this context, it may be pointed out that an alluvial substratum as compared to a sandy substratum would naturally encompass a higher carbon content. The fields around Cochin has this advantage. In addition, the organic content resulted from the decay of stems and roots of paddy is also another source of food for an omnivorous feeder such as the prawns. The phosphorus and potash available in the mud and which will be regenerated in the overlying water are also additional pointers towards a higher sustainable yield.

The particulate organic matter is an indication of the total food available to the prawns during the various stages of its growth without any additional inputs. As has been pointed out by Qasim et al.(1969), a general lack of zooplankton grazers in the estuary leaves behind a considerable surplus of unconsumed basic food, much of which seems to be lost by sinking below the narrow euphotic zone. Based on these parameters, the size of the stock and the capacity of the water body to sustain it could be theoretically computed, but would require actual field trials in different locations for confirmatory results.

As an estuary proceeds from marine condition at its mouth to an almost freshwater environment at its head, a wide range of communities can occur both spatially and temporarily. This could also perhaps account for the observed variation in the relative productivity. A typical estuarine food-web is composed of rooted vegetation, benthic algae and phytoplankton at its base with dependent zooplankters, organic debris and bacteria and benthic micro-fauna (Qasim, 1970). The aquatic invertebrates such as prawns are direct feeders of deposits and micro-fauna. As such all these parameters are required to be investigated in its totality to get a comprehensive picture of the ecosystem.

Thus the amount of nutrient level, as well as the magnitude of primary production together could be taken as the criteria for estimating the stocking potential and also to determine the other inputs required for taking an optimum sustainable yield from the seasonal and perennial fields. It may be pointed out here that the yield of fish or other resources have been estimated from productivity and certain other easily measurable parameters by developing what is termed as 'morpho-edaphic-index' (Ryder, 1965) which has been successfully applied in certain African lakes (Henderson _et al_. 1973). It may therefore be suggested that fields with a productivity of 2000 mgC/m^3/day and having a relatively high detrital concentration could be stocked intensively without any additional inputs as fertilizers. Other fields with varying levels of productivity would require addition of organic material or inorganic manure, the requirement of which should be carefully calculated on the basis of the productivity of an ecosystem already available.

With regard to the mangroves in the Cochin Backwater, as it is found today, could be described as isolated patches which have undergone degradation due to man made changes. Blasco (1975) has pointed out that out of the estimated 7 lakh ha of mangrove areas, Kerala backwaters have only a vestige of less than 1000 ha. Although the backwater channels are shallow, narrow and well connected to the sea with good amount of rainfall annually, mangrove development has been very much restricted in the estuarine system of Cochin. The area bordering the canals are over populated and what could have been potential mangrove areas have been converted into coconut grooves and paddy fields.

Wide seasonal fluctuations have been noticed in the physico-chemical parameters in the mangrove areas investigated. The Cochin backwaters where the mangrove areas are located is subjected to considerable influence of various factors such as warming during summer months, lowering of surface salinity and temperature during monsoon months, rainfall, turbidity, tidal oscillation and regeneration of nutrients.

Several authors have remarked on the high productivity of the mangrove ecosystems. The ecology of mangroves in Mandovi and Zuari estuaries of Goa has been studied by Untawale _et al_. (1973). Krishnamurty and Sundararaj (1973) report a high rate of production by what they call a 'direct estimate of primary production' in the Pichaivaram mangrove (Porto Novo), made during March-April 1972. Teixeira _et al_. (1969) who found considerable variation in daily primary production in the mangrove swamps of Brazil, with values ranging from 580-640 mgC/m^3/day. Prakash (1971) has drawn attention to the rate of humic acid exuded from the soil and from the roots of mangrove plants which give a stimulus to primary productivity. The leaching of the humic acid together with the shallowness of the area have been attributed for the high productivity.

It is well known that these areas are nursery grounds for the juveniles of prawns which feed on detritus rich benthos and flora of micro-algae. In many parts around Cochin, paddy cum prawn culture is practiced and for the prawn seed requirements, the numerous creeks and canals around the mangroves serve as potential collection grounds. The enrichment of estuarine waters in this area to an extent is aided by the organic material supplied by the mangroves due to high litter-fall which showed good amount of carbon content in addition to the large quantities of organic debris brought by the rivers particularly during monsoon months.

2. Mud Bank

Area of study:

During the south west monsoon season, while rough seas prevail all along the coast, at some parts of south west coast of India, especially along the Kerala coast, the near-shore waters become very calm over limited areas of varying extent ranging from 10 to 25 sq. km in somewhat semi-circular form on account of fine clayey mud of 1 to 2 m thickness, the surface layers of which are kept in a colloidal solution that absorbs all the wave energy. Such calm areas are called the Mud Banks, popularly known as 'chakara'. Mud banks have been reported to have appeared at several places between Mangalore in the north and Quilon in the south. Among them some are permanent mud banks and few are temporary depending upon the source of mud for its formation. The Ambalapuzha-Purakkad mud bank near Alleppey is a permanent one with a slight shift to north or south directions. The studies related to the phytoplankton productivity and chlorophylls together with related aspects of this mud bank are presented in this account.

The study of phytoplankton production in a special type of ecosystem as the mud bank is confronted with certain problems. Due to man-made and natural causes, the turbidity is high which affects light penetration, thereby decreasing the depth of the euphotic zone.

though in the adjacent waters, the euphotic zone may extend anywhere between 15-50 m, in the mud bank area it is generally less than 4 m during the season of the mud bank (June-August). So the normal *in situ* measurements are not applicable in these waters which necessitates the measurement of potential assimilation in *in vitro* conditions. Most of the techniques for measuring standing crop do not give data on the relative abundance of the dead and non living chlorophyll fractions and therefore the amount of food available for the demersal forms is not known. The magnitude of potential resources as a fraction of primary production cannot also be assessed for the mud bank as in other waters. The measurement of potential productivity at best can only give a general idea on the production potential of the ambient waters of the mud bank year after year which may lend a clue to the causes of the fluctuations in the yield.

This is the first study conducted on phytoplankton productivity in the mud bank region, apart from Bristow's (1938) brief mention on the planktonic algae. The earlier accounts on the mud banks are those of Ducane *et al.* (1938), Seshappa (1954), Seshappa and Jayaraman (1956), Damodaran and Hridayanathan (1966), Nair *et al.* (1966), Varma and Kurup (1969), Kurup (1972), Damodaran (1972) and Gopinathan and Qasim (1974). But none of these authors has dealt with phytoplankton productivity. The two aspects of the mud bank, potential productivity and quantitative variation in phytoplankton, form part of a comprehensive investigation on the ecology of this unique phenomenon.

Fortnightly or monthly collections of water samples from the surface and bottom and phytoplankton net samples were collected from 4 stations in the mud bank area (Pl. XIII, fig.A).

Results

Potential productivity:

The study conducted during the formation of the mud bank and the preceding and succeeding periods show that there is seasonal and spatial variability within the mud bank region itself and hence the phytoplankters are not homogenously distributed in this ecosystem. The potential productivity values collected from July 1971 to July 1972, covering the 4 seasons are presented in Table - 22. Maximum potential productivity for the surface waters of the mud bank was observed during the pre-monsoon period, whereas along the west coast the maximum rate of production was observed during June-September.

The productivity parameters of both surface and bottom waters during the mud bank season and those preceding and succeeding seasons (pooled values of four stations) are given in Pl. XIV, fig. A B. The rate of potential assimilation is uniformly high, averaging 35 $mgC/m^3/hr$ with the maximum potential productivity

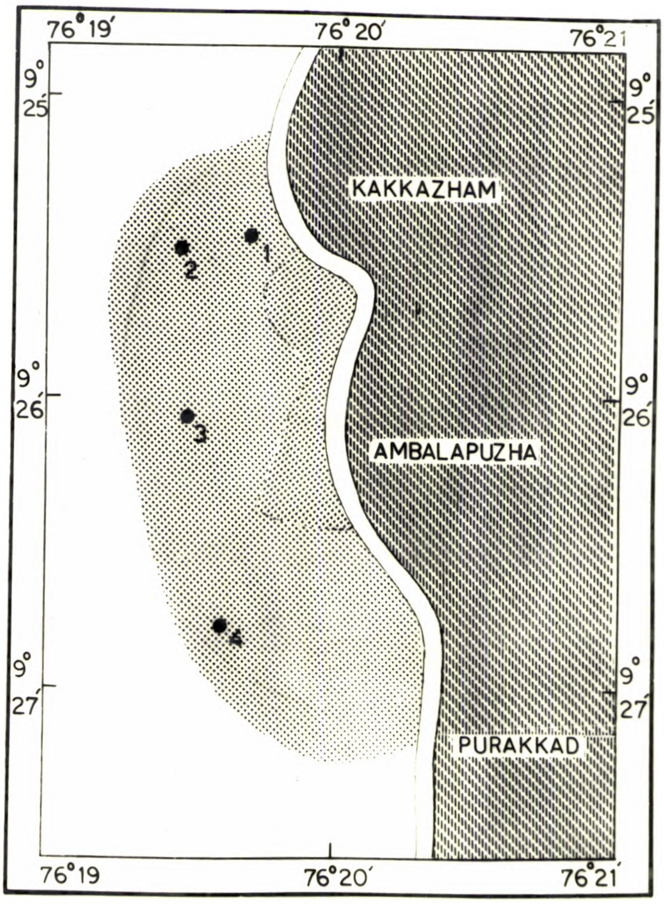
PLATE - XIII

Figs. A-B. Fig. A, Location of sampling stations at the mud bank region of Ambalapuzha-Purakkad, near Alleppey during 1971-72.

Fig. B, Biomass of phytoplanktön at 4 stations during 1971-72.

PLATE XIII

A



B

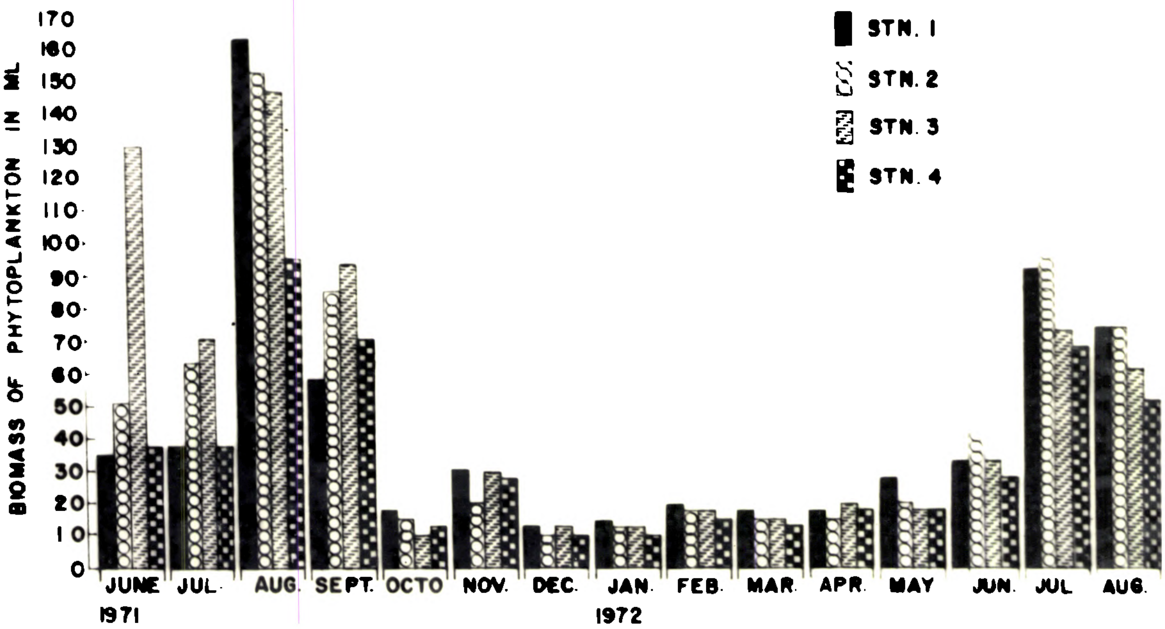


Table - 22

Potential productivity of the mud bank ($mgC/m^3/hr$)

			St. 1	St. 2	St. 3	St. 4
1971	July	S*	5.26	13.93	31.05	14.74
		B**	-	-	-	-
	August	S	71.85	28.19	71.82	24.49
		B	13.98	10.0	41.40	82.60
	September	S	1.16	1.95	1.96	0.52
		B	0.69	-	-	-
	October	S	26.84	26.19	16.35	27.07
		B	17.40	12.61	-	26.26
	November	S	8.76	8.98	7.68	23.36
		B	1.41	1.31	3.48	12.75
	December	S	4.75	7.68	2.08	7.55
		B	3.40	3.12	6.85	5.03
1972	January	S	59.64	40.87	29.25	36.64
		B	30.88	43.40	13.83	25.92
	February	S	41.28	9.69	20.93	22.60
		B	11.71	5.69	14.06	14.08
	March	S	115.88	39.21	86.52	59.81
		B	84.16	59.96	39.18	43.08
	April	S	49.67	177.15	93.86	38.93
		B	19.77	37.79	57.50	21.89
	May	S	81.53	97.03	58.68	60.20
		B	61.91	-	-	9.91
	June	S	31.05	116.72	28.63	38.00
		B	-	-	-	-
	July	S	21.31	5.16	2.25	4.50
		B	8.21	10.48	33.55	33.12

* surface, ** bottom

during the February-May period. In vitro production under constant light has been found to be as high as 52 $mgC/m^3/hr$ (Nair, 1974) on the south west coast during the monsoon season.

The bottom samples do not exhibit a similar trend. The potential assimilation as well as rate of production is low compared to the surface. In contrast to the high rate of surface production during February-May period, the bottom production showed high values during the period June-August. September, November-December period show lower values both at the surface and bottom.

Chlorophylls:

The standing crop measured in terms of the chlorophylls a, b and c for the four stations are presented in Table - 23. It is believed that magnitude of chlorophyll a of a water body gives a true index of the standing crop. The pooled values of chlorophyll a at the surface and bottom for the four seasons are given in Pl. XIV, fig.B. The values indicate that unlike in other ecosystems, the chlorophyll a values of mud bank are not true indices of standing crop due to the presence of non-living chlorophyll released from the mud. The pooled values of production and chlorophyll show a negative co-relation (Pl. XV, fig.A), which is a clear indication that the chlorophyll values are not indicative of the standing crop.

PLATE - XIV

Figs. A-B. Fig. A, Seasonal variation of primary production (pooled values) of surface and bottom waters in the mud bank.

Fig. B, Pooled values of chlorophyll a for the four stations in the mud bank.

PLATE XIV

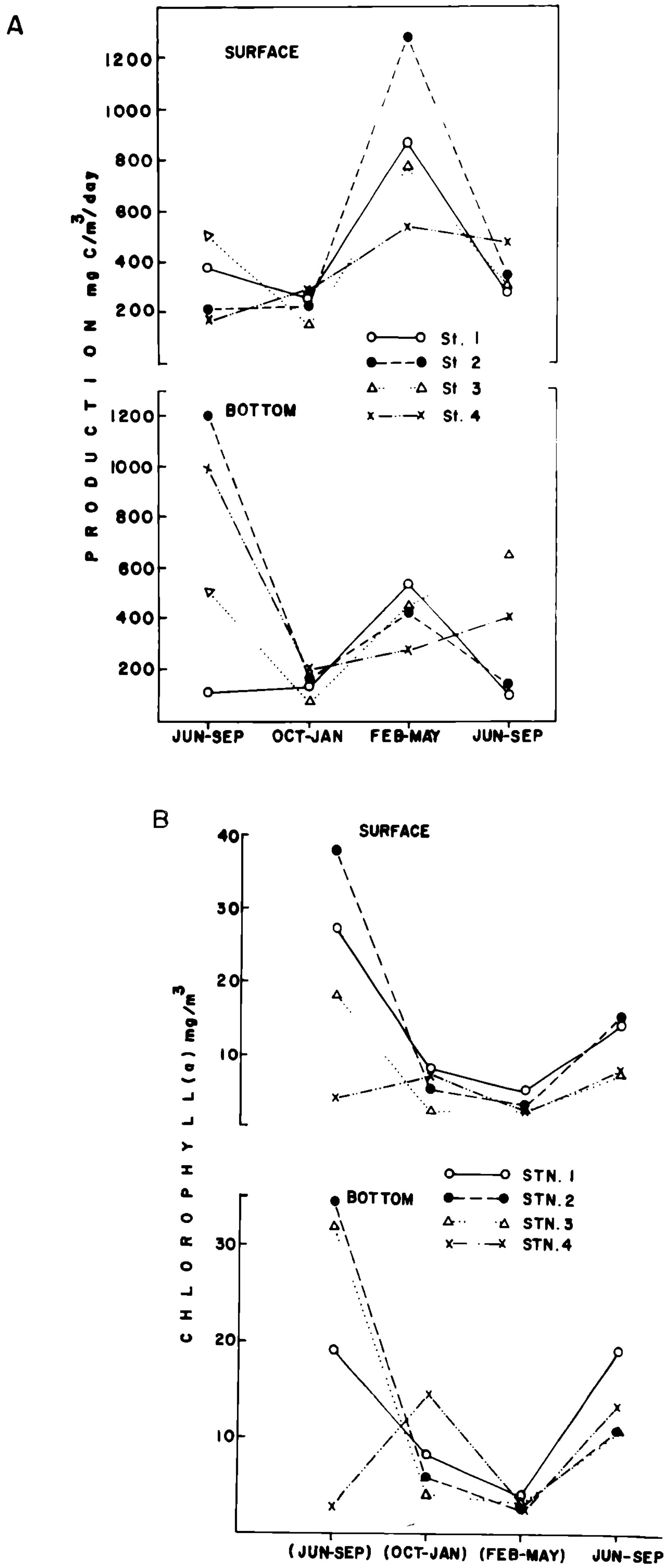

A
SURFACE
BOTTOM
PRODUCTION mg C/m3/day
1200
1000
800
600
400
200
St. 1
St 2
St 3
St. 4
JUN-SEP
OCT-JAN
FEB-MAY
JUN-SEP
B
SURFACE
BOTTOM
CHLOROPHYLL (a) mg/m3
40
30
20
10
STN. 1
STN. 2
STN. 3
STN. 4
(JUN-SEP)
(OCT-JAN)
(FEB-MAY)
JUN-SEP

Table - 23

Chlorophylls (mg/m^3) in the mud bank area

	St. 1			St. 2			St. 3			St. 4		
	a	b	c	a	b	c	a	b	c	a	b	c
1971												
June	26.7	16.2	64.7	18.4	-	4.7	55.1	48.5	17.4	-	-	-
July	33.2	3.7	27.1	16.1	32.8	54.9	15.5	15.9	26.8	8.0	-	4.7
August	13.7	-	7.0	16.1	3.5	18.8	16.6	5.4	16.4	0.7	2.0	2.0
September	14.3	6.4	5.5	4.9	-	23.5	8.6	-	26.0	-	-	-
October	14.8	1.0	1.5	8.5	-	4.2	0.4	-	6.4	9.2	3.6	-
November	5.8	-	9.1	2.6	0.5	3.0	3.1	1.0	2.5	12.9	-	9.0
December	-	-	-	0.6	0.6	0.4	0.5	0.9	3.9	2.5	-	3.0
1972												
January	9.7	1.4	7.2	9.0	1.7	2.3	3.3	0.3	2.4	3.2	-	-
February	4.5	1.1	3.8	1.8	-	-	1.2	0.8	2.3	3.3	2.0	5.4
March	6.5	6.4	3.5	1.3	0.7	4.1	2.2	1.8	4.8	1.3	1.2	6.5
April	3.0	1.0	1.8	4.0	1.8	5.3	3.7	1.5	4.9	1.7	1.6	2.5
May	5.7	1.8	6.1	3.4	1.8	4.6	2.3	1.2	3.0	3.1	1.3	5.2
June	16.7	18.3	-	15.8	-	15.9	11.3	1.9	4.4	16.0	7.3	4.2
July	10.6	4.3	10.3	6.7	2.9	27.1	6.2	1.4	29.3	2.9	0.3	3.8

The table - 23 reveals that all the chlorophylls show an increasing trend during the period of mud bank formation for the 3 stations, but in the 4th station, which is deeper than the others, the chlorophylls show uniformly low values throughout the period. During the pre and post monsoon period, the chlorophyll a values are generally less than 10 mg/m^3 at the surface and bottom while during June-September period excepting in station 4, the values are of the order of 2-3. The same trend is seen for chlorophylls b and c. The ratio of chlorophyll b by a and c by a is given in Table - 24. Moreover, the chlorophyll c values indicated an exceptionally high range in the mud bank area during the active period of formation of the mud bank revealing the uniqueness of the ecosystem.

Table - 24

Inter-relationship of chlorophylls in the mud bank

Chlorophyll b/a ratio				
Period	St. 1	St. 2	St. 3	St. 4
June-September	0.568	0.790	0.781	1.620
October-January	0.110	0.134	0.620	-
February-May	0.470	0.520	0.629	0.745
June-September	0.495	0.501	0.365	0.302
Chlorophyll c/a ratio				
June-September	0.829	0.120	0.212	4.524
October-January	2.659	0.520	2.677	5.463
February-May	10.177	1.427	1.580	1.747
June-September	0.241	0.282	0.758	0.496

Biomass:

The phytoplankton biomass as indicated by the displacement volume in general showed a gradual increase from June onwards, reaching its maximum in August, which was primarily due to high abundance of the dinoflagellate, Noctiluca miliaris Suriray. There was a gradual decrease in succeeding months attaining its minimum in December. After December, there was a secondary rise in the volume of plankton in the succeeding months (unimodel) reaching its peak in the second season of the mud bank (Pl. XIII, fig.B). A notable feature in the biomass distribution of the mud bank was its spatial variability. In the first and second stations, the values were high while in the 4th, it was very low. There was a gradual decrease in the volume of plankton from the first to the fourth station.

Quantitative and qualitative studies:

The quantitative distribution of the different phytoplankters in terms of total cell counts present in one litre of water from the surface and bottom for the four seasons are presented in Table - 25. The quantitative study showed that the magnitude of phytoplankton production is not uniform every year. Diatoms dominate during the south west monsoon and dinoflagellates are abundant during the post monsoon period, while the pre monsoon season is characterised by the dominance of both the groups in equal proportions. In the inshore and oceanic environments the

Table - 25

Seasonal abundance of phytoplankton of the mud bank. One litre settling chamber counts (average of 4 stations)

		Diatoms	Dinofl.	Silico-fl.	Cocco-lith.	Cyano. phyceae	Nanno. pl.	Total
1971								
June	S*	183600	650	100	-	650	213200	398200
	B**	16100	240	60	-	300	111000	127700
July	S	181000	4400	-	-	-	211100	396500
	B	17200	300	-	-	-	112600	130100
August	S	35500	12600	-	-	-	116500	164600
	B	24000	17500	-	-	-	118500	160000
September	S	2300	16700	-	-	-	111000	130000
	B	14300	1600	-	-	-	123600	139500
October	S	15510	690	-	-	-	128000	144200
	B	20900	1200	-	-	-	116000	128100
November	S	12100	100	-	-	-	132000	144200
	B	4000	100	-	-	-	121000	125100
December	S	17220	1080	-	-	3800	114000	136100
	B	14400	700	-	-	3000	112000	130100
1972 January	S	15200	300	-	-	1800	122400	139700
	B	15100	200	-	-	1600	114000	130700
February	S	13600	420	-	80	600	116200	130900
	B	13050	340	-	60	250	112600	126300
March	S	6360	690	-	-	-	116250	123300
	B	3300	400	-	-	-	114000	117700
April	S	34440	970	90	-	-	118500	154000
	B	19820	450	30	-	-	113400	133700
May	S	245800	2100	400	1100	-	26400	275800
	B	44300	600	100	100	-	123600	168700
June	S	26280	1920	-	-	-	316800	345000
	B	22050	1050	-	-	-	246200	269500

* surface, ** bottom

occurrence of these two groups is at variance. Some change in the pattern of occurrence also has been observed between the two seasons of study which could be due to the high abundance of Noctiluca. Silicoflagellates were found to occur during April and June. The Cyanophycean members particularly Trichodesmium sp. were present during June, December and January. The Coccolithophore, Coccolithus sp. was found to occur only during March to May. Unidentified forms of nannoplankters besides Chlorella salina and Tetraselmis sp. were found to be abundant during the season of the mud bank.

From one litre of water sampled examined, about 58 species of phytoplankters were identified; 38 species of diatoms, 15 species of dinoflagellates, 2 Silicoflagellates, one Coccolithophore and 2 species of blue-green algae. The species-wise distribution of the above mentioned phytoplankters have been given in Appendix - II.

The mud of the mud bank, though considered to be a store-house of various nutrients does not have an abundant benthic flora. The results of the quantitative estimation of the flora in 1 cc of mud (periphyton layer of 1 cc of mud taken by a syringe, dissolved in distilled water of 100 ml, out of which 10 ml counted and calculated) collected at the centre of the mud bank, are presented in Table - 26. Benthic diatoms, unidentified nannoplankters and other algal components constitute the benthic flora.

Table - 26

Quantitative estimation of the benthic flora of the mud bank

		Benthic diatoms	Other algae	Total cells/1 cc
1971	June	140	90	230
	July	90	60	150
	August	60	50	110
	September	30	40	70
	October	30	20	50
	November	40	30	70
	December	40	20	60
1972	January	60	40	100
	February	30	50	80
	March	50	40	90
	April	30	30	60
	May	80	10	90
	June	70	50	120

However, an increasing trend in the total number of floral components in the benthos is seen during the season of the mud bank compared to that in other months.

Diurnal observations:

The evidence of a daily photosynthetic periodicity has been observed by several workers in different types of ecosystems and it had been suggested that the fluctuation of photosynthesis is a real and not just an experimental artifact - the cause being fluctuations in the chlorophyll a content of the population under observation (Yentsch and Scagel, 1958). In order to test this hypothesis, in a special environment as the mud bank, two series of diurnal studies were conducted during May and August 1975. As may be seen from the Table - 27, the maximum photosynthesis was observed at noon and the afternoon hours in May with a production rate of 60 $mgC/m^3/hr$. But in August (Table - 28) the maximum photosynthesis observed was in the classical pattern with a higher production at 8 a.m, gradually reaching the maximum of 229 $mgC/m^3/hr$ by 10 a.m followed by a noon depression and again an increased rate of production by 1600 hrs reaching the lowest value at sun down. This variation may be due to the relative abundance of 'sun' and 'shade' adapted forms in the surface waters during the two days of observation.

The standing crop of phytoplankton in terms of chlorophyll a and total cell counts during the diurnal study in May showed almost similar pattern without much fluctuations. But the observations in August showed much fluctuations in the values of chlorophyll a and total cell counts during day and night hours. The chlorophyll a concentration at the bottom in majority of the observations were found slightly higher than that at the surface. This may be attributed to the presence of non-living chlorophyll liberated from the mud.

Other observations:

In August and September for 3 seasons, bright red patches were observed in the surface waters all along the mud bank region. The discolouration was due to extremely

Table - 27

Diel variation of productivity parameters during May at the mud bank

	Time	sample	Production mgC/m^3/hr	Chlorophyll *a* mg/m^3	Total cells/l
16-5-'75	0900 hrs	S	35.4	23.50	336000
		B	-	10.68	307000
	1200 "	S	106.2	17.62	282000
		B	-	22.43	233000
	1500 "	S	40.6	13.35	225000
		B	-	14.45	240000
	1800 "	S	-	13.35	335000
		B	-	14.95	360000
	2100 "	S	-	6.41	240000
		B	-	10.68	225000
	2400 "	S	-	13.88	158000
		B	-	23.50	115000
17-5-'75	0300 "	S	-	29.37	188000
		B	-	26.70	191000
	0600 "	S	18.2	16.55	145000
		B	-	16.02	115000
	0900 "	S	24.5	17.09	235000
		B	-	19.22	205000

Table - 28

Diel variation of productivity parameters

during August at the mud bank

	Time	sample	Production $mgC/m^3/hr$	Chlorophyll a mg/m^3	Total cells/l
16-8-'75	1800 hrs	S	-	6.68	243000
		B	-	13.35	313000
	20.00 "	S	-	13.26	352000
		B	-	2.67	123000
	22.00 "	S	-	6.68	216000
		B	-	5.34	184000
	24.00 "	S	-	6.68	231000
		B	-	4.01	114000
17-8-'75	02.00 "	S	-	5.34	179000
		B	-	26.72	256000
	04.00 "	S	-	24.71	219000
		B	-	33.38	285000
	06.00 "	S	89.41	13.35	193000
		B	-	20.03	217000
	08.00 "	S	176.03	66.88	482000
		B	-	49.52	267000
	10.00 "	S	228.93	100.38	568000
		B	-	80.25	302000
	12.00 "	S	36.46	20.03	312000
		B	-	33.38	240000
	14.00 "	S	24.67	26.70	168000
		B	-	13.38	192000
	16.00 "	S	96.77	13.35	243000
		B	-	26.70	153000
	18.00 "	S	11.10	16.02	178000
		B	-	18.69	162000

high concentration of the dinoflagellate, Noctiluca miliaris. A green colouration was also noticed during August 1971, which was caused by the 'green' Noctiluca (Noctiluca with a green euglenoid symbiont, Protoeuglena noctilucae Subrahmanyan). In September 1971, also a green discolouration of the water was noticed which turned out to be due to the high incidence of the diatom Fragilaria oceanica.

A pinkish discolouration of the water was noticed during August 1972 as a long patch extending from north Kakkazham to south Purakkad at Ambalapuzha (Pl. XIII, fig.A). The colour of the patch varied from brilliant orange to pinkish-orange depending on the density with a very distinct demarcation. The colour was quite different compared to the usual 'red water' or 'red tide' caused by other dinoflagellates such as Gymnodinium or Goniaulax species. The Noctiluca cells due to their high buoyancy were concentrated at the surface where they were so closely packed that the number of cells per unit volume within the surface layer appeared to be limited only by their size. All the cells appeared to be in a healthy active state. Large numbers of Noctiluca were also present in the apparently clear patches of water and even here they were numerous enough to be visible to the naked eye when the water was closely examined. The settling chamber counts of water collected during August 1972 from the surface were more than 5 lakh cells/l.

It is known that instances of such outbreaks of organisms bring about certain changes in the hydrological conditions and sometimes mortality also among organisms in the water including fish due to the effect of toxins liberated into the water. But instances of mortalities do not seem to have occurred in the mud bank region, probably because of the high fishing effort in the region. Generally during the outbreak of these organisms in high concentrations, the normal constituents of the plankton were found to be absent or scarce.

Discussion:

The regional and seasonal variability and magnitude of primary production in the inshore environment of the west coast of India have been studied in relation to the potential fishery resources (Prasad et al. 1970). But the ecology, as well as the productivity of the mud bank together with their nature of formation, existence and dissipation make this ecosystem a unique one from the rest of the inshore regions of the west coast of India and hence both cannot be directly compared.

The mud banks are characterised by high productivity and chlorophylls with rich phytoplankton standing crop. During the season of mud bank, June-August, abundant rainfall and enrichment of nutrients, favour a high production of phytoplankton. Another reason for the high abundance of phytoplankton is that the mud of the mud bank is a rich store-house of various nutrients which also enrich the ambient water during the active period of the mud bank. In fact, this enriched water will act as an ideal culture medium from which phytoplankton draws its requirements and rapidly multiply during this season. The plankton observations of this period showed that the environmental conditions are favourable for the process of rejuvenation of the protoplast of the diatom cells as a result of which auxospores will be formed due to gametic fusion. At times, blooming of one species will occur as observed in the case of Fragilaria oceanica. But this blooming is not the result of sexual reproduction, but by vegetative cell division.

It has been observed that for the west coast, the monsoon period is the most productive season with values exceeding 2 $gC/m^2/day$. During the post monsoon period also, the daily rates are fairly high. The rate of production is mainly governed by the availability and replenishment of the nutrients. The low rate of primary production during the pre-monsoon and the high rates during monsoon and post-monsoon periods as well as the lower values observed seaward can be accounted directly to the availability of nutrients. But in the offshore waters, it is the inter-relationship of the euphotic zone and mixed layer that determines the rate of production (Nair, 1974). These factors however, do not hold true for the mud bank waters. In the mud bank area, the euphotic zone is reduced to less than 2 metres, while the average depth of the area is only 4 metres.

Though light is never a limiting factor in the tropical waters, in the mud bank, light penetration and thereby utilization by phytoplankton is considerably restricted due to the suspension of fine particles of mud. In addition to this, during the season of the mud bank, incident radiation is very much reduced due to highly overcast or rainy weather conditions. Hence photosynthetic production takes place only at the top few centimetres, while there is live phytoplankton throughout the water column as the mixed layer reaches to the very bottom.

The diurnal studies indicated that the diel variation which is significantly higher as compared to oceanic waters could be correlated to the decreased light penetration. According to Yentsch and Scagel (1958) the changes in the pigment content of the population is brought about by the action of light which produces two opposing reactions, the photo-destruction in the pigments of the cells and an opposing synthetic reaction. The same authors as well as Lorenzen (1963) have observed that the greater fluctuation in the pigment occured at same depth below the surface where the total radiation was less. The greater variation in the diurnal rhythm therefore could be attributed to the decreased light in the mud bank area. The order of variation in the well-lit region of Gulf of Mannar was only 2 (Nair, 1974) while in the mud bank the variation has been of the order of 10.

As may be seen from the table - 23, there is a more or less uniform distribution of three chlorophylls throughout the year except in station 4 which being deeper is less influenced by the occurrence of the mud bank. The ratio of chlorophyll b/a and c/a gave a varied picture of the pigment and their inter-relationship. The chlorophyll b/a ratio is generally less than 1.0. But the chlorophyll c/a ratio is fairly high. A similar increase in the ratio of chlorophyll c/a with a high chlorophyll c content had been observed in the deeper layers of Cochin backwater by Qasim and Reddy (1967) which has been explained as the result of pigments coming from the stirred up mud from the bottom which contained more of chlorophyll degradation product and which reacted similarly to chlorophyll c. This phenomenon which was observed in the mud bank is similar to that of the estuarine environment.

It is likely that the chlorophyll values do not represent a true index of standing crop in view of the presence of non-living chlorophyll released from the mud by wind and wave action. Low assimilation ratios (Table - 29), except during February-May, when stable conditions prevail, also indicate this fact.

The species composition of the phytoplankton population is presented in Appendix - II. It is observed that in July-September, there is very high concentration of Noctiluca, approximating bloom conditions and this

Table - 29

		Chlorophyll a mg/m^3	Phytopl. cells/l	Potential assimilation mg/m^3/hr	Assimilation ratio
June-September	S	21.80	272,700	26.06	1.2
	B	22.16	139,300	58.43	2.8
October-January	S	5.51	161,000	19.13	3.5
	B	8.08	129,000	11.55	1.4
February-May	S	3.11	171,000	72.06	23.2
	B	3.19	136,700	34.51	10.8
June-September	S	10.81	387,000	29.00	2.7
	B	13.77	269,500	26.34	2.0

S - surface, B - bottom

resulted in considerable decrease of other phytoplankters. Noctiluca are able to multiply rapidly by binary fission and form swarms when calm conditions prevail in the area. There is an indication that the high abundance of diatom population also coincide with the calm conditions and consequent enrichment of water from the bottom. It was observed earlier that there is a swarming of Noctiluca, there will be a significant reduction in the diatom population or total absence of other phytoplankters (Prasad and Jayaraman, 1954). Thus such a rapid reduction of diatom population seriously affect the herbivorous zooplankters and organisms in the subsequent trophic levels. The causes responsible for the sudden outbreak of Noctiluca, particularly during the season of the mud bank are not fully known, yet there is evidence that it may be due to the rapid replenishment of nutrients resulting in their high concentration and consequent production of diatoms. Noctiluca will feed on diatoms due to its holozoic nature. Subrahmanyan (1954) and Prasad and Jayaraman (1954) found that at the time of the occurrence of intense bloom of Noctiluca, diatoms were almost absent in the water and silica content of the water had gone up considerably even comparable with high values obtained during the monsoon. In the mud bank also this phenomenon was noticed, followed by a decline in the relative abundance of other phytoplankters.

Though the inter-relationship with regard to the fishery potential and the presence of mud bank are contradictory, and the evidences almost conclusively point that there is absolutely no relationship between the two. Though the total landings of fishes and the potential productivity of the waters during the season of the mud bank studied for a period of six years (1972-77) reveal a seeming correlation (Pl. IV, fig.B), and this could perhaps be only a reflection of the increased production at all trophic levels over the whole west coast during the monsoon

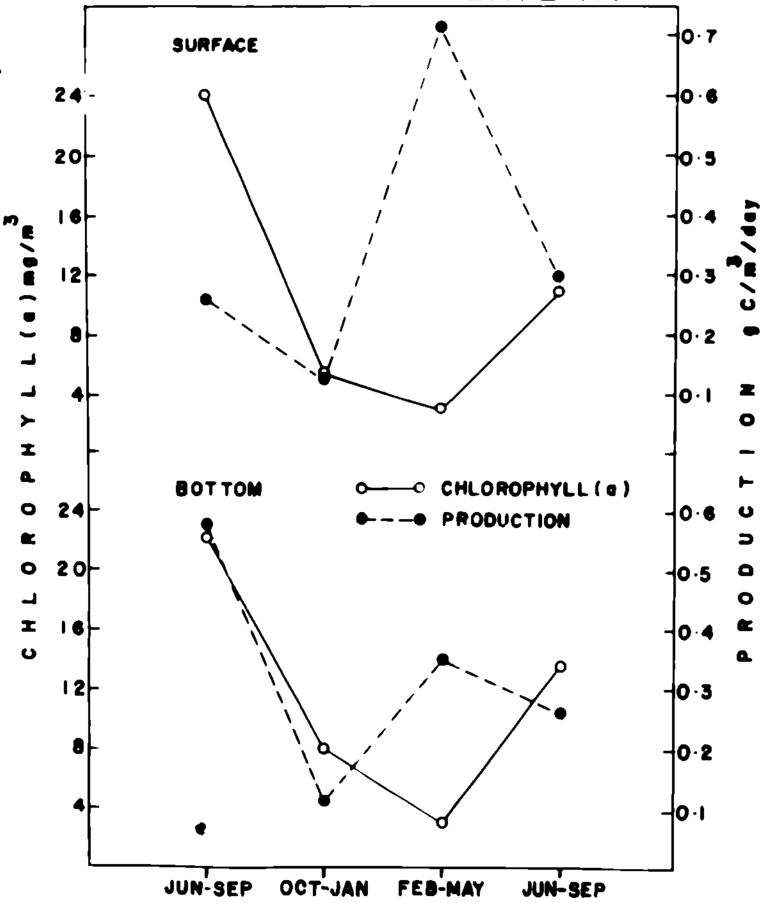
PLATE - XV.

Figs. A-B. Fig. A, Correlation of primary production and chlorophyll a at the surface and bottom regions in the mud bank area.

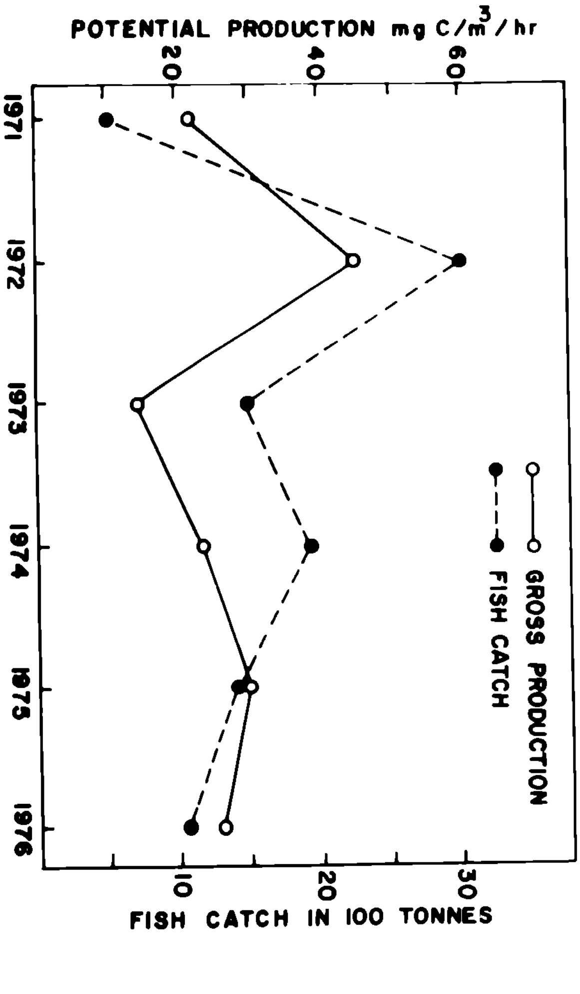
Fig. B, Primary production in relation to fish landed at the mud bank region of Ambalapuzha-Purakkad during 1972-77.

PLATE XV

A


SURFACE
BOTTOM
CHLOROPHYLL (a) mg/m³
PRODUCTION g C/m³/day
CHLOROPHYLL (a)
PRODUCTION
JUN-SEP
OCT-JAN
FEB-MAY
JUN-SEP

B


POTENTIAL PRODUCTION mg C/m³/hr
FISH CATCH IN 100 TONNES
GROSS PRODUCTION
FISH CATCH
1971
1972
1973
1974
1975
1976

period, which in turn is manifested in the magnitude of the catches. It is also possible that if sampling had been done outside the mud bank, a similar trend would have been obtained as the transfer of the primary producticity into the fish biomass is taking place in the entire area.

Appendix - II

Seasonal variations of different phytoplankton components present in one litre of water (Surface)

	J	F	M	A	M	J	J	A	S	O	N	D
Diatomaceae												
1. *Melosira sulcata*	-	-	-	-	R	R	R	-	-	-	-	-
2. *Hyalodiscus subtilis*	-	-	-	R	R	-	-	-	-	-	-	-
3. *Stephanopyxis palmariana*	R	-	-	R	-	R	R	-	C	-	-	-
4. *Skeletonema costatum*	A	A	A	B	A	A	A	C	R	B	-	R
5. *Thalassiosira decipiens*	-	R	-	R	-	R	R	F	-	C	-	F
6. *T. subtilis*	C	-	F	R	F	C	-	-	-	A	-	R
7. *Coscinodiscus* spp.	C	C	C	A	A	A	F	A	C	A	F	F
8. *Planktoniella sol*	-	-	-	R	A	-	-	R	R	-	R	-
9. *Lauderia annulata*	-	-	-	R	-	F	R	-	-	-	R	R
10. *Schoederella delicatula*	-	R	-	F	A	R	-	-	R	-	-	R
11. *Guinardia flaccida*	-	F	-	F	R	F	C	R	A	-	F	R
12. *Rhizosolenia* spp.	F	-	F	A	R	C	R	C	-	F	R	-
13. *Bacteriastrum varians*	-	-	-	R	-	-	R	-	-	-	-	-
14. *Chaetoceros lorenzianus*	R	R	-	C	R	C	C	-	R	-	A	R
15. *C. decipiens*	-	-	-	R	F	F	-	-	R	-	A	R
16. *C. curvisetus*	-	F	-	R	-	R	R	-	-	-	R	-
17. *C. affinis*	-	-	R	R	R	-	-	-	R	-	-	-
18. *Eucampia zoodiacus*	-	-	-	R	-	R	R	-	-	-	-	-
19. *Climacodium frauenfeldianum*	-	R	-	-	-	-	R	A	-	-	R	-
20. *Streptotheca themensis*	-	-	F	-	-	R	A	-	-	R	-	-
21. *Bellerochea malleus*	-	-	-	-	-	-	-	-	-	R	F	-
22. *Ditylum brightwellii*	R	R	C	F	A	F	R	-	-	-	R	

	J	F	M	A	M	J	J	A	S	O	N	D
23. <u>Triceratium favus</u>	F	-	-	F	R	-	R	-	R	-	-	-
24. <u>Biddulphia sinensis</u>	-	R	F	F	C	A	R	-	-	R	-	-
25. <u>B. mobiliensis</u>	-	R	C	C	C	-	R	A	R	A	R	C
26. <u>Cerataulina bergonii</u>	R	R	R	-	-	-	-	-	-	-	R	-
27. <u>Hemiaulus sinensis</u>	-	-	-	-	-	R	C	-	-	R	F	-
28. <u>Hemidiscus hardmannianus</u>	R	R	R	-	-	-	-	-	-	-	-	-
29. <u>Fragilaria oceanica</u>	A	-	-	A	A	-	A	B	-	-	-	-
30. <u>Thalassionema nitzschioides</u>	R	R	-	A	A	F	R	A	-	C	-	-
31. <u>Thalassiothrix frauenfeldii</u>	R	-	-	A	-	-	A	F	-	-	F	F
32. <u>Asterionella japonica</u>	R	F	C	C	A	R	R	F	-	-	-	C
33. <u>Pleurosigma elongatum</u>	-	-	R	-	F	-	-	-	R	-	R	-
34. <u>P. normanii</u>	-	R	-	-	F	-	-	F	-	-	-	R
35. <u>P. directum</u>	-	-	-	R	F	-	-	F	-	-	-	-
36. <u>Navicula</u> sp.	-	-	C	-	-	-	-	F	-	-	-	-
37. <u>Nitzschia longissima</u>	C	-	R	A	-	-	-	A	C	R	-	-
38. <u>N. seriata</u>	R	R	-	C	-	-	R	-	-	C	R	-
Dinophyceae												
39. <u>Prorocentrum micans</u>	-	-	-	-	A	C	-	-	-	C	R	R
40. <u>Dinophysis caudata</u>	-	-	-	-	R	-	-	-	-	-	-	R
41. <u>D. miles</u>	-	-	-	-	-	-	-	-	-	-	R	R
42. <u>Ornithocercus magnificus</u>	-	-	-	-	R	-	-	-	-	-	R	R
43. <u>Noctiluca miliaris</u>	-	-	-	-	-	F	A	B	B	F	R	R
44. <u>Pyrophacus horologium</u>	-	-	R	R	-	-	-	-	-	-	-	-
45. <u>Peridinium depressum</u>	R	-	R	R	R	-	R	R	-	-	-	R

	J	F	M	A	M	J	J	A	S	O	N	D
46. *Peridinium oceanicum*	-	-	-	-	-	-	-	-	-	-	-	R
47. *P. claudicans*	-	-	R	-	R	-	-	-	-	-	-	-
48. *P. pentagonum*	-	-	-	-	R	-	-	-	-	-	-	-
49. *Diplopsalis lenticula*	-	R	-	-	R	-	-	-	-	-	-	-
50. *Goniaulax polyhedra*	-	-	R	-	-	-	-	-	-	-	-	-
51. *Ceratium furca*	-	R	R	R	R	-	F	-	-	-	-	R
52. *C. fusus*	-	R	R	-	-	-	R	-	-	-	-	R
53. *C. breve*	-	R	R	-	-	-	-	-	-	-	R	R
Silicoflagellatae												
54. *Dictyocha fibula*	-	-	-	R	R	-	-	-	-	-	-	-
55. *Distephanus speculum*	-	-	-	R	R	-	-	-	-	-	-	-
Coccolithophore												
56. *Coccolithus* sp.	-	-	-	R	R	R	-	-	-	-	-	-
Cyanophyceae												
57. *Oscillatoria* sp.	-	-	-	-	-	C	-	-	-	-	-	R
58. *Trichodesmium theibautii*	-	-	-	-	-	-	-	-	-	-	F	C

B - Bloom 10,000 cells

A - Abundant 1000 "

C - Common 500 "

F - Few cells, 250 "

R - Rare, less than 100 cells

\- sign absent

3. Andaman Nicobar Waters

The investigations on the phytoplankton productivity in the Andaman Sea are very meagre. The Danish GALATHEA Expedition during her round the world cruise, made some measurements across the Indian Ocean through the equitorial current system and in the Bay of Bengal, of which two stations were located in the Andaman Sea. GALATHEA was followed by R.V.VITYAZ in 1956-60 with a few measurements during her 31-33 cruises in the Andaman Sea. The IIOE started its intensive programme and collected extensive data relating to various biological and hydrological parameters with few observations on phytoplankton productivity. Other measurements of primary production were those by Nair et al. (1968) and Nair and Pillai (1972) which cover the pre-monsoon season.

Area of study:

In recent years, much emphasis has been laid on coastal aquaculture or mariculture to augment the natural food production. In view of this, an investigation has been conducted in the entire stretch of Andaman Nicobar Islands to study the suitable areas for the culture of economically important cultivable organisms based on primary production. The area of study covers from Diglipur (North Andamans) in the north to Campbell Bay (Great Nicobar) in the south. This account embodies the results of productivity measurements made during the pre-monsoon period of 1978, viewed against the overall spectrum of productivity parameters developed by various workers during the last decade and also include a discussion on the suitability of different areas for the development of mariculture.

Light penetration and mixed layer

The major factor limiting the production is the depth of the euphotic zone which has been found by GALATHEA to be rather low in the northern regions of the Bay of Bengal, presumably due to the organic and inorganic material conveyed by Ganges, Brahmaputra and other river systems. Around the Andamans on the other hand, there is an increase of the depth of the euphotic zone which is between 65-75 m during the pre monsoon period and 75-90 m during the monsoon period. Further, in the offshore regions it exceeds 90 m indicating clear oceanic conditions, while for the major part of the Bay of Bengal, towards the coast, it is less than 50 m. The other important factor governing the production is the depth of the mixed layer which is around 60 m during most part of the year, while in the central part of the Bay it exceeds 80 m.

Productivity

The GALATHEA measurements showed that the vicinity of the western side of Andaman had a rate of production of 0.31 gC/m^2/day (Steemann Nielsen and Jensen, 1957). Nair (1970) calculated the production rate for the offshore waters of the Bay of Bengal as 0.19 gC/m^2/day.

Radhakrishna's (1978) recent measurements also give a comparable average 0.16 gC/m^2/day. Nair and Pillai (1972) observed that the annual production of the reef area in the Andaman Sea was 1200 gC/m^2, which is of a less order than that of similar reef areas.

Kabanova (1964) found that the primary production in the central part of the Andaman Sea was 114–176 mgC/m^2/day and that the area was characterised by greater concentration of nitrates than the other regions. According to this author, in the Bay of Bengal and in the Andaman Sea, phosphate was almost exhausted by the production of phytoplankton. The surface production of the Bay of Bengal is relatively less when compared to that of the Arabian Sea. This can be attributed to the greater cloud cover over the Bay of Bengal as compared to Arabian Sea which reduces the incident radiation that inhibits the primary production at the surface and also due to the heavy load of nitrogen and phosphorus brought about by rain run off (Qasim, 1977).

The primary production values for the Andaman Sea during the monsoon period averaged for 0–50 m depth is over 50 mgC/m^3/hr which would amount to nearly 2 gC/m^2/day. This is comparable to the higher rates in some productive regions of the Arabian Sea. So it can be reasonably inferred that the production rate of Andaman Sea in the upper 50 m is of a higher order èqual to the northern regions of the Bay of Bengal. Rest of the Bay especially the western regions during the corresponding period exhibits a low rate of production (2 mgC/m^3/hr) (Krey and Babenard, 1976).

Results and Discussion

During this investigation, various productivity parameters including hydrological features were studied.

Hydrography: The temperature of the coastal waters during the period of observation ranged from 27-32°C and salinity 27-33‰. The pH ranged from 7 - 8.5, especially in the mangrove areas investigated and the dissolved oxygen content was 4.0 to 5.5 ml/l. Due to lack facilities, the nutrient content of the water could not be analysed.

Phytoplankton: During the present investigation, the phytoplankton samples were collected by means of a ½ metre bolting nylon net by surface haul of 10 minutes duration. Altogether 39 samples were collected from the Andaman-Nicobar Islands. Since the samples were obtained by means of a net, the quantitative estimation of the organisms could not be possible. The qualitative studies reveal that 56 species of phytoplankters occur in the samples, viz. 22 species of Diatomaceae, 33 species of Dinophyceae and one species of Cyanophyceae. It is interesting to note that the Dinophyceae dominated in the inshore samples, especially species of *Ceratium*, *Peridinium*, *Ornithocercus*, *Dinophysis*, *Phalacroma*, *Pyrocystis* and *Pyrophacus*; in the nearshore samples, the dominant group was Diatomaceae, represented by species of *Rhizosolenia*, *Guinardia*, *Biddulphia*, *Chaetoceros* and *Streptotheca*. The blue-green alga *Trichodesmium theibautii* was present in all the inshore samples collected from around Nicobar group of Islands. The Silicoflagellates and Coccolithophores were totally absent in these samples.

During the 31st cruise of VITYAZ, Sukhanova (1962) also found that the Indian Ocean region near Nicobar Islands, the phytoplankton component dominated by dinoflagellates. This feature reveals a basic 'Indo-Oceanic Complex' as suggested by Sukhanova.

During the 33rd cruise of VITYAZ, Zernova (1962) made a study of the quantitative distribution of the phytoplankton of the Bay of Bengal and Andaman Sea and she found that the total quantity of phytoplankton was high (6100 cells/m^3) in the Andaman Sea compared to the low values (1200 cells/m^3) of Arabian Sea. However, Zernova and Ivanov (1964) found in the Bay of Bengal, phytoplankton number did not exceed 500 cells/m^3. According to them, a higher phytoplankton number was found south-west of the Nicobar Islands and in the Andaman Sea, the phytoplankton number was considerably more than 5000 cells/m^3.

The chlorophyll values also indicate a high seasonal variability in the Andaman Sea. The values reported in the IIOE Atlas (Krey and Babenerd, 1976) is considerably higher during the period November-April. A zone of higher phytoplankton production near the Nicobar Islands is evident reaching upto 300-500 mg/m^3. Values ranging between 200-300 mg/m^3 have also been observed near Car Nicobar, Little Andaman and part of South Andamans.

This high density of chlorophyll is observed in the Andaman Sea even upto 75 m depth in certain regions. But in May-October period, the values are considerably less. This is in contrast to the occurrence of chlorophyll in the Arabian Sea where in general a higher concentration is observed during the period May-October.

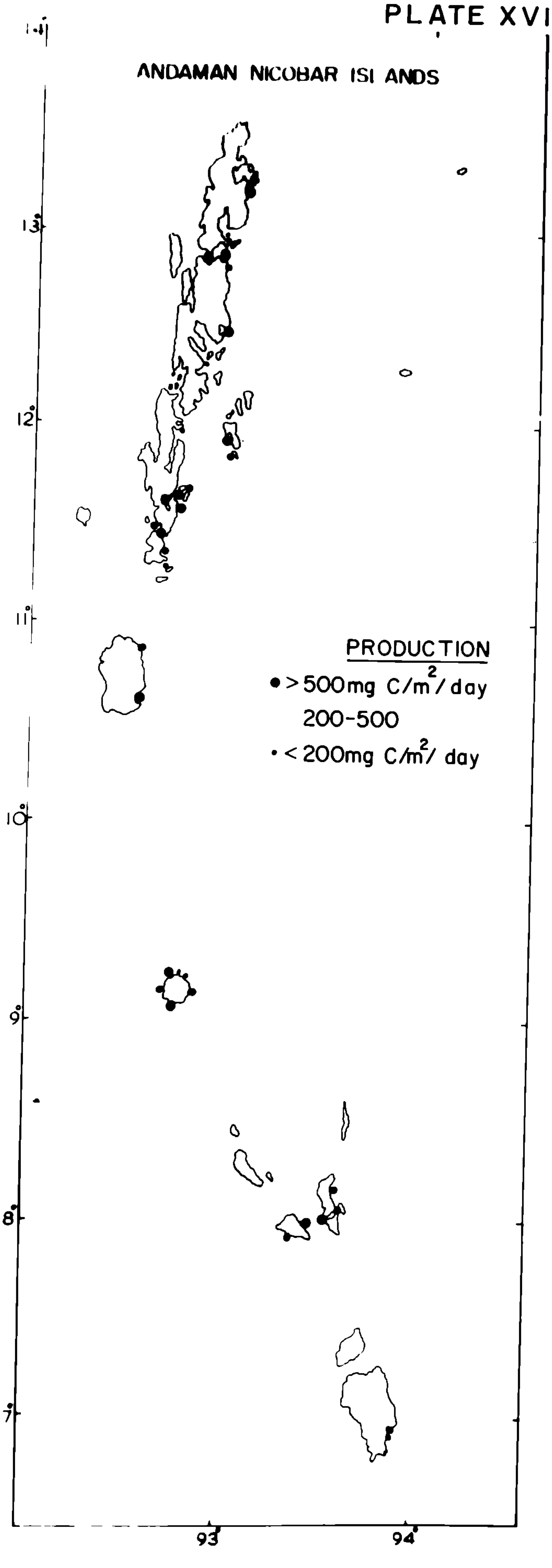
Primary Production:

The primary production measurements by ^{14}C technique were carried out at 44 stations in the Andaman Nicobar Islands in the areas stretching from Diglipur in the north to Campbell Bay in the south. Of these 28 stations are from typical coastal waters and 16 stations from the mouth of the mangrove areas. The results are presented in the Table - 30., which indicate that there is considerable variation in unit production (mgC/m^3/day) as well as the production per unit area (gC/m^2/day) which has been graphically represented in the Pl. XVI. The daily production ranged from 0.07 to 3.6 gC/m^2/day. The main areas where production rate exceeds 0.5 - 1 gC/m^2/day are Mayabander, Rangat, Chidiatop, Havelock, Carbyn's Cove, Navy Bay, Phoenix Bay, Shoal Bay regions of Andamans; Hut Bay of Little Andamans, Kimois Bay and Sawai Bay of Car Nicobar, East Bay of Katchal and Spiteful Bay of Nancowry. The depth of the euphotic zone ranges to 30-50 m depending on the depth of the area. This is in contrast to the open ocean area of Andaman Sea where the euphotic zone extends from 75-90 m.

PLATE - XVI

General level of primary production in the coastal waters of Andaman-Nicobar Islands.

PLATE XVI


ANDAMAN NICOBAR ISLANDS
PRODUCTION
> 500mg C/m²/ day
200-500
< 200mg C/m²/ day
14°
13°
12°
11°
10°
9°
8°
7°
93°
94°

It has been generally observed that as the continental shelf edges of the Oceans are approached, the standing crop will increase. The same increase is presumed to exist with nearness to island shores. This hypothesis has been tested by Doty and Oguri (1965) in the Hawain waters which has been termed as 'Island Mass Effect'. These authors noted a consistent increase in carbon fixation as shore is approached. This phenomenon could be applicable in the case of Andaman Sea as well. The values obtained by GALATHEA, IIOE and other Expeditions show that the deeper water stations between 1000-3000 m have on the whole a production rate of 0.1 to 0.2 gC/m^2/day where as the shallow water stations, both in the continental shelf and near island masses have a production rate exceeding 0.5 gC/m^2/day. Doty and Oguri (1958) have attributed this increase in production due to run off from high islands and perculation from low islands. It is also postulated (Doty, 1954) that the benthic algae as well as the endozoic species and those found in the reef regions accumulate inorganic nutrients from the passing waters which are relatively poor in nutrients which will in turn be leached out, thus making available to planktonic algae. Thus, there is overwhelming evidence to conclude that as island masses are approached, productivity increases. The higher values noted on the eastern side of the Andaman Islands by Nair et al. (1968) as compared to the values observed from offshore waters could be due to this process of local enrichment.

The mangrove areas in general contrast with the mangrove swamps of the mainland are found to be highly productive. The reason for the high production may perhaps be to due to the greater quantity of detritus and oxygen content besides the highly enriched water which stimulates the planktonic algae to multiply very rapidly. Of course some of the areas are found to be less productive. This low production may be attributed to the less availability of light and greater quantity of detritus reducing the oxygen content.

Reef areas of the Andamans have an annual production of 1200 gC/m^2 (Nair and Pillai, 1972) and the respiratory requirements of the organisms in the reef far exceeds production and hence the reef in the south Andamans appears at least to be non-autotropic. The efficiency of gross production is also low here because of the comparative sparseness of phytoplankton and paucity of benthic algae. Further they stated that the reefs of the Andaman Sea especially of the Nicobar Islands are comparatively high due to luxuriant growth of corals, it lends support to the contention raised by Gorden and Kelly (1962) that there is considerable variability between different coral reefs at the level of total community metabolism.

For determining the potential for mariculture activities it may be more advantageous to assess the potential productivity of the surface waters for the different seasons. It would appear that the potential productivity of the surface waters is distinctly higher during the period May-October and the integrated values of daily production of the euphotic layer is also higher during the corresponding period. However, all data indicate that though the waters of the Nicobar Islands seem to be highly productive, larger part of the production is consumed by the luxurient reef fauna leaving very little surplus for the ecosystem as a whole. Therefore, in certain regions of Andamans, it is likely that the potential productivity of the ambient waters may not be available to the ecosystem as a whole. The possible areas for mariculture practices as indicated by higher production and lower consumption would be Mayabander, Rengat, Havelock, Chidiatop, Carbyn's Cove, Navy Bay, Pheenix Bay and Shoal Bay regions of Andamans; Hut Bay of Little Andamns, Kimois and Sawai Bay of Car Nicobar, East Bay of Katchal and Spiteful Bay of Nancowry.

Table - 30

Primary production values of Andaman Nicobar Islands

	mgC/m^3/day	gC/m^2/day	Nature of ecosystem
ANDAMAN ISLANDS			
1. Mayabander - North		2.7	Rocky and sandy
Middle channel		2.3	Sandy and marshy
Oyster point		0.57	Rocky area
Mayabander jetty		0.16	Boulders with sand creek
2. Diglipur (surface)	169		Muddy area
3. Tabke Islands		0.86	Rocky shore
4. Rengat (surface)	923		Mangrove, fringed shallow area
Mangrove mouth		0.32	Marshy area
Jetty		0.61	Marshy and sandy
5. Havelock		1.47	Rocky inter-tidal area
6. Carbyn's Cove		3.60	Muddy, flat with creeks
7. Sesostris Bay		0.7	Mangrove fringed sandy area
8. Rose Island		0.23	Fouled reef area
9. North Bay		0.18	Reef area
10. Chidiatop		0.57	Sandy reef area
11. Rutland Island		0.14	Rocky area, deep water
12. Mcpherson Straight		0.85	Deep water area
13. North Chinque		0.07	Sandy shore
14. Phoenix Bay		2.09	Slushy mangrove shore
15. Navy Bay		2.09	Muddy shallow area

	mgC/m^3/day	gC/m^2/day	Nature of ecosystem
16. Shoal Bay		0.57	Muddy exterior deep area
17. Murma-nulla(Surface)	375		Sand stone flat area
18. Wandoor	470		Slushy mangrove area
19. South Point (CMFRI)	1040		Rocky reef area
20. Little Andaman:			
Hut Bay		0.54	Sandy area
Butler Bay		0.48	Rocky inter-tidal sandy area
NICOBAR ISLANDS			
1. Car Nicobar:			
Kimois Backwater		0.51	Marshy mangrove area
Sawai Bay		1.02	Sandy area
Hog Point		1.63	Sandy area
T-Top jetty	140		Sandy-rocky area
Passa	1370		Sandy area
Arong	1010		Rocky, rough area
Malacca	230		Reef area
2. Katchal:			
East Bay		2.35	Sandy reef area
West Bay	340		Rocky rough area
3. Kamorta:			
Jetty		0.22	Marshy reef area
Kakana		0.27	Sandy reef area
Kamorta-Trinkat channel	280		Deep water area

	$mgC/m^3/day$	$gC/m^2/day$	Nature of ecosystem
4. Nancowry:			
Champin		0.39	Sandy calm area
Spiteful Bay		0.56	Calm, magrove fringed area
Mangrove area	280		Marshy area
5. Trinkat Island	230		Reef area
6. Great Nicobar:			
Vijayanagar	980		Sandy reef area
Campbell Bay		0.17	Sandy area with dead corals.

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IX. STUDIES ON PHYTOPLANKTON CULTURE

Large scale culturing of unicellular algae was viewed with great enthusiasm as an alternative method for producing single cell protein (SCP) in the fifties. But in the late sixties this enthusiasm diminished when it seemed that the process was uneconomical because of a combination of technical problems, especially the recovery of the algal product and its subsequent conversion as a human food supplement. Quite recently there has been renewed interest in producing single cell protein by mass culturing unicellular algae such as diatoms and green nannoplankters for feeding the secondary producers and subsequent to the crustacean and fish larvae. Several publications (Fogg, 1965; Provosoli *et al*. 1957; Guillard, 1975; Guillard and Ryther, 1962; Goldman and Ryther, 1976) provide excellent background information especially on the modern techniques employed for the mass production of the microscopic algae.

It is an established fact that the success of any hatchery operation will depend mainly on the availability of the primary source of natural food, the phytoplankton. The general practice of rearing the larvae of crustaceans is on mixed diets of phytoplankton as the primary food followed by zooplankters. The maintenance and supply of the required species at appropriate period form a major problem facing the algal culturists. Research was directed to this aspect of study as well as to the solution of other key problems such as (i) preparation of the suitable culture media and isolation of the required species, (ii) large scale culture of phytoplankters under controlled conditions of light, temperature and aeration and their constant supply in different phases of growth, (iii) developing viable methods for intensive culture, its maintenance, preservation and harvest during its optimum and peak densities and (iv) developing economical feeds which will provide nutritional needs of the crustacean and fish larvae.

Culture media:

Since the phytoplankton require nitrates and phosphates in the water roughly in a ratio 16:1 (N:P) by atom for its normal growth and reproduction, the culture media used should have sufficient quantities of these elements besides other growth promoting substances including amino acids and vitamins. Hence, the media used in the laboratory has to provide nutrients for the algae for their rapid growth and multiplication and thereby mass production. The important culture media used in the laboratory are:

1. Schreiber's medium (Schreiber, 1925)
2. Miquel's medium (Miquel, 1892)
3. 'f' medium (Guillard and Ryther, 1962)
4. Conway medium or Walne's medium (Walne, 1974)
5. TMRL (Tung-Kong Marine Research Laboratory) medium
6. PM (Pantastico's medium) (Pantastico, 1977)

Besides the above mentioned media, commercial fertilizers are also used in the outdoor tanks for the large scale culture of phytoplankters.

Procedure for the isolation and laboratory culture:

Phytoplankton samples were collected either by using bolting nylon net (Nos. 20-25) or by direct centrifuging of the water samples. The desired species were isolated by the micro-capillary pipetting technique or by using the phototactic movement of the particular species. However, the agar plating method is the most advanced one which gives good results.

After the isolation, the specimens are kept in culture tubes, having the enriched medium for 4-5 days. Within this time the algae begin to multiply and on examination under the microscope that no contamination has taken place, the sample is transferred to a one litre flask in which sufficient aeration is possible. Within 3-4 days, the alga completes its exponential phase of growth and attains its peak density and this can be used as a starter for the 20 l glass carbuoys, 200 l vinyl tanks and later one ton tanks for its mass production.

Mass culture of different species:

1. Chaetoceros calcitrans

This centric diatom is widely used as one of the best food for feeding the crustacean larvae, especially species of Penaeus. Rapid multiplication within short period is a characteristic feature of this diatom. Media like 'f', TMRL, PM and Conway are the most suitable for its mass production. This diatom can tolerate a wide range of salinity from 15-35‰. From an initial inoculum of $20x10^3$ cells/ml, within 5-6 days about 5-6 million cells/ml could be produced. Feeding experiments using P. monodon larvae revealed 66% and P. indicus 92% survival rate when compared to other algal feeds.

2. *Skeletonema costatum*

This colonial diatom was widely used as one of the preferred food for feeding the prawn larvae especially during the initial stages of growth. Rapid multiplication within limited time is the characteristic feature of this diatom too. Media like TMRL, PM and 'f' have been found to give good results. From an initial inoculum of $65x10^3$ cells/ml, within 4-5 days, about 5 million cells/ml could be produced. Feeding experiments conducted in the laboratory indicated that 47% survival rate for the *Penaeus* sp. from zoea to post larval stages.

3. *Phaeodactylum tricornutum*

This pinnate diatom is a Japanese strain, perhaps a hybrid strain of *Nitzschia closterium* f. *minutissima*. This is also widely used as a good food for the crustacean larvae. Media like 'f', TMRL, PM, Schreiber and Miquel's give satisfactory results. Peak density could be observed with about 8 million cells/ml from an initial inoculum of $65x10^3$ cells/ml and maximum growth is attained in 4-5 days.

During high concentration, high nitrate levels are noticed in the culture due to liberation of extracellular products (Goldman and Ryther, 1976). Experiments indicated that survival rate of prawn larvae will be very high (78%) if this diatom is used in the early stages.

4. Tetraselmis spp.

For feeding the mysis stage of prawn larvae, Tetraselmis spp. are used in addition to rotifers, brine shrimp and other zooplankters. Three species are commonly used, T. gracilis, T. chuii and T. tetrahele, of which T. chuii is slightly bigger than the other two. Conway, 'f' and Miquel's are the suitable media for its mass production. From an initial inoculum of 65×10^3 cells/ml, within 4-5 days a peak density of 2 - 2.5 million cells/ml could be produced. Unlike diatoms, Tetraselmis could not be stored for longer periods in the culture tanks since their density normally decline within two weeks time. Feeding experiments conducted in the laboratory using this flagellate as feed indicated 49% survival rate for P. monodon larvae.

5. Chlorella spp.

These are marine green nannoplankters used mainly for feeding the rotifers, but not for feeding the crustacean larvae. Two species are available, C. marina and C. virginica. Conway and Miquel's media are the suitable ones for the indoor mass culture and commercial fertilizers for large scale production in outdoor tanks. From an initial inoculum of 20×10^3 cells/ml, within 4-5 days about 8-10 million cells/ml could be produced. Though _Chlorella_ contain a good amount of protein (47%), the survival rate of prawn larvae is very poor when it is used as a feed.

6. _Isochrysis galbana_

This chrysophycean flagellate was tried for feeding the prawn larvae as a substitute to _Tetraselmis_. But when compared to _Tetraselmis_, the survival rate of larvae is very poor. However, this can be given as a feed for rotifers, copepods, mussels and oysters. Media like 'f', conway and PM are better for the mass culture of this flagellate. From an initial inoculum of 20×10^3 cells/ml, within 6-7 days, 8-10 million cells/ml could be produced. Feeding experiments showed that only 30% survival rate for _P. monodon_ larvae as compared to diatoms like _Skeletonema_ and _Chaetoceros_.

Mass culture of phytoplankton in open tanks

1. _Diatoms_

Basically the mass culture of diatoms is similar to the indoor culture techniques employed. But in the open systems, instead of the different culture media, commercial fertilizers are used for their mass production. The media for the mass culture of diatoms consists of the following chemicals:

Urea 46		100 mg/l
Agrimin	..	1 "
$FeCl_3$		2 "
16-20-0	..	5 "
Na_2SiO_3		2 "
K_2HPO_4	..	5 "

The inoculum for the mass production will be the same from the laboratory culture. 200 l vinyl tank culture is pumped to bigger tanks constructed near a hatchery. After 3 days of growth in sun light under strong aeration, the diatoms could be harvested with a peak density of 2-3 million cells/ml in its exponential phase of growth. The diatoms can be concentrated and washed in a fine sand filter before pumping into the larval rearing tanks.

2. *Tetraselmis* spp.

Since *Tetraselmis* spp. is used as an effective algal feed for rearing the larvae of prawns, the mass production of this flagellate assumes significance. The culture techniques employed for the mass production of this flagellates are similar to those used for the diatoms, but there is no need to add sodium silicate to the above culture medium. Unlike the diatoms, this flagellate could not be concentrated by sand filtration, since it passes through the sand particles.

3. *Chlorella* spp.

The inoculum for *Chlorella* mass production is the same culture from the laboratory with a peak density of one million cells/ml and this was added to an open culture tank already with filtered seawater. The fertilizers used for the open culture in the bigger tanks were:

Urea 46		10 mg/l
21-0-0	..	100 "
16-20-0		10 "

As the Chlorella cells multiply in number, water is gradually added and approprite amounts of fertilizers are added. A stock of Chlorella can last for a considerable period, provided there is good water management and lack of contamination. Chlorella mass culture is more suitable for feeding the rotifers.

Viability Experiments with Chaetoceros calcitrans

Making use of 5 culture media already prepared in the laboratory such as 'f', Conway, TMRL, PM and Miquel's, an experiment was conducted using *Chaetoceros calcitrans* to study the viability, growth rate and differentiation, effect of removal of certain elements and the peak density of this diatom in various media. Enrichment experiments using different media was also carried out in the laboratory to determine which of the nutrients is particularly limiting the growth of the diatom.

Growth of the diatom in 'f' medium

Three one litre flasks were used for this experiment. One served as control and in the second flask, except silicate all other ingradients were added while in the 3rd the nutrients were added eliminating the vitamins. An initial inoculum of 5 ml having 516×10^3 cells/ml of Chaetoceros was added to each flask. The experiment was continued upto 8 days with sufficient light (20 k lux) and aeration throughout. The control reached its peak density on 4-6th day, the number of cells being 6.7×10^5 cells/ml and gradually entered the stationary and death phases on 8th day. When compared to control, the culture devoid of silicate showed an early development on 2-3rd day but further growth was not noticed in subsequent days. Whereas, the culture without vitamins showed no growth (Pl. XVII, fig. A). This reveals that the diatom could not thrive well in 'f' medium without vitamins.

Growth of the diatom in Conway medium

Similar set up was arranged as in 'f' medium. Here the experiment was conducted using different proportions of the medium and the growth rate was noted. Usual procedure is to add 1 ml of the Conway medium to 1 litre of seawater. To the second flask is added 2 ml/l of the prepared medium while to the third only ½ ml/l is added. The control showed peak density of 55×10^4 cells/ml on 2nd day after inoculation and no further growth was observed. In the second flask with double dose of medium, 28×10^4 cells/ml was observed on the second day. The 3rd flask with half the quantity of medium showed no growth (Pl. XVII, fig. B). As far as Chaetoceros culture

PLATE - XVII

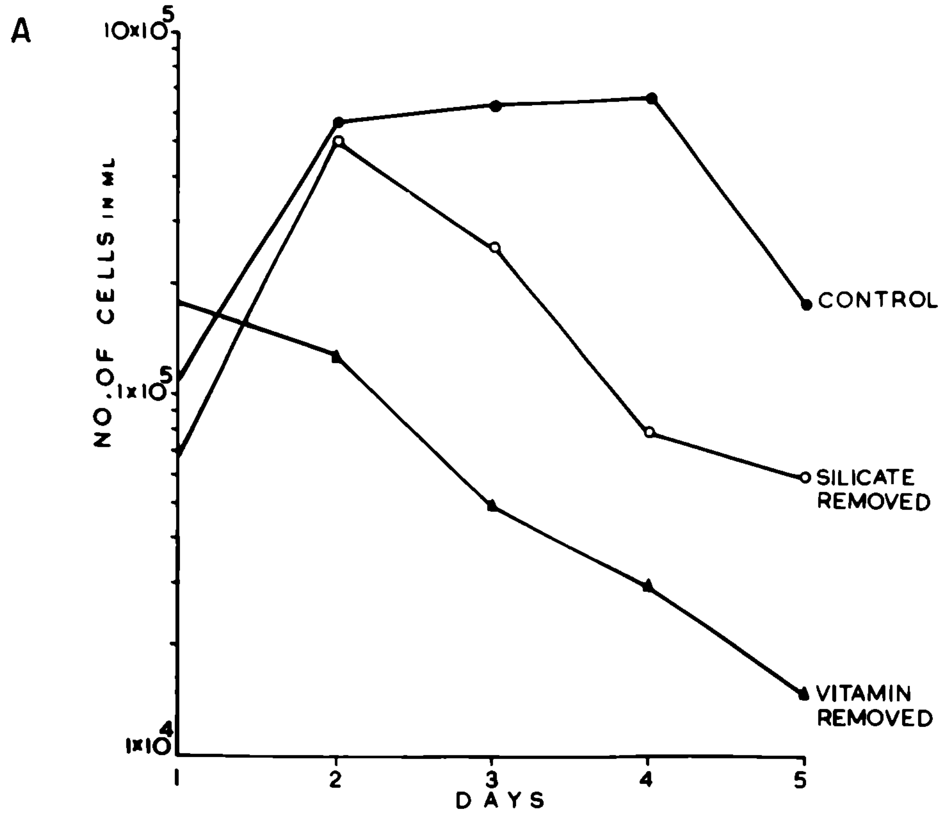
Figs. A-B. Fig. A, Viability experiments with <u>Chaetoceros</u> <u>calcitrans</u> in different culture media. Growth of the diatom in 'f' medium under varying concentration of the constituents.

Fig. B, Growth of the diatom in Conway medium under varying concentration of the constituents.

PLATE XVII

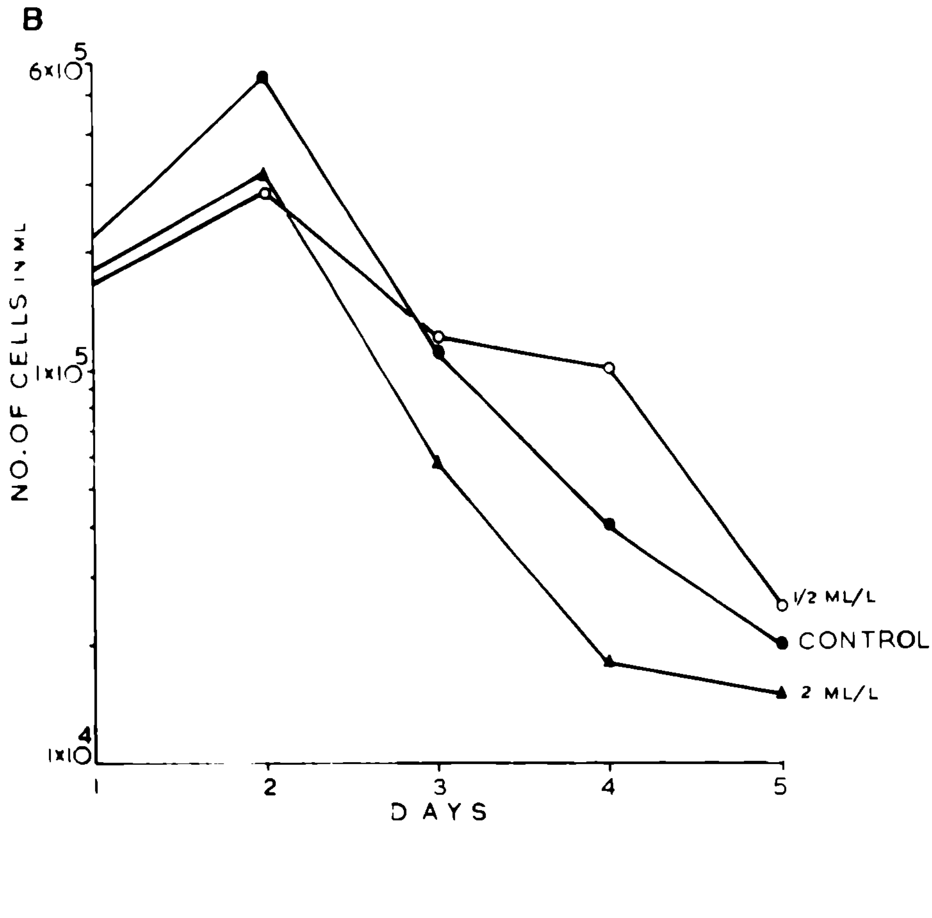
CHAETOCEROS CALCITRANS

IN 'f' MEDIUM



CHAETOCEROS CALCITRANS

IN CONWAY



is concerned, Conway medium irrespective of its concentration is not suitable for mass culture.

Growth of the diatom in TMRL medium

In this experiment, silicate was removed from the second flask and ferric chloride from the 3rd. The control showed maximum growth on 2nd day. However, it did not show good growth as in the case of 'f' medium. In the second flask where the silicate was eliminated, decreased growth was observed from 2nd day onwards and gradually entered the declining phase on subsequent days. In the third where ferric chloride was eliminated, no significant growth was observed revealing that iron is a limiting factor for the growth of the diatom (Pl. XVIII, fig. A).

Growth of the diatom in PM

In this experiment, silicate was eliminated in the second flask and vitamins were eliminated in the third. The control flask showed maximum growth on the 3rd day (3.4×10^6 cells/ml) and decreasing gradually in subsequent days. Silicate and vitamins proved limiting factors for the diatom if PM medium is used for the culture (Pl. XVIII, fig. B). For the mass culture of this diatom, PM is an ideal medium.

Growth of the diatom in Miquel's medium

The normal procedure for Miquel's medium is to add 0.55 ml of A and 0.5 ml of B to one litre of filtered seawater. In this experiment, the first flask

PLATE - XVIII

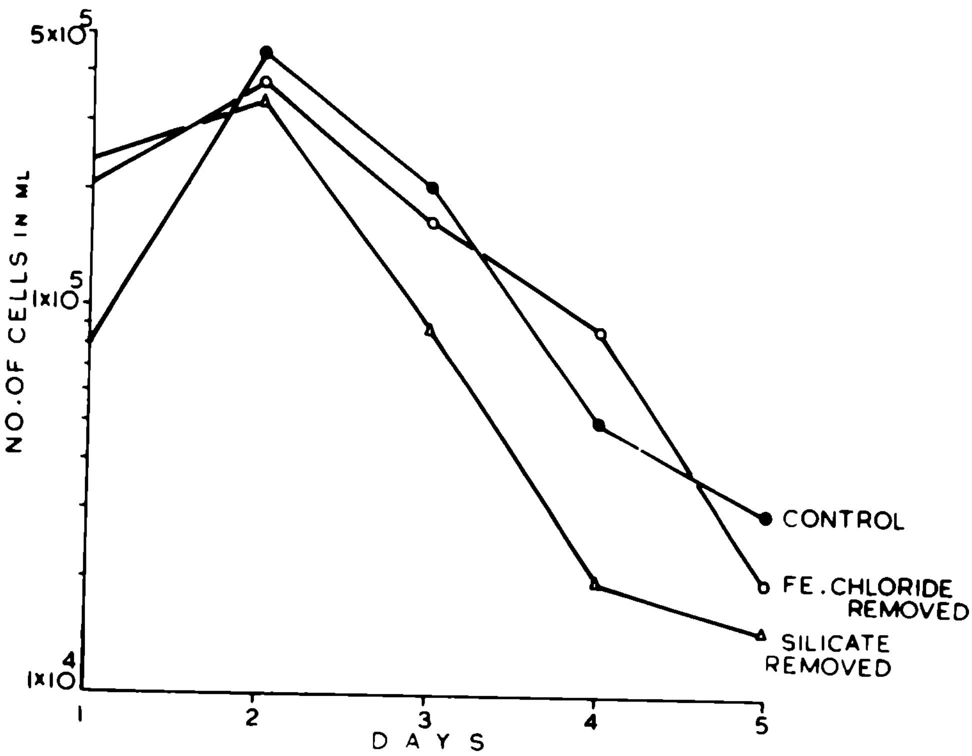
Figs. A-B. Fig. A, Growth of *Chaetoceros calcitrans* in TMRL medium under varying concentration of the constituents.

Fig. B, Growth of the diatom in Pantastico's medium (PM) under varying concentration of the constituents.

PLATE XVIII

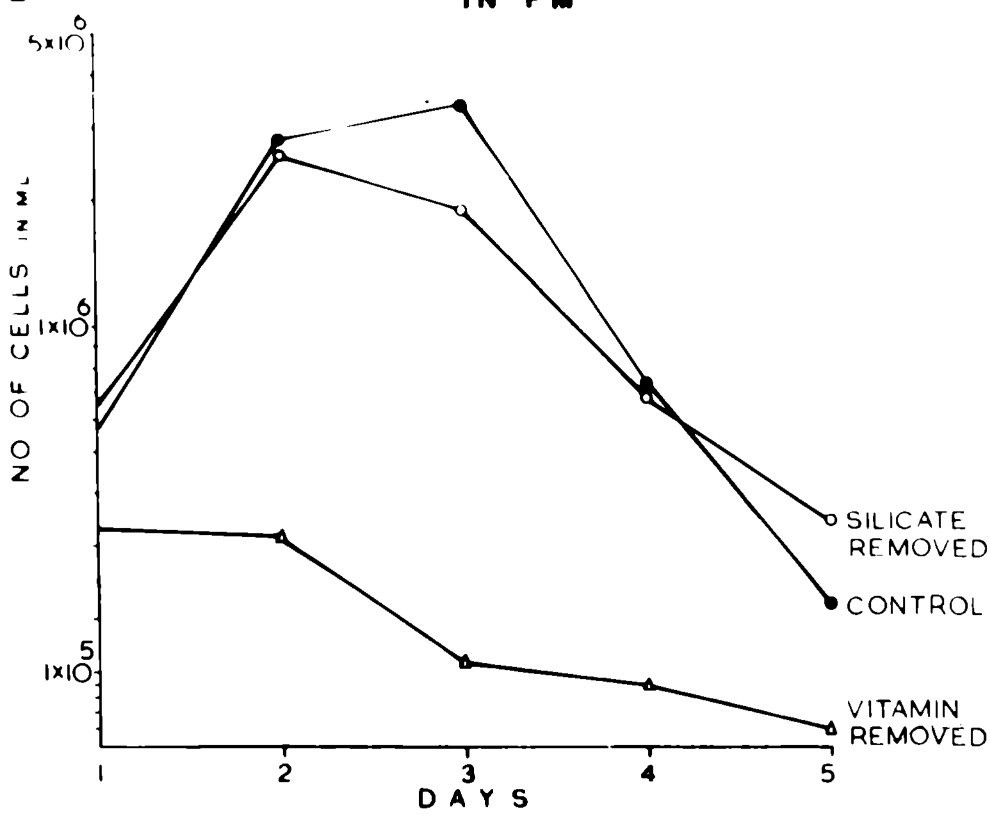
CHAETOCEROS CALCITRANS IN TMRL

A



CHAETOCEROS CALCITRANS IN PM

B



served as control and in the second silicate was added extra besides 2 ml of A and 1 ml of B and in the third 1 ml of A and B each were added. The control and the one with the silicate showed good growth, while the third did not show any sustained development, as the double dose of the medium might have inhibited the growth of the diatom (Pl. XIX, fig. A). This experiment confirms the requirement of silicate in the media for the building up of cell walls of diatoms in the initial phase of growth.

<u>Comaparison of growth in different media</u>

Another set of experiment was conducted to test the variability and differential growth rate of 3 species of micro-algae (<u>Nitzschia closterium</u>, <u>Tetraselmis chuii</u> and <u>Isochrysis galbana</u>) using 4 culture media ('f', Conway, TMRL and PM).

Growth of <u>Nitzschia closterium</u>

Four flasks with four culture media in standard proportions were used. From an initial inoculum of 12.76×10^6 cells/ml of this pinnate diatom culture, 5 ml was added to each flask under strong aeration and sufficient light. The growth was noted daily at 10 a.m, using the Heamocytometer counting method. Even from second day onwards a significant rate of growth was noted in the flask where Conway, 'f' and PM were added. However, the PM indicated rapid cell multiplication followed by Conway and 'f' and in TMRL slow

PLATE - XIX

Figs. A-B. Fig. A, Growth of *Chaetoceros calcitrans* in Miquel's medium under varying concentrations of the constituents.

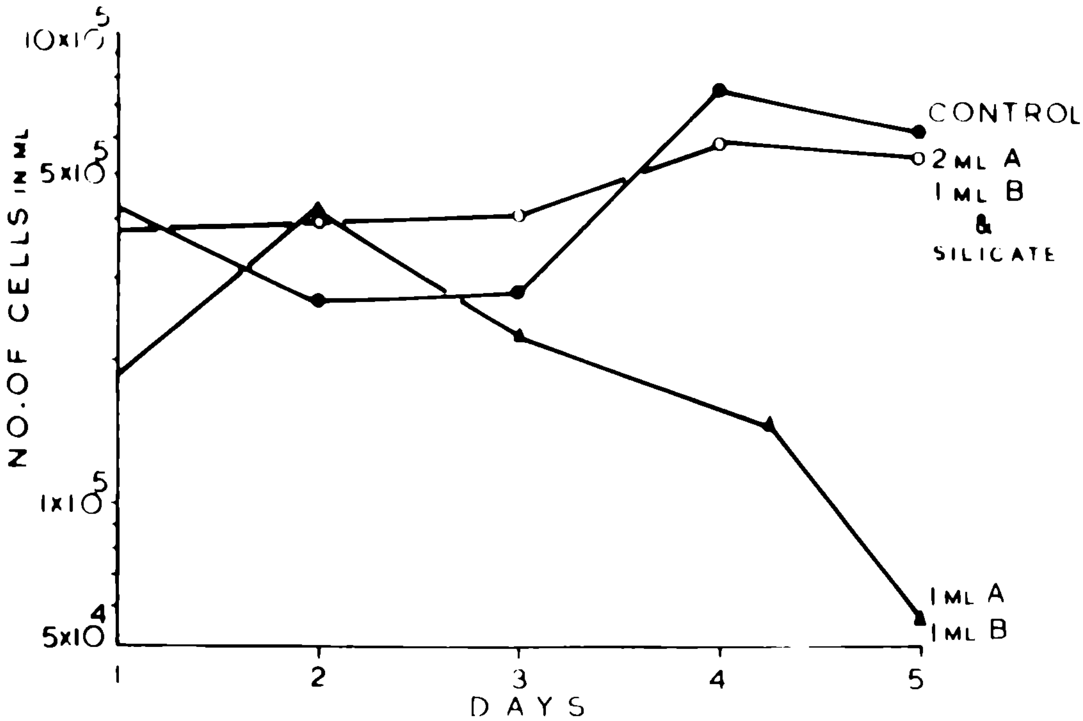
Fig. B, Growth of the diatom *Nitzschia closterium* in four culture media.

PLATE XIX

CHAETOCEROS CALCITRANS

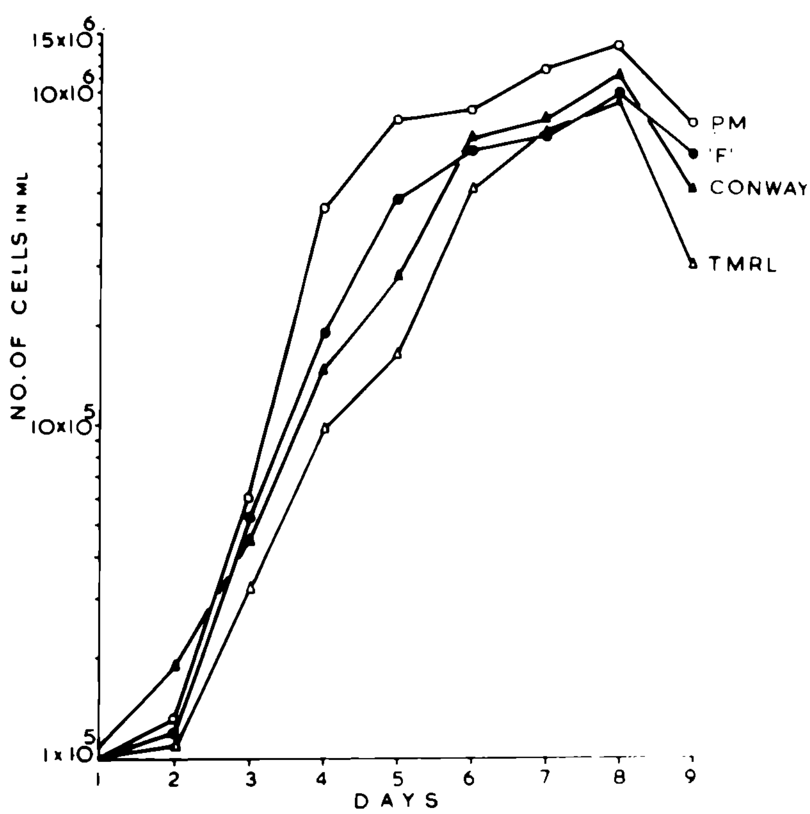
IN MIQUEL'S MEDIUM

A



NITZSCHIA CLOSTERIUM

B



growth rate was observed. The peak density of 13-14 million cells/ml was noted on the 8th day in PM and 11 million cells/ml in Conway and 10 million cells/ml in 'f' medium. Even upto 9th day the diatom was found to thrive well in the PM medium (Pl. XIX, fig. B), then only entered the declining phase.

Growth of Tetraselmis chuii

As in the previous experiment, 4 flasks were set up by adding the four culture media to test the viability of this flagellate in controlled conditions. Five ml of an initial inoculum of 19.2 x 10^5 cells/ml of T. chuii was added to each flask and the cell counts were taken daily. Initially all the media showed gradual growth rate and from 3rd day onwards, TMRL, 'f' and Conway showed significant increase in the total number of cells. A peak density of 1.0 - 1.8 million cells/ml was noted in Conway on 7th day. In PM after 4th day cells entered the declining phase although reached a peak (1.3 million cells/ml) on 4th day. From 8th day onwards the cells grown in all the media were found to enter the declining phase (Pl. XX, fig. A).

Growth of Isochrysis galbana

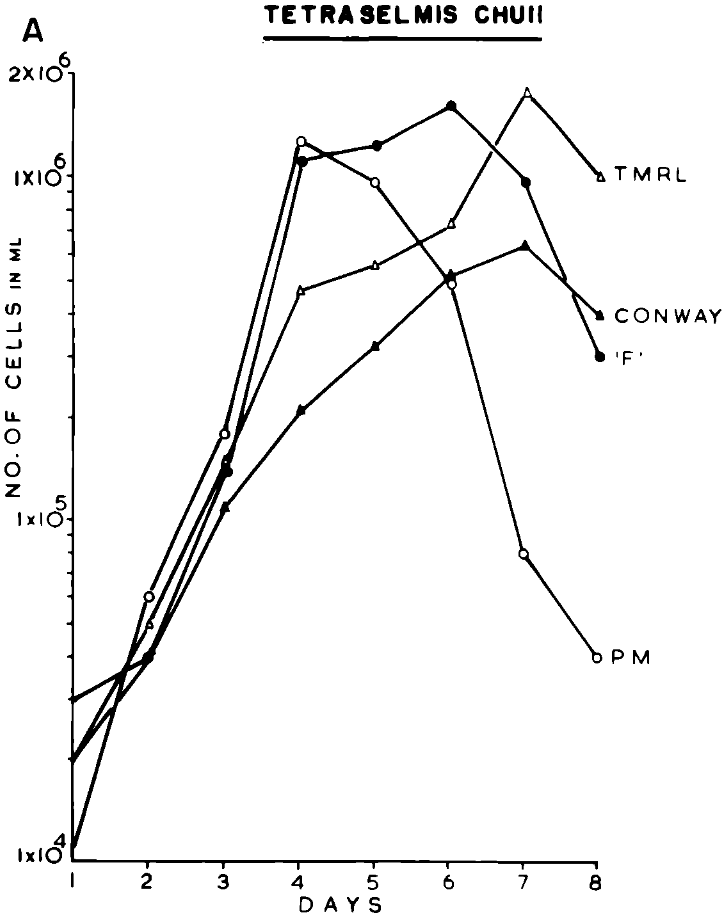
Four media were used in four flasks and an initial inoculum of 5 ml having 19.2 x 10^5 cells/ml of I. galbana was added to each flask. As compared to Nitzschia and Tetraselmis, the growth rate was very slow in all the flasks. From 3rd day onwards a significant increase in the

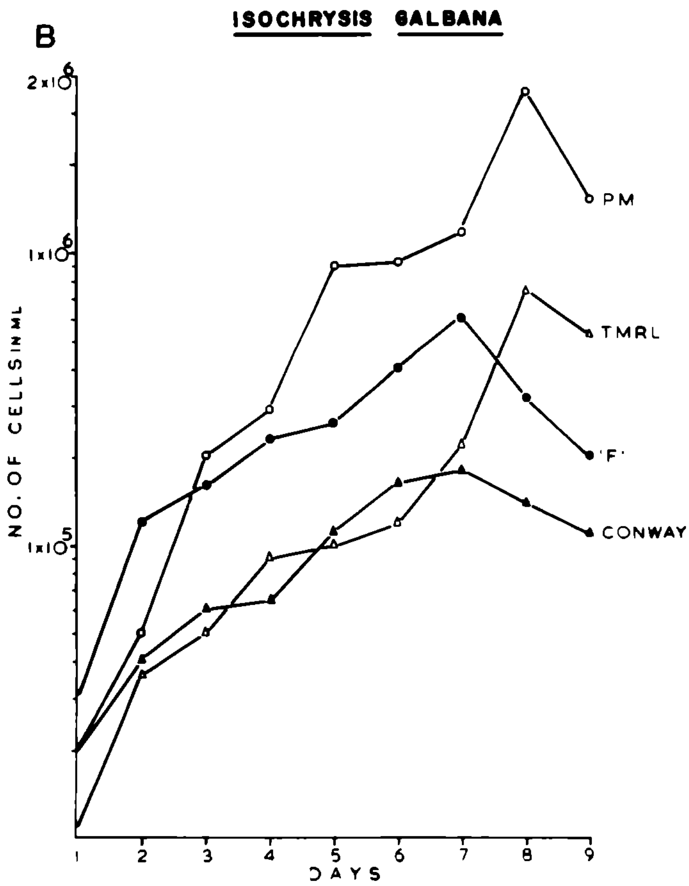
PLATE - XX

Figs. A-B. Fig. A, Growth of the flagellate *Tetraselmis chuii* in four culture media.

Fig. B, Growth of *Isochrysis galbana* in four culture media.

PLATE XX


A
TETRASELMIS CHUII
2x10^6
1x10^6
1x10^5
1x10^4
NO. OF CELLS IN ML
1
2
3
4
5
6
7
8
DAYS
TMRL
CONWAY
'F'
PM


B
ISOCHRYSIS GALBANA
2x10^6
1x10^6
1x10^5
NO. OF CELLS IN ML
1
2
3
4
5
6
7
8
9
DAYS
PM
TMRL
'F'
CONWAY

growth rate was noted in 'f' and PM media. Though initially TMRL showed a slow growth and on 8th day about 7.2×10^5 cells/ml were noted. However, PM showed fluctuation in growth rate reaching the peak on 8th day with 3.52×10^6 cells/ml (Pl. XX, fig. B).

From the laboratory culture as starter for one ton or bigger tank culture, media like TMRL and PM are very useful as compared to other media since all the ingredients are easily available at economical price.

For the mass production of diatoms, PM was found to be suitable when compared with other media especially those enriched with vitamins and EDTA. The results of these experiments indicate the possible limiting factors which control the growth rate and point out the variability among species.

Preservation and harvest of algae

As already stated the maintenance of pure culture of algae and constant supply of the same whenever required is a problem facing the phycologists especially during adverse weather conditions. In this case, the preservation of the algae either by freezing or by sun drying is important in the sense that during scarcity of the feed, the rearing operations could be successfully maintained. Moreover, the frozen algae can be kept for a long time and will be viable for conducting experiments and for mass production. Sun dried algae could be used directly as feed, but viability test is impossible.

This method of preservation is more advantageous since dried algae can be stored for a long time in a vaccum bottle. The process of harvesting should be done at the peak density period or in the exponential phase of growth of the algae.

Harvesting of the algae is done by simple chemical flocculation technique either by adding alum, lime or by the adjustment of pH using sodium hydroxide. Usually the addition of alum or lime will not give satisfactory results, but the pH adjustment with sodium hydroxide is the advanced technique used in the laboratory. After determining the pH of the culture, the dosage of sodium hydroxide required to form floc of the algae is estimated. After adding sufficient quantity of sodium hydroxide, vigorous mixing of the culture should be done for a few minutes. Within one hour, the algae will settle down. After settling, the clear water decanted and the settled precipitate is collected and neutralised by adding HCl to regain its original pH. The harvested algae are thus ready for preservation either by freezing or by sun drying. Before freezing at $0^{o}C$, protectants like glycerol or Dimethyl sulfoxide, 1-2 ml may be added and kept in plastic bags.

Simple freezing was found to be a suitable method for preserving the diatom Chaetoceros for a period of 2 months without protectants. Viability tests of the algae reveal that Chaetoceros calcitrans remain viable upto six months, Tetraselmis chuii upto 3 months with protectants and Skeletonema costatum for two months. The techniques of preservation is not effective in the case of Isochrysis galbana.

Feeding the larvae using the preserved materials gives good results. The rate of feeding is 0.25 to 1.0 mg/ larvae/day for the sun dried ones. Using the sun dried algae such as Chaetoceros, 65% survival rate was observed; for Tetraselmis 55%; while Isochrysis galbana showed only 25% survival rate. During preservation, the protein content is also maintained by the algae. Thus preserved samples of Chaetoceros have 25% of protein, Tetraselmis 47-49%, and Skeletonema retained 45-47% of protein.

Future scope

The development of mass culture of microscopic algae offers immense scope and should run concurrently with mariculture programmes. At the same time it offers a challenge for the phycologists. Considerable research would be needed for elucidating the problems of growth kinetics of different species and also the period of economically viable harvest. In the matter of waste recycling unicellular algae holds out much promise. Maximisation of solar energy utilization, under controlled conditions of temperature and aeration, development of viable methods for intensive culture, maintenance, preservation and harvest during the optimum and peak densities, formation of extra-cellular products and their significance are promising lines of investigation.

X. STUDIES ON PHYTO-TOXICITY

Though several authors have investigated the ecological and physiological effects of hydrocarbons and pesticides on fishes, crustaceans and molluscs (Mironov, 1968, 1969, 1970; Blumer, 1969; Carthy and Arthur, 1968; Mitchel _et al_. 1970), comparatively very little information is available on the effects on planktonic algae and thereby the basic productivity which initiates the food chain in the aquatic environment. The stimulation and retardation of algal growth and the inhibition of algal photosynthesis by petroleum hydrocarbons have been demonstrated by Mironov and Lanskaya (1967). Hutchinsen _et al_. (1972) have shown the effect of crude oil and selected components on fresh-water phytoplankton, both in the field and in the laboratory. Menzel _et al_. (1970) have observed that photosynthesis and growth in cultures of marine phytoplankton were affected by chlorinated hydrocarbons to varying extent ranging from complete insensitivity to toxicity. Furthermore, estimation of growth and photosynthesis at low oil concentration have also been noted both in pure algal cultures (Kauss and Hutchinsen, 1974) and in natural population of phytoplankton (Gordon and Prouse, 1973). The latter authors observed an enhancement of ^{14}C fixation in natural phytoplankton over a 24 hr incubation period in low concentrations ($<$ 50 ppb) of Venezuelen crude aqueous extract. Prouse _et al_. (1975) found that both crude oil and No.2 fuel oil, when added after the lag phase in concentrations similar to those reported in oil-contaminated waters, did not significantly affect cell division of Dunaliella sp. and Fragilaria sp. over a period of 24 hrs. Thus changes in concentrations or in the composition of oil or individual hydrocarbons during the course of experimental studies and of the growth recovery following the initial inhibition reported, have been ascribed solely to decreasing concentration and changing composition of hydrocarbons in the medium.

The studies conducted here primarily measure the effect of algal growth in terms of ^{14}C uptake on oil spills and various fractions of hydrocarbons. During the lst two decades, the ^{14}C technique has been extensively used to measure the marine photosynthesis by the planktonic algae and thereby to estimate the potential resources available in the water bodies. This technique, though very simple in the field application requires extreme care and precision in the preparation of the stock solution, standardization and computation which involve the estimation of the quantity of CO_2 available. If the stock solutions are made up with distilled water, it is essential that glass distilled water should be used. Stocks prepared during the earlier periods by the CSIRO, Australia, showed retardation in photosynthesis amounting to 50 to 60% (Prasad et al. 1964), which was finally traced to ordinary distilled water containing copper in extremely low concentrations (Steemann Nielsen and Wium Andersen, 1970). All these indicate that any sort of contamination can bring down the rate of photosynthesis of the phytoplankton. The sensitivity of this technique therefore, can be used as an index of pollutional stress brought about by industrial effluents, oil spills and run off pesticides from agricultural operations.

Unialgal cells, isolated from the backwater and inshore areas of Cochin and maintained in Miquel's medium were grown in mass cultures under natural or fluorescent light. Cultures were harvested during their exponential phase of growth and made into appropriate concentrations using fresh medium and were treated with varying concentrations of petroleum hydrocarbons and the photosynthetic response measured by radioactive isotope of carbon (^{14}C) at different periods. The uptake of ^{14}C as a percentage of the control was taken as an indication of the stimulatory or inhibitory effect of various pollutants.

It has been estimated that about 10 million tons of petroleum products reach the marine environment annually (Blumer, 1970). The rather large amount of oil that reaches the sea, causes ecological damages and the counter measures often enhance this. After major oil spills, the volatile fractions which are considered more toxic evaporate fast leaving the non-volatile fractions in the environment. Hence, it is necessary to have reliable information on the immediate effects of the volatile fractions and the long-term effects of non-volatile residues on the primary producers.

Results and Discussion

Toxicity of Hydrocarbons:

Experiments were conducted to study the different toxic levels of hydrocarbons on the natural populations of phytoplankton and on selected species of culture. Six hydrocarbons, both petroleum and low boiling aromatics such as crude oil, diesel oil, furnace oil, xylene, hexane and benzene have been used by direct application of 0.1 ml to 1 litre of the natural population of phytoplankton. Photosynthetic response was measured by ^{14}C uptake after 6 hours. It was found that the inhibition of photosynthesis was comparatively less in furnace oil as compared to other hydrocarbons (Pl. XXI, fig. A). Crude and diesel were found to be more toxic, but hexane, xylene and benzene, the low boiling aromatics showed highest toxicity. When aqueous extracts of these hydrocarbons in different proportions were added to the natural population, a decreased trend in relative photosynthesis was observed with slight variation (Pl. XXI, fig. B). With extract from crude oil, a distinct stimulatory effect was noticed with 25% and 50% concentrations, but there was inhibition of growth with higher concentrations. This indicates that the soluble fractions of crude oil at low concentrations seem to enhance the rate of photosynthesis. However, with diesel and furnace oil extracts, there was no stimulatory effect, but only

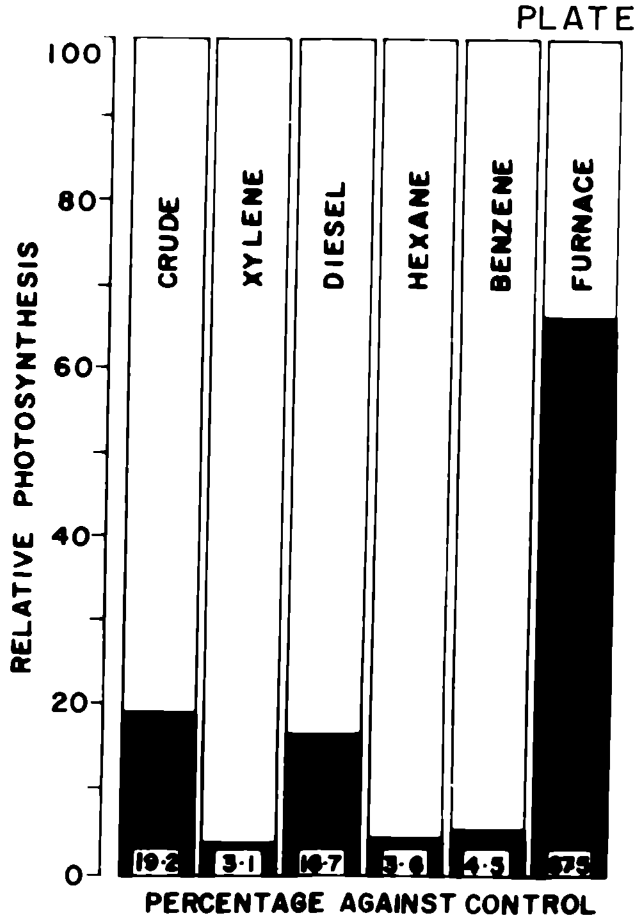
PLATE - XXI

Figs. A-B. Fig. A, Relative toxicity of 6 petroleum hydrocarbons as reflected by photosynthetic response in natural population of phytoplankton.

Fig. B, Effect of aqueous extracts of hydrocarbons on natural populations of phytoplankton.

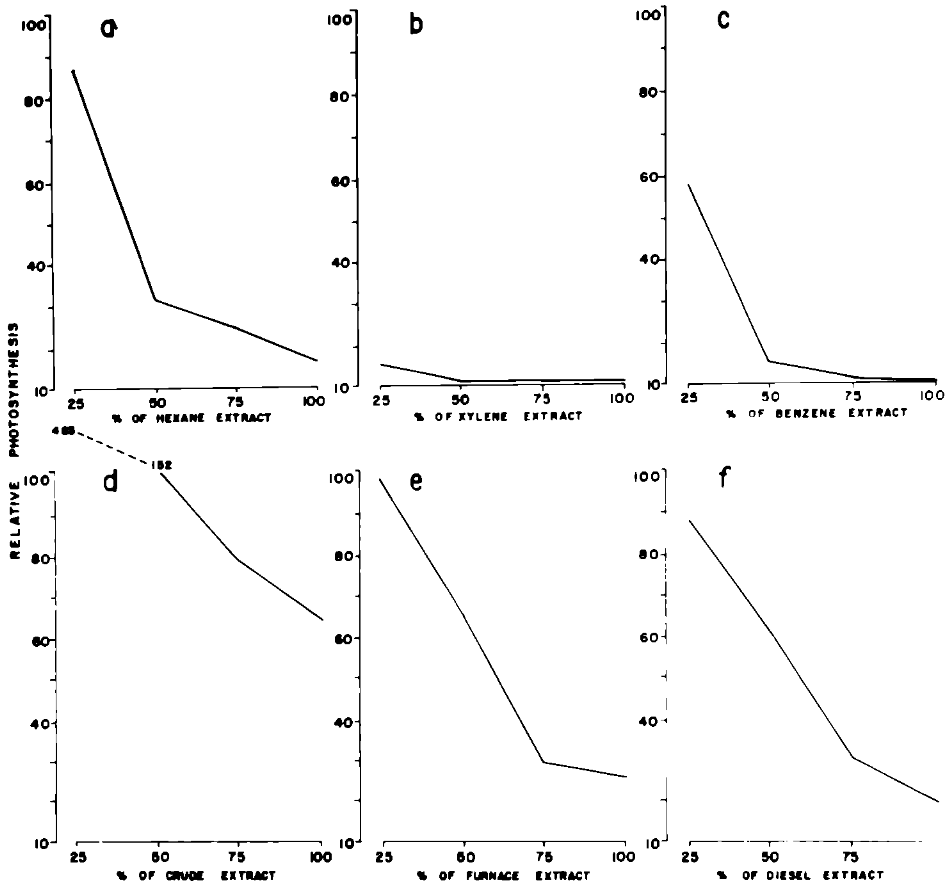
PLATE XXI

A



RELATIVE PHOTOSYNTHESIS
CRUDE
XYLENE
DIESEL
HEXANE
BENZENE
FURNACE
19·2
3·1
16·7
4·5
PERCENTAGE AGAINST CONTROL

B



a
b
c
d
e
f
RELATIVE PHOTOSYNTHESIS
% OF HEXANE EXTRACT
% OF XYLENE EXTRACT
% OF BENZENE EXTRACT
% OF CRUDE EXTRACT
% OF FURNACE EXTRACT
% OF DIESEL EXTRACT

progressive inhibition of growth with increasing concentrations. Among the aromatic hydrocarbons, the xylene extract exhibited the maximum retardation and hexane and benzene showed similar response.

It is probable that the activity of the flagellates are stimulated in low concentrations of oil, since _Tetraselmis_ _gracilis_, a green flagellate in culture showed slight increase in activity with extracts of crude oil and also furnace oil and the residue discharged during the grounding of the American oil tanker 'Trans Huron' at Kiltan Island in the Lakshadeep Sea (Pl. XXII). The residue of the furnace oil after 3 days of leakage at Kiltan also stimulated photosynthesis initially. However, with residue after prolonged exposure of 15 days, there was strong inhibition of growth.

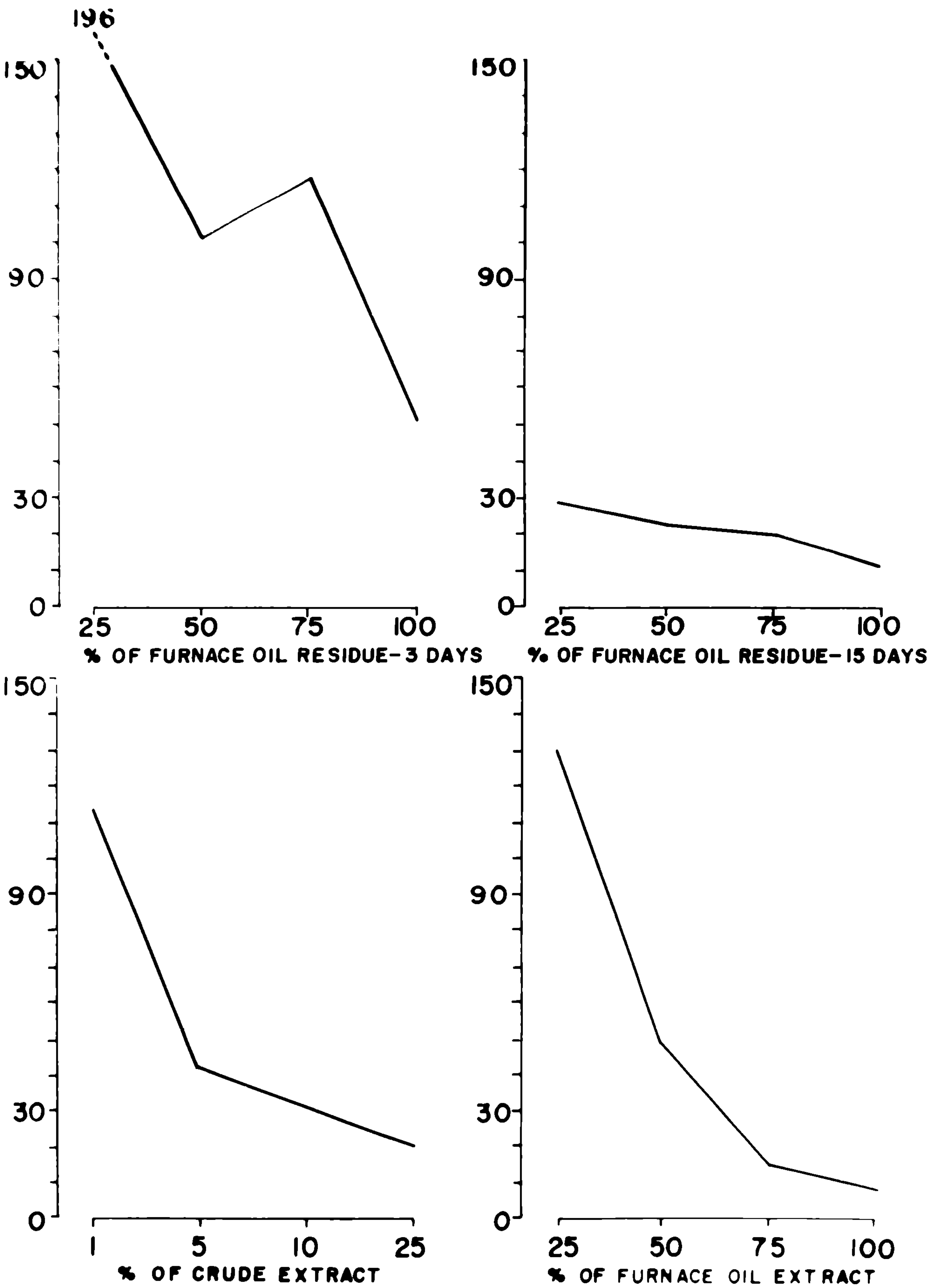
Experimental work conducted both in the field and in the laboratory elsewhere suggest that the low boiling aromatic hydrocarbons have greater toxicity (Kunhold, 1969; Griffith, 1972). Further, they constitute an important part of aqueous oil extracts and they show considerable solubility in both fresh and seawater. The observations of Hutchinsen _et_ _al_. (1972) also showed that benzene has relatively little effect upto concentrations of 500 ppm, but the higher levels are inhibitory. These authors noted that certain species are inhibited in their growth while certain species do not appear to be affected and a number of species are stimulated.

PLATE - XXII

Effect of Hydrocarbons on relative photosynthesis in the flagellate Tetraselmis gracilis

PLATE XXII

TOXICITY OF HYDROCARBONS ON TETRASELMIS



The water soluble components of the crude oil generally reduce the pH (even in 1% solution by 0.7). The increase in the acidity of the water by itself could reduce algal growth. This may perhaps account for the decreasing rate of photosynthesis with increasing concentrations of extracts of crude oil.

As mentioned before, different phytoplankton components respond in different ways with various hydrocarbons. Diatoms such as Ditylum brightwellii and Coscinodiscus granii are killed in concentrations of kerosene less than 0.01%, while Melosira moniliformis and Grammatophora marina tolerate upto 1%. Very low concentrations affect more sensitive species. Mironov and Lanskaya (1967) and Lacaze (1967) reported a depression in the growth of culture of Phaeodactylum tricornutum exposed to 1% extract of crude oil. But for Nitzschia closterium retardation was observed only when the oil concentration exceeded 25% while lower levels have a slight stimulatory effect.

Studies with certain distilled fractions of No. 2 fuel oil have demonstrated interesting specific susceptibility. Growth of the green alga Chlorella autotrophica was severely inhibited by lower boiling-point fractions, although a general toxicity was exerted by all fractions. In contrast, the diatom Thalassiosira pseudonana was found to be most susceptible to the high boiling fractions (Vandermeulen and Ahern, 1976). However, aqueous extracts of Kuwait and Southern Lousiana crude oil did not appear to affect algal growth, but specific fractions of Southern Lousiana crude tested separately showed toxicity both to the diatom and the green alga. These observations suggest that the range of response vary with species according to whether the crudes are introduced wholly or as aqueous extracts.

The experimental evidence therefore suggest that hydrocarbons can affect the matabolic process of algae. However, the real threat of hydrocarbons to the aquatic organisms probably lie not in the toxicity of a single pollutant, but in the synergistic effects of several factors acting together.

XI. DISCUSSION ON PHYTOPLANKTON ECOLOGY

All the classical studies made in the earlier periods in temperate seas on phytoplankton have indicated a 'spring bloom' with high magnitude consequent on incident radiation during the summer months, followed by an 'autumn bloom' with less magnitude during the winter months. This spring peak may be in March-April or may be delayed. In the inshore and particularly in estuarine environment, the maximum crop may not appear until about June with a decline or irregular fluctuation in the rest of the summer. There is considerable variation from this classical picture in the warmer waters towards the coast as well as in the upwelling regions. The seasonal cycle may primarily be nutrient-limited rather than light-limited as in the temperate waters. Probable reasons for the large fluctuations in the phytoplankton crop in different ecosystems may be partly due to local climatic conditions and partly to different grazing intensity.

Cushing (1975), with limited data has described production cycle of the tropics as a low amplitude one with a continuous trend in contrast to a single peak in the arctic and double peaks in temperate waters. Environmental factors adduced for this variation is the algal reproductive rate, depending on the compensation depth and depth of mixing.

In the light of the variations in the environmental factors, the seasonal distribution of phytoplankton discussed in the foregoing chapters can be examined. In the Cochin Backwater, the primary peak of phytoplankton has been found to be during the pre-monsoon months with low magnitude and a secondary peak of high magnitude during the post-monsoon months. The species appear to be adapted to the lowered salinity and temperature over the monsoon period and are benefitted by the availability of abundant nutrients generated during this period. The nannoplankters contribute about 60-70% of the total standing crop. However, in the net hauls, diatoms dominate. Further statistical studies revealed that in the Cochin Backwater, the spatial variation of phytoplankton production is as high as the seasonal variations. The correlation coefficients between chlorophyll a and total cells of phytoplankton also indicate that a common relationship exists in the estuary (Gopinathan et al. 1974). The multiple regression analysis conducted in the present study further confirmed the relationship of various parameters for the phytoplankton production in the estuary and indicate that the contributing factors are different and stand independently from each other. The variable and usually larger algal crop and the general species diversity of estuarine phytoplankters in tropical areas are in sharp contrast to the estuarine flora of the temperate regions which are monospecific blooms brought about by eutrophication.

Taking into consideration all the environmental factors that influence the phytoplankton production, it is generally accepted that light is never a limiting factor in the tropical waters, except perhaps on extremely cloudy days when the average solar radiation falls below 60 ly/day. But due to turbidity, the light penetration and thereby the depth of euphotic zone is limited to 1 - 1.5 m as was observed in the Cochin Backwater (Qasim _et al_. 1969) and also in the Mud bank area of Alleppey (Nair _et al_. MS). However, in the nearshore waters of the marine environment, the euphotic zone extends to about 14 m, while in the offshore waters, it extended upto 50-60 m and in the clear blue waters of the oceanic regions especially near the Lakshadweep and Andaman-Nicobar Islands, it extends upto 80-90 m (Nair _et al_. 1968).

Temperature plays an indirect role on phytoplankton production by setting up a thermocline in the Oceans above which forms the mixed layer. The thermal stratification of the Arabian Sea show the following features. The maximum surface layer temperature occurs in April-May when the entire area with the exception of the northern-most subarea exceeds 28°C. The August minimum temperature at the surface is generally colder than the January minimum, particularly in the coastal regions of the north. The decay of the summer thermocline in July-August causes a second increase in the mixed layer during this time. The vertical spreading of the isotherms observed during March-May period show that from surface (29^{o}C) to 100 m depth (23^{o}C) a gradual decrease in temperature was observed, whereas the second peak (August-October) show permanent shallow thermocline with wide fluctuations from surface to 100 m (26–16^{o}C). Thus the seasonal variations of thermal structure in the Arabian Sea show distinct bimodal variation (Corlborn, 1971) which is also reflected in the phytoplankton production.

According to Steemann Nielsen (1959), the replenishment of the nutrients in the open ocean is provided primarily by water circulation whereas in shallow coastal waters, it is provided by decomposition taking place in the upper layers of the bottom sediments by microbiological process which is dependent on temperature. However, in coastal waters of temperate zone, temperature is the most important factor governing the growth of phytoplankton in water masses that are in contact with the bottom (Grøntved and Steemann Nielsen, 1957). In the shallow coastal regions, the waters are mixed to the bottom and the phytoplankters have access to the nutrients in the water column and also what is generated from the bottom. But in the offshore waters, the euphotic zone and the depth of the mixed layer determines the rate of phytoplankton production. The depth of the mixed layer during the pre-monsoon period is about 60 m which becomes less than 20 m during the monsoon period and during the post monsoon period it deepens to 40 m (Sharma, 1974). In the pre-monsoon period as there is no further addition of nutrient rich waters, the rate of production is maintained at a lower level till the commencement of upwelling. During the post-monsoon period when the mixed layer deepens, the nutrients are not depeleted and hence moderately high production continue during this period. The difference in the phyto-plankton production between one area and another as a whole from year to year can be chiefly attributed to the variation in vertical mixing, by regeneration and the supply of nutrients. Thus the lower rate of phytoplankton production during the pre-monsoon and the higher rates during monsoon and post-monsoon in the west coast of India as well as the lower values observed seaward can be accounted directly by the availability of nutrients.

Salinity variations have also some effect on the rate of photosynthesis. It was observed that phyto-plankton grow well in salinity of 15-25‰; diatoms grow poorly in salinity greater than 35‰. Salinity appears to be another controlling factor for the phytoplankton production in the estuarine systems. In the inshore and oceanic environ-ments also sudden fall in salinity during monsoon months associated with high nutrient enrichment favour the phyto-plankton production. From observations made in the various estuarine systems of Indian seas, it is seen that the 'Biological spring' falls during the monsoon months, when the phytoplankton peaks coincide with low salinity and temperature associated with high concentrations of nutrients. Qasim _et al_. (1972) have indicated that in the estuarine area of Cochin, the direct correlation of phytoplankton production with low salinity could be an adaptation by the planktonic algae to utilize the available nutrients. Moreover, the distribution of phytoplankton standing crop in the different estuaries vary from place to place and time to time as a result of the water masses being constantly renewed by the inflow of freshwater from the rivers and land run off and seawater from the inshore area.

The variations of nutrient concentration along the west coast of India from Cape Comorin to Karwar have been given by D.S. Rao (personal communication). The nutrient concentrations in the water over the shelf on the west coast of India follows a pronounced seasonal rhythm reaching the maximum during the south west monsoon months, The regional and seasonal variation in the nutrients in the upper layer show the same trend as in the production of phytoplankton. During the period of south west monsoon, the nutrient concentration is found to increase in the central region. The whole continental shelf waters are rich in phytoplankton and a gradual increase in standing crop from south to north is observed. During the post-monsoon period though there is fall in the values of nutrients, the concentrations are high enough to maintain moderate rates of phytoplankton production. During the transition period of January to February, the values are less. Reddy and Sankaranarayanan (1968) from the vertical profiles of nutrients in the Arabian Sea during the monsoon months inferred that the enrichment of coastal waters is by the nutrients brought up from the subsurface layers.

Among the phenomena governing the distribution of phytoplankton in the sea, the divergence and convergence play a significant role. Regions of divergence are generally rich in nutrients and have high density of phytoplankton, while in regions of convergence, there is great accumulation of zooplankton (Hela and Laevatsu, 1961). Accordingly, in the coastal region of eastern Arabian Sea, there is weak divergence from March reaching its maximum of over 20 units in the southern region by May (Sharma, 1974). From June, there is a decrease and only convergence occurs from August to December. However, a time lag can be expected with the production of phytoplankton following the divergence and the rise of enriched water as mentioned before.

The phenomenon of upwelling on the west coast of India has a pronounced effect on the replenishment of nutrients and thereby on phytoplankton production. The maximum effect of upwelling can be observed on the surface layers only when the deepest possible water enters the surface layers. During the south west monsoon period, all along the west coast of India from Karwar southwards, upwelled water is in evidence, the maximum intensity being north of Calicut (Banse, 1959, 1968; Patil and Ramamirtham, 1963). According to Ramamirtham and Jayaraman (1960), upwelling on the west coast occurs upto even September or October and sinking from November to February. According to Sharma (1966, 1974) upwelling in the coastal waters occurs from February to July-August and sinking from September to January. According to him, the upward tilting of the thermocline reaches the surface almost by July indicating upwelling.

On the west coast, the bloom of phytoplankton during the south west monsoon noticed off Trivandrum Coast from January onwards reaching a peak in May and at Cochin and Calicut and northwards, the peak is attained in July-August. This would indicate the commencement of upwelling much earlier. From September onwards, the phytoplankton abundance showed a decline indicating the cessation of upwelling and initiation of the reversal process. Thus the positive co-relation of phytoplankton production and the phenomenon of upwelling fully support the view of Sharma (1966).

In contrast to the different production cycles in the various estuarine systems, on the east coast, the primary maxima of phytoplankton showed north to south direction: at Waltair, it commences in February, at Madras in March and at Gulf of Mannar, it is from May-June. Similar sequence in the production is noticed on the west coast also, which however moves in a south to north direction; at Trivandrum it commences from January-May, at Cochin it is from May-August, at Calicut, it is from May-September and at Bombay, it is from September to February.

The International Indian Ocean Expedition results, especially the investigations of R.V.VITYAZ also indicate rich standing crop of phytoplankton in the Arabian Sea, east and west coasts of India and North-Eastern part of Indian Ocean in general. The 31st cruise of VITYAZ which covered the open parts of the Indian Ocean from Madagascar to Sri Lanka and also its north-estern part from Northern Madagascar and Zanzibar to southern Arabian Sea observed a number of areas with large biomass of plankton mostly in the region of upwelling (Bogorov and Rass, 1961). A direct co-relation between phytoplankton production and nitrate was observed by Kabanova (1964) during the 33rd cruise of VITYAZ in the Indian Ocean. In the central part of the Arabian Sea, nitrate was found to be exhausted by phytoplankton in contrast to Bay of Bengal, where phosphates were exhausted by phyto-plankton.

The observations of Zernova (1962) based on material collected during 33rd cruise of VITYAZ also indicate maximum concentration of phytoplankton in the Andaman Sea, Aden Bay, Arabian Sea and south of Bay of Bengal and lowest in the equatorial region. During south west monsoon, in the north-eastern part of the Indian Ocean, Sukhanova (1964) found near the equator and southern part of Bay of Bengal, areas very rich in phytoplankton, the quantity was 2 to 2.5 times that of the north east monsoon. Zernova and Ivanov (1964) record for the transition period between the monsoons, October-December, rich phytoplankton, north of 12^{o} and south of 8^{o}. In the Bay of Bengal, the phytoplankton was poor except south west of Nicobar and the Andaman Sea.

Thus, these investigations as well as several other publications (Shomura et al. 1967; Prasad et al. 1970; Krey and Babenerd, 1976; Qasim, 1977) also indicate that standing crop and production of phytoplankton are of a high order in areas of upwelling, that it is more than 2-3 times during the south west monsoon than the north east monsoon and generally Arabian Sea is the richest of all the areas. It is also seen that the eastern regions of the Arabian Sea over the continental shelf have got phytoplankton production comparable to the more productive regions elsewhere.

General level of phytoplankton production in the Exclusive Economic Zone of India and potential resources

The magnitude of the production of phytoplankton in different seas has been estimated by various workers during different Expeditions. After the cruise of Danish GALATHEA Expedition around the world, the world oceanic production was estimated as 1.5 to 2×10^{10} tons of carbon (Steemann Nielsen and Jensen, 1957). Later Ryther (1959) estimated the total production as 2×10^{10} tons of carbon/year for the world oceans. Recently Koblentz-Mishke et al. (1970) have estimated the total production of phytoplankton in the world oceans in terms of carbon as $2.5 - 3 \times 10^{10}$ tons which is the gross production and $1.5 - 1.8 \times 10^{10}$ tons as the net production. The estimation of Koblentz-Mishke et al. (op.cit) is thus nearer to the figures given by Steemann Nielsen and Jensen.

Prasad *et al*. (1970) estimated that total production in an area of 51 million sq. km of the Indian Ocean as 3.9×10^9 tons of carbon which amounts as 1/5th of world oceanic production. This estimate is in agreement with the estimate of Koblentz-Mishke *et al*. (1970), ie. 4.1×10^9 tons for Indian Ocean as a whole. Nair *et al*. (1968) calculated the potential production of phytoplankton in terms of carbon for the west coast as 46×10^6 tons for an area of 283,310 sq. km and for the east coast as 15×10^6 tons for an area of 111,150 sq. km.

Though the values are not strictly comparable, as the technique was based on nitrogen consumption, the standing crop of phytoplankton was estimated by Gilson (1937) in the Arabian Sea as amounting to 14.4 gm/m^2/day for a depth of 55 m in the open sea. Later Subrahmanyan (1959 b) who made extensive studies off Calicut estimated the standing crop of phytoplankton in Harvey Units and indicated a high rate of production on the west coast. According to him, the level of production was more than 6 times that of English channel. Following the method adopted by Cooper (1933) in the English channel, Subrahmanyan (1959) estimated the total standing crop of phytoplankton in an area of 155,400 sq. km of the Indian Seas as 1813×10^6 tons and pointed out the low percentage of exploitation of the resources.

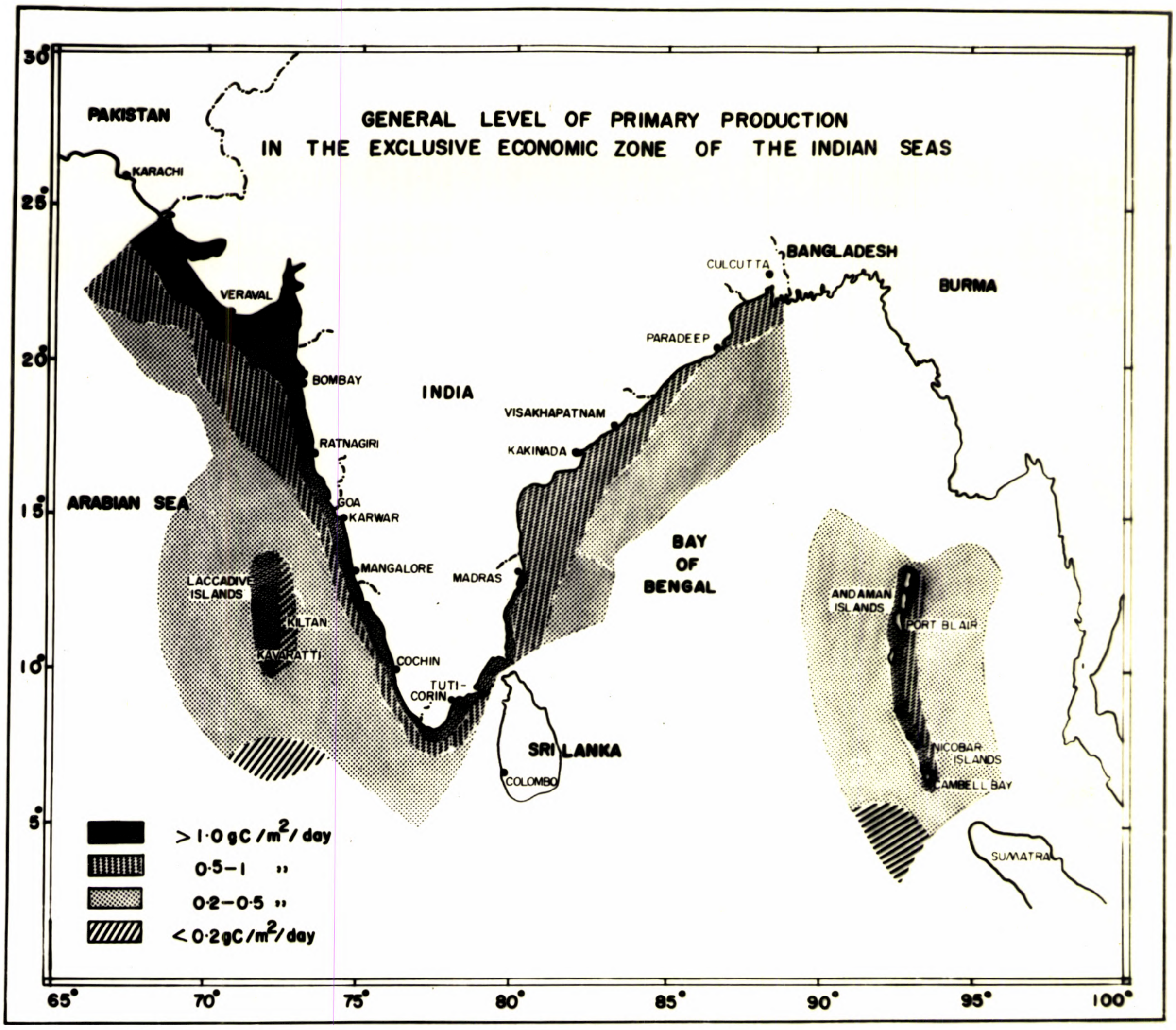
In view of the declaration of 200 miles Exclusive Economic Zone, having a total area of 2.02 million sq. km for the country, it would be worthwhile to compute the total phytoplankton production of this area. The different gradients for the shelf and outside when integrated give a total production of 283 x 10^6 tons of carbon which will be roughly 4½ times the magnitude for 5 times the area over the shelf. This is quite understandable in view of the lower production rates from outside the shelf compared to that inside the shelf. This would be equivalent to 12 x 10^9 tons of phytoplankton by wet weight, calculated by the conversion factor of Cushing et al. (1958). The different levels of primary production in the Exclusive Economic Zone of the Indian Seas is represented in Pl. XXIII.

In recent years, various projections of potential yield have been made from the estimates of primary production. The optimum yield from organic production generally varies from 0.3 to 0.4% (in terms of carbon - 10% of the wet weight or 50% of the protein content). The potential yield from the Indian Ocean has been estimated by various authors which ranges from 10.3 to 14.4 million tons of harvestable resources (Prasad et al. 1970; Gulland, 1971; Marr et al. 1971). In general, the potential yield of the Indian Ocean appears to be between 10-14 million tons of fish (George et al. 1977). About 40% of this could be expected from the Exclusive Economic Zone of the Indian seas.

PLATE - XXIII

General level of primary production in the Exclusive Economic Zone of Indian Seas

PLATE XXIII



GENERAL LEVEL OF PRIMARY PRODUCTION
IN THE EXCLUSIVE ECONOMIC ZONE OF THE INDIAN SEAS
PAKISTAN
KARACHI
VERAVAL
BOMBAY
INDIA
RATNAGIRI
GOA
KARWAR
ARABIAN SEA
MANGALORE
LACCADIVE ISLANDS
KILTAN
KAVARATTI
COCHIN
TUTI-CORIN
MADRAS
SRI LANKA
COLOMBO
VISAKHAPATNAM
KAKINADA
PARADEEP
CULCUTTA
BANGLADESH
BURMA
BAY OF BENGAL
ANDAMAN ISLANDS
PORT BLAIR
NICOBAR ISLANDS
CAMBELL BAY
SUMATRA
> 1·0 gC / m² / day
0·5–1 ,,
0·2–0·5 ,,
< 0·2gC / m² / day
30°
25°
20°
15°
10°
5°
65°
70°
75°
80°
85°
90°
95°
100°

Earlier George et al. (1977) have estimated a potential harvest of 4.5 million tons of resources from this area. The present yield from the Indian Seas is only 1.3 million tons which comes mostly from inshore and nearshore regions. The potential yield from the shelf regions of both the coasts has been estimated to be 2-3 times the present yield (Nair et al. 1968; Prasad and Nair, 1975).

In view of the distance involved and the sparseness of distribution, a minimum possible exploitation of 0.2% could be expected from the entire Exclusive Economic Zone. Therefore the exploitable yield of the living resources from the EEZ of India would amount to 5.5 million tons, both pelagic and demersal. This would mean that the harvest from the EEZ could exceed the present catch from the Indian Ocean (3.6 million tons) as a whole by about 50%.

Assuming an yield of 0.1% of net primary production, a minimum estimate of 2.8 million tons of fish could be harvested from the EEZ, which is rather an under-estimate considering the 6000 miles coastal area and 200 miles economic zone. Hence, a potential harvest of 5.5 million tons seems to be fairly optimistic which would still amount to only 50% of the yield from intensively exploited areas.

The fish biomass estimated from phytoplankton biomass based on the method adopted by Subrahmanyan (1959b) (after incorporating the correction factor) will amount to

7.2 million tons, ie. 0.06% of the wet weight of phyto-plankton. Considering the conventional resources and their scope for further expansion of the harvestable stock and non-conventional resources (Horse-mackerel, flying fish, myctophids, gonostomatids, deep water prawns and crabs, cephalopods and molluscs), an yield of 5 million tons from the Exclusive Economic Zone of India is a very reasonable estimate from phytoplankton production.

XII. SUMMARY

This account deals with the results of investigations on phytoplankton productivity and related aspects conducted in various ecosystems such as estuarine, inshore and oceanic environments and certain special ecosystems including the prawn culture fields and associated mangroves, mud bank and the seas around the Andaman-Nicobar Islands. This study also includes the qualitative and quantitative variations of phytoplankton production, their seasonal abundance, factors controlling the same and the magnitude of the potential resources derived from it.

A taxonomic account of 109 forms of diatoms, including one new to science and 67 species of dinoflagellates together with their occurrence and distribution have been presented. Of these 49 species of diatoms and 8 species of dinoflagellates are found to be new distributional records for the Indian Seas. This forms a supplement to the existing knowledge on estuarine and marine phytoplankton of the Indian Seas.

The results of investigations in the estuarine area of Cochin based on a study of four station-grid for one year relating to the magnitude of the standing crop of phytoplankton in terms of chlorophyll, primary production and total cell counts along with the environmental parameters indicated that there is regional and seasonal variations in the magnitude of production of phytoplankton. This aspect of

study has been further strengthened by a statistical analysis of the data using a micro-computor and a multiple regression relationship has been brought out with all parameters. The correlation coefficient and standard regression coefficients have been worked out which revealed that plankton production and related parameters at all the stations are independent of each other and contributing parameters also vary from station to station. The probable reasons for this variations may be due to the dynamic nature of the estuarine ecosystem.

Investigations on the phytoplankton productivity of the inshore environment of Cochin upto 30 m depth for the period 1976-78 also indicated seasonal and spatial variation in the standing crop. As in the estuarine area of Cochin, in the inshore environment, the indices of standing crop indicated that the primary production and total cell counts are independent variables and no strong correlation exists between the two. A grouping of the bio-geographical types of the different components of phytoplankton in the inshore area showed that the principal constituent of the diatom population is the pelagic species of neritic and oceanic provinces.

The weeds, Salvinia molesta and Eichhornia crassipes which float down from the Vembanad Lake to the inshore area cause changes of the benthic productivity and associated fauna which has been the subject of study for the year 1978.

Seasonal variations of the phytoplankton biomass and primary production in the oceanic environments from Cape Comorin to Karwar have been studied. The qualitative variation of 74 species of diatoms, 79 species of dinoflagellates, 2 Silicoflagellates, one Coccolithophore and 5 species of blue-green algae based on cell numbers have been presented.

Phytoplankton production in special ecosystems such as prawn culture fields and associated mangrove areas, mud bank region and oceanic Islands (Andaman-Nicobar) has been investigated based on measurements of primary production and related parameters for specific periods.

The prawn culture fields of the Cochin estuarine system have been classified into highly productive, medium productive and low productive areas based on the productivity parameters of 50 stations. It was found that the fields situated north and south of Cochin bar mouth and around Azhikode bar mouth, where there is constant incursion of seawater are highly productive. The stocking capacity of the seasonal and perennial prawn fields has been worked out based on primary production. It is suggested that the fields with a productivity of 2000 $mgC/m^3/day$ and having a relatively high detrital concentration could be stocked intensively without any additional inputs as artificial food.

The productivity of the associated mangrove ecosystem has been studied along with relevant hydrological properties. Wide seasonal fluctuations have been noticed in the physico-chemical parameters in the mangrove areas. The seasonal variations in the productivity of the mangroves and adjacent backwater when compared indicated that the mangrove ecosystem is highly productive.

The primary production, chlorophylls and phytoplankton biomass of the mud bank at Ambalapuzha, near Alleppey together with the composition of different phytoplankton groups have been studied. The seasonal variations of the productivity parameters, diurnal variation in the standing crop as well as special observations relating to the fishery of the area reveal a unique ecosystem.

The productivity of the different regions of the Andaman-Nicobar Sea has been studied from the point of view of the assessment of these waters for mariculture practices. The results of investigations indicated that the mangrove areas and bays of the east coast of these islands are highly productive and suggested as suitable regions for mariculture practices based on primary production measurements.

Phytoplankton culture studies, based on 6 different media, carried out with emphasis on mass production of the microscopic algae for hatchery operations. Procedure for the mass culture of diatoms such as *Chaetoceros*, *Skeletonema* and *Phaeodactylum* species and flagellates like *Tetraselmis* spp. and *Isochrysis galbana* and micro-green alga *Chlorella* sp. have been described. Growth and viability of 2 diatoms and 2 flagellates in different culture media have been studied. The techniques of harvest and preservation of the algae and the future scope of the development of mass culture have been pointed out.

Toxicity experiments, especially the photosynthetic response of algae, based on 6 hydrocarbons have been conducted and the toxic effects of these pollutants have been studied. The results of these experiments indicate varying nature of inhibition and stimulation of the algae with different hydrocarbons.

A general discussion on the seasonal and spatial variation of phytoplankton in the estuarine, inshore and oceanic environments in relation to the various physico-chemical factors and phenomena like upwelling has been included. The general level of productivity of the EEZ (Exclusive Economic Zone) of India having an area of 2.02 million sq. km has been computed and an estimate of the potential yield of about 5 million tons of harvestable resources from this area has been worked out based on phytoplankton production.

Six published papers, 3 of which are collaborative work relating to phytoplankton productivity investigations and new distributional records of diatoms and dinoflagellates are appended.

XIII. REFERENCES

Abe, T.H. 1927. Report on the biological survey of Mutsu Bay. 3. Notes on the protozoan fauna of Mutsu Bay. 1. Peridiniales. Sci. Rep. Tohoku Univ. Ser. 4,2(4):386-438.

Aiyar, R.G., K.S.Menon and M.G.K.Menon. 1936. Plankton records for the years 1929 and 1930. J. Madras Univ. 8, 1-43.

Aleem, A.A. 1950. Distribution and ecology of British marine littoral diatoms. J. Ecol.,38(1):75-106.

Allen, W.E. and E.E. Cupp. 1935. Plankton diatoms of the Java Seas. Ann. Jord. Bot. Buitenz., 44: 404-474.

*Agardh, C.A. 1824. Systema Algarum. Lund.

*__________ 1827. Aufzahlung einiger in den ostriechi-schen Landern gefunderen neuen Gattungen und Arten von Algen, nebst ihrer Diagnostik und beigefugten Bemerkungen. Flora, 10,625-640.

*__________ 1828. Icones Algarum Europaearum.

*__________ 1830. Consepctus criticus Diatomacearum, Lund.

Anderson, G.C. 1965. Fractionation of phytoplankton communities off the Washington and Oregon coasts. Limnol. Oceanogr., 10,477-480.

*Apstein, C. 1909. Die Pyrocysteen der plankton Expedition. Ergebn. Plankton Exped. Humboldt. Stift. 4, M.C., 1-27.

Aruga, Y. 1973. Primary production in the Indian Ocean. II. In the Biology of the Indian Ocean, Ecological Studies. 3. Ed. B.Zeitzschel. pp. 117-30. Berlin Springer Verlag.

*Aurivillius, C.W.S. 1898. Die plankton. Fauna des Skageraks. K.Sv. Vet. Akad. Hardl.,30(3):1-426.

Bailey, J.W. 1842. A sketch of the Infusoria of the family Bacillaria, etc. American J. Sci. Arts.42,88-105.

*_________ 1850. Microscopical examination of soundings made by the U.S. coast survey off the Atlantic coast of U.S. Smithson. Contr. Knowl., 2(3):1-15.

*_________ 1851. Microscopical observations made in South Carolina, Georgia and Florida. Smithson. Contr. Knowl., 2(8):1-48.

*_________ 1855. Notes on new species and localities of microscopical organisms. Smithson. Inst. Contr. Knowl., 7(3):1-16.

Balasubrahmanian, T and M.V.M. Wafar. 1974. Primary productivity of some fringing reefs of south-east India. Mahasagar, Bull. Nat. Inst. Oceanogr., 7,157-64.

_________________ and _____________ 1975. Primary productivity of some seagrass beds in the Gulf of Mannar. Mahasagar, Ibid., 8, 87-91.

Balech,E. 1962. Tintinnoineae y Dinoflagellata del Pacifico, segum material de las expediciones Nerpac y Down wind del Instituto Scripps de Oceanografia. Revta Mus. Cienc. nat. Zool., 7(1):1-253.

_________ 1964. Tercera contributional conocimien to del genero 'Peridinium'. Hydrobiologie, 1(6):179-195.

Ballantine, D. 1961. Gymnodinium chukwanii n. sp. and other marine Dinoflagellates collected in the vicinity of Zanzibar. J. Protozool., 8(2):217-228.

Banse, K. 1959. On upwelling and bottom trawling off the south-west coast of India. J. mar. biol. Ass. India., 1(1):33-49.

_________ 1968. Hydrography of the Arabian Sea shelf of India and Pakistan and effects on deme rsal fishes. Deep Sea Res., 15(1):45-79.

*Bergh, R.S. 1881. Der organismus der Cilioflagellaten Eine phylogenetische studies. Morphol. Jahrb. 7(2): 178-288.

Bhargava, R.M.S., P.M.A.Bhattathiri and V.P.Devassy. 1977. Relative contribution of nannoplankton to the primary production of two estuaries of Goa. Mahasagar, Bull. Nat. Inst. Oceanogr., 10(1&2): 61-66.

Bhaskaran, M and P.Gopalakrishnan. 1971. Observations on the marine plankton in the Gulf of Kutch, off Port Okha. Indian J. Fish., 18,99-108.

Bhatt, V.S. 1972. Zuari and Mandovi estuaries. Mahasagar, Bull. Nat. Inst. Oceanogr., 5(2):95-99.

Bhattathiri, P.M.A., V.P.Devassy and R.M.S. Bhargava. 1976. Production at different trophic levels in the estuarine system of Goa. Indian J. Mar. Sci., 5,83-86.

Bhimachar, B.S. and P.C.George. 1950. Abrupt set-backs in the fisheries of the Malabr and Kanara coasts and 'Red water' phenomenon as their probable cause. Proc. Indian Acad. Sci., 36(6):105-118.

Blasco, F. 1975. Mangroves of India. Inst. Francaise. Pondich. Trav. Sec. Sci. tech., 14(1):154-156.

Blumer, M. 1969. Oil pollution of the Oceans. Oceanus, 15(2):2-7.

________ 1970. Dissolved organic compounds in seawater and saturated and olefinic hydrocarbons and singly branched fatty acids. Publ. Inst. Mar. Sci. Alaska, 1.

________, M.Ehrhardt and J.H.Jones. 1973. The environmental fate of stranded crude oil. Deep Sea Res., 20,239-259.

Bohm, A. 1931 a. Zur Verbreitung einige Peridinien. Arch. Protistenk., 75: 498.

Bohm, A. 1931b. Distribution and variability of Ceratium in the northern and western Pacific. Bernice P. Bishop Museum Publ. 87, 1-47.

* _______ 1935. Zum variations problem der Peridineen. Osterr. bot. Z., 84(4):271-84.

_______ 1936. Dinoflagellates of the coastal waters of the western Pacific. Bernice P. Bishop Museum, Bull. 137, 1-54.

Bogorov, V.G and T.S. Rass. 1961. On the productivity and prospect of fishing in waters of the Indian Ocean. Okeanologia, 1, 107-109.

Boyer, C.S. 1900. The Biddulphioid forms of North American Diatomaceae. Proc. Acad. nat. Sci. Philadelphia, 50, 685-748.

_______ 1916, The Diatomaceae of Philadelphia and vicinity. Philadelphia.

_______ 1927. Synopsis of North American Diatomaceae. Parts 1 and 2. Proc. Acad. nat. Sci. Philadelphia. 78, supp. 3-228; 79, supp. 229-583.

Braarud, T. 1951. Taxonomical studies of marine dinoflagellates. Nyt. Mag. Naturv., 88:43-48.

* Brebisson, A.de. 1838. Considerations sur les diatomies et essai d'une classification des genres et des especes appartenant a cette famillie. Falaise.

Brightwell, T. 1856. Further observations on the genus Triceratium, with descriptions and figures of new species. Quart. J. micr. Sci., 4, 272-276.

_______ 1858. Further observations on the genera Triceratium and Chaetoceros. Quart. J. micr. Sci., 6, 153-155.

Brightwell, T. 1859. On some of the rarer or undescribed species of Diatomaceae. Part 1. Quart. J. micr. Sci., 7, 179-181.

____________ 1860. On some of the rarer or undescribed species of Diatomaceae. Part 2. Ibid, 8, 93-96.

Bristow, R.C. 1938. History of Mud Banks. Vol. 1 and II. Cochin Govt. Press.

*Broch, H. 1906. Bemerkungen uber den formenkreis non Peridinium depressum. S. lat. Nyt. Mag. Naturvidensk, 44, 151-157.

Brunel, Jules. 1962. Le Phytoplankton de la Baie des Chalurs. Contri. Inst. Bot. Univ. Montreal, 77:1-365.

*Buch, K. 1951. Das Kohlensaure gleichwicht system in Meerwasser. Havsforskn Inst. Skr. Helsingf., 151.

Burchall, J. 1968. An evolution of primary productivity studies in the continental shelf regions of the Agulhas Current near Durban. S. Afr. Ass. Mar. biol. Res., 21:1-44.

*Busch, W. 1851. Beobachtungen über Anatomie und Entwicklung einiger wirbellosen suthiere. Berlin Hirschwald, 8, 1-143.

Carthy, J.D. and D.R. Arthur. (Ed.) 1968. The biological effects of oil pollution on littoral communities. Field studies Council., 2, suppl.99.

*Castracane, A.F. 1875. Contribuzione all a'ne florula della Diatomee del Mediterraneo, etc. Atti. Acad. Nuoci Lincea, 28, 377-396.

____________ 1886. Report on the Diatomaceae. Report on the scientific results of the voyage of H.M.S. Challenger during the years 1873-76. Challenger Reports, Botany, 2.

Chacko, P.I. 1950. Marine plankton from waters around the Krusadai Island. Proc. Indian Acad. Sci. 31, 162-74.

Chennubhotla, V.S.K. 1969. Distribution of phytoplankton in the Arabian Sea between Cape Comorin and Cochin. Indian J. Fish., 16(1&2):129-136.

Claparade, E and Lachmann, J. 1859. Etudes sur les Infusoires et les Rhizopodes. Mem. Inst. Genevois., 6(1): 261-482.

__________ 1861. Etude sur les infusoires et less rhizopodes. Ibid., 7(1):1-291.

Cleve, P.T. 1873. Examination of diatoms found on the surface of the sea of Java. Bish. svensk. Vetensk. Akad. Handl., 1(11):1-13.

__________ 1878. Diatoms from the West Indian Archipelago. Ibid., 5(8):1-22.

__________ 1894. Synopsis of the naviculoid diatoms. Part I. K. svenska Vitensk Akad. Handl. n.f. 26(2):1-194.

__________ 1895. Diatoms from Baffin Bay and Davis strait. Bish. svensk. Vetensk Akad. Handl., 22(4).

__________ 1896. Report on the phytoplankton collected on the expedition of H.M.S. 'Research'. XVth Ann. Rept. Fish. Bd. Scotland, Edinburgh.

__________ 1900. Plankton from the Red Sea. Vet. Akad. Forhandl., 57(9):1025-1038.

__________ 1901. Plankton of the Indian Ocean and the Malay Archipelago. K. sv. Vet. Akad. Handl., 35(5):1-58.

__________ 1903. Report on plankton collected by Mr. Thorild Wulff during a voyage to and from Bombay. Ark. Zool., 1:329-391.

__________ and A. Grunow. 1880. Beitrage zur Kenntnis der Arktischen Diatomeen. K. sv. Vet. Akad. Handl. 17(2).

Cleve-Euler, A. 1952. Die Diatomeen von Schweden und Finnland. K. sv. Vet. Akad. Handl. ser. 3(3): 1-153.

__________ 1953. Die Diatomeen von schweden und Finnland. Ibid., 4(1):1-158.

Colborn, J.G. 1971. Thermal structure dynamics in the upper 500 metres of the Indian Ocean. NOC TP 266, Ocean Science Dept., San Diego, 1-99.

Cooper, L.H.N. 1933. J. mar. biol. Ass. U.K., 18,729-53.

Cupp, E.E. 1937. Seasonal distribution and occurrence of marine diatoms and dinoflagellates at Scotch Cap, Alaska. Bull. Scripps Inst. Oceanogr. 4, 71-100.

__________ 1943. Marine plankton diatoms of the west coast of North America. Bull. Scripps Inst. Oceanogr., 5,1-237.

Currie, R.I. 1958. Some observations on organic production in the North East Atlantic. Rapp. cons. perm. int. Explor. Mer., 144:96-102.

Cushing, D.H. 1959. On the nature of production in the sea. Fish. Invest. Ser., 11,22:1-40.

__________ 1971. Upwelling and the production of fish. Adv. mar. biol., 9:255-334.

__________ 1973. Production in the Indian Ocean and the transfer from the primary to the secondary level. The Biology of the Indian Ocean, Bernt Zeitzschel (Ed.), pp.475-486.

__________ 1975. Marine Ecology and Fisheries. Cambridge Univ. Press. Cambridge., pp.1-278.

__________, G.F. Humphrey, K.Banse and T. Laevatsu. 1958. Report of the committee on terms and equivalents. Rapp. Reun. Cons. Int. Explor. Mer.,144, 15-16.

Damodaran, R. 1973. Studies on the benthos of the mud banks of the Kerala coast. Bull. Dept. Mar. sci., Univ. Cochin., 6, 1-126.

__________ and C. Hridayanathan. 1966. Studies on the mud banks of the Kerala coast. Bull. Dept. Mar. Biol. Oceanogr. Univ. Kerala., 2:61-68.

*Dangeard, P. 1926a. Sur la flore des Peridiniens de la Marche occidentale. C.R. Acad. Sci.Paris., 182:80-82.

*__________ 1926b. Sur la variations des plaques chez les Peridiniens. Ibid., 183, 984-986.

*__________ 1927a. Peridiniens nouveaux on few comus de la croisere du 'Sylvana'. Bull. Inst. Ocean. Monaco., 491:1-16.

*__________ 1927b. Notes sur la variation dans le genre Peridinium. Bull. Inst. Oceanogr. Monaco, 507:1-16.

Dehadrai, P.V and R.M.S. Bhargava. 1972. Distribution of chlorophyll, carotenoides and phytoplankton in relation to certain environmental factors along the central west coast of India. Mar. Biol., 17,30-37.

*De Toni, G.B. 1894. Sylloge Algarum omnium hacusque cognitarum. 2. Bacillariae, sect. 3, Patavia.

Devassy, V.P. and P.M.A. Bhattathiri. 1974. Phytoplankton ecology of the Cochin backwater. Indian J. Mar. Sci., 3,46-50.

Devasundaram, M.P and J.C. Roy. 1954. A preliminary study of the plankton of the Chilka Lake for the year 1950-51. Symp, Marine and Freshwater plankton in the Indo-Pacific. Indo-Pacific Fish. Council. Publ., 1-7.

Donkin, A.S. 1858. On the marine diatoms of North umberland, with a description of eighteen new species. Trans. micr. Soc. Lond., 6,12-34.

Donkin, A.S. 1870-73. The natural history of the British Diatomaceae. Pts. 1-3. London.

Doty, M.S. 1954. Floristic and ecological notes on Raroia. Atoll. Res. Bull., 33,1-41.

________ and M. Oguri. 1956. The Island Mass effect. J. Cons. Int. Explor. Mer., 22:33-37.

____________________ 1957. Evidence for a photosynthetic daily periodicity. Limnol. Oceanogr.,2:37-40.

____________________ 1958. Selected features of the isotopic carbon primary productivity technique. Rapp. Reum. Cons. perm. imb. Explor. Mer., 144,47-55.

____________________ 1959. The carbon fourteen technique for determining primary plankton productivity. Publ. Staz. zool. Napoli. 31, suppl., pp.70-94.

Ducane, C.G., R.C.Bristow, J.Coggin Brown, B.A.Keen and E.W. Russel. 1938. Report of the special committee on the movement of mud banks., Cochin, 1-57.

*Dujardin, F. 1841. Histoire naturelle des zoophytes, Infusoire, comprenant la physiologie et la classification de ces animaux, et la mariere de les etudier à laide du macroscope. Suites a Buffon, Paris. pp.1-684.

Dutta, N.J., C.Malhotra and B.B.Bose. 1954. Hydrology and seasonal fluctuation of the Chilka Lake for the year 1950-51. Symp. Marine and Freshw. plankton in the Indo-Pacific. Indo-Pacific Fish. Counc. Publ., 1-7.

Dyson, N., H.R. Jitts and B.D. Scott. 1965. Techniques for measuring oceanic primary production using radioactive carbon. CSIRO, Div. Fish. Oceanogr. Tech. Pap., 18.

*Ehrenberg, C.G. 1833. Organisation in der Richlung des klensten Raumes. Dritter Beitrag zur Kenntnis grosser organisationen in der Richlung des klensten Raumes. Abh. Akad. Wiss. Berlin, 145-336.

*______________ 1834. Das Leuchten des Meers. Neue Beobachtung nebst. Uber sicht der Haupt nomente der geschichtlichen Ent wicklung dieses merk wurdigen Phaomen. Ibid., 145-336.

*______________ 1836. Das Leuchten des Meers. Neue Beobachtung nebst Uebersicht der Haupt nomente der geschichtlichen Ent wicklung dieses merk wurdigen Phaomen. Ibid., 411-575.

*______________ 1838. Die Infusionsturchen als vollkommene organismem. Leipzig., 1-547.

*______________ 1840. Uber noch jezt zahl reich libende Thierarten der Kreidebildung und den Organismus der Polythalmier Berlin. Ibid., 81-174.

*______________ 1841. Uber noch jezt zahlreich libende Thierarten der Kreidebildung und den Organismus der Polythalmier. Ibid., 81-174.

*______________ 1843. Verbreitung und Einfluss des mikroskopischen Lebens in Sudund Nord Amerika. Berlin Akad. Wiss. Berlin., 291-446.

*______________ 1844. Resultate Untersuchungen des ihm Sudpolreise des Capt. Ross in den Jahren, 1841-43. Ibid., 57-97.

*______________ 1854. Die Systematische characteristik der neuen mikroskopischen organismen des tiefen Atlantischen ozeans. Monatsber. Akad. Wiss. Berlin, 236-250.

*______________ 1856. Mikrogeologie das enden und filsen schaffende wirken des unsichtbar kleinen silbstandigen lebens auf der ende. Leipzig.

*Ehrenberg, C.G. 1860. Uber des Leuchten und uber neue mikroskopische Leuchthiere des Mittelmeeres. Mber. dt. Akad. Wiss. Berlin, 1859,727-738.

El-Sayed,S.Z and H.R. Jitts. 1973. Phytoplankton production in the south eastern Indian Ocean. The Biology of the Indian Ocean. Ecological Studies 3. (Ed. B.Zeitzschel), 131-142.

Foged, N. 1975. Some littoral diatoms from the coast of Tanzania. In: Bibliotheca Phycologica,Bd.18,128.

Fogg, G.E. 1958. Extracellular products of phytoplankton and the estimation of primary production. Rapp. Proc. Verb. Cons. Expl. Mer., 144:56-60.

___________1963. The role of algae in organic production in aquatic environments. Brit. Phycol. Bull., 2: 195-205.

___________ 1975. Algal cultures and phytoplankton ecology. The Univ. Wisconsin Press., pp.1-175.

*Forti, A. 1922. Ricerche sur la flora pelagica (fitoplancton) diquar to die mib. Venzia C. Ferrari.

Fritsch, F.E. 1935. The structure and reproduction of the Algae. Vol. 1. Cambridge Univ. Press.,Cambridge. pp. 1-791.

Gaarder, K.R. 1943. Dinoflagellatae from the 'Michael Sars' North Atlantic Deep Sea Expedition. Rep. Sci. Res.'Michael Sars' Expedition, 2(3):1-62.

___________ 1954. Dinoflagellatae. Ibid.,12(3).

Gaarder, T and H.H. Gran. 1927. Investigations of the production of plankton in the Oslo Fjord. Rapp. Proc. Verb. Cons. Expl. Mer., 42:1-48.

Ganapati, P.N. and V.S.R. Murty. 1953. Phytoplankton production in relation to depth and distance in the Bay of Bengal off the Waltair coast. Proc. 8th Pacific. Sci. Congr. Manila., 102.

Ganapati, P.N. and Murty, V.S.R. 1955. Preliminary observations on the hydrography and inshore plankton in the Bay of Bengal off Visakhapatnam coast. Indian J. Fish., 2:84-95.

____________ and C.G. Rao. 1953. Observations on the seasonal variations in the phytoplankton production on the Indian coast with special reference to Waltair coast. Indian Sci. Congr. Part III., 184.

____________ and D.V.S. Rao. 1957. On upwelling and productivity of the waters off Lawson's Bay, Waltair. Curr. Sci., 26,347-348.

____________ and ________ 1958. Quantitative study of plankton off Lawson's Bay, Waltair. Proc. Indian Acad. Sci., XLVIII, B4:189-209.

____________ and D.V.R. Sarma. 1958. Hydrography in relation to the production of plankton off Waltair coast. Andhra Univ. Mem. Oceanogr., 62(11):168-192.

____________, M.V.L. Rao and D.V.S. Rao. 1959. Tidal rhythms of some diatoms and dinoflagellates inhabiting the inter-tidal sands of the Visakhapatnam coast. Curr. Sci., 28,450-451.

Gandhi, H.P. 1955. A contribution to the knowledge of fresh water diatomaceae of south western India. J.Indian Bot. Soc., 34:307-338.

__________ 1956. Contribution to the knowledge of fresh-water diatomaceae of south western India. Ibid., 35:194-209.

__________ 1960. The diatom flora of Bombay and the Salsette Island. J. Bomb. Nat. Hist. Soc., 57: 78-122.

George, P.C. 1953. The marine plankton of the coastal waters of Calicut with observations on the hydrological conditions. J. Zool.Soc.India., 5(1):76-107.

George, P.C., B.T. Antony Raja and K.C. George. 1977. Fishery resources of the Indian Economic Zone. Souvenir, IFP, Cochin, 79-116.

*Giglioli, E.H. 1870. La fosforescenza del mare note pelagiche ed osservazioni fatte durante un viaggio di circumnavigazione 1865-68, colla descrizione di due nuove Noctiluche. AH. Acc. Torino, 5, 485-505.

Gilson, H.C. 1937. The Nitrogen Cycle. The John Murray Expedition, 1933-34. Scientific Rep. 11(2):21-81.

Goldman, J.C. and J.H. Ryther. 1976. Temperature influenced species competetion in mass culture of marine phytoplankton. Biotech. Bioeng., 18:1125-1144.

Gonzalves, E.A. 1947. Variations in the seasonal composition of the phytoplankton of Bombay harbour. Curr. Sci. 16, 304-305.

Gopalakrishnan, P. 1972. Studies on the marine planktonic diatoms off Port Okha in the Gulf of Kutch. Phykos, 11(1&2):37-49.

Gopalakrishnan, V. 1971. The biology of the Hooghly-Matlah estuarine system (W.Bengal) with special reference to its fisheries. J. mar. biol. Ass. India., 13(2):182-194.

Gopinathan, C.P. 1972. Seasonal abundance of phytoplankton in the Cochin Backwater. Ibid., 14(2):568-577.

______________ 1975. On new distributional records of plankton diatoms from the Indian Seas. Ibid., 17(1):223-240.

______________ and C.T. Pillai. 1974. On two new records of Dinophyceae of the Indian Seas. Ibid., 16(3): 845-847.

______________ and __________ 1975. Observations on some new records of Dinophyceae from the Indian Seas. Ibid., 17(1):177-186.

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.

Gopinathan, C.K. and S.Z. Qasim. 1974. Mud banks of Kerala - their formation and characteristics. Indian J. Mar. Sci., 3:105-114.

Gordon, M.S and H.M. Kelly. 1962. Primary production of an Hawaiin coral reef. A critique of flow respirometry in turbulent waters. Ecology, 43:474-480.

Gordon, D.C and N.J. Prouse. 1973. The effects of 3 oils on marine phytoplankton photosynthesis. Mar. Biol., 22:329-333.

*Gourret, P. 1883. Sur les Peridinees du Golfede Marseille. Ann. Mus. Hist. Nat. Marseille. Zool. Mem., 1:1-144

Graham, H.W. 1942. Studies in the morphology, taxonomy and ecology of the Peridiniales. Corneigie Inst. Publ., 542.

__________ and N. Broniskovsky. 1944. The genus Ceratium in the Pacific and North Atlantic Oceans. Ibid., 565.

*Gran, H.H. 1902. Das Plankton des Norwegischen Nordmeers. Rep. Norweg. Fish. Invest., 2(5):1-222.

__________ 1905. Diatomeen in 'Nordisches Plankton'. 19, 1-146.

__________ 1906. Diatomeen, Nordisches Plankton von Brandt and Apstein. Botanischer, 8(19). Kiel and Leipzig.

__________ 1929. Quantitative plankton investigations carried out during the expedition with the 'Michael Sars', 1924. Rapp. Cons. Explor. Mer., 56,1-50.

__________ and E.C.Angst. 1931. Plankton diatoms of Puget Sound. Publ. Puget Sound Biol. St. Univ. Washing. 417-519.

Gray, S.F. 1821. A natural arrangement of British Plants. London.

Gregory, W. 1857. On new forms of marine Diatomaceae found in the firth of Clyde and in Loch Fine. Trans. roy. Soc. Edinb., 21:473-542.

*Greville, R.K. 1823-28. Scottish cryptogamic flora, or coloured figures and descriptions of cryptogamic plants, belonging chiefly to the order Fungi, and intended to serve as a continuation of English Botany. 6 vols. 360 plts, with descriptive text. Edingburgh, London.

____________ 1857. Description of some new diatomaceous forms from the West Indies. Quart. J. Micr. Sci. 5, 7-12.

____________ 1859a. Descriptions of Diatomaceae observed in California guano. Ibid., 7,155-166.

____________ 1859b. Description of some new species and varieties of Naviculae etc. observed in Californian guano. Edinb. New Phil. J., 10,25-30.

____________ 1863. Descriptions of new and rare diatoms. Ser. 10. Quart. J. Micr. Sci., 3,227-237.

Griffith, D. de G. 1972. Toxicity of crude oil and detergents to two species of edible molluscs under artificial tidal conditions. Mar. Poll. Sea Life, FAO, 224-229.

Grøntved, J and E. Steemann Nielsen. 1957. Investigations on the phytoplankton in sheltered Danish marine localities. Medd. Kom. Havunders. Kbh. Plankton., 5:1.

*Grunow, A. 1862. Die osterrichischen Diatomaceen nebst Anschluss einiger neuen Arten van anderen Lokalitaten und einer Kritischen Uebersight der bisher bekannten Gattungen und Arten. Verbh. zool. Bot. Ges. Wier., 12, 315-472.

*Grunow, A. 1863. Uber einige neue und ungenugend bekannte Arten und Gattungen von Diatomaceae. Verh. Zool. bot. Ges.Wien, 13,137-62.

* ________ 1867. Nachtragliche Bemerkungen uber die von Hern landig gesamnelton Diatomeen von Honduras. Hedwigia, 6, 33-37.

* ________ 1870. Algae in 'Reise der Osterreichschen Fregatte Novura um die Erde inden Jahrer, 1857,1858,1859'. Bot. Theil., 1,1-104.

________ 1877. New diatoms from Honduras. Mon. Micr. J., 18,165-86.

________ 1880. On some new species of Nitzschia. J. R. micr. Soc., 3,394-97.

Guillard, R.R.L. 1975. Culture of phytoplankton for feeding marine invertebrates. In: Culture of Marine Invertebrate Animals. Plenum Publ. Corp., New York, 26-60.

________ and J.H. Ryther. 1962. Studies on marine planktonic diatoms. 1. Cyclotella nana Hustedt and Detonula confervaceae (Cleve) Grunow. Canadian J. Microbiol., 8, 229-239.

Gulland, J.A. 1970. The fish resources of the Ocean. FAO, Fish. Tech. Pap., (97):1-425.

________ 1971. The fish resources of the Ocean. Fishing News (Books) Ltd. England, 255 p.

Haeckel, E. 1889. Report on the Radiolaria collected by H.M.S. Challenger during the years 1873-1876. Zoology, 18.

Halim, Y. 1963. Microplancton des eaux egyptiens. Le genre Ceratium Schrank (Dinoflagellates). Rapp. Cons. Explor. Mer., 17(2):495-502.

________ 1967. Dinoflagellates of the south east Caribbean Sea. Int. Rev. Ges. Hydrobiol., 52(5):701-755.

Harvey, H.W. 1957. The chemistry and fertility of seawaters. Cambridge Univ. Press. 2nd Ed.

Hela, I and T. Laevatsu. 1961. Fisheries Hydrography. Fishing News (Books) Ltd., London.

Henderson, H.F., R.A. Ryder and A.W. Kudhangania. 1973. Assessing fishery potentials of lakes and reservoirs. J. Fishe Res. Bd. Canada, 30(12): 2000-2009.

Hendey, N.I. 1937. The plankton diatoms of the southern seas. Discovery Rep., 16,151-364.

__________ 1951. Littoral diatoms of Chichester Harbour with special reference to fouling. J. R. micr. Soc., 71,1-86.

__________ 1964. An introductory account of the smaller algae of the coastal waters. Part V. Bacillariophyceae (Diatoms). Fish. Invest. Ser., 4:1-317.

Hornell, J and M.R. Nayudu. 1923. A contribution to the life-history of sardines with notes of the plankton of the Malabar coast. Madras Fish. Bull., 17, 129-197.

*Hovasse, R. 1932. Contribution a l etude des Silicoflagelles, multiplication, variabilite, heredite, affinities. Bull. Biol., 66,448-501.

Huang, R. 1979. Marine diatoms of Langyu Island, Taiwan. Acta Oceanogr. Taiwanica Sci. Rep. Nat. Taiwan Univ., 10, 194-210.

Humphrey, G.F. 1960. The concentration of plankton pigments in Australian waters. CSIRO, Div. Fish. Oceanogr. Tech. Pap.No.9.

__________ 1963. Seasonal variation in plankton pigments in waters off Sydney. Aust. J. Mar. Freshw. Res. 14(1):24-36.

__________ 1963a. Chlorophyll a and c in cultures of marine algae. Ibid., 14(2):148-154.

Humphrey, G.F. 1966. The concentration of chlorophyll *a* and *c* in the south east Indian Ocean. *Aust. J. Mar. Freshw. Res.*, *17*:135-145.

__________ and J.D.Kerr. 1969. Seasonal variations in the Indian Ocean along 110°E. III. Chlorophyll *a* and *c*. *Ibid.*, *20*; 55-64.

Hustedt, F. 1927. Die Kiesalalgen, in Rabenhorst's Kryptogamenflora von Deutschland. *Oster-reich und der Schweiz.*, Leipzig.

__________ 1930. Bacillariophyta. Die Susswasser-Flora Mitteleuropas (Ed. Pascher), 10.

__________ 1931-32. Die Kieselalgen in Dr.L.Rabenhorsts Kryptogamen-Flora, *Deutschland Oster-reich und der Schweiz.*, 7,1-4.

__________ 1955. Marine littoral diatoms of Beufort, North Carolina. *Duke Univ. Mar. Stat. Bull.*, 6, 1-67.

__________ and A.A. Aleem. 1951. Littoral diatoms from the Salstone, near Plymouth. *J. Mar. biol. Ass. U.K.*, *30*:177-196.

Hutchinsen, T.C., P. Kauss and M. Griffith. 1972. The phytotoxicity of crude oil spills in freshwater. *Symp. Water Pollut. Res. Inst. Environment. Sci. Eng., Univ. Toronto.*, 52-58.

Ichimura, S and H. Fukushima. 1963. On the chlorophyll content in surface water of the Indian and the Antarctic Oceans. *Bot. Mag. Tokyo.*, 76:395-399.

Iyengar, M.O.P. and G. Venkataraman. 1951. The ecology and seasonal succession of the algal flora of the river Cooum at Madras with special referance to the Diatomaceae. *J. Madras Univ.*, 21,140-192.

Janisch, C. 1862. The diatoms of the 'Gazelle' Expedition. In: *Kieselalgen des 'Gazelle' Expedition.*

Jitts, H.R. 1963. The simulated in situ measurements of oceanic primary production. Aust. J. Mar. Freshw. Res., 14(2):139-147.

__________ 1965. The summer characteristic of primary productivity in the Tasman and Coral seas. Ibid., 16(2):151-62.

__________ 1969. Seasonal variations in the Indian Ocean along 110°E. IV. Primary Production. Ibid., 20, 65-75.

__________, C.D. McAllister, K.Stephens and J.D.H.Strickland. 1964. The cell division rates of some marine phytoplankters as a function of light and temperature. J. Fish. Res. Bd. Canada, 21(1):139-157.

*Jorgensen, E. 1899. Protophyten und Protozoen in plankton aus der norwegischen Westkuste. Bergen Mus. Aarbog. 6, 1-112.

__________ 1911. Die Ceratium Eine Kurze Monographie der Gattung Ceratium Schrank. Int. Rev. Hydrobiol. 4, suppl.1.

*__________ 1912. Bericht uber die von der schwedischen hydrographisch, biologischen Kommission in den Schwedischen gewasseru in den Jahren 1909-1910. Skr. Schw. Hydrog. biol. Kom., 4,1-20.

__________ 1920. Mediterranean Ceratia. Rep. Danish. Oceanogr. Exped. Medit. J. Biol., 1.

__________ 1923. Mediterranean Dinophyceae. Ibid.,2J, 2.

Josanto, V. 1971. The bottom salinity characters and the factors that influence the salt water penetration in the Vembanad Lake. Bull. Dept. Mar. biol. Oceanogr., 5, 1-16.

Joseph, K.J and V.K. Pillai. 1975. Seasonal and spatial distribution of phytoplankters in Cochin backwater. Bull. Dept. Mar. Sci. Univ. Cochin., 7(1):171-80.

Kabanova, J.G. 1961. Primary production and nutrient salts content in the waters of the Indian Ocean. Okeanol. Issled., 4, 72-75.

__________ 1964. Primary production and nutrient salts content in the Indian Ocean waters in October-April 1960-61. Trud. Inst. Okeanol., 64:85-93.

__________ 1968. Primary production of the northern part of the Indian Ocean. Oceanology, 8, 214-225.

Karsten, G. 1905. Das Phytoplankton des antarktischen meers den material der deutschen Tiefsee Expedition, 1898-99. Wiss. Ergebn. disch. Tiefsee Exp. auf. dem Dampfer 'Valdivia' 1898-99., 1, 1-219.

__________ 1906. Das Phytoplankton des antarktischen meers den material der deutschen Tiefsee Expedition. Ibid., 2, 139-219.

__________ 1907. Das Indische phytoplankton nach den Material der deutschen Tiefsee Expedition 1898-99. Ibid., 3, 223-584.

__________ 1928. Bacillariophyta (Diatomeae). Die Nat. Pflan. Zweit. Auf., 11, 105-303.

Kauss, P., T.C. Hutchinsen and M. Griffith. 1972. Phytotoxicity of crude oil to algae. Proceed. 18th Ann. Tech. Session Inst. Environment. Sci., New York.

Kauss, P.B. and T.C. Hutchinsen. 1974. Studies on the susceptability of Ankistrodesmus species to crude oil components. In: Proc. 19th Congr. Int. Ass. Theor. Applied Limnol., Winnipeg., Canada.

Kisselev, E.A. 1950. (Dinoflagellata of marine and freshwaters of USSR) (in Russion). Publ. Acad. Nauk. SSSR, Moskova.

Koblentz-Mishke, O.J., V.V.Volkovinsky and J.G. Kabanova. 1970. Plankton primary production of the World Ocean. Sci. Expl. of the S. Pacific., National Acad. Sci. Washington, D.C.

Kofoid, C.A. 1907a. New species of Dinoflagellates. Bull. Mus. Comp. Zool. Harward., 50:161-208.

__________ 1907b. Dinoflagellates of the San Diego region. III. Description of new species. Univ. Cal. Publ. Zool., 3:299-340.

__________ 1909. On Peridinium steinii Jorgensen with a note on the nomenclature of the skeleton of the Peridiniaceae. Arch. Protistenk., 16:25-47.

__________ 1931. Report of the biological survey of Mutzu Bay. 18. Protozoan fauna of Mutsu Bay. Sub Class: Dinoflagellata, Tribe Gymnodinioidae. Sci. Rep. Tohoku Univ., ser. 4, 6(1):1-43.

__________ and J.R. Michener. 1911. New genera and species of dinoflagellates. Bull. Mus. Comp. Zool. Harward., 54:265.

__________ and O. Swezy. 1974. The free living unarmoured dinoflagellata. Mem. Univ. Calif., 5,1-538.

Krey, J. 1958. Chemical methods of estimating standing crop of phytoplankton. Rapp. Proc. Verb. cons. Expl. Mer., 144:20-27.

_______ 1973. Primary production in the Indian Ocean. 1. In the Biology of the Indian Ocean. Ecological Studies. 3. (Ed. B.Zeitzschel) pp.115-126.

_______ and B. Babenerd. 1976. Phytoplankton Production. Atlas of the International Indian Ocean Expedition. Inst. Meer. Univ. Kiel., 1-70.

Krishnamurty, K. 1969. Plant pigments in mangrove water. Seminar. some aspects of hydrobiology of shallow waters. CAS in Marine Biology, Porto Novo.

____________ 1971. Phytoplankton pigments in Porto Novo waters (India). Int. Rev. der ges. Hydrobiol., 56,273-282.

Krishnamurty, K and R. Santhanam. 1974. Species distribution of phytoplankton of the Porto Novo region. Proc. 2nd Int. Symp. Phycol. Tax. of Algae.

_____________ and V. Sundararaj. 1973. A survey of environmental features in a section of the Vellar-Coleron estuarine system, S. India. Marine Biology, 23, 229-237.

Krishnamurty, T.M. and R. Viswanathan. 1968. Primary productivity studies in Bombay harbour bay using ^{14}C. Indian J. Exp. Biol., 6, 115-116.

Kunhold, W.W. 1969. Effect of water soluble substances of crude oil on eggs and larvae of Cod and Herring. ICES, CM 1969/E, 18(mimeo).

Kurup, P.G. 1972. Littoral currents in relation to the mud bank formation along the coast of Kerala. Mahasagar, 5(3):158-161.

*Kutzing, F.T. 1844. Die Kieselschaligen Bacillarien oder Diatomeen. Nordhausen.

_____________ 1849. Species Algarum, Leipzig.

*Lacaze, J.C. 1967. E'tude de la croissance d'une algae planctonique en presence d'un detergent utilise pour la distruction des noppes de petrole en mer. C. r. hebd. Seances. Acad. Sci. Paris., 265,489.

*Lagerstedt, N.G.W. 1876. 'Salvattens - Diatomaceer Fran Bohnstan'. Bih. t.k.Svensk. Vet. Akad. Handl. Stockholm, 1(14):1-52.

Laird, B.B., Breivogel and C.S. Yentsch. 1964. The distribution of chlorophyll in the western Indian Ocean during the south-west monsoon period, July 30- Nov., 12, 1963. Woods Hole Oceanogr. Inst. Rep. No.64, 33:1-52.

*Lamarck, J.B. 1816. Histoire naturelle des animaun sans vertebres, presentant les caracters generaud et particuliers de ce animaun leur distribution, leurs classes, leurs familles, leurs genres, et la citation des principales especes qui S'y rapportent (Paris, Verdierel, 2,568.

Lebour, M.V. 1917. The Peridiniales of Plymouth Sound from the region beyond the breakwater. J. Mar. biol. Ass. U.K., 11:83- 200.

__________ 1922. Plymouth Peridinians. 1. Diplopsalis lenticula and its relatives. Ibid., 12,795-812.

__________ 1925. The Dinoflagellates of Northern Seas. Plymouth.

__________ 1930. The planktonic diatoms of Northern Seas. Ray Soc. Publ., 116,1-244.

Lefe'bure, P. 1947. Atlas pour la determination des Diatomees. Laboratoire de micrographie. Pls. 1-31.

*Lewis, F.W. 1861. Notes on new and rare species of Diatomaceae of the United States sea board. Proc. Acad. nat. Sci. Philadelphia, 61-71.

*Lemmermann, E. 1899. Ergebnis einer Reise nach dem Pacific. Plankton Algen. Abh. Nat. Ver. Brem., 16:318-398.

*__________ 1904. Das plankton schwedischen Gewasser. Arch. Bot., 2(2):1-209.

*__________ 1905. Das phytoplankton des Meers. III. Beit. Bot. Central., 19:1-74.

Li, C.W. 1978. Notes on marine littoral diatoms of Taiwan. 1. Some diatoms of Pescodores. Nova Hedwigia, 29:787-812.

*Lindemann, E. 1924. Mitteilungen uber nicht genugend behannte Peridinium. Arch. Protistenk., 47:431-439.

*__________ 1925. Peridineen aus seen der schweiz. Schr. Susswass. Meer., 10:205-208.

Lindemann, E. 1928. Peridineae (Dinoflagellatae) in Engl. Prantl. Natur. Pflanzenfam., 2:3-104.

Lopez, J. 1955. Variacion alometrica en Ceratium tripos. Investigacion pesq., 2,131-159.

Lorenzen, C.L. 1963. Diurnal variation in photosynthetic activity of natural phytoplankton populations. Limnol. Oceanogr., 8(1):56-62.

___________. 1967. Determination of chlorophyll and phaeopigments: spectrophotometric equations. Limnol. Oceanogr., 12,343-346.

Lund, J.W.G., C. Kipling and E.D. Le Cren. 1958. The inverted microscope method of estimating algal numbers and the statistical basis of estimation by counting. Hydrobiologia, 11:143-170.

*Lyngbye, H.C. 1819. Tentamen Hydrophytologiae Danicae. Copenhagen.

Macartney, J. 1810. Observations upon luminous animals. Phil. Trans. Roy. Soc. London., 238-293.

Madhupratap, M., T.S.S. Rao and P. Haridas. 1977. Secondary production in Cochin backwaters, a tropical monsoonal estuary. Proc. Symp. Warm water Zoopl., NIO, Goa., 515-519.

Malone, T.C. 1971. The relative importance of nannoplankton and net plankton as primary producers in the California current system. Fishery Bull., 69: 799-802.

Mangin, M.L. 1922. Phytoplankton Antarctique (Exped, Antarctique de la 'Scotia' 1902-1904). Mem. Acad. Sci. Inst. France., 27(5):1-134.

Marr, J.C., D.K. Ghose, Giulio Pontecory, B.T.Rothschild and A.R. Tussing. 1971. A plan for fishery development in the Indian Ocean. IOFC/DEV/71/1, FAO, Rome, 78p.

Matzenauer, G. 1933. Die Dingflagellaten des Indischen Ozeans. Bot. Arch., 35:437-510.

McAllister, C.D., T.R. Parsons and J.D.H. Strickland. 1960. Primary productivity and fertility at station 'P' in the North-East Pacific Ocean. Ext. J. Consel. Internat. Pour L'explor. de la mer., 25(3):240-259.

____________, __________, K.Stephens and J.D.H.Strickland. 1961. Measurements of primary production in coastal seawater using a large volume plastic sphere. Limnol. Oceanogr., 6(3):237-258.

____________, N.Shah and J.D.H. Strickland. 1964. Marine phytoplankton photosynthesis as a function of light intensity: a comparison of methods. J. Fish. Res. Bd. Canada., 21:159-181.

McGill, D.A and T.J.Lawson. 1966. The distribution of chlorophyll in the western Indian Ocean during the north east monsoon period. Tech. Rep., WHOI, 66.

Menon, K.S. 1931. A preliminary account of the Madras plankton, Rec. Ind. Mus., 33,489-516.

Menon, M.A.S. 1945. Observations on the seasonal distribution of the plankton of Trivandrum coast. Proc. Ind. Acad. Sci., 22, 31-62.

Menzel, D.W., J.Anderson and Ann Randtke. 1970. Marine phytoplankton vary in their response to chlorinated hydrocarbons. Science, 167(3926):1724-1726.

*Meunier, A. 1919. Microplankton de la mer Flamarde. Les. Peridiniens. Mem. Mus. Hist. Nat. Belg., 8(1):3-116.

*Michaelis, G.A. 1830. Ueber das Leuchten der Ostsee nach eigenen Biobachtungen (Handburg, Perthes & Besser) 1-52.

Miquel, P. 1892. De la culture artificielle des Diatomees. C.R. Acad. Sci. Paris, 44,780.

Mironov, O.G. 1967. The effect of oil and oil products upon some molluscs in the littoral zone of the Black Sea (in Russian). Zool. Zh., 46,134-136.

__________ 1968. Hydrocarbon pollution of the sea and its influence on marine organisms. Helgoland. Wiss. Meeresunters., 17, 335-339.

__________ 1970. The effect of oil pollution on the flora and fauna of the Black Sea. FAO Tech. Conf. Mar. Pollut., Rome, E-92.

__________ and L.A. Lanskaya. 1967. Biology and distribution of plankton of the Southern Seas (in Russian). Oceanogr. Commission, Moscow.

Misra, J.N. 1956. A systematic account of some littoral marine diatoms from the west coast of India. J. Bomb. Nat. Hist., 53(4):537-568.

Mitchell-Innes, B.A. 1967. Primary production studies in the south west Indian Ocean 1961-63. S. African Ass. Mar. Biol. Oceanogr. Res. Inst. Investigation Rep., 20:1-16.

Mitchell, C.T., E.K.Anderson, L.G.Jones and W.J. North. 1970. J. water Pollut. Control. , 4(5 pt):812-818.

Moiseev, P. 1969. Living resources of the world oceans. Moscow, pp.1-330.

*
Muller, O.F. 1786. Animalcula infusoria fluviatila et marina. Op. Post. O. Fabricia. Hauniae, pp. 1-367.

Murray, J. 1876. Preliminary reports to Prof. Wyville Thompson, F.R.S., Director of the Civilian Scientific staff on work done on board the 'Challenger'. Proc. R. Soc. London., 24(170):471-543.

Murray, G and F.G. Whitting. 1899. New Peridiniaceae from the Atlantic. Trans. Linn. Soc. London., 5(9): 321-342.

Nair, P.V.R. 1959. The marine planktonic diatoms of the Trivandrum coast. Bull. cent. Res. Inst. Univ. Kerala, ser. C, 7(1):1-63.

Nair, P.V.R. 1966. Standardization of ^{14}C stock solution using scintillation and bilogical methods in primary production studies. Proceed. All India Symp. Radioact. Meterol. Radionucleides, Atomic Energy Comm., Trombay., pp.15-20.

__________ 1970. Primary productivity in the Indian Seas. Bull. cent. Mar. Fish. Res. Inst., 22, 1-56.

__________ 1972. Phosphorus fractions in Gulf of Mannar and their relation to organic production. J. mar. biol. Ass. India., 14(2):752-757.

__________ 1974. Studies on the Primary Production in the Indian Seas. Ph.D. thesis. Univ. Cochin.

__________, G. Luther and C.Adolph. 1965. An ecological study of some pools near Mandapam (S. India) formed as a result of the cyclone and tidal wave of 1964. J. mar. biol. Ass. India., 7(2):420-39.

__________, S. Samuel, K.J.Joseph and V.K.Balachandran. 1968. Primary production and potential fishery resources in the seas around India. Proceed. Symp. Living Resources. seas around India, Cochin., 184-198.

__________, C.S.G. Pillai. 1972. Primary productivity of some coral reefs in the Indian Seas. Proceed. symp. corals and coral reefs., pp.33-42.

__________ and K.J.Joseph. 1975. Standardization and inter-calibration trials with ^{14}C isotope. Proc. symp. use of Radiations and Radioisotopes in studies on animal production, IVRI, Izatnagar, 421-430.

__________, K.J.Joseph, V.K.Balachandran and V.K.Pillai. 1975. A study on the primary production in the Vembanad Lake. Bull. Dept. Mar. Sci. Univ. Cochin. 7(1): 161-170.

__________ et al. (MS) Studies on phytoplankton productivity of the Mud Bank. Bull. CMFRI.

Nair, R.R., P.S.N.Murty and V.V.R. Varadachari. 1966. Physical and chemical aspects of mud deposit of Vypeen Island. Internat. Indian Ocean Exp. Newsletter., 4(2):10.

Okamura, R. 1907. An annotated list of plankton organisms of the Japanese coast. Annotations Zool. Jap., 6(2):121-151.

O'Meara, E. 1871. On some new species of the genus Amphiprora, Amphiprora sulcata. Quart. J. micr. Sci., 11, 1-21.

Ostenfeld, C.H. 1899. Plankton in 1898. In Knudson and Ostenfeld., pp.47-93.

____________ and J. Schmidt. 1901. Plankton fra det Rode Hav og Adenbugten. Vidensk. Medd. Naturh. Foren., 141-182.

Pantastico, J.B. (MS) 1977. Techniques of the mass culture of diatoms. SEAFDEC Tech. Rep.

Parsons, T.R. 1961. On the pigment composition of eleven species of marine plankters. J.Fish.Res.Bd. Canada, 18:1017-1025.

____________ and J.D.H. Strickland. 1963. Discussion of spectrophotometric determination of marine plant pigments with revised equations for asserntaining chlorophylls and carotenoides. J. Mar. Res., 21:155-163.

*Pascher, A. 1927. Die braume Algenreihe aus der Verwandstchaft der Dinoflagellaten (Dinophyceen). Arch. Protostenk, 58(1):1-54.

Patil, M.R. and C.P. Ramamirtham. 1963. Hydrography of the Laccadives offshore waters. A study of the winter conditions. J. mar. biol. Ass. India ., 5:159-165.

Patnaik, S. 1973. Observations on the seasonal fluctuations of plankton in the Chilka Lake. Ind. J. Fish., 20(1):43-55.

Paulson, O. 1904. Plankton investigations in the waters around Iceland in 1903. Medd. Komm. Hav.Ser. Plankton., 1(1):1-40.

__________ 1905. On some peridineae and plankton diatoms. Ibid., 1(3).

__________ 1907. The Peridiniales of the Danish waters. Ibid., 1, 1-25.

__________ 1908. Peridiniales in Nordischen Plankton., 18:1-124.

__________ 1931. E'tude sur le microplancton de la Mer d'Alboran. Trab. del Inst. Espanol. Oceanogr., Madrid, 4,1-108.

*Pavillard, J. 1909. Sur les Peridinien du Golfedesion. Bull. Soc. Bot. France., 9:277-284.

*__________ 1916. Recherches sur les Peridiniens du Golfe dusion. Trav. Inst. Bot. Univ. Montpellier. ser. 4:9-70.

*__________ 1931. Phytoplancton (Diatomees, Peridiniens) provenant des campagne scientifiques de Prince Albert ler de Monaco. Result. Camps. Saint., 82:1-203.

*Peragallo, H. 1897-1908. Diatomees marines de France, et des districts maritimes voisins. Grez-sur-Loing.

*Peters, N. 1930. Peridinea in Tierwelt der Nord und Ostsee.

*__________ 1934. Die Bevolkung des nidatlantischen ozeans mit Ceratien. Wiss. Ergebn. Dt. Exped. 'Meteor' 12(1):1-69.

Pillai, V.K.P, K.J.Joseph and A.K.K. Nair. 1975. The plankton production in the Vembanad Lake and adjacent waters in relation to the environmental parameters. Bull. Dept. mar. Sci. Univ. Cochin, 7(1):137-50.

*Pouchet, G. 1883. Contribution a l'histoire des cilio-flagelles. J. Anat. Physiol., 19:399-455.

Prakash, A. 1971. Terrigenous organic matter and coastal phytoplankton fertility. In J.D. Costlow (Ed.) Fertility of the Sea, vol.2, Gordon & Breach, New York, pp. 351-368.

__________ and A.H.V. Sarma. 1964. On the occurrence of 'Red water' phenomenon on the west coast of India. Curr. Sci., 33(6):168-170.

Prasad, R.R. 1953. Swarming of Noctiluca in the Palk Bay and its effects on the 'choodai' fishery, with a note on the possible use of Noctiluca as an indicator species. Proc. Indian Acad. Sci., 38B, 40-47.

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

__________ 1958. A note on the occurrence and feeding habits of Noctiluca and their effects on the plankton community and fisheries. Proc. Indian Acad. Sci., 47(6):331-337.

__________ 1964. Preliminary observations on the productivity of certain tuna waters off the west coast of India. Proc. Symp. Scomb. Fishes., Pt, II; 794-798.

__________ 1966. Some aspects of Productivity and fisheries of the west coast of India. Seafood Trade J., 1(8):11-15.

__________ and R. Jayaraman. 1954. Preliminary studies on certain changes in the plankton and hydrological conditions associated with the swarming of Noctiluca. Proc. Indian Acad. Sci., 40B:49-57.

__________, V.K.Pillai and P.V.R. Nair. 1958. A note on the organic production in the inshore waters of the Gulf of Mannar. Curr. Sci., 27:302-303.

Prasad, R.R. and P.V.R. Nair. 1960. A preliminary account of primary production and its relation to fisheries of the inshore waters of the Gulf of Mannar. Indian J. Fish., 7:165-168.

__________ and __________ 1963. Studies on organic production. 1. Gulf of Mannar. J. mar. biol. Ass. India., 5(1):1-26.

__________ and __________ 1973. India and the Indian Ocean fisheries. Ibid., 15(1):1-19.

__________, P.V.R. Nair and J.J.A. McLaughlin. 1964. Standardization of ^{14}C stock solution and filter efficiency in the comparison of primary productivity measurements. Proceed. Indian Acad. Sci., 59(5):245-251.

__________, S.K. Banerji and P.V.R. Nair. 1970. A quantitative assessment of the potential fishery resources of the Indian Ocean and adjoining seas. Indian J. Anim. Sci., 40(1):73-98.

Pringsheim, E.G. 1949. Pure cultures of algae. Their preparation and maintenance. Cambridge Univ. Press., pp.1-119.

Pritchard, A. 1861. A history of Infusoria. 4th Ed. London.

Provosoli, L., J.J.A. McLaughlin and M.R. Droop. 1957. The development of artificial media for marine algae. Arch. Mikrobiol., 25:392-428.

Prouse, N.J., D.C. Gordon and P.D. Keizer. 1975. The effects of oil contaminated water on the exponential growth of unialgal batch cultures of marine phytoplankton. J. Fish. Res. Bd. Canada.

Qasim, S.Z. 1970. Some problems related to the food chain in a tropical estuary. In: J.H.Steele (Ed) Marine Food Chains, pp.45-51. Oliver & Boyd, Edinburgh.

Qasim, S.Z. 1973. Productivity of backwaters and estuaries. The Biology of the Indian Ocean, Ecological Studies-3. B. Zeitzschel (Ed.), pp.143-154.

___________ 1977. Biological Productivity of the Indian Ocean. Indian J. Mar. Sci., 6, 122-137.

___________ 1979. Primary production in some tropical environments. Marine Production Mechanics (Ed. M.J.Dunbar). Internat. Biol. Progr. Cambridge, Univ., pp.31-69.

___________ 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.

___________, P.M.A. Bhattathiri and S.A.H. Abidi. 1968. Solar radiation and its penetration in a tropical estuary. J. Exp. Mar. Biol. Ecology., 2,87-103.

___________ and C.K. Gopinathan. 1969. Tidal cycle and the environmental features of Cochin backwater. Proc. Indian Acad. Sci., 19,336-348.

___________, S. Wellershaus, P.M.A. Bhattathiri and S.A.H. Abidi. 1969. Organic production in a tropical estuary. Ibid., B69:51-94.

___________ and P.M.A. Bhattathiri. 1971. Primary production of a seagrass bed on Kavaratti Atoll (Laccadives). Hydrobiologia, 38,29-38.

___________, ___________ and V.P.Devassy. 1972 a. The influence of salinity on the rate of photosynthesis and abundance of some tropical phytoplankton. Mar. Biol., 12, 200-206.

___________, ___________, ___________. 1972 b. The effect of intensity and quality of illumination on the photosynthesis of some tropical phytoplankton. Mar. Biol., 16,22-27.

Qasim, S.Z., P.M.A. Bhattathiri and C.V.G. Reddy, 1972 c. Primary production of an atoll in the Laccadives. Internat. Rev. ges. Hydrobiol., 57,207-225.

__________, ______________ and V.P. Devassy. 1973. Growth kinetics and nutrient requirements of two tropical marine phytoplankton. Mar. Biol., 21, 299-304.

__________, S. Vijayaraghavan, K.J.Joseph and V.K.Balachandran. 1974. Contribution of microplankton and nannoplankton in the waters of tropical estuary. Indian J. Mar. Sci., 3, 146-149.

__________, M.V.M. Wafar, S.Vijayaraghavan, J.P.Royan and L.Krishnakumari. 1978. Biological productivity of coastal waters of India, from Dabhol to Tuticorin. Indian J. Mar. Sci., 7, 84-93.

Rabenhorst, L. 1864. Flora Europea Agarum. 1. Algae, Diatomaceae.

Radhakrishna, K. 1969. Primary productivity studies in the shelf waters off Alleppey, south-west India, during the post-monsoon, 1967. Mar. Biol., 4: 174-181.

______________ 1978. Primary productivity of the Bay of Bengal during March-April 1975. Indian J. Mar. Sci., 7(1):58-60.

______________, P.M.A. Bhattathiri and V.P.Devassy. 1978. Primary productivity of the Bay of Bengal during August-September 1976. Indian J. Mar. Sci. , 7, 94-98.

______________, V.P.Devassy, P.M.A.Bhattathiri and R.S. Bhargava. 1978. Primary productivity in the North-eastern Arabian Sea. Ibid., 7(2):137-139.

______________, __________, R.S. Bhargava and P.M.A. Bhattathiri. 1978. Primary production in the Northern Arabian Sea. Ibid., 7, 271-275.

Ramamirtham, C.P. and R. Jayaraman. 1960. Hydrographical features of the continental shelf waters off Cochin during the years 1958-59. J. mar. biol. Ass. India.,2(2):199-207.

______________ and ____________ 1963. Some aspects of the hydrographical conditions of the backwaters around Wellington island (Cochin). Ibid., 5: 170-177.

______________ and M.R. Patil. 1965. Hydrography of the west coast of India during the pre-monsoon period of the year 1962. II. In and offshore waters of the Konkan and Malabar coasts. Ibid., 7(1):150-168.

Ramasastry, A.A and P. Myrland. 1960. Distribution of temperature, salinity and density in the Arabian Sea along the south Malabar coast during the post monsoon season. Indian J. Fish., 6(2):223-255.

*Rampi, L. 1939. Su qualche Peridinea nana, nuova o curiosa nel fitoplancton del mare Ligure. Nuovo giorn bot. ital. N.S., 46:456-469.

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

Reddy, C.V.G and V.N.Sankaranarayanan. 1968. Distribution of nutrients in the shelf waters of the Arabian Sea along the west coast of India. Bull.nat. Inst. Sci. India., 38:206-220.

Reinhold, T. 1937. Fossil diatoms of the Neogene of Java and their zonal distribution. Verhand. Geol. Ser. xii, 1-132.

*Rich, F. 1937. Contributions to our knowledge of the fresh-water algae of Africa. 10. Trans. Roy. Soc. S. Africa, 20, 149.

Roper, F.C.S. 1858. Notes on some new species and varities of British Marine Diatomaceae. Quart. J. Micr. Sci., 6:17-25.

Roy, H.K. 1949. Some potamological aspects of the river Hooghly in relation to Calcutta water supply. Science and culture, 14(8):318-324.

________ 1955. Plankton ecology of the river Hooghly at Palta, W. Bengal. Ecology, 36(2):169-175.

Roy, J.C. 1954. Periodicity of the plankton diatoms of the Chilka Lake for the years 1950 and 1951. J. Bomb. Nat. Hist. Soc., 52(1):112-123.

Ryder, R.A. 1965. A method for estimating the potential fish production of north- temperate lakes. Trans. Amer. Fish. Sàc., 94(3):214-218.

Ryther, J.H. 1959. Potential productivity of the sea. Science, 130:602-608.

________ and D.W. Menzel. 1959. Light adaptation by marine phytoplankton. Limnol. Oceanogr., 4(9):492-497.

________, J.R. Hall, A.K. Pease, A.Bakeem and M.M. Jones. 1966. Primary organic production in relation to the chemistry and hydrography of the western Indian Ocean. Limnol. Oceanogr., 11,371-380.

Saijo, Y. 1964. Size distribution of photosynthesizing phytoplankton in the Indian Ocean. J. Oceanogr. Soc. Japan., 19(4):187-189.

Samuel, C.T., N.M.Shah and G.E. Fogg. 1971. Liberation of extracellular products of photosynthesis by tropical phytoplankton. J. Mar. biol. Ass. U.K., 51, 793-798.

Sankaranarayanan, V.N. and S.Z. Qasim. 1969. Nutrients of the Cochin Backwater in relation to environmental characteristics. Mar. Biol., 2,236-247.

Santhanam, R., K. Krishnamurty and V.Sundararaj. 1975. Quantitative phytoplankton ecology. Bull. Dept. Mar. Sci. Univ. Cochin., 7(4):769-779.

Sato, S. 1958. Ecological studies on attaching diatoms with special reference to the relations to planktonic and benthic diatoms. 1. General aspects of the seasonal variation of the attaching diatoms at the Shiogama harbour. Bull. Tohoku Reg. Fish. Lab., 11,94-111.

*Saville-Kent, W. 1882. A manual of the Infusoria. London.

Schiller, J. 1928. Die planktischen vegetationes des Adriatischen meers. c. Dinoflagellata. 1 Teil. Adiniferidae, Dinophysidaceae. Systematischer. Arch. Protistenk., 61(1):38-44.

__________ 1929. Ueber eine biologische und hydrographie sche untersuchung des Ober flachen wasser imm West-lichem Mittelmeer imm August 1928. Bot. Arch. 27:384 - 419.

__________ 1933. Dinoflagellatae (Peridineae). In: Rabenhorst's Kryptogamenflora. Deutchland, Osterreich und der schweiz. , 10:Abt, 3, 1-617.

__________ 1937. Dinoflagellatae (Peridineae). In: Rabenhorst Kryptogammenflora. Ibid., 2, 1-590.

Schmidt, A. 1874-1944. Atlas der Diatomaceen-Kunde. Plts. 1-460. Leipzig.

Schmidt, J. 1901. Peridiniales. In: Flora of Koch Chang by Johs. Schmidt. Bot. Tiddsk., 24:212-221.

*Schreiber, E. 1925. Zur Kenntnis der Physiologie und Sexualitat hoperer Volvocales. Z. Bot., 17,336.

Schröder, B. 1900. Phytoplankton des Golfes von Neapel. Mitt. Zool. Stat. Neapel., 14:1-38.

__________ 1906. Beitrage zur Kenntnis der Phytoplankton warmer meere. Veutekjahr. naturf. Ges. Zurich., 51:319-377.

*Schutt, F. 1892. Ueber organisation ventral nisse des plasmaleibes der Peridineen. SB Akad. Wiss. Berlin, 1892, 377-384.

__________ 1895. Die Peridineen der Plankton Expedition de Humboldt Stiflung. 1. Algae muner Teil. Quarto, 170.

__________ 1896. 'Peridiniales' in Engler und Prantl. 'Die naturlichen Pflanzenfamilien', 2: 30 pp. Leipzig.

__________ 1897. Bacillariales. Naturlichen Pflanzenfamilien. 1, 1b, 31-150.

__________ 1900. Die Erklarung des centrifugalen Dickenwachs der membran. Bot. Ztg., 58(16-17): 245-273.

Seshadri, B. 1957. Seasonal variations in the total biomass and total organic matter of the plankton in the marine zone of the Vellar estuary. J. zool. Soc. India, 9, 183-191.

Seshappa, G. 1954. Phosphate content of mud banks along Malabr coast. Nature, London, 171:526.

__________ and R. Jayaraman. 1956. Observations on composition of bottom muds in relation to the phosphate cycle in the inshore waters of the Malabar coast. Proc. Indian Acad. Sci., 43B:287.

Shadbolt, G. 1854. A short description of some new forms of Diatomaceae from Port Natal. Trans. micro. Soc., London., 2, 13-18.

Shah, N.M. 1967. Certain features of diurnal variation of phytoplankton pigments in the Arabian Sea off Cochin. Proceed. Symp. Indian Ocean., Nat. Inst., Sci. India, Bull., 38:727-732.

__________ 1973. Seasonal variation of phytoplankton pigments and some of the associated oceanographic parameters in the Laccadive Sea off Cochin. In: The Biology of the Indian Ocean, 175-185, (Ed.B.Zeitzschel).

Sharma, G.S. 1966. Thermocline as an indicator of upwelling. J. mar. biol. Ass. India., 8(1):8-19.

__________ 1968. Seasonal variation of some hydrographic properties of the shelf waters off the west coast of India. Bull. Nat. Inst. Sci. India., 38, 263-276.

__________ 1974. Upwelling off the west coast of India. Vayumandal (spl. publ. Indian Met. Soc.).

Shetty, H.P.C., S.B.Saha and B.B. Ghosh. 1961. Observations on the distribution of plankton in the Hooghly-Matlah estuarine system with notes on their relation to commercial fish landings. Indian J. Fish., 8(2):326-363.

Shomura, R.S. 1971. Indian Ocean, in: The Fish Resources of the Ocean. (J.A.Gulland, ed.), Fishing News (Books) Ltd., England, 97-108.

__________, O. Menasveta, A. Suda and F. Talbot. 1967. The present status of fisheries and assessment of potential resources of the Indian Ocean and adjacent seas., FAO, Fish. Rep., 54:1-32.

Silas, E.G., P.V.R. Nair and C.P.Gopinathan. 1975. Application of carbon isotope technique in fishery research in the seas around India. Proc. Symp. Use of Radiations and Radioisotopes in studies on animal production. IVRI, Izatnagar, 431-439.

Silva, E de, S. 1955. Dinoflagellidos do plancton marinho de Angola. Anais Junta Invest. Ultramar, 10:1-85.

Smith, W.M. 1852. Notes on the Diatomaceae with description of British species included in the genus Pleurosigma. Ann. Mag. nat. Hist., 9:1-12.

__________ 1853-56. A synopsis of the British Diatomaceae. vols. 1 (1853), vol. 2(1856). London.

Sournia, A. 1967. Contribution a'la connainance des Peridinium microplanktonique du canal de Mozambique. Bull. Museum Nat. Hist. Nat. Ser. 11,39(2):417-438.

Sournia, A. 1967a. Le genre Ceratium (Peridinein) planctonique dans le canal de mozambique. Contribution a une revision mondiale. Vie et milieu, Serie A: Biologie marine, 18(2&3): 375-499.

__________ 1968. Diatomees planctonique du canal de Mozambique et de l'ile Maurice. Mem. O.R.S.T.O M, 31:1-120.

__________ 1970. A check list of planktonic diatoms and dinoflagellates from the Mozambique channel. Bull; Mar. Sci., 20(3):678-696.

Spencer, C.P. 1964. The estimation of phytoplankton pigments. J. Cons. perm. int. Explor. Mecr., 28:327-334.

Steele, J.H and C.S.Yentsch. 1960. The vertical distribution of chlorophyll. J. Mar. biol. Ass. U.K.,39: 217-226.

*Steemann Nielsen, E. 1934. Untersuchungen uber der Verbreitung Biologie und variation der Ceratium in Sudlichen, stillen ozean. Carlsberg Foundation Oceanogr. Rep. Exped. 'Dana', 1(4).

__________ 1949. A reversible inactivation of chlorophyll in vivo. Physiol. Plant., 2,247-265.

__________ 1952. The use of radioactive carbon (14C) for measuring organic production in the sea. Extract. du. J. consel. Internat. Pour. L'explor. de la mer., 18(2):117-140.

__________ 1954. On organic production in the Oceans. Extract. du. J. consel. Internat. Pour. L'explor. de la mer., 19(3):309-328.

__________ 1959. Primary production in tropical marine areas. J. mar. biol. Ass. India., 1(1):7-12.

Steemann Nielsen, E. 1965. On the determination of the activity in ^{14}C ampoules for measuring primary production. Limnol. Oceanogr., 10, 247-252.

________________ and E.A. Jensen. 1957. Primary organic production - the autotrophic production of organic matter in the Oceans. Galathea Rep. 1, 49-136.

________________ and V.K.Hansen. 1959. Measurement with the respiration rates in natural populations of phytoplankton. Deep Sea Res., 5:222-223.

________________ and S. Wium-Anderson. 1970. Copper ions as poison in the sea and freshwater. Mar. Biol., 6(2):93-97.

Stefansson, V and F.A. Richards. 1963. Limnol. Oceanogr. 8, 394-410.

Steidinger, K.A and J. Williams. 1970. Dinoflagellates. Mem. Hourglass Cruises., 2, 1-251.

*Stein, F.R. 1883. Der organismus der Infusions thiere nach eigenen forchungen in systematischen reipenfolge bear beite. Abt. III, Die Naturgeschiate der arthorodelen Flagellaten, 30 pp. Leipzig.

Stoll, D.R. and R.R.L. Guillard. 1974. Synergestic effect of naphthalene, toxicity and phosphate dificiency in a marine diatom. Abst. 37th Ann. Meet. Amer. Soc. Limnol. Oceanogr.

Strickland, J.D.H. 1958. Solar radiation penetrating the ocean. A review of requirements, data and methods of measurements with particular reference to photosynthetic productivity. J. Fish. Res. Bd. Canada, 15:453-493.

________________ 1960. Measuring the production of marine phytoplankton. Ibid., 122, 172 p.

Strickland, J.D.H and T.R. Parsons. 1968. A practical handbook of seawater analysis. Fish. Res. Bd. Canada, 167, 1-311.

Subrahmanyan, R. 1946. A systematic account of the marine plankton diatoms of the Madras coast. Proc. Indian Acad. Sci., 24, 85-197.

_____________ 1954. A new member of the Euglenineae, *Protoeuglena noctilucae* Gen. et. sp. nov., occurring in *Noctiluca miliaris* Sur., causing green discolouration of the sea off Calicut. Ibid., 39:118-127.

_____________ 1954a. On the life-history and ecology of *Hornellia marina* Gen et sp. nov., (Chloromonadineae) causing green discolouration of the sea and mortality among marine organisms off the Malabar coast. Indian J. Fish., 1, 182-203.

_____________ 1958. Phytoplankton organisms of the Arabian Sea off the west coast of India. J. Indian Bot. Soc., 37(4):435-441.

_____________ 1958a. Ecological studies on the marine phytoplankton on the west coast of India. Ibid., 37(4):145-151.

_____________ 1959. Phytoplankton on the waters of the west coast of India and its bearing on fisheries. Proc. Symp. Algology., 292-301.

_____________ 1959a. Studies on the phytoplankton of the west coast of India. Part I and II. Proc. Indian Acad. Sci., 50.

_____________ 1960. Observations on the effect of the monsoons in the production of phytoplankton. J. Indian Bot. Soc., 39(1):78-89.

_____________ 1965. Studies on the plankton of the east coast of India. Proc. Indian Acad. Sci. 59, 12-24.

Subrahmanyan, R. 1967. Studies on the phytoplankton of the west coast of India. Part IV. J. mar. biol. Ass. India., 7(2):406-419.

______________ 1968. The Dinophyceae of the Indian Seas. Part 1. Genus Ceratium Schrank. Mem. II., Ibid., 1-118.

______________ 1971. The Dinophyceae of the Indian Seas. Part II. Family Peridiniaceae Schutt emend Lindemann. Ibid., 1-334.

______________ and A.H.V. Sarma. 1960. Studies on the phytoplankton of the west coast of India. Part III. Indian J. Fish., 7(2):307-336.

______________ and R. Sen Gupta. 1963. Studies on the plankton of the east coast of India. Proc. Indian Acad. Sci., 57(1):1-14.

______________, C.P.Gopinathan and C.T. Pillai. 1971. Phytoplankton of the Indian Ocean: some ecological problems. J. Mar. biol. Ass. India., 17(3):

Sukhanova, I.N. 1962. On the specific composition and distribution of the phytoplankton in the North Indian Ocean (in Russian). Trud. Inst. Okeanol. Akad. Nauk. SSSR., 58:27-39.

______________ 1964. The phytoplankton of the north eastern part of the Indian Ocean in the season of the south west monsoon (in Russian). Ibid., 65:24-31.

Sundararaj, V and K. Krishnamurty. 1973. Photosynthetic pigments and primary production. Curr. Sci., 42(6):185-189.

Sverdrup, H.U, M.W. Johnson and R.H. Fleming. 1942. The Oceans, their physics and chemistry and general biology. New York. Prentice-Hall Inc.

Talling, J.F. 1960. Comparative laboratory and field studies of photosynthesis by a marine planktonic diatom. Limnol. Oceanogr., 5,62-77.

Talling, J.F and D. Driver. 1963. Some problems in the estimation of chlorophyll a in phytoplankton. Proceed. Conf. Primary Prod. measurements., Univ. Hawaii, 142-146.

Taylor, F.J.R. 1966. Phytoplankton of the south western Indian Ocean. Nova Hedwigia, 12(3&4):433-476.

Teixeira, C. 1963. Relative rate of photosynthesis and standing stock of the net phytoplankton and nanno-plankton. Boletin do Inst. Oceanogr. Univ. Sao Polo. 13:53-60.

__________ and J. Tundisi. 1967. Primary production and phytoplankton in equatorial waters. Bull. mar. Sci. 17(4):884-891.

__________, J. Tundisi and Y.J.Santoro. 1969. Inst. Revue Ges. Hydrobiol., 54,289-301.

Thwaites, G.H.K. 1848. Further observations on the Diatomaceae with descriptions of new genera and species. Ann. Mag. nat. Hist. ser., 2, 161-72.

Untawale, A.G., S.N.Dwivedi and S.Y.S. Singbal. 1973. Ecology of mangroves in Mandovi and Zuari estuaries and the inter-connecting Cumbarjua canal, Goa. Indian J. Mar. Sci., 2, 47-53.

Vallentyne, J.R. 1965. Net primary productivity and photo-synthetic efficiency in the biosphere. Mem. Inst. Ital. Idrobiol., 18,309-311.

Vandermeulen, J.H and T.P. Ahern. 1976. Effect of petroleum hydrocarbons on algal physiology: review and progress report. In: Effects of pollutants on aquatic organisms (Ed. A.P.M. Lockwood) pp.108-125.

Van Heurck, H. 1880. Synopsis des diatomees de Belgique. Atlas (1880-83), Text 1885. Anvers.

__________ 1899. Traite des Diatomees. Anvers. (A treatise on the Diatomaceae) English Trans. (Ali Baxter, 1896).

*Vanhoffen, E. 1897. Botanische Ergebnisse der Gesellschaft fur Ergebnisse zu Berlin unter Leitung Dr. von Drygelski ausgesandten Gronlands, Expedition nach Dr. Vanhoffen's sammlungen beurbeitet. A. Krypt. III. Peridineen und Dinobryon. Bibl.Bot.8:25-27.

Varma, P.U and P.G.Kurup. 1969. Formation of the 'chakara' (mud bank) on the Kerala coast. Curr. Sci., 38 (23):559-560.

Velappan Nair, R and R.Subrahmanyan, 1955. The diatom Fragilaria oceanica Cleve, an indicator of abundance of the Indian oil sardine, Sardinella longiceps Cuv. & Val. Curr. Sci., 24, 41-42.

Venkataraman, G. 1939. A systematic account of some south Indian diatoms. Proc. Indian Acad. Sci., 10(6): 293-368.

Venugopalan, V.K. 1969. Primary production in the estuarine and inshore waters of Porto Novo. (11°29'N - 79° 49'E). Bull. Nat. Inst. Oceanogr., 9, 57-62.

Vijayaraghavan, S., K.J.Joseph and V.K.Balachandran. 1974. Preliminary studies on nannoplankton productivity. Mahasagar, Bull. Nat. Inst. Oceanogr., 7,125-29.

Vollenweider, R.A. (Ed.). 1969. A manual on methods for measuring primary production in aquatic environments. IBP Hand Book. 12, Blackwell Sc. Publ., Oxford, pp.1-213.

Walne, P.R. 1974. Culture of bivalve molluscs, 50 years experience at Conway. Fishing News (Books) Ltd., pp. 1-173.

West, T. 1860. Remarks on some Diatomaceae, new or imperfectly described and a new desmid. Trans. Micr. Soc. London., 8, 147-153.

Wood, E.J.F. 1954. Dinoflagellates in the Australian region. Austr. J. Mar. Freshw. Res., 5(2):171-351.

Wood, E.J.F. 1963a. Dinoflagellates in the Australian region. II. Recent collections. Austr. CSIRO. Div. Fish. Tech. Pap., 14,1-55.

__________ 1963b. Dinoflagellates in the Australian region. III. Further collections. Austr.CSIRO. Div. Fish. Tech. Pap., 17, 2-20.

__________ 1963c. Checklist of Dinoflagellates recorded from the Indian Ocean. Austr. Div. Fish. Oceanogr. Rep., 28:1-55.

__________ 1963d. A study of the diatom flora of fresh sediments of the south Texas Bay and adjacent waters. Inst. Mar. Sci., 9, 237-310.

__________ 1966. Phytoplankton studies in the eastern Indian Ocean. Int. Oceanogr. Congr. Moscow., Abst., 396-397.

Wooster, W.S., M.B.Schaefer and M.K.Robinson. 1967. Atlas of the Arabian Sea for fisheries oceanography. Univ. Calif. Inst. Mar. Resources., 67-112.

Yentsch, C.S. and D.W. Menzel. 1963. A method for the determination of phytoplankton chlorophyll and pheophytin by fluorescence. Deep Sea Res., 10(3):221-231.

__________ and R.F. Scagel. 1958. Diurnal study of phytoplankton pigments an in situ study in east sound, Washington. J. Mar. Research., 17,567-583.

Zernova, V.V. 1962. Quantitative distribution of the phytoplankton in the Northern Indian Ocean. (in Russian) In: P.I.Usachev (Ed.) Biological marine studies. Izd. Akad. Nauk. SSSR, 58:45-53.

__________ and A. Ivanov. 1964. On the distribution of phytoplankton as depending from hydrological conditions in the northern part of the Indian Ocean. (in Russian). Trud. Inst. Okeanol. Akad. Nauk., SSSR, 64:257-264.

*Not referred in original. .....