STUDIES ON THE ECOLOGY AND PRODUCTION OF ALGAE IN PRAWN CULTURE SYSTEMS

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CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON THE ECOLOGY AND PRODUCTION OF ALGAE IN PRAWN CULTURE SYSTEMS" embodies the research of original work conducted by Mr. R. Devapiriyan under my supervision and guidance. I further certify that no part of this thesis has previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.

Dr. P. Parameswaran Pillai,
Senior Scientist,
Central Marine Fisheries Research Institute,
Cochin.

DECLARATION

I hereby declare that this thesis entitled "STUDIES ON THE ECOLOGY AND PRODUCTION OF ALGAE IN PRAWN CULTURE SYSTEMS" is a record of original and bonafide research carried out by me under the supervision and guidance of Dr. P. Parameswaran Pillai, Senior Scientist, Centre Marine Fisheries Research Institute, Cochin and that no part thereof has been presented before for any other degree in any University.

(R. Devapiriyan)

PREFACE

Successful planning and utilization of the vast brackishwater areas, inland bays, tidal pools, lakes and backwaters along the entire coastline of India for cultivation of prawns under controlled conditions requires very urgent consideration in the context of increased food production in the country. Although a small portion of these areas, especially those in Kerala, are being utilized for capture of prawns by a special indigenous process called filtration, vast stretches of these backwaters and estuaries still remain unattended. These areas in most cases provided biologically potential environment for healthy growth of many a species of fishes and prawns.

BACKGROUND

Existing method of culture were largely based on empirical knowledge. Lacking a scientific basis as such methods did, they were often wasteful and suffered severe limitation. Modern methods of fish and prawn culture based on scientific research, have revolutioned the industry in recent years and not only extended its scope to cover the whole country but led to increased fish and prawn production. An understanding of the biological capability of the water in the perennial and seasonal culture ponds, and the nature and extent of the influence of the abiotic factors on the production of organisms in the primary level of food chain would contribute to effectively implement management measures in the stocking strategies and in the evaluation of economics of production of prawns.

It is against this background that the present topic of investigation "Studies on the ecology and production of algae in prawn culture systems" was selected.

Investigations were carried out on the hydrological characteristics, seasonality in the concentration of nutrients, algal production and nutrient enrichment aspects in prawn culture ecosystems during the three monsoon season, viz., pre-monsoon, monsoon and postmonsoon period of 1986 and 1987. Three different prawn culture ecosystems were selected for the present study viz., a perennial prawn culture pond of Central Institute of Brackishwater Aquaculture (referred to as CIBA pond in the text, area 0.6 ha), perennial canals in the coconut grove where prawns are farmed (referred to as COCO field in the text, area: 1.0 ha), and a seasonal culture pond locally called POKKALI field (area, : 0.8 ha), all of which are situated at Narakkal near Cochin.

The thesis is presented in five Chapters.

In Chapter I, a review of the status of shrimp aquaculture in the artisanal sector is included in order to assess the trend in recent production, demand and export of these organisms in Kerala State.

Chapter II presents an introduction to the topic of study. A review of relevant works done in the same field is made in order to bring an awareness of the present status of our knowledge on the subject, and also stress the importance of such study for shrimp aquaculture operations in the coastal bodies of water on scientific lines. The material and methods adopted in the field collections and laboratory analyses, and also in the experimental work are presented in this chapter.

RESULTS of investigations carried out during 1986 and 1987 on the variations in the hydrological characters, nutrient distribution, production and distribution of algae and experimental aspects of nutrient enrichment of the medium on algal production along with the results of statistical analyses are presented in three parts under Chapter III.

Spatial and temporal variation in the distribution of hydrological properties such as salinity, dissolved oxygen, temperature, hydrogen-ion concentration (pH) and redox potential (Eh) in the three culture systems are described in Part - I. Part - II deals with the pattern of distribution of the available nutrients such as reactive phosphate (PO_4), nitrite (NO_2), nitrate (NO_3) and ammonia (NH_4) of water in the ecosystems.

The magnitude of gross primary production (GP) and net primary production (NP) was estimated and the results presented in Part - III(A). Nature and extent of variation in the concentration of Chlorophyll a, b, c and carotenoids, and their possible ratios were estimated and presented in Part - III(B). In Part - III(C), results of observation on the seasonal numerical variation of algal cells during 1987 are presented and explained. Results of computer analyses of the correlation between ecological and productivity parameters are presented, and the significance of correlation by multiple regression analysis highlighted in Part - III(D). In Part - III(E) an assessment of the status of production at primary level has been made through NP:GP ratio, assimilation number and ratio of Chlorophyll pigments.

In order to delineate the effect of fertilisation on the primary production in the culture ponds, nutrient enrichment experiments were conducted under _in situ_ during pre- and post-monsoon seasons (1987-'88) and _in vitro_ during monsoon season. Nutrients such as nitrogen, phosphorus and silica and trace metals such as zinc, manganese, molybdenum, cobalt, copper, iron and EDTA were employed in the experiment individually and in combination. ANOVA technique was used to test the significance of the effects of treatments. The results of the experiments and statistical interpretation of the findings form the subject matter of Chapter IV.

In data on the above aspects, whenever necessary are given in tabular and graphiçal forms for effective representation of the results.

In Chapter V (DISCUSSION), an overall assessment of the interrelations between abiotic environmental factors and productivity has been attempted, and a critical evaluation of the implication of primary productivity on the economic production of prawns under farming presented and both the above aspects discussed in detail.

An executive summary of the results of investigation is presented in the final section of the thesis which is followed by a detailed list of references on the subject matter.

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CHAPTER - I

REVIEW OF THE STATUS OF SHRIMP AQUACULTURE IN THE ARTISANAL SECTOR

Aquaculture has gained momentum throughout the world during recent decades which is probably unparalleled in other branches of food production. Cropping fish, prawn and other aquatic organisms for food is to a large extent based on very old methods. All the traditional methods together with their modern high technology counterparts are commonly described as aquaculture.

Aquaculture is the farming of aquatic animals and plants for commercial purposes. Aquaculture, as a promising primary and alternative agricultural enterprise and as a source of livelihood for people, has grown considerably in recent years. Its role in integrated rural development, generation of employment and earning of foreign exchange is being increasingly appreciated around the world, particularly in developing countries.

The annual world wide harvest of fishery products from our oceans has more or less remained static for the past few years at about 70-72 million tonnes. Yet the population has crossed the [illegible] million mark and is expected to double in the beginning of the [illegible] centuary. Hence the demand for fishery products has increased with increasing population and income. In order to meet the demand for fish in the world, fish production must double its present level of catch by the year 2000. Both researchers and producers are striving hard to develop useful techniques to meet this goal through fish and prawn farming apart from diversification of capture fisheries.

Aquaculture industry is well its way to solving the problems of production and growing demand for animal protein. Aquaculture produced about 10.2 million tonnes of fish and other aquatic products equal to 13% of the total world fisheries harvest. Interestingly all the first five leading coutries such as China, Japan, India, South Korea and Phillipines are in Asia, and account for 75% of total global aquaculture production. If the world's aquaculture production is projected for the year 2000 based on productivity growth, it will amount to about 22.2 million tonnes or about double the present level of production. At this rate, aquaculture will account for approximately 25% of the total contribution of world fisheries production.

The fisheries resources are renewable and are available year after year, if their stocks are suitably utilized and managed. Increasing and indiscriminate fishing in both marine and contiguous coastal waters considerably dwindle the marine fishery yield. Due to increasing demand for prawn in overseas market, the fishermen explore even the undersized prawn for local market. This indiscriminate fishing, especially in the nursery areas, considerably reduce the adjoining marine prawn fishery. This emerging danger due to over exploitation of spwaners and nursery population should be properly adjudicated and remedial measures such as aquaculture oriented fishery management aspect should be developed to rehabilitate the fishery potential, and procure maximum sustainable harvest.

Export earning of India from processed seafoods touched an all time high of Rs. 461 crores in 1986-87, involving a quantity of 86,160 tonnes. Out of this, frozen prawn/shrimps constituted 57.32% in quantity and 82.03% in value. Compared to the year 1986-87, during 87-88, export of seafood registered an impressive growth rate of 13.21% in volume and 15.31% in value. Total export during 1987-88 reached an all-time high of 97,179 tonnes. From 461 crore in 1986-87, export earnings from sea food reached the level of Rs. 531 crores during 1987-88. It touched to the tune of Rs. 598 crores during 1988-89.

Kerala, the land of 'Palms and Canals' is equally well known for its fishery wealth. Despite the fact that Kerala possesses only one tenth of the coastal line of India it is the major fish producing state in the country with an area of 33,364 sq.km. and a coastal line is that 586 KM long. Total continental shelf area is about 40,000 KM. There are 44 rivers in Kerala of which 41 flow westward, discharging their contents into the Arabian Sea, thus enriching the southwest coast. Kerala has the highest fishermen population in the country with 6.40 lakh people engaged in fishing industry of these, 1,31,101 fishermen are engaged in actual fishing operation. They operate about 3019 mechanised boats and 26271 non-mechanised boats.

Marine fish production in Kerala has witnessed many ups and down in the last decade. Shrimp landing has also shown wide fluctuation as can be seen from the summary statement below:-

INDIA

Year	Total Marine Landings X1000 T	Prawn Landing X1000 T	Marine Export Quantity T	Marine Export Value X1000 Rs.
1980	1249.8	170.7	75,542	2188756
1981	1378.5	144.9	75,375	2867128
1982	1420.6	161.9	75,136	3422429
1983	1548.4	166.9	86,169	3623231
1984	1630.6	192.0	89,912	3859983
1985	1534.7	189.0	80,588	3756683
1986	1707.9	212.1	89,283	4828841
1987	1647.5	199.6	89,125	4895540

KERALA

Year	Total Marine Landings X1000 T	Prawn Landing X1000 T	Marine Export Quantity T	Marine Export Value X1000 Rs.
1980	279.5	54.3	28,138	883122
1981-82	304.8	21.9	31,901	1242952
1982-83	348.4	32.3	32,946	1383385
1983-84	383.0	26.2	32,514	1402609
1984-85	377.4	37.8	30,385	1402456
1985-86	320.9	28.2	30,043	1383094
1986	1707.9	212.1	34,212	1640146
1987	1647.4	199.5	34,874	1866178

The stagnation point in shrimp production from our vast inshore resources through capture fisheries has driven us to explore the ways and means to increase fish production by resorting to scientific shrimp farming in our hitherto utilized brackishwater areas. It is worthwhile to mention that India is endowed with highly productive areas such as mudflats, swamps, marshy lands, lagoons, mangroves, backwater and estuaries. Regarding this, it is estimated that about 0.80 million ha backishwater area, is identified as suitable for aquaculture practices.

The economic details of the traditional paddy field cultivation reveal that the preposition of paddy cultivation and prawn cultivation are still encouraging if properly managed and operated. On comparing the two, it is evident that almost double the profit is realised by way of traditional prawn culture than that of paddy cultivation. It also reveals that more or less equal quantity of prawn and fishes are exploited through the traditional operation, the increased yield of prawns being mainly contributed by penaeid prawns and fishes such as mullets, milkfish, pearlspot and telapia. Among prawns, *Metapenaeus dobsoni* (52.63%) *Penaeus indicus* (37.59%) *Metapenaeus monoceros* (9.02%) and *Penaeus monodon* (0.75%) are exploited in the order of preference. Most of the prawns are caught by way of filteration through sluice gates during favourable tides of the full moon and new moon phases. Several other harvesting methods such as cast netting, gill netting, dragging, scooping and hand picking are also employed during the terminal fishing time.

Analysis of the data from the view point of production shows that the system is still capable of producing a potential yield of 665 kg. of prawns and 750 kg. of fishes from unit area (ha). Nevertheless, if we exclude the cost of fishes, the sale proceeds from prawn viz. 255 kg. of penaeids and 410 kg. of metapenaeids from unit area could not balance the expenditure leading to the endeavour in a team position. This seems to be obviously due to the spiralling rates of lease amount prevailing in the system especially during recent years. Again, the prepondence of low priced prawns over the quality prawns can also be attributed to be another factor. This situation calls for urgent and pragmatic implementation of measures at least to maintain the statusque of the system. Thus it becomes imperative to undertake need based research pertaining to this field to find out a variable alternative.

CHAPTER - II

INTRODUCTION

Prawn farming in ponds has a long history of empirical development and 'green-thumb' expertise, but the scientific investigation and documentation are relatively far from complete. The availability and growth of micralgae/phytoplankton is the most critical aspect of fish production in ponds culture. The phytoplankton growth and the interlinked ecological factors in fish ponds is of concern to the fish farmers the world over.

The requirement of studies on the biology and ecology of the phytoplankton of the various estuarie systems in India include those of Iyangar and Vengatraman (1951) for the Cooum estuary; Roy (1954), Devasundaram and Roy (1954), Patnaik (1973) on the planktonic algae of Chilka Lake, and Dutta et al. (1954), Roy (1949 & 1955), Shetty et al. (1961), Gopalakrishnan (1971) in the Hoogly estuary. 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 Shantharam (1974) and Shantharam et al. (1975) gave a descriptive account of the species distribution and quantitative ecology of phytoplankton of the same region. Dehadari (1970), Dehadari and Bhargava (1972) reported the range of primary productivity of Goa estuarine complex. Krishnamurty and Viswanathan (1968) measured primary productivity in the Bombay Harbour. Venugopal (1969) estimated primary productivity of the Vellar - Coolrum estuarine system and Bhatnagar (1971) for the Killai Backwaters.

Untawale and Parulekar (1976) studied the ecology of mangroves in the estuarine of Goa. Krishnamurty and Sundaraj (1973) gave an average primary production rate for Pichavaram mangroves and Gopinathan and Rajagopalan (1983) for the mangroves ecosystem of the Andaman - Nicobar area.

Some studies were undertaken on the hydrographical condition and trace metal concentrations (Ganapathi and Raman, 1973; Sharma et al., 1982; Satyanarayana et al., 1985), distribution and abundance of Oscillatoria nigroviridis (Premila and Umamahaswara Rao, 1977) and on blooms of Skeletonema costatum (Ganapathi and Raman, 1979) and a detailed investigations to evaluate the ecological effect of pollution on phytoplankton communities of the Visakhapatnam Harbour in recent year (Umamahaswar Rao and Mohanchand, 1988) and distribution of particulate matter by Sarma et al., (1989).

A detailed examination of the temporal dynamics of Phytoplankton has been made in Mondovi - Zuari estuarine complex. In addition, phytoplankton community structure and succession were discussed in relation to the prevalent environmental conditions (Devassy and Goes, 1988). Also include primary production recently by Sumitra-Vijayaraghavan and Krishnakumari (1989).

The Cochin estuaries system have been studied intensively by Qasim and Reddy, (1967) for plant pigments; tidal amplitude (Qasim and Gopinathan, 1969), organic production

(Qasim *et al*., (1969); salinity tolerance of phytoplankton (Qasim *et al*., (1972), seasonal abundance of phytoplankton (Gopinathan *et al*., 1974; Joseph *et al*.,1975, contribution of homoplankton (Qasim *et al*., 1974; Vijayaraghavan *et al*., 1974) and on primary productivity of the entire estuarine system (Nair *et al*., 1975).

Detailed description of the environmental condition and other particulars of the backwaters are reported earlier (Ramamirthan and Jayaraman, 1963; Wellershaus, 1971; Qasim, 1972). Extensive hydrographic data have been collected (George and Krishnakartha, 1963; Desai and Krishnankutty, 1967; Qasim and Gopinathan 1969; Shynamma and Balakrishnan, 1973; Balakrishnan and Shynamma, 1976) and nutrient distribution (Joseph, 1974, Sreedharan and Mohammed Salih, 1974; Lakshmanan *et al*., 1987). Considerable amount of work in relation to primary productivity has been done by Qasim *et al*. (1969), Qasim (1973, 1979), Gopinathan *et al*. (1984) and Rajagopalan (1985).

The Cochin estuarine system

The estuarine system of Cochin includes a system of inter-connected lagoons, bays and swamps, penerating the main land with innunmerable prawn culture fields, both seasonal and perennial ones, enclosing many islands in between, and with a total area approximately amounting to 500 sq.km. The backwater around Cochin is located along lattitude 9 58'N and longitude 76 15'E, and this part of the estuary form a more or less a north ward extension of the Vembanad Lake. The upper reaches of backwater are connected to 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 ebbtides 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 two permanent openings into the Arabian Sea - one at Cochin and the other at Azhikode. There are five major rivers which empty into the backwater system through their tributories and branches. On the southern half, the river Pamba and Muvattupuzha join the Vembanad Lake. On the northern half, the river Periyar joins the backwaters through its tributories. All the rivers periodically enrich the area by bringing along with them nutrient-rich water and considerable quantity of particulate organic matter. The northern half of the estuary has high saline concentration and high tidal amplitude because of the two openings 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 chief characteristics feature of the estuary is that during the monsoon months, it receives a considerable amount of freshwater from the rivers and other sources and the habitat becomes highly turbid. The total annual average rain fall of the Cochin area is about (3200 mm) of which nearly 75% occurs during the months from May - September.

Prawn culture systems

The dynamic environment of the estuarine system of Cochin and the connected backwater play a significant role in the fishery of the area in general and the prawn fishery in particular. In recent years, due to high demand for prawns, efforts are being made to augment their production through prawn/shrimp farming. It is estimated that about 5120 ha. of cultivable fields are situated in and around the Cochin estuarine system.

Several publications namely, Qasim *et al*. (1969), Qasim and Gopinathan (1969); Qasim and Shankaranarayanan (1972); Gopinathan *et al*. (1974); Nair *et al*. (1975); Pillai *et al*. (1975); Madhupratap *et al*. (1977) provide information on the hydrobiology and ecology of the Cochin Backwater and adjacent areas, but aimed accounts dealing with productivity parameters of prawn culture system situated in the estuarine complex are limited. The main objective of this study is to assess the productivity of the seasonal and perennial culture ponds through data our primary production in detail and related hydrological properties of the ponds since estimation of the biological capacity of the water in the ponds is a prerequisite in determining the stock strategies and in the evaluation of the production.

Abiotic factors

Abiotic factors particularly chemical characteristics of the environment exert profound influence on the growth and survival of aquatic organisms. The culture ponds are mostly the extension of the estuarine and backwater system, and are therefore subjected to wide variation in the environmental condition when compared to the sea. Regular monitoring of the environmental conditions therefore become essential to understand optimum environmental condition for the culture of the organisms. In depth investigations on the fluctuations of hydrological properties such as salinity, dissolved Oxygen, temperature, hydrogen-iron concentration (pH) and Redox potential (Eh) as well as the nutrients such as nitrates, phosphates and silicates essential to phytoplankton assumes importance as they play a major role in regulating the growth, abundance, recruitment and distribution of the fauna and flora in a given culture ecosystem.

Biotic factors

(i) Algal production

Estimation of primary production is of considerable basic value because of its significance to fisheries science and problem connected with aquatic ecology. In the studies related to marine or estuarine food chain in the culture ecosystem, the estimation of standing crop of phytoplankton is a pre-requisite since animals need food for growth and survival and therefore the chlorophyll estimation indicate total plant material available at the primary stage of food chain. Further, availability phytoplankton pigments, and the possible ratio between different pigments and the taxonomic identification of phytoplankton species, play major roles in the assessment of production in the culture ecosystems.

(ii) Algal population

It is well known that the most important factors which lead to the occurance of fish and prawn in an aquatic environment is the availability of food and hence basic productivity controls the distribution and abundance of the organisms cultured. Phytoplankton, mainly constituted by diatoms, dinoflagellates, blue-green algae and a variety of minute forms called nanoplanktons are the primary producers in the culure systems. The utilization of the organic materials produced by them is carried out by zooplankton and both form the forage of prawns and fishes.

Enrichment studies:

A significant input of enriching substances into the estuarine environment inevitably induces a modification in the ecosystem. This in turn influence the energy circuit and food web as well as the structure and dynamics of the animal communities.

In view of this, an indepth study on the fluctuations in hydrography and availability and abundance of nutrients, and their linkage on the production and population characteristies of algal communities has been taken up in selected prawn culture ponds in and around the estuarine habitat at Cochin and the results presented and discussed, and conclusions drawn in the document.

STUDY AREA

The present investigation was carried out at Narakkal (76 14'E Long., 10 03'N Lat.,), a fishing hamlet in Vypeen

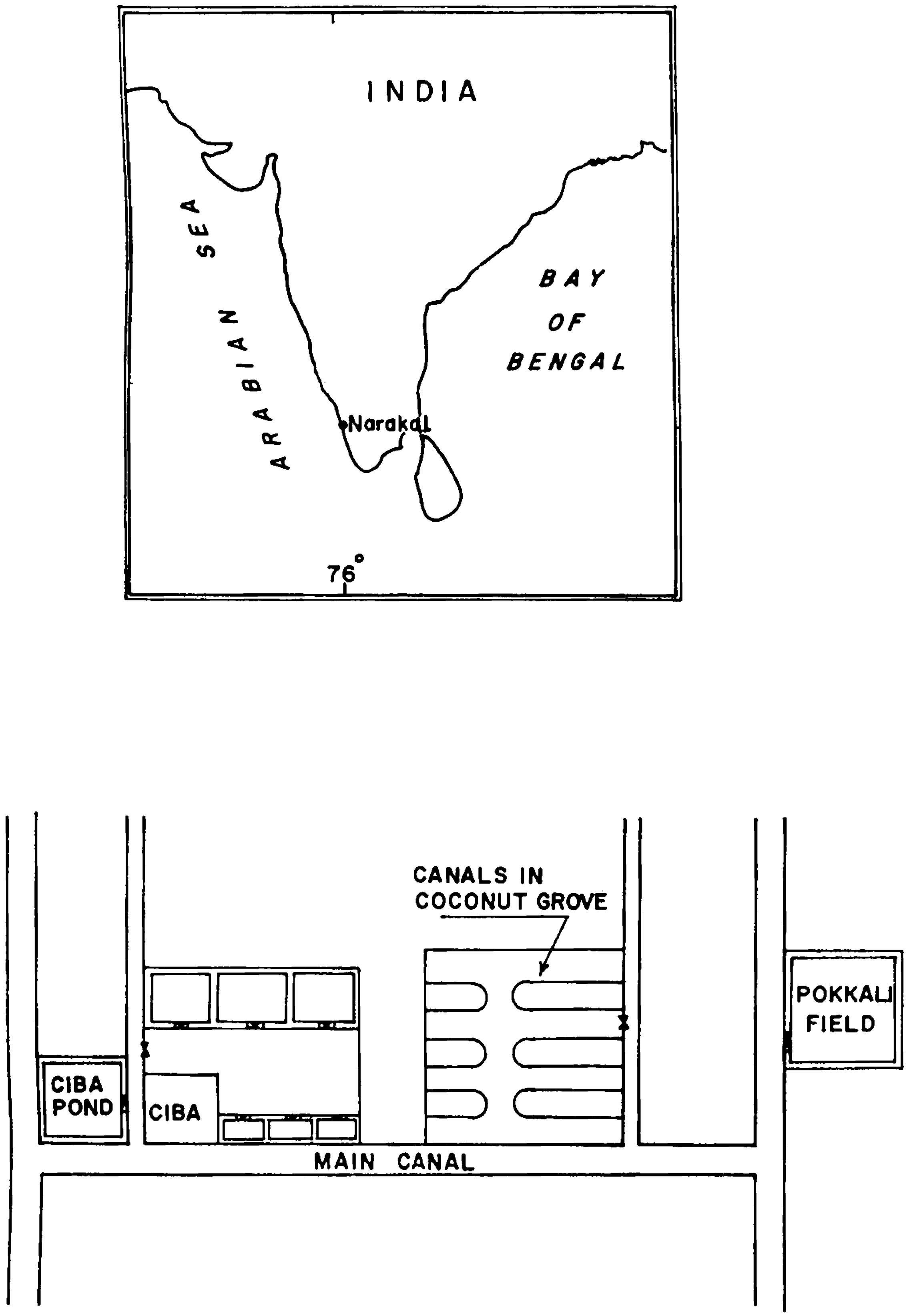

Fig. 1 STUDY AREA

Island about 10 km north-west of Cochin, Kerala (Fig. 1). The land strip enclosed within the Arabian Sea on the western side and the Vypeen Channel, a branch of the Cochin backwater system on the eastern side, is characterised by several low-lying fields and coconut groves, interconnected by brackishwater canals. The canals are connected to the Cochin backwater system through a gut located at the mouth of estuary, in the south and by another at Azhikode at the northwern end of the island, which facilitate entry of tidal water. Three different prawn culture ecosystems were selected for the present study viz., a perennial prawn culture pond of Central Institute of Brackishwater Aquaculture (referred to as CIBA Pond in the text, area 0.6 ha), perennial canals in the coconut grove where prawns are farmed (referred to as COCO Field in the text, area: 1.0 ha) and a seasonal culture pond locally called POKKALI Field (area, : 0.8 ha), all of which are situated at Narakkal near Cochin.

The experimental pond (Plate - Ia) selected for the study (0.6 ha. area) is connected to the mainfeeder canal by a wider sluice gate. The average depth was found to be 100 cm. The pond is stocked predominately with prawns and chanos.

The canals in the coconut grove (Plate - Ib) are primarily dug up between rows of coconut treas to irrigate the grove, but the waterbody is profitably utilized as a culture system by trapping seeds brought in by the tide, and allowing them to grow within the canals. The canals are connected to be mainfeeder canal by a small inlet. The depth of these canals ranges from 40-50 cm. Water circulation was found to be relatively low when compared to the other two culture system. It had an area of about 1.0 ha.

The 'pokkali' field, (Plate - Ic) located further away from both the canals of the coconut grove and the experimental pond, is used for culture of fish and prawns from Decemeber to April, during which period, the saline nature of water in conducive for culture. The culture is wound up by April when the field is utilized for cultivating a special variety of paddy called 'pokkali'. The mean depth of the field was found to be 50 cm and it had an area about 0.8 ha. Though further away from the other two culture systems, it is connected by the same feeder canal that supplies water to the other two culture systems.

HYDROGRAPHY

There are a number of reports on the prawn culture practices in Kerala (Panikkar, 1937; Menon, 1954; Gopinath, 1956; George *et al*., 1960; George, 1974; Gopinathan *et al*., 1982) but they are mainly concentrated on the biological aspects of shrimp culture. The culture ponds are mostly the extension of the estuary and backwaters, and therefore subjected to wider variation in environmental conditions when compared to the open sea. A regular monitoring of the environmental conditions therefore becomes essential to understand the optimum environmental conditions for the culture of prawn. Physico-chemical factors, such as temperature, salinity, dissolved oxygen, pH and Eh was carried out during the period of investigations.

Water temperature influences the bio-chemical reactions and microbial release of nutrients taking place in the pond ecosystem, as well as the physiology of fauna. The pond having the optimum height of water, the bottom water will be less warm than the surface water, which exposed to the Sun. Such variation will not be felt much in shallower ponds. As temperature increases, the ability of water to dissolve oxygen decreases.

The degree of salinity in water reflects geological and hydrological conditions. Farmers should have a through knowledge of the salinity profile of the tidal water of the site before selecting the site for construction of farm. It should also be ascertained that there is no chance of large scale fresh water influx to the farm as sudden fall in salinity would give stress to the prawn.

In a normal pond, the oxygen producing and consuming processes keep a dynamic balance which maintains the concentration of dissolved oxygen within the range tolerable to all the organisms. Concentration of dissolved oxygen decreases with increasing temperature and salinity.

Water that contains dissociated or free hydrogen and hydroxyl ions which give an acidic or neutral reaction to water depending upon their relative concentration pH of the water which is influenced by the soil pH and concentration of carbon dioxide, carbonates and bicarborates in the water. Phytoplankton and other aquatic vegetation remove carbondioxide from the water during photosynthesis, so the pH of a body of water rises during the day and decreses during the night.

Material and Method:

The following parameters were measured during sampling at fixed time of 0600 hrs for a period of two years from January 86 to December, 1987. The termperature was measured in situ with the help of an ordinary thermometer. Salinity of water was measured by Mohr-titration method (Strickland & Parsons, 1968). Dissolved oxygen content estimated by Winkler method (Strickland & Parsons, 1968) with due precaution.

pH was measured using a digital pH meter, and Eh was also measured by the same instrument but using an Eh electrode specifically designed for this purpose.

AVAILABLE NUTRIENTS

The plant life in seawater require certain micronutrients for their growth. The most important micronutrients are compounds of nitrogen and phosphorus. Those type of organisms which have siliceous frustules (diatoms) also require a supply of silicon. The principal inorganic form of nitrogen is as nitrates, nitrites and to a certain extent as ammonia. Inorganic phosphate exist in the seawater practically as orthophosphate. The principal sources of silicate in the ocean, are river run off and the glacial weathering of rocks. The growth and sedimentation of siliceous plankton is the principal biological processes stripping silicon from the ocean.

Tidal water is one of the sources which supplies nutrients to the pond ecosystem. Land run off through river discharge and consistant incursion of sea water have profound influence on the nutrient concentration of the tidal water prawn fields around the Cochin and Azhikode bar mouths which also are highly productive because of the influence of the Pampa and the Periyar rivers and the constant incursion of sea water through the two bar mouths.

Some work has been done on the estuarine by Suryanarayana Rao and George (1959); Krishnamoorty and Vincent (1981); De Sousa et al. (1981). Sarala Devi et al. (1983); Lakshmanan et al. (1987) but the prawn culture systems in this area around Cochin were not extensively studied until recently by Gopinathan et al. (1982) and Gopalakrishnan et al. (1988).

Material and Methods

Sampling was done between January to December, 1986 and 1987 in the perennial ponds; and from January to May 1986 as well as 1987 in the seasonal pond in 4 sites. Samples were collected in the morning 0600 hrs. and analysed immediately.

For the determination of inorganic nutrients nitrate-N, nitrite-N, ammonia-N, phosphate-P and silicate-Si the method given in the FAO Technical Paper No. 137 (1975) was adopted.

ALGAL PRODUCTION

Considerable amount of work on productivity studies in Cochin backwaters has been done by Qasim et al. (1969) Qasim

(1973, 1979) Gopinathan *et al*. (1974) and Nair *et al*. (1975). According to them the gross production ranged from 0.35-1.50 gC/m^3 /day. The estimated annual gross production for the entire Vembanad Lake comprising about 300 KM is about 1,00,000 tonnes of Carbon (Nair *et al*., 1975).

Several attempts have been made to relate productivity parameters with that of potential yield or optimum sustainable yield (Subramanyam, 1959; Prasad and nair, 1963; Nair *et al*., 1969; Prasad *et al*., 1979; 1970; Qasim *et al*., 1978). It has been observed by Steemann Nielsen and Jensen (1957) that the landings of commerical fish catch in intensity exploited water is about 0.4% of the organic matter produced by the phytoplankton. A maximum sustainable yield of 0.2% would be a more realistic estimate which would amount to just about 5 million tonnes of fish for the EEZ (Nair and Pillai, 1983).

In the case of prawn culture systems the carrying capacity of the pond depends mainly on its primary production, which is the organic matter produced in the pond in the form of microflora including phytoplankton, benthic algae and photo synthetic bacteria using the radient energy of the Sun and the nutrients available in the pond. The floras thus formed is the food of the fauna of the pond directly and indirectly. Growth and production of prawn in the pond varies according to the level of primary production.

Based on the degree of Primary Productivity, prawn fields has be classified as: highly productive (1500 mg C/m^3 /day) moderately productive (500-1500 mgC/m^3/day) low productive (500 mgC/m^3/day), (Gopinathan et al., 1982).

The rate of primary production can be measured either directly or indirectly by estimating the standing stock of phytoplankton and using a conversion factor. For direct estimation, the production is either measured experimentally by enclosing water samples in bottles or by utilising difference in the water masses during a certain period by measuring the property at the begining and the end of this period. All of the pioneer works concerning productivity were based on the standing stock.

In recent years, the concentration of pigments active in photosynthetis, primarily chlorophyll has been employed as an index of the standing stock of plants and also as a means of estimating the rate of primary production (Ryther and Yentsch 1957). Consumption of carbon dioxide (Atkins, 1922) or nutrient salt (Steele, 1956; Cooper, 1957) as a means of measuring primary production have also been used. Daily variation the oxygen content of the water between morning and afternoon has also been used as a means of estimating the organic production in certain marine acreas (Dedosov, 1958).

The plant pigment content of phytoplankton assumes great importance in productivity studies because of the use of these compounds for estimating the primary production and gross photosynthetic potential. Either total pigments, total chlorophyll, or the single pigments may be measured. Pigment analysis primarily chlorophyll determinations, have been used in recent year (Krey, 1958). The spectrophotometric technique introduced by Richards with Thompson (1952) with subsequent revisions (Parsons and Strickland, 1968) have long replaced the less accurate standardisation procedure of visual matching of pigment extract with standard methyl sulphate and potassium chromate (Harvey, 1534).

The conversion factors as given by Cushing (1958) for plant pigment unit and that of chlorophyll is as follows:-

1 P.P.U. = 3.9 - 5.2 µg Carbon

1 µg. Chlorophyll = 13.6 - 17.3 µg Carbon

Using Harvey's (1934) method, Subramaniyam (1959) made quantitative determination of the standing crop of phytoplankton of the west coast. He found that the standing crop in terms of carbon varies from 0.06 g to 12.28 g over a metre square area of the sea surface with the highest values during the south-west monsoon. From these measurements he concluded that the west coast of India is one of the highly productive regions of the world.

A close relationship usually exists between the concentration of chlorophyll a in the culture pond and the total abundance of phytoplankton.

Material and Methods

Samples of water for measuring primary production were collected from surface in the ponds in the morning at 0600 hrs and incubated *in situ* for 6 hours regularly and data collected for a period of two years (1986 to 1987).

Primary production measurements were made using Grander and Gram's (1927) light and dark bottle method as described by Strickland and Parson (1968). Dissolved oxygen was estimated by Winkler's titration method from which gross and net photosynthesis were calculated and expressed as $mgC/m^3/day$.

Productivity was calculated as follows:-

<u>Gross primary production</u> = Light bottle - dark bottle

<u>Net primary production</u> = Light bottle - initial bottle

$$\text{Production A} = \frac{\underline{O_2\ (ml)} \times \underline{0.598}}{p.q.}$$

$$\text{Productivity in } mgC/m^3/day = A \times \frac{10}{T} \times 1000$$

PQ (1.25)

T (duration of the experiment)

10 (assumed that photosynthesis takes place for 10 hours during a day)

For the estimation of phytoplankton pigments, one litre surface samples were collected and filtered through Millipore filters (type HB, 47mm, 0.45 micron pores) and dissolved in 10 ml of 90% acetone and stored under refrigeration over night. The acetone extract was centrifuged at 3000 rpm for 5 minutes and the sample analysed spectrophotometrically.

The spectrophotometric method described by Timothy Parson <u>et al</u>. (1984) with modification was followed for evaluating different fractions of chlorophylls <u>viz</u>., chlorophyll '<u>a</u>', '<u>b</u>', '<u>c</u>', and also carotenoids.

Calculation

(Ca) Chlorophyll a $= 11.85\ E_{664} - 1.54\ E_{647} - 0.08\ E_{630}$

(Cb) Chlorophyll b $= 21.03\ E_{647} - 5.43\ E_{664} - 2.66\ E_{630}$

(Cc) Chlorophyll c $= 24.52\ E_{630} - 1.67\ E_{664} - 7.60\ E_{647}$

mg Chlorophyll/m^3 $= \frac{C \times v \times 10}{V \times 10}$

Where v is the colume of acetons in ml (10 ml),

V is the volume of seawater in litres.

(Cp) Carotenoide $= 7.6\ (E_{480} - 1.49\ E_{510})$

ALGAL POPULATION

There are several aspects of phytoplankton ecology that need elucidation such as factors leading to succession of phytoplankton to changes in environmental conditions. Answers to these involved problems could be obtained through experimental studies employing laboratory culture of selected phytoplankton organism. One of the pre-requisites for such studies is to know the distribution pattern of phytoplankers.

Species composition of phytoplankton communities in the pond is important because different taxa of planktonic algae present different dietary values in various development stages of fish or zooplankton. In general, phytoplankton species occurring in culture ponds includes members of Chrysophyta (diatoms and golden brown algae), Chlorophyta (green algae), Cyanophyta (blue-green algae) Pyrrophyta (dinaflagellates) and some flagellates.

The phytoplankton species composition in ponds may vary from few to a large number of species. The species diversity concept developed by Margalef (1958) for phytoplankton, is useful in describing the significance of species abundance in relation to the stability of the phytoplankton community. In general, higher species diversity indicates a greater stability in a given ecosystem (Odum, 1971), because the fluctuation in abundance of individual species would have influence on the entire community than the system of lower diversity.

In this area the prawn culture system was not extensively studied until recently. In view of the growing importance of prawn culture in these system, a general ecology study was taken up. The environmental characteristics of these systems were described by Nair et al. (1988). Qualitative and quantitative aspect of phytoplankton and zooplankton in the seasonal and perennial prawn culture system of Cochin backwaters in relation to the environmental parameters were described by Gopalakrishnan et al. (1988).

Material and Methods

Sampling was done early in the morning from fixed stations in the ponds. During 1986, surface samples were brought to the laboratory and examined the phytoplankton in live condition and data recorded. Qualitative and quantitative studies on algae were carried out by "counting chamber method" during 1987.

The model now in common use is a combined plate chamber consisting of a top cylinder of 50 ml capacity and a bottom plate chamber. The principle is to remove the upper part of the chamber (the sedimentation cylinder) after sedimentation leaving organisms in the bottom part, which can directly be examined under the microscope and enumerated. An aliquot of 25 ml of the sample was used, and Lugol's Iodine was used as preservative.

ENRICHMENT EXPERIMENT

In most fish ponds, nutrient enrichment by artificial fertilization is commonly practiced in order to increase fish production (Shen 1976; Hepher 1962; Chiou and Boyd 1974). As a result, the phytoplankton species diversity is minimized in the nutrient enriched system, which lead to relatively wide population density. The individual species of phytoplankton in fertilized pond water often undergo rapid cycles of population bloom, and massive die-off and may cause oxygen super-saturation as well as severe oxygen depletion. Excessive blooms of blue green algae frequently occur in nutrient rich water.

Since ponds which are managed, are often fertilized, nutrients concentration is generally high and phytoplankton productivity greater than the average natural waters. Boyd (1973) reported that chlorophyll concentration in a series of fertilized ponds than those in the unfertilized ponds. He also observed that chlorophyll values in fed catfish ponds averaged 102 mg/L, stimulated mainly by the nutrients released from the feed.

Studies on nutrient limitation have also shown that for marine coastal waters nitrogen in the form of nitrate and nitrate is usually the important limiting nutrient for the survival and growth of phytoplankton biomass (Berland *et al*., 1980; Nixon and Pilson, 1983; Canaco *et al*., 1987). For brackish waters, phosphorus may play an important role, especially if fresh water inflow is high the case in Trandheim fjord (Sakshaug & Myklestad, 1973), the inner part of Manreille Bay (Berland *et al*., 1980), Bothnian Bay, located at the northern part of the Baltic sea (Alassarela, 1979) and Chesapeake Bay during winter (D'Elia *et al*., 1986).

Material and Methods

In vitro nutrient enrichment experiments with the natural population of phytoplankton from the culture pond were carried out during August, 1987 which represent the period monsoon. Water from the surface of the culture pond was collected early in the morning and maintained in circular type ten litre capacity tank. Experiments were conducted under the glass-roof laboratory of the hatchery of the Central Institute of Brackishwater Aquaculture (formerly Marine Prawn Hatchery Laboratory).

Nutrient experiments were performed *in situ* during the post-monsoon period of December, 1987 and pre-monsoon period of March, 1988, using twenty five litre capacity plastic tubs encircled by a net fixed in the culture pond (Plate - 1d).

Nutrients were added to the 20 litre sample, alone and in combination, to the water at the beginning of the experiments follows: 500 µg/l nitrogen, 1000 µg/l phosphorus and 5000 µg/l silica. For EDTA and tracemetal additions the amounts used are of

10 µg/l zinc, 100 µg/l manganese, 5 µg/l molybdenum, 5 µg/l cobalt, 5 µg/l copper, 1300 µg/l iron and 1300 µg/l iron and 1300 µg/l EDTA. Effects were measured with treatments such as N, P, S, N+P, N+S, P+S, N+P+S, T, N+P+S+T and along with the non-treated one. Phytoplankton biomass as well as their production was measured through the content of chlorophyll '*a*'. Effects of treatment were also tested statistically for individual sampling on each date.

In general, the significance of prawn culture fishery and prospects and management were those of Muthu (1978b); Rao (1980); Silas *et al*. (1981); Silas (1983) and George (1983).

CHAPTER - III

RESULTS

PART - I : HYDROGRAPHY

Monthly mean variation in the hydrographic parameters in the CIBA pond* such as salinity, dissolved oxygen and temperature during 1986, and salinity dissolved oxygen, temperature, hydrogen-ion concentration and redox potential during 1987 are presented in Table - 1 and Fig. 2. Observed distribution pattern of these parameters in the COCO field** are presented in Table - 2 and Fig. 3. Results of observation on the hydrographic parameters in the POKKALI field, which was limited to the premonsoon season of 1986 and 1987 are presented in Table - 3 and Fig. 4.

Salinity:-

(i) CIBA pond:-

During 1986, the salinity values ranged between 3.31 and 23.45%., with high values recorded during the premonsoon season. The values gradually increased from January, and after reaching a peak in the May (23.45%.) declined to 4.30%. in July with the onset of monsoon. A secondary peak was observed in December. Lowest salinity condition was recorded in November, and in December the values recorded was 13.62%..

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* Abbreviation of the prawn culture pond belonging to the Central Institute of Brackishwater Aquaculture used in the text.

** Abbreviation of canal system among coconut plantation used in the text.

TABLE - 1

Distribution of hydrographic parameters in the CIBA pond during 1986 and 1987 (Monthly mean value)

		Salinity ($X\ 10^3$)	Dissolved oxygen (ml/l)	Water temperature (C)	pH	Eh
Jan.	1986	17.87	3.60	310		
	1987	19.18	3.34	28.5	4.40	137
Feb.	1986	21.84	3.56	32.0		
	1987	22.49	3.40	30.0	7.54	132
Mar.	1986	23.07	4.39	33.5		
	1987	20.72	2.53	31.0	7.87	157
Apr.	1986	23.31	4.57	34.0		
	1987	17.41	3.39	30.0	8.13	169
May	1986	23.45	4.90	34.0		
	1987	15.40	3.44	30.0	8.22	175
June	1986	8.50	3.16	30.0		
	1987	5.23	6.96	30.0	7.77	168
July	1986	4.30	3.10	30.0		
	1987	3.78	4.86	28.0	7.73	231
Aug.	1986	4.54	2.57	30.0		
	1987	4.25	3.08	28.0	7.75	254
Sep.	1986	5.96	3.20	30.0		
	1987	4.39	2.61	30.0	7.62	267
Oct.	1986	3.34	5.61	31.0		
	1987	3.31	2.92	30.5	6.91	275
Nov.	1986	3.31	4.74	31.0		
	1987	2.89	2.93	30.0	7.53	269
Dec.	1986	13.62	5.77	31.0		
	1987	4.39	3.40	30.0	7.64	267

TABLE - 2

Distribution of hydrographic parameters in the COCO field 1986 and 1987 (Monthly mean values)

		Salinity ($X 10^3$)	Dissolved oxygen (ml/l)	Water temperature (C)	pH	Eh
Jan.	1986	17.54	2.65	31.0		
	1987	19.03	2.34	28.0	7.40	124
Feb.	1986	19.10	2.17	32.0		
	1987	23.41	2.33	29.5	7.37	127
Mar.	1986	20.85	3.56	33.0		
	1987	18.62	3.26	30.5	7.66	144
Apr.	1986	22.41	3.71	34.0		
	1987	16.42	2.20	30.0	7.62	168
May	1986	22.96	3.75	34.0		
	1987	14.88	1.70	30.0	7.65	176
June	1986	8.32	8.53	29.0		
	1987	4.89	3.55	29.5	7.48	163
July	1986	4.35	4.94	30.0		
	1987	3.91	4.34	27.0	7.72	221
Aug.	1986	4.58	2.92	30.5		
	1987	4.01	1.91	27.5	7.58	249
Sep.	1986	5.10	5.06	29.5		
	1987	4.15	1.22	29.0	7.44	263
Oct.	1986	3.40	5.04	31.0		
	1987	3.07	1.50	29.5	6.80	253
Nov.	1986	3.11	3.56	31.0		
	1987	2.51	1.73	29.0	7.29	272
Dec.	1986	13.66	2.34	30.0		
	1987	3.96	1.93	29.0	7.45	263

TABLE - 3

Distribution of hydrographic parameters in the POKKALI field during the premonsoon period of 1986 and 1987 (Monthly mean values)

		Salinity ($X\ 10^{3}$)	Dissolved oxygen (ml/l)	Water temperature (C)	pH	Eh
Jan.	1986	18.15	4.31	31.4		
	1987	21.98	3.31	28.0	7.31	123
Feb.	1986	21.75	3.63	32.0		
	1987	22.49	3.79	30.0	7.46	125
Mar.	1986	23.35	4.51	33.0		
	1987	20.76	2.52	30.5	7.76	145
Apr.	1986	23.35	4.51	34.0		
	1987	17.61	4.51	29.0	7.65	172
May	1986	23.55	4.35	34.0		
	1987	15.21	2.49	29.0	7.68	179

During 1987, the recorded range in salinity values was between 2.89 and 22.49%.. However, monthly mean of salinity distribution evinced variation when compared to the previous year. Peak value of salinity was recorded in February (22.49%.) which gradually showed reducing tendency towards a secondary peak the salinity of the pond decreased to 2.89%. in November with the advancement of monsoon and evinced on increasing trend in December.

	Premonsoon	Monsoon	Postmonsoon
1986	17.88 - 23.45%.	4.30 - 8.56%.	3.31 - 13.62%.
1987	15.40 - 22.49%.	3.78 - 5.23%.	2.89 - 4.39%.

(ii) COCO field:-

During 1986, the salinity, values ranged between 3.11 and 29.48%. with high values recorded during the premonsoon season. The values gradually increased from January, and after reaching a peak in May (22.98%.) declined to 4.35%. in July. A secondary peak was observed in September. Lowest salinity was recorded in November, and in December the value recorded was 13.66%..

During 1987, the recorded range in salinity was between 2.51 and 23.41%.. However, monthly pattern of salinity distribution evinced variation when compared to the previous year. Peak value of salinity was recorded in February (23.41%.) which gradually showed reducing tendency towards July (3.91%.). After recording a secondary peak the salinity of the pond decreased with the occurence of monsoon to 2.51%. in November and evinced on increasing trend in December.

The range of salinity values during the three seasons of 1986 and 1987 in the COCO field is summarised below:

	Premonsoon	Monsoon	Postmonsoon
1986	17.54 - 22.98%.	4.35 - 8.32%.	3.11 - 13.66%.
1987	14.68 - 23.41%.	3.91 - 4.89%.	2.51 - 3.96%.

(iii) POKKALI field:-

During 1986, the salinity values ranged between 18.15 and 23.55%. with high values recorded increasingly during premonsoon. During 1987, the recorded range in salinity values was between 15.21 and 23.35%.. However, the monthly pattern of salinity distribution evinced variation when compared to the previous year. Peak value of salinity was recorded in February (22.49%.) which gradually showed reducing tendency towards monsoon season.

Dissolved Oxygen:-

(i) CIBA pond:

During 1986, the dissolved oxygen values ranged between 2.57 and 5.77 ml/l. The values gradually increased from January, and after reaching a peak in May (4.90 ml/l), declined to 2.57 ml in August with the onset of monsoon. A secondary peak was observed in October with an increasing trend again in December.

During 1987, the recorded range in dissolved oxygen values was between 2.53 and 6.96 ml/l. However, monthly pattern of dissolved oxygen evinced variation when compared to the previous year. Peak value of dissolved oxygen was record in June, on the preexisting condition of the premonsoon prevailed and non-occurence of monsoon in June and gradually decreased with the onset of monsoon and a recording peak in December (3.40 ml/l) with an increasing trend.

The range is dissolved oxygen values during the three seasons of 1986 and 1987 in the CIBA pond is summarised below:

	Premonsoon	Monsoon	Postmonsoon
1986	3.56 - 4.90 ml/l	2.57 - 3.16 ml/l	3.20 - 5.77 ml/l
1987	2.53 - 3.44 ml/l	3.08 - 6.96 ml/l	2.61 - 3.40 ml/l

(ii) COCO field:

During 1986, the dissolved oxygen values ranged between 2.17 and 5.06 ml/l. The values gradually increased from January and after reaching a peak in May (3.75 ml/l) declined to 2.92 in August. A secondary peak was observed in September.

During 1987, the recorded range in dissolved oxygen values was between 1.70 and 4.34 ml/l. However, monthly pattern of dissolved oxygen distribution evinced variation when compared to the previous year. Peak value of dissolved oxygen was recorded in March (3.28 ml/l) which gradually showed reducing tendency. A secondary peak value was recorded in August on the pre-existing condition of the premonsoon season prevailed in August.

The ranged in dissolved oxygen values during the three seasons of 1986 and 1987 in the COCO field are summarised below:

	Premonsoon	Monsoon	Postmonsoon
1986	2.17 - 3.75 ml/l	2.53 - 4.94 ml/l	2.34 - 5.06 ml/l
1987	1.70 - 3.28 ml/l	1.91 - 4.34 ml/l	1.22 - 1.93 ml/l

(iii) <u>POKKALI field</u>:

During 1986, the dissolved oxygen values ranged between 3.63 and 4.51 ml/l. During 1987, the recorded range in dissolved oxygen values was between 2.49 and 4.51 ml/l. However, monthly pattern of dissolved oxygen distribution evinced variation when compared to the previous year. Peak value of dissolved oxygen was recorded in April (4.51 ml/l) which gradually showed reducing tendency.

<u>Temperature</u>:

(i) <u>CIBA pond</u>:

During 1986, the temperature values ranged between 30 and 34° C, with high values recorded during the premonsoon season. The values gradually increased from January, and after reaching a peak in April and May (34° C) declined to 30° C in the monsoon season. A secondary peak of increasing tendency was observed in the postmonsoon.

During 1987, the recorded range in temperature values was between 28 and 31° C. Monthly mean of temperature distribution followed the some pattern when compared to the previous year.

The range in temperature values during the three season of 1986 and 1987 in the CIBA pond is summarised below:

	Premonsoon	Monsoon	Post monsoon
1986	31 - 34°C	30°C	30 - 31°C
1987	28.5 - 31°C	28 - 30°C	29 - 31°C

(ii) COCO field:

During 1986, the temperature values ranged between 30 and 34°C, with high values recorded during the premonsoon season. The values gradually increased from January and after reaching a peak in April and May (34°C) declined to 30°C in the monsoon season. A secondary peak of increasing tendency was observed in the postmonsoon.

During 1987, the recorded range in temperature was between 27 and 30.5°C. Monthly mean of temperature distribution allowed the same pattern when compared to the previous year.

The range in temperature values during the three seasons of 1986 and 1987 in the COCO field is summarised below:

	Premonsoon	Monsoon	Postmonsoon
1986	31 - 34°C	29 - 30°C	30 - 31°C
1987	28 - 30°C	27.5 - 29°C	29 - 30°C

(iii) POKKALI field:

During 1986, the temperature values ranged between 31.5 and 34°C. During 1987, the recorded range in temperature values was between 28 and 30.5°C. However, monthly mean of temperature evinced variation when compared to the previous year. Peak value of temperature was recorded in march (30.5°C) which gradually showed reducing tendency.

Hydrogen-ion concentration:-

(i) CIBA pond:

During 1987, the recorded range in hydrogen-ion concentration values was between 7.40 and 8.22. Peak value of hydrogen-ion concentration was recorded in May (8.22).

(ii) COCO field:

During 1987, the recorded range in hydrogen-ion concentration values was between 7.29 and 7.66. Peak value of hydrogen-ion concentration was recorded in March (7.66).

(iii) POKKALI field:

During 1987 premonsoon season, the recorded range in hydrogen-ion concentration values was between 7.31 and 7.76 with apeak value in March.

Redox potential

(i) CIBA pond:

During 1987, the recorded range in redox potential values was between 132 and 269 with an increasing trend observed.

(ii) <u>COCO field</u>:

During 1987, the recorded range in redox potential values was between 124 and 272 with an increasing trend observed.

(iii) <u>POKKALI field</u>:

During 1987 premonsoon, the recorded range in redox potential values was between 123 and 179 with an increasing trend observed.

PART - II : NUTRIENTS

Mean monthly distribution of nutrients in the CIBA pond such as inorganic phosphorus, dissolved silicon, nitrite, nitrate and ammonia during 1986 and 1987 are represented in Table - 4 and Fig. 2. Observed distribution pattern of these parameters in the COCO field are presented in Table - 5 and Fig. 3. Results of observation on the nutrients in the POKKALI field - which was limited to the premonsoon season of 1986 and 1987 are presented in Table - 6 and Fig. 4.

CIBA POND

Inorganic phosphorus:

During 1986, the inorganic phosphorus content in water ranged between 1.58 and 3.36 µg-at/l, with high values recorded during premonsoon season. The values gradually increased from January, and after reaching a peak in May (3.36 µg-at/l) declined to 1.45 µg-at/l during August. A secondary peak (2.39 µg-at/l) was observed in November.

During 1987, the recorded range in inorganic phosphorus content was between 1.40 and 5.30 µg-at/l. The values gradually increased from January, and after reaching a peak in May (3.16 µg-at/l) declined to 2.63 µg-at/l during June. A secondary peak was observed in July (5.39 µg-at/l) with a subsequent increase except in October (2.12 µg-at/l).

TABLE - 4

Concentration of nutrients in the CIBA pond
during 1986 and 1987
(Monthly mean values)

		Ammonia µg at/l	Phosphate µg at/l	Silicate µg at/l	Nitrite µg at/l	Nitrate µg at/l
Jan.	1986	4.12	1.58	19.40	0.97	11.75
	1987	4.94	1.40	29.85	1.36	12.90
Feb.	1986	4.57	2.02	20.00	1.06	8.94
	1987	5.88	2.21	32.97	1.00	6.00
Mar.	1986	5.40	2.27	24.30	0.87	4.80
	1987	5.07	2.25	24.75	0.72	5.98
Apr.	1986	7.81	3.20	15.00	1.65	7.00
	1987	8.98	2.89	10.43	1.84	8.92
May	1986	10.67	3.36	12.70	2.12	10.02
	1987	16.46	3.16	9.70	2.37	10.48
June	1986	6.67	2.73	11.10	2.16	6.94
	1987	22.80	2.63	10.90	5.10	9.52
July	1986	2.76	1.74	4.85	2.30	8.70
	1987	7.15	5.39	30.50	3.16	5.90
Aug.	1986	2.55	1.45	26.10	1.22	26.80
	1987	6.25	2.05	37.16	1.22	5.32
Sep.	1986	1.42	1.98	13.37	0.90	3.00
	1987	2.33	2.15	43.00	0.10	2.41
Oct.	1986	1.51	1.84	31.20	0.95	6.05
	1987	4.83	2.12	43.10	0.36	4.27
Nov.	1986	1.95	2.39	26.50	1.10	4.95
	1987	6.33	2.35	30.90	0.78	4.31
Dec.	1986	2.43	1.04	17.30	0.80	7.05
	1987	6.01	2.46	26.27	0.97	5.17

TABLE - 5

Concentration of nutrients in the COCO field
during 1986 and 1987
(Monthly mean values)

		Ammonia µg at/l	Phosphate µg at/l	Silicate µg at/l	Nitrite µg at/l	Nitrate µg at/l
Jan.	1986	4.57	1.91	20.90	1.15	6.91
	1987	10.04	3.03	31.00	1.40	7.50
Feb.	1986	5.55	2.41	20.05	1.30	7.47
	1987	9.82	2.70	28.30	1.35	5.16
Mar.	1986	7.45	2.85	20.10	0.97	6.32
	1987	7.70	3.20	13.95	1.10	6.77
Apr.	1986	9.90	3.44	13.50	1.47	6.35
	1987	11.46	3.21	9.50	1.55	7.35
May	1986	13.15	3.03	12.10	1.87	6.75
	1987	15.22	2.86	9.45	1.80	9.02
June	1986	7.87	3.35	10.35	2.15	7.36
	1987	17.78	4.21	7.95	2.03	10.24
July	1986	5.45	2.66	4.57	2.02	8.10
	1987	15.60	6.76	21.00	1.66	12.77
Aug.	1986	6.60	2.56	28.65	1.30	23.98
	1987	17.32	4.76	36.95	2.05	4.12
Sep.	1986	4.87	2.92	21.40	2.05	7.85
	1987	2.78	4.02	33.85	0.80	2.76
Oct.	1986	7.02	5.00	23.30	1.22	4.59
	1987	6.35	4.01	34.76	0.85	5.97
Nov.	1986	5.70	4.60	22.25	2.40	5.55
	1987	6.61	2.62	31.15	0.85	4.16
Dec.	1986	4.22	2.24	16.50	1.00	5.30
	1987	6.62	2.72	29.20	0.95	4.74

TABLE - 6

Concentration of nutrients in the POKKALI field during the premonsoon period of 1986 and 1987 (Monthly mean values)

		Ammonia µg at/l	Phosphate µg at/l	Silicate µg at/l	Nitrite µg at/l	Nitrate µg at/l
Jan.	1986	4.95	2.00	20.50	1.25	16.55
	1987	8.40	2.36	23.55	1.30	20.11
Feb.	1986	5.10	2.34	20.35	1.45	9.87
	1987	8.45	2.48	27.00	1.90	12.78
Mar.	1986	6.00	3.07	24.80	1.61	7.02
	1987	7.20	4.27	14.70	2.03	9.17
Apr.	1986	9.75	3.63	15.65	1.85	8.76
	1987	7.47	3.04	11.10	3.05	11.93
May	1986	8.35	2.90	12.05	2.45	11.03
	1987	8.51	2.65	10.10	2.80	10.41

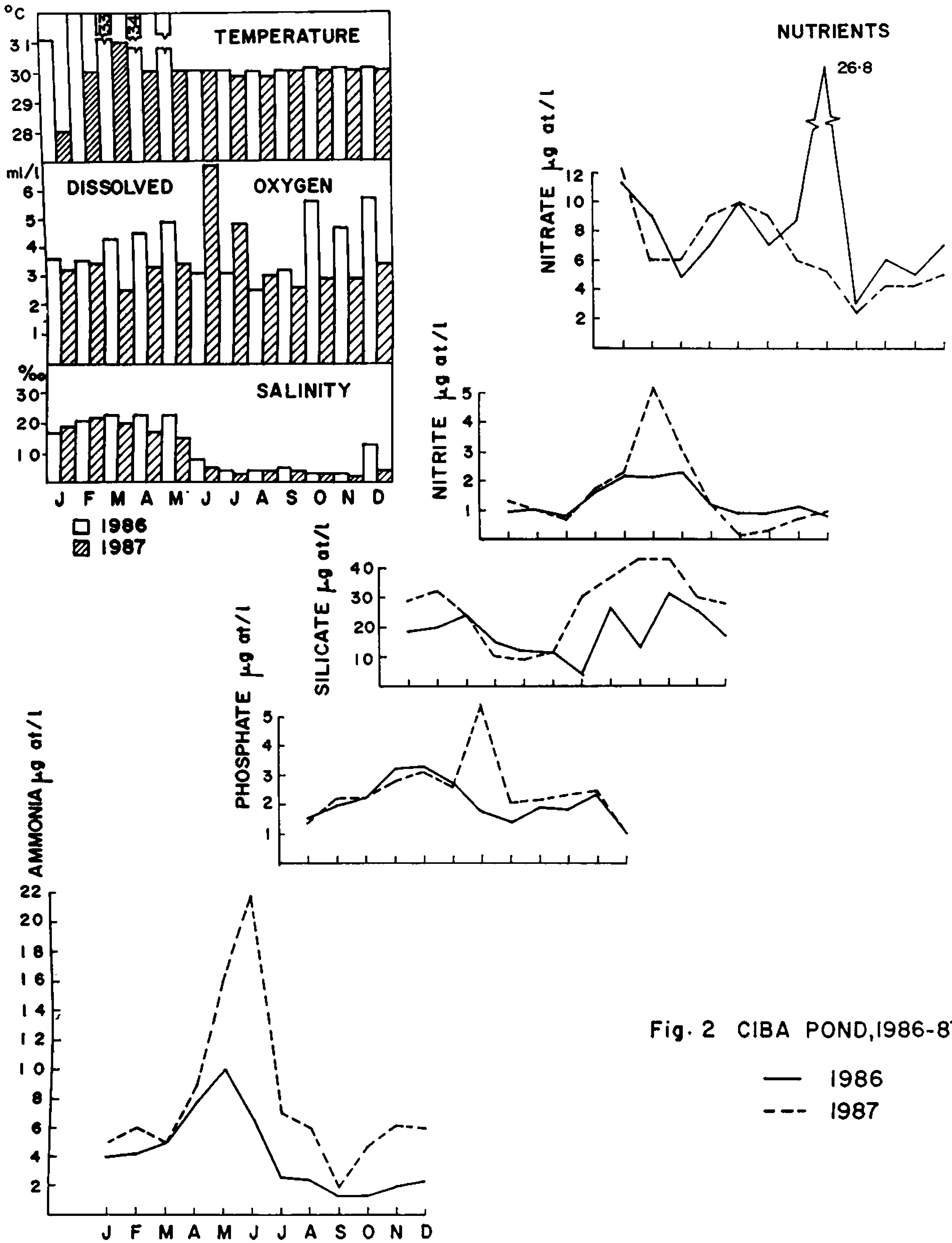


Fig. 2 CIBA POND,1986-87

— 1986
--- 1987

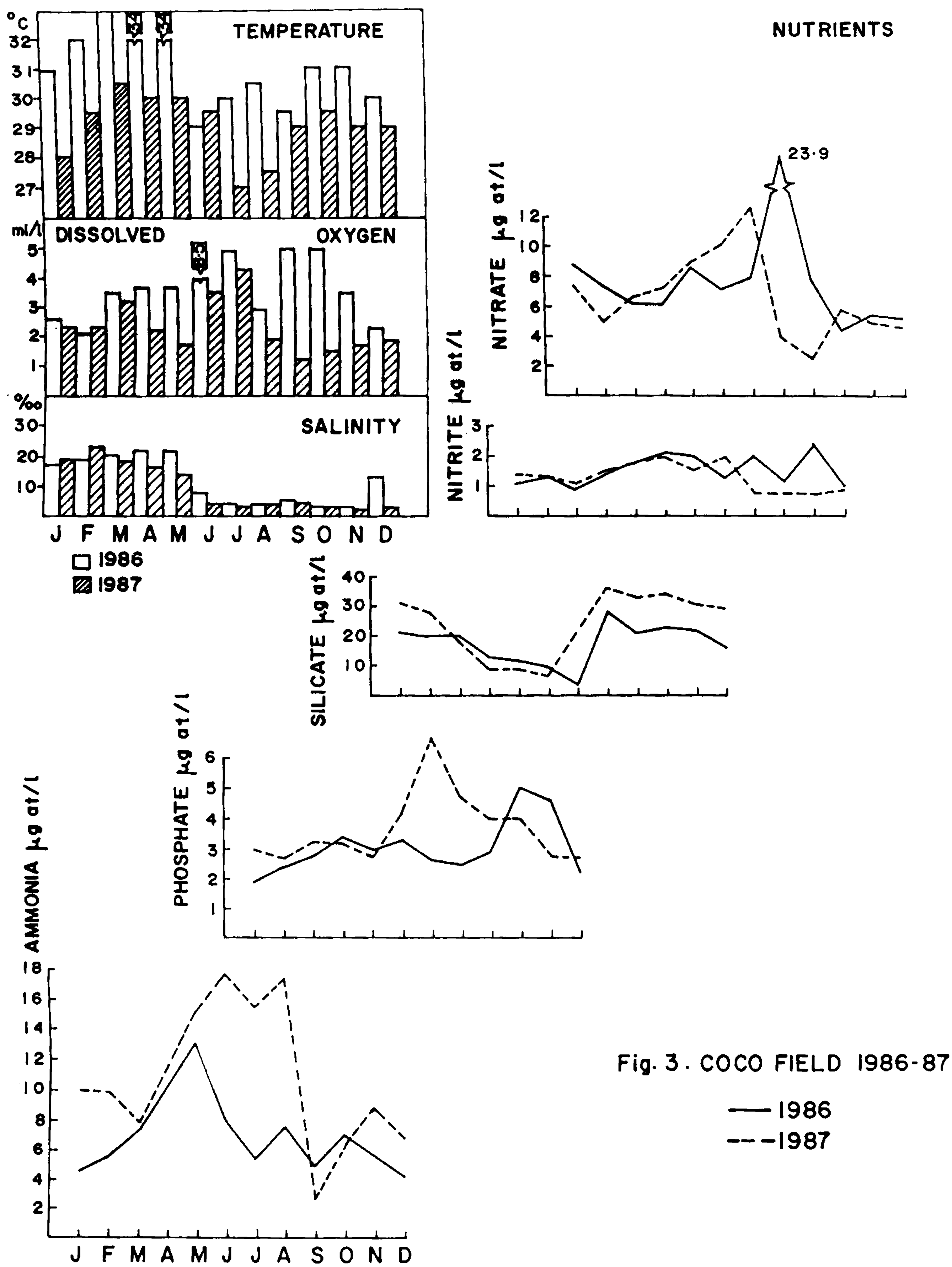


Fig. 3. COCO FIELD 1986-87

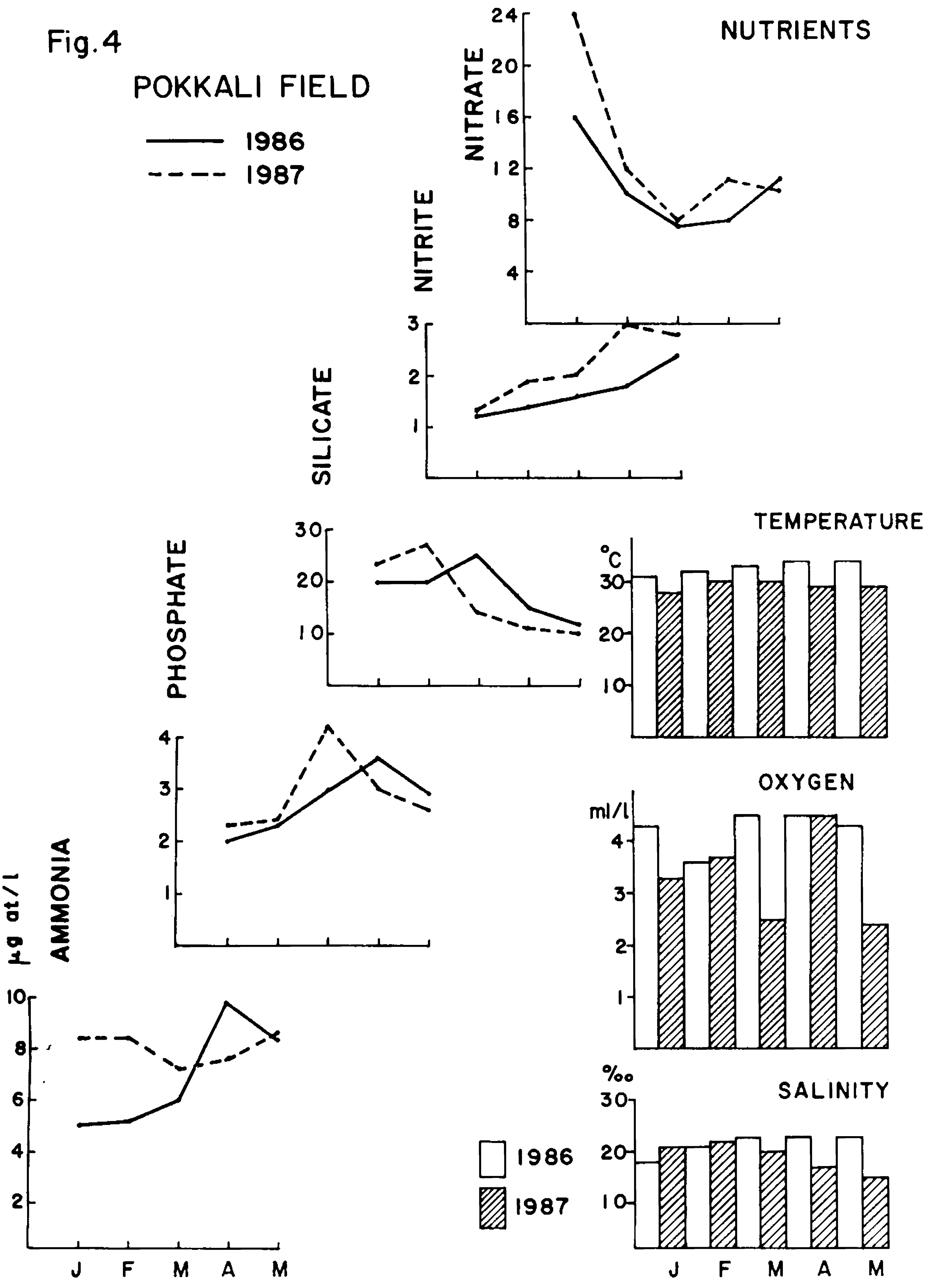


Fig. 4
POKKALI FIELD
1986
1987
NUTRIENTS
NITRATE
NITRITE
SILICATE
PHOSPHATE
AMMONIA
µg at/l
TEMPERATURE
°C
OXYGEN
ml/l
SALINITY
‰
1986
1987
J F M A M
J F M A M

	Premonsoon	Monsoon	Postmonsoon
1986	1.58 - 3.36	1.45 - 2.73	1.04 - 2.39 µg-at/l
1987	1.40 - 3.16	2.05 - 5.39	2.12 - 2.46 µg-at/l

Dissolved silicon:

During 1986, the dissolved silicon content in water ranged between 4.85 and 31.20 µg-at/l. The values gradually increased from January and after reaching a peak in March (24.30 µg-at/l) declined to 4.25 µg-at/l during July. High values were recorded in August (26.10 µg-at/l), November (26.50 µg-at/l) and the highest in October (31.20 µg-at/l).

During 1987, the recorded range in dissolved silicon content was between 9.70 and 43.10 µg-at/l. The values decreased from February (32.97 µg-at/l) onwards and reached 9.70 µg-at/l during May. Subsequently the values increased and reached a peak in October (43.10 µg-at/l) with a reducing tendency.

	Premonsoon	Monsoon	Postmonsoon
1986	12.7 - 24.3	4.85 - 26.10	13.37 - 31.20 µg-at/l
1987	9.70 - 32.97	10.90 - 37.16	28.27 - 43.10 µg-at/l

Nitrite:

During 1986, the nitrite content in water ranged between 0.87 and 2.30 µg-at/l. The value decreased from February (1.00 µg-at/l) to 0.87 µg-at/l in March and increased gradually and reached the peak in July (2.30 µg-at/l) with a subsequent decrease. A second peak was recorded in November (1.10 µg-at/l).

During 1987, the recorded range in nitrite content was between 0.10 and 5.10 μg-at/l. The values decreased from January (1.36 μg-at/l) to 0.72 μg-at/l in March which gradually increased to a peak in June (5.10 μg-at/l) with a subsequent decreasing to 0.10 μg-at/l in September and subsequently an increasing trend.

	Premonsoon	Monsoon	Postmonsoon
1986	0.87 - 2.12	1.22 - 2.30	0.80 - 1.10 μg-at/l
1987	0.72 - 2.37	1.22 - 5.10	0.10 - 0.97 μg-at/l

<u>Nitrate</u>:

During 1986, the nitrate content in water ranged between 3.00 and 26.80 μg-at/l. The values decreased from January (11.75 μg-at/l) to 4.80 μg-at/l in March and reached a peak in May (10.02 μg-at/l). A subsequent increasing trend and a peak in August (26.8 μg-at/l) was recorded. A secondary peak in nitrate content was observed in October (6.05 μg-at/l) and a tertiery one in December (7.05 μg-at/l).

During 1987, the recorded range in nitrate content was between 2.41 and 12.90 μg-at/l. The values decreased from January (12.9 μg-at/l) to March (5.98 μg-at/l). A subsequent increase and a peak was recorded in May (10.48 μg-at/l) with subsequently decreasing trend to 2.41 μg-at/l in September which gradually increasing and a secondary peak in December (5.17 μg-at/l).

	Premonsoon	Monsoon	Postmonsoon
1986	4.80 - 11.75	6.94 - 26.80	3.00 - 7.05 μg-at/l
1987	5.98 - 11.90	5.30 - 9.52	2.41 - 5.17 μg-at/l

Ammonia:

During 1986, the ammonia content ranged between 1.42 and 10.60 µg-at/l, with a high values recorded during premonsoon season. The values gradually increased from January (4.12 µg-at/l) and showed a peak in May (10.67 µg-at/l) and subsequently declined to September (1.42 µg-at/l). With subsequent increase in trend, a secondary peak was observed in December (2.43 µg-at/l).

During 1987, the recorded range of ammonia content in water was between 2.33 and 22.80 µg-at/l. However, mean monthly distribution of ammonia content evinced variation when compared to that in the previous year. The values increased from January (4.94 µg-at/l) onwards and reached a peak in June (22.80 µg-at/l). A secondary peak was observed in November (6.33 µg-at/l) and in December the value recorded was 6.01 µg-at/l.

	Premonsoon	Monsoon	Postmonsoon
1986	4.10 - 10.67	2.55 - 6.67	1.42 - 2.43 µg-at/l
1987	4.57 - 16.46	6.25 - 22.80	2.33 - 6.33 µg-at/l

COCO FIELD

Inorganic phosphorus

During 1986, the inorganic phophorus content ranged between 1.91 and 5.00 µg-at/l. The values gradually increased from January (1.91 µg-at/l) to a peak in April (3.44 µg-at/l) with subsequently decrease in trend and a secondary peak in October (5.00 µg-at/l) with a subsequent decreasing trend.

During 1987, the recorded range of inorganic phosphorus content in water was between 2.70 and 6.76 µg-at/l. The values decreased from January (3.30 µg-at/l) and increased subsequently and showed a peak in April (3.21 µg-at/l). A second peak was observed in July (6.76 µg-at/l) and subsequently decreased in trend.

	Premonsoon	Monsoon	Postmonsoon
1986	1.97 - 3.44	2.50 - 3.35	2.24 - 5.00 µg-at/l
1987	2.70 - 3.21	4.21 - 6.76	2.72 - 4.02 µg-at/l

Dissolved silicon:

During 1986, the dissolved silicon content ranged between 4.57 and 28.65 µg-at/l. The values decreased from March (20.10 µg-at/l) to July (4.57 µg-at/l) and subsequently increased and showed a peak in August (28.65 µg-at/l). A second peak was observed in October (23.30 µg-at/l) with a subsequent decreasing in trend.

During 1987, the recorded range of dissolved silicon in water was between 7.95 and 36.95 µg-at/l. The values decreased from January (31.00 µg-at/l) to June (7.95 µg-at/l) and increased subsequently and showed a peak in August (36.95 µg-at/l). A secondary peak was observed in October (34.78 µg-at/l) with a suusequent decreasing in trend.

	Premonsoon	Monsoon	Postmonsoon
1986	12.10 - 20.90	4.57 - 28.65	16.50 - 23.30 µg-at/l
1987	9.45 - 31.00	7.95 - 36.95	29.20 - 34.78 µg-at/l

Nitrite:

During 1986, the nitrite content ranged between 0.97 and 2.40 µg-at/l. The value decreased from February (1.30 µg-at/l) to March (0.97 µg-at/l) and subsequently increased and showed a peak in June (2.15 µg-at/l). Subsequently it showed fluctuations and a secondary peak in September (2.05 µg-at/l) and a teriery one in November (2.40 µg-at/l).

During 1987, the recorded range of nitrite content in water was between 0.80 and 2.05 µg-at/l. The values decreased from January (1.40 µg-at/l) to March (1.10 µg-at/l) and subsequently increased and showed a peak in June (2.03 µg-at/l). A subsequent secondary peak was observed in August (2.05 µg-at/l) with a subsequent decrease. An increasing trend was observed from October onwards.

	Premonsoon	Monsoon	Postmonsoon
1986	0.97 - 1.87	1.30 - 2.15	1.00 - 2.40 µg-at/l
1987	1.10 - 1.80	1.60 - 2.05	0.80 - 0.95 µg-at/l

Nitrate:

During 1986, the nitrate content ranged between 4.59 and 23.92 µg-at/l. The values decreased from January (8.91 µg-at/l) to March (6.32 µg-at/l) and gradually increased and showed a peak in May (8.75 µg-at/l) and a secondary peak in August (23.90 µg-at/l) with a decrease in trend.

During 1987, the recorded range of nitrate content in water was between 2.76 and 12.77 µg-at/l. The values gradually increased from February (5.18 µg-at/l) and showed a peak of maximum in July (12.77 µg-at/l) with a decrease in trend. A secondary peak was observed in October (5.97 µg-at/l) with subsequent increase in trend.

	Premonsoon	Monsoon	Postmonsoon
1986	6.32 - 8.91	7.36 - 23.98	4.59 - 7.85 µg-at/l
1987	5.18 - 9.02	4.12 - 12.77	2.76 - 5.97 µg-at/l

Ammonia:

During 1986, the ammonia content ranged between 4.22 and 13.15 µg-at/l with high values recorded during pemonsoon season. The values gradually increased from January, and after recording a peak in May (13.15 µg-at/l) declined to 4.87 µg-at/l in August. A secondary peak was observed in October (7.02 µg-at/l).

During 1987, the recorded range of ammonia content in water was between 2.78 and 17.78 µg-at/l. However, mean monthly distribution of ammonia content evinced variation when compared to that in the previous year. The values decreased from January (10.04 µg-at/l) to March (7.70 µg-at/l) with a subsequent increase and showed a peak in June (17.78 µg-at/l). A subsequent secondary peak in August (17.32 µg-at/l) and a tertiery one in November (8.81 µg-at/l).

	Premonsoon	Monsoon	Postmonsoon
1986	4.57 - 13.15	5.45 - 7.87	4.22 - 7.02 µg-at/l
1987	7.70 - 15.22	15.61 - 17.78	2.78 - 8.81 µg-at/l

POKKALI FIELD

Inorganic phosphorus

During the premonsoon season of 1986, the inorganic phosphorus content ranged between 2.00 and 3.63 µg-at/l. The values gradually increased from January (2.00 µg-at/l) and showed a peak in April (3.63 µg-at/l) with subsequently a decrease in trend.

During 1987, the recorded range of inorganic phosphorus content in water was between 2.36 and 4.27 µg-at/l. The values gradually increased from January (2.36 µg-at/l) and showed a peak in March (4.27 µg-at/l) and subsequently a decrease in trend.

Dissolved silicon:

During the premonsoon season of 1986, the dissolved silicon content ranged between 10.10 and 27.00 µg-at/l. The value increased from January (23.00 µg-at/l) and showed a peak in February (27.00 µg-at/l) and subsequently a decrease in trend.

During 1987, the recorded range of dissolved silicon content in water was between 12.05 and 24.80 µg-at/l. The values decreased from January (20.50 µg-at/l) and increased and showed a peak in March (24.80 µg-at/l) and subsequently a decrease in trend.

Nitrite:

During the premonsoon season of 1986, the nitrite content ranged between 1.30 and 3.05 µg-at/l. The values increased gradually from January (1.30 µg-at/l) and showed a peak in April (3.05 µg-at/l) and subsequently a decrease in trend.

During 1987, the recorded range of nitrite content in water was between 1.25 and 2.45 µg-at/l. The values gradually increased from January (1.25 µg-at/l) and a peak in May (2.45 µg-at/l).

Nitrate:

During the premonsoon season of 1986, the nitrate content ranged between 9.17 and 20.11 µg-at/l. The values decreased gradually from January (20.11 µg-at/l) to March (9.11 µg-at/l) and subsequently an increase in April (11.93 µg-at/l) with a decrease in trend.

During 1987, the recorded range of nitrate content in water was between 7.02 and 16.55 µg-at/l. The values gradually decreased from January (16.55 µg-at/l) to March 7.02 µg-at/l) and subsequently an increase in trend.

Ammonia:

During the premonsoon season of 1986, the ammonia content ranged between 4.95 and 9.75 µg-at/l. The values gradually increased from January (4.95 µg-at/l) and showed a peak in April (9.75 µg-at/l) and subsequently a decrease in trend.

During 1987, the recorded range of ammonia content in water was between 7.20 and 8.51 µg-at/l. However, mean monthly distribution of ammonia content evinced variation when compared to that in the previous year. Ammonia content was observed to vary between 7.20 µg-at/l in March and 8.45 µg-at/l in February. A peak value was recorded in May (8.51 µg-at/l).

PART - III (A) : PRIMARY PRODUCTIVITY

Results of observations on the variation in the rate of primary productivity during 1986 & 1987 are presented in Table - 7 and Fig. 5.

(i) CIBA pond:

During 1986, the values of Gross primary productivity ranged between 2154.77 and 8182 mg C/m^3/day. The primary productivity rate gradually increased from January (2154.77 mg C.m^3/day) to reach a peak in April (3894.94 mg C/m^3/day). This condition of high rate of production prevailed upto June and subsequently a high value of 7110.96 mg C/m^3/day was recorded in August. A tertiary peak was recorded in September (8182.96 mg C/m^3/day). The production rate declined drastically in October (2858.67 mg C/m^3/day) and in December (4037.88 mg C/m^3/day) a high increase in the value was recorded.

During 1987, the observed values of Gross primary productivity ranged between 2179.74 and 6896.56 mg C/m^3/day. The production rate gradually increased from January (2179.74 mg C/m^3/day) and showed a peak in April (6896.50 mg C/m^3 /day) which evinced a declining trend till August (2857.54 mg C/m^3/day) with the onset of monsoon. A secondary peak was recorded in September (3537.34 mg C/m^3/day) and a tertiery one in November (3573.34 mg C/m^3/day). The peak period of primary production was observed to be during the months of July-September in 1986, where as it was during April-June in 1987.

TABLE - 7

Magnitude of Primary productivity mg C/m^3/day
(Monthly mean values)

		CIBA Pond		COCO Field		POKKALI Field	
		Gross	Net	Gross	Net	Gross	Net
Jan.	1986	2154.77	2001.07	2072.67	1715.20	2394.14	2144.00
	1987	2179.74	2072.54	4824.02	4573.88	1250.67	1180.19
Feb.	1986	2572.81	2251.20	2501.13	2001.07	2751.47	2179.74
	1987	2501.34	2382.67	6789.36	6324.83	2465.61	2215.47
Mar.	1986	2966.14	2715.74	2644.27	2429.87	3430.91	2572.81
	1987	4859.75	4395.22	12864.05	12464.84	15865.67	15079.53
Apr.	1986	3894.94	3466.14	3358.94	3858.66	4859.75	4002.15
	1987	6896.56	6789.36	14541.05	14293.39	13078.45	11934.98
May	1986	3716.28	3537.61	2930.14	2644.27	4502.42	4145.08
	1987	6646.43	6360.56	12685.39	12292.32	12077.91	11934.98
Jun.	1986	4002.14	3573.34	3501.88	2858.68		
	1987	6587.77	6025.45	15007.77	14993.93		
Jul.	1986	7110.96	5074.15	7396.83	5324.24		
	1987	5032.70	4533.50	1785.00	1593.00		
Aug.	1986	6610.69	6074.69	3216.01	2751.47		
	1987	2857.54	2286.07	1535.10	1396.30		
Sep.	1986	8182.96	7575.50	6646.42	5860.29		
	1987	3573.34	2822.94	821.87	678.93		
Oct.	1986	2858.67	2489.33	3216.55	1965.34		
	1987	3487.78	2622.94	821.86	535.99		
Nov.	1986	2930.14	2072.54	2179.74	1536.53		
	1987	3573.34	2793.64	1107.73	714.66		
Dec.	1986	4037.86	3356.94	2787.21	1572.27		
	1987	3356.94	2930.14	1572.27	1106.23		

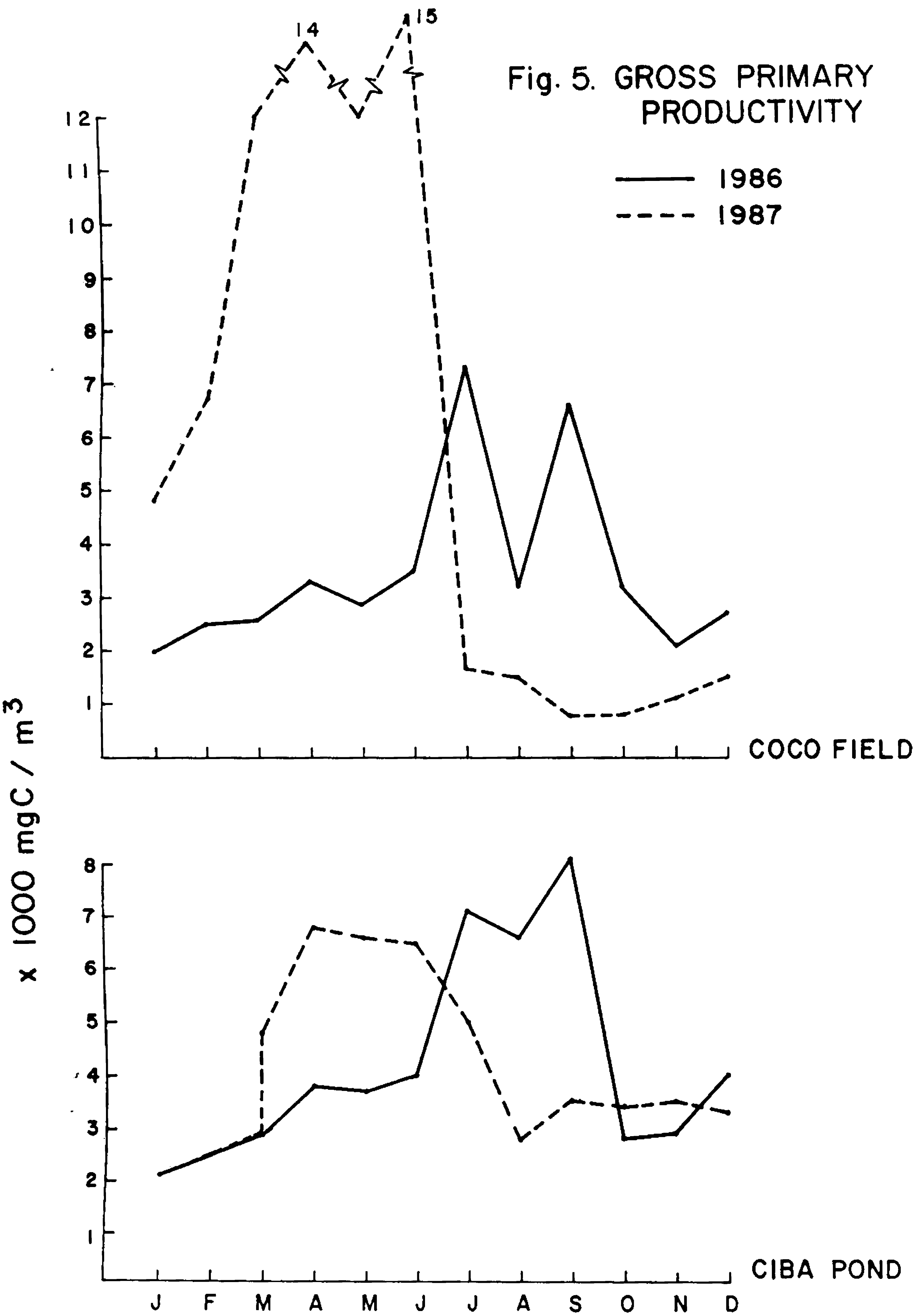


Fig. 5. GROSS PRIMARY PRODUCTIVITY
1986
1987
14
15
x 1000 mgC / m3
COCO FIELD
CIBA POND
J F M A M J J A S O N D

(ii) <u>COCO field</u>:

During 1986, the values of Gross primary productivity ranged between 2072.67 and 7396.83 mg C/m^3/day. The productivity rate gradually increased from January (2072.67 mg C/m^3 /day) to reach a peak in April (3358.94 mg C/m^3/day). This condition of high rate of production prevailed upto June and subsequently a high value of 7396.83 mg C/m^3/day was recorded in August. A tertiery peak was recorded in September (6646.42 mg C/m^3 /day). The production rate declined drastically in October (3216.55 mg C/m^3 /day) and in November (2179.74 mg C/m^3/day) with a slight increase in the value in December (2787.21 mg C/m^3 /day) was found.

During 1987, the observed values of Gross primary productivity ranged between 821.87 and 15007.77 mg C/m^3/day. The production rate gradually increased from January (4824.02 mg C/m^3/ day) and showed a peak in April (14541.03 mg C/m^3 /day) which evinced a declining trend in May (12695.39 mg C/m^3 /day). A secondary peak of high production rate was recorded in June (15007.77 mg C/m^3 /day) which declining drastically in July (1765.00 mg C/m^3 /day) till October (621.86 mg C/m^3 /day) and subsequently increased to a tertiary peak in December (1572.27 mg C/m^3/day). The peak period of primary production was observed to be during the months of July - September in 1986, where as it was during April - June in 1987.

(iii) POKKALI field:

During the premonsoon season of 1986, the observed value of Gross primary productivity ranged between 2394.14 and 4859.75 mg C/m^3/day. The production rate gradually increased from January to April and a peak of high production rate of 4859.75 mg C/m^3/day which subsequently decrease in the trend.

During 1987, the recorded production value ranged from 1250.67 and 15865.67 mg C/m^3/day. The productivity rate increased from January and showed a production rate of 15865.67 mg C/m^3 /day in April and subsequently a decrease in trend. High production rate of 15805.67 mg C/m^3/day was reached comparatively to that in the previous year (4859.75 mg C/m^3/day).

PART - III (B) : CHLOROPHYLL 'a'

Measurement of variation in chlorophyll 'a' content was carried out in the three culture ponds selected for the study. Observations were made during 1986 and 1987 in the CIBA pond and COCO field and the results are presented in Table - 8 and Fig. 6. However, this study was limited to the premonsoon months of January - May in the POKKALI field during 1986 and 1987.

(i) CIBA pond:

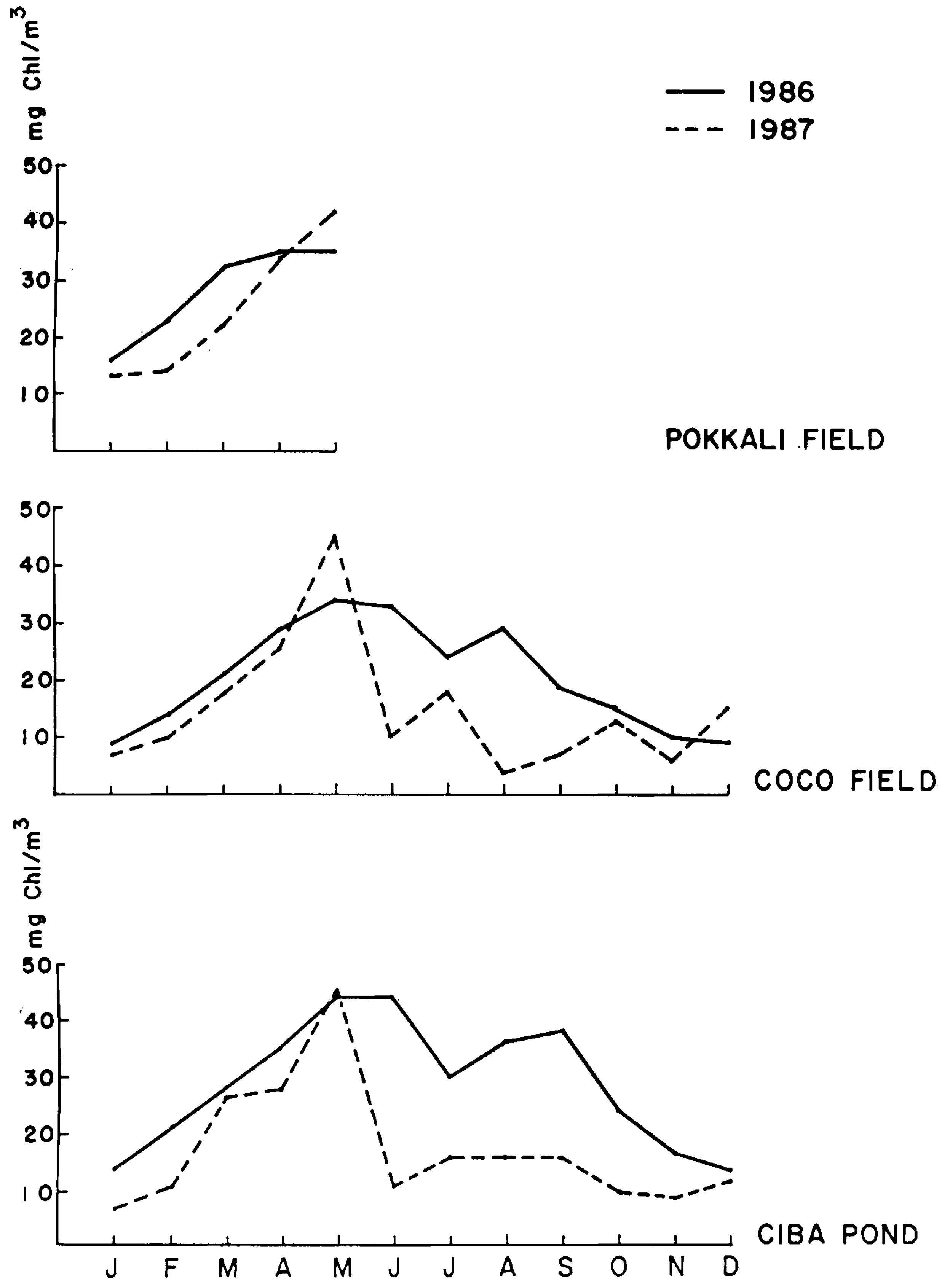
During 1986, the content of chlorophyll 'a ranged between 14.15 and 44.75 mg chl/m^3. Its concentration gradually increased from January (14.15 mg chl/m^3) and reached a peak in May (44.75 mg chl/m^3). It evinced a decline trend from June and

TABLE - 8

Concentration of Chlorophyll 'a' (mg Chl/m^3)
(Monthly mean values)

		CIBA pond	COCO field	POKKALI field
Jan.	1986	14.15	9.59	16.54
	1987	7.49	7.34	13.42
Feb.	1986	21.55	14.61	23.41
	1987	11.79	10.39	14.90
Mar.	1986	28.66	21.71	32.07
	1987	27.59	18.91	22.79
Apr.	1986	35.92	29.66	35.66
	1987	28.94	26.74	34.54
May	1986	44.75	34.66	35.96
	1987	45.65	45.12	42.17
Jun.	1986	44.56	33.71	
	1987	11.75	10.11	
Jul.	1986	30.95	24.75	
	1987	16.61	18.79	
Aug.	1986	36.63	29.64	
	1987	16.47	4.56	
Sep.	1986	38.44	19.69	
	1987	16.05	7.43	
Oct.	1986	24.99	15.20	
	1987	10.91	13.13	
Nov.	1986	17.60	10.62	
	1987	9.20	6.89	
Dec.	1986	14.17	9.52	
	1987	12.30	15.94	

Fig. 6 CONCENTRATION OF CHLOROPHYLL a



subsequently showed a secondary peak in September (38.44 mg chl/m^3) after which the values were observed to decline.

During 1987, the observed values of chlorophyll '<u>a</u>' ranged from 7.49 and 45.85 mg chl/m^3. Its concentration gradually increased from January (7.49 mg chl/m^3) and showed a peak in May (45.85 mg chl/m^3) and the value drastically declined with the onset of monsoon in June (11.75 mg chl/m^3). The chlorophyll '<u>a</u>' value subsequently increased in July (16.67 mg chl/m^3) and established till September. After evincing a decline in November (9.20 mg chl/m^3) the value increased to 12.30 mg chl/m^3 in December.

(ii) <u>COCO field</u>:

During 1986, the content of chlorophyll '<u>a</u>' ranged between 9.59 and 34.86 mg chl/m^3 . The chlorophyll content gradually increased from January (9.59 mg chl/m^3) and reached a peak in May (34.86 mg chl/m^3). It evinced a decline till July (24.75 mg chl/m^3) and subsequently increased and showed a secondary peak in August (29.84 mg chl/m^3) followed by a decrease in trend in the rest of the year.

During 1987, the observed values of chlorophyll '<u>a</u>' ranged from 6.89 and 45.12 mg chl/m^3. Its concentration gradually increased from January (7.34 mg chl/m^3) and showed a peak in May (45.12 mg chl/m^3). It evinced a drastic decline with the onset of monsoon in June (10.11 mg chl/m^3). The content evinced a secondary peak in July (18.79 mg chl/m^3), and subsequently a tertiary was observed in October (13.13 mg chl/m^3). After recording a low value of 6.89 mg chl/m^3 in November, its concentration increased to 15.94 in December.

(iii) POKKALI field:

During the premonsoon season of 1986, the content of chlorophyll 'a' ranged between 16.54 and 35.96 mg chl/m^3 . Its concentration gradually increased from January (16.54 mg chl/m^3) and reached a peak in May (35.96 mg chl/m^3).

During 1987, values of chlorophyll 'a' was observed to be between 13.42 and 42.17 mg chl/m^3 . The content gradually increased and showed a peak in May. Its concentration was relatively low during all the month of the premonsoon season in comparison to that of the same period in 1986.

PART - III (C) : CELL COUNTS

Enumeration of cells were made in the three culture systems during 1987. The results of observation carried out during all the months in the CIBA pond and COCO field, and during the premonsoon season in the POKKALI field are presented in Table - 9 and 10 and Fig. 7.

(i) CIBA pond:

During the premonsoon season, numerical abundance of diatoms was recorded (monthly mean 5431 cells/25ml) when compared to that of the dinoflagellates (2005 cells/25ml) and the blue-green algae (473 cells/25ml). During monsoon season cell count

TABLE - 9

Estimation of phytoplanktons (cells/25 ml) during 1987
(Monthly mean values)

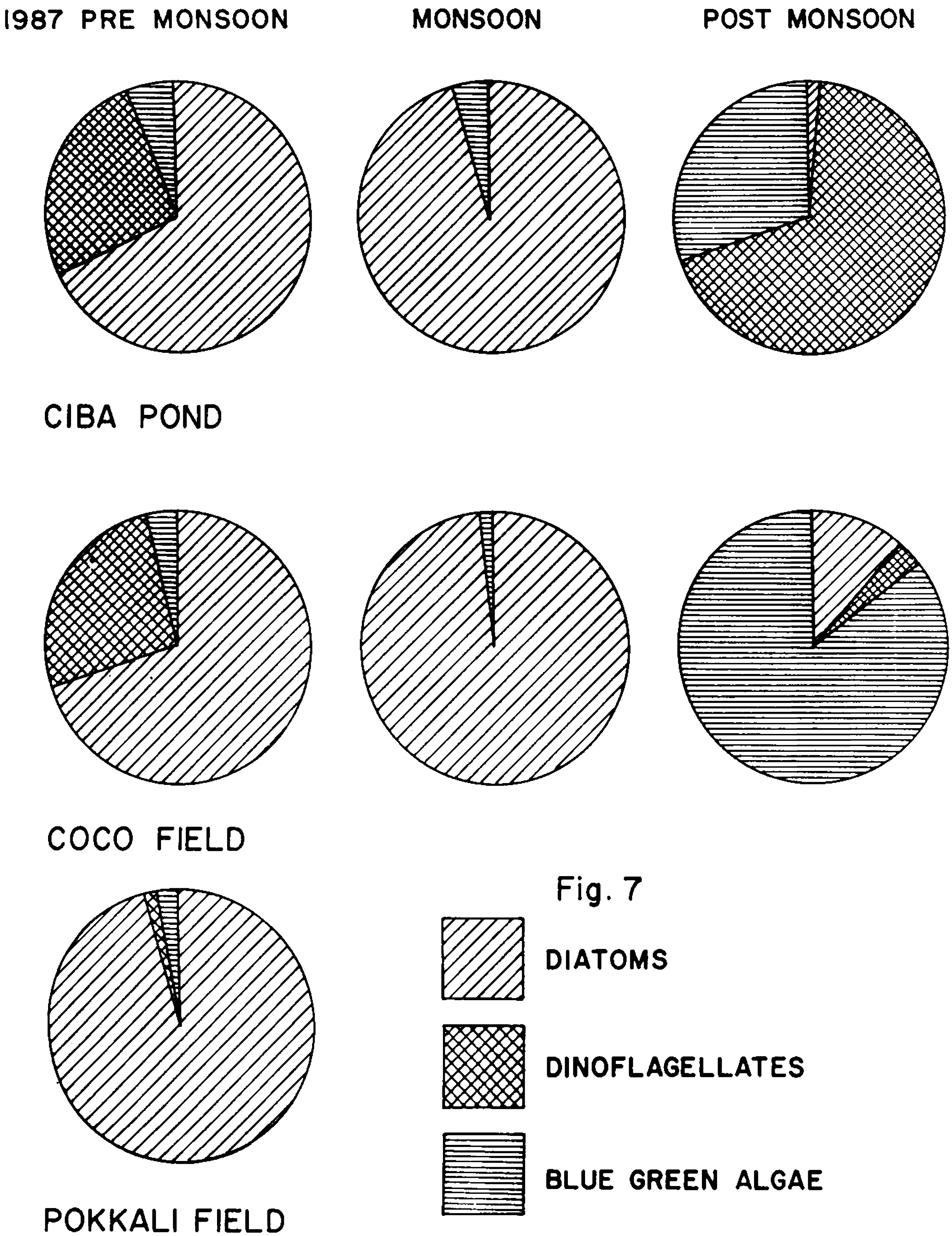
		CIBA pond	COCO field	POKKALI field
	DIA	980	890	146
Jan.	DIN	15	9	5
	BGA	704	16	470
	DIA	3598	2323	2311
Feb.	DIN	-	-	-
	BGA	1091	-	1000
	DIA	2137	3745	2995
Mar.	DIN	13	166	20
	BGA	572	714	383
	DIA	216	4494	359
Apr.	DIN	10000	8000	1500
	BGA	-	-	-
	DIA	20230	10690	80273
May	DIN	-	-	-
	BGA	-	78	10
	DIA	6131	5261	
Jun.	DIN	-	-	
	BGA	-	-	
	DIA	634	2950	
Jul.	DIN	-	-	
	BGA	-	32	
	DIA	82	21	
Aug.	DIN	-	-	
	BGA	318	284	
	DIA	43	346	
Sep.	DIN	-	-	
	BGA	8230	3295	
	DIA	66	73	
Oct.	DIN	90000	86	
	BGA	2066	2419	
	DIA	249	162	
Nov.	DIN	-	-	
	BGA	2340	205*	
	DIA	2204	482	
Dec.	DIN	199	-	
	BGA	25000	2050	

*Excludes unidentified BGA

TABLE - 10

Seasonal pattern of distribution of phytoplanktons (Cells/25 ml)

	Premonsoon			Monsoon			Postmonsoon		
	DIA	DIN	BGA	DIA	DIN	BGA	DIA	DIN	BGA
CIBA pond	27157	10028	2367	6847	--	318	2562	90199	37636
COCO field	22342	2177	810	8232	--	316	1083	88	7969
POKKALI field	26086	1525	1863	-	-	-	-	-	-


1987 PRE MONSOON
MONSOON
POST MONSOON
CIBA POND
COCO FIELD
POKKALI FIELD
DIATOMS
DINOFLAGELLATES
BLUE GREEN ALGAE
Fig. 7

was relatively low, and the monthly mean count of diatoms was 2282 cells/25ml and blue-green algae 106 cells/25ml. Dinoflagellates were totally absent in the collection. During the postmonsoon season, sporadic occurrence of bloom of dinoflagellates 22549 cells/25ml and blue-green algae 9409 cells/25ml.

(ii) COCO field:

During the premonsoon season diatoms were numerically abundant (monthly mean No. 4468 cells/25ml) followed by the dinoflagellates (1635 cells/25ml) and the blue-green algae (162 cells/25ml). Cell count was relatively low during the monsoon season when the diatoms recorded a numerical value of 2744 cells/25ml, blue-green algae 105 cells/25ml and dinoflagellates were absent in the samples. During the postmonsoon season, the monthly mean values of diatoms was 270 cells/25ml, dinoflagellates 22 cells/25ml and blue-green algae 1992 cells/25ml.

(iii) POKKALI field:

During the premonsoon season, preponderance of diatoms with their bloom was recorded (17217 cells/25ml). Numerical value of dinoflagellates was 305 cells/25ml and that of blue-green algae was 372 cells/25ml.

PART - III (D) : STATISTICAL ANALYSIS

In order to assess the correlation and extent of influence between the parameters studied, the following characters were selected and correlation coefficient 'r' was calculated.

1986		1987	
1.	Salinity	1.	Salinity
2.	Dissolved oxygen	2.	Dissolved oxygen
3.	Temperature	3.	Temperature
4.	Ammonia	4.	pH
5.	Phosphate	5.	Eh
6.	Silicate	6.	Ammonia
7.	Nitrite	7.	Phosphate
8.	Nitrate	8.	Silicate
9.	Primary productivity	9.	Nitrite
10.	Chlorophyll '<u>a</u>'	10.	Nitrate
		11.	Primary productivity
		12.	Chlorophyll '<u>a</u>'
		13.	Cell count

The result of these parameters during 1986 in the CIBA pond are presented as correlation matrix in Table - 11.

Salinity was positively correlated with temperature (r=0.67) and ammonia (r=0.70). Temperature was positively correlated with ammonia (r=0.69) and phosphate (r=0.48). Ammonia was positively correlated with the phosphate (r=0.56), nitrite (r=0.53) and chlorophyll '<u>a</u>' (r=0.49). Phosphate was positively correlated with nitrite (r=0.41) and chlorophyll '<u>a</u>' (r=0.54). Silicate was negatively correlated with nitrite (r=0.63). Primary productivity was positively correlated with chlorophyll '<u>a</u>' (r=0.41).

TABLE - 11

CIBA pond, 1986:
MEAN AND STD. DEVIATION OF DIFFERENT CHARACTERISTICS

CHR #	MEAN	S.D.
1. Salinity	12.765	8.465
2. Dissolved Oxygen	4.099	1.293
3. Temperature	27.667	3.031
4. Ammonia	4.325	2.946
5. Phosphate	2.136	0.844
6. Silicate	18.443	7.912
7. Nitrite	1.343	0.594
8. Nitrate	9.505	8.649
9. Primary Productivity	3677.522	1900.445
10. Chlorophyll '$\underline{a}$'	29.397	11.045

CORRELATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1.	1.000									
2.	0.181	1.000								
3.	0.672	0.217	1.000							
4.	0.703	-.012	0.696	1.000						
5.	0.354	0.059	0.487	0.584	1.000					
6.	-.141	0.217	-.198	-.373	-.154	1.000				
7.	0.004	-.190	0.230	0.539	0.416	-.637	1.000			
8.	-.160	-.360	-.034	-.079	-.180	0.200	0.014	1.000		
9.	-.352	-.163	-.257	-.259	-.101	-.345	0.136	0.225	1.000	
10.	0.014	-.372	0.267	0.498	0.543	-.391	0.601	0.171	0.417	1.000

The results of these parameters during 1987 in the CIBA pond are represented as correlation matrix in Table - 12.

Salinity was negatively correlated with redox potential (r=0.87). Dissolved oxygen was positively correlated with ammonia (r=0.45) and nitrite (r=0.56). Temperature was positively correlated with ammonia (r=0.52). Hydrogen-ion concentration was negatively correlated with silicate (r=-.54) and positively with the primary productivity (r=0.68) and chlorophyll '<u>a</u>' (r=0.61). Redox potential was positively correlated with silicate (r=0.45) and negatively with nitrate (r=-.50).

Ammonia was negatively correlated with silicate (r=-.53) and positively with nitrite (r=0.78) and primary productivity (r=0.65). Phosphate was positively correlated with primary productivity (r=0.42). Silicate was negatively correlated with nitrite (r=-.50), nitrate (r=-.43) and primary productivity (r=-.68). Nitrite was positively correlated with nitrate (r=0.60) and primary productivity (r=0.55). Primary productivity was positively correlated with chlorophyll '<u>a</u>' (r=0.66).

The results of these parameters during 1986 in the COCO field are represented as correlation matrix in Table - 13.

Salinity was negatively correlated with dissolved oxygen (r=-.40) and positively with temperature (r=0.76) and ammonia (r=0.41). Dissolved oxygen was positively correlated with phosphate (r=0.41) and primary productivity (r=0.59). Temperature was positively correlated with ammonia (r=0.67). Ammonia was positivly correlated with primary productivity (r=0.59). Silicate

TABLE - 12

CIBA pond, 1987:
MEAN AND STD. DEVIATION OF DIFFERENT CHARACTERISTICS

CHR #	MEAN	S.D.
1. Salinity	10.284	7.765
2. Dissolved Oxygen	3.806	1.553
3. Temperature	25.292	1.351
4. pH	7.685	0.364
5. Eh	208.667	56.330
6. Ammonia	8.089	6.103
7. Phosphate	2.586	1.241
8. Silicate	27.669	14.652
9. Nitrite	1.579	1.527
10. Nitrate	7.014	4.040
11. Primary Productivity	3857.662	1689.417
12. Chlorophyll 'a'	18.333	10.997
13. Cell count	17690.500	41111.800

CORRELATION MATRIX

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	**1.000**												
2.	0.030	**1.000**											
3.	-.393	0.322	**1.000**										
4.	0.329	0.264	0.035	**1.000**									
5.	**-.872**	-.285	0.237	-.350	**1.000**								
6.	-.021	**0.453**	**0.529**	0.397	-.345	**1.000**							
7.	-.176	0.117	0.064	0.266	0.069	0.173	**1.000**						
8.	-.267	-.390	-.175	**-.540**	**0.456**	**-.537**	-.041	**1.000**					
9.	-.089	**0.580**	0.285	0.340	-.289	**0.788**	0.185	**-.503**	**1.000**				
10.	0.346	0.325	-.064	0.283	**-.505**	**0.458**	-.003	**-.438**	**0.602**	**1.000**			
11.	0.162	0.398	0.374	**0.683**	-.332	**0.653**	**0.428**	**-.689**	**0.551**	0.394	**1.000**		
12.	0.335	-.034	-.010	**0.610**	-.217	0.260	0.269	-.351	0.082	0.207	**0.662**	**1.000**	
13.	-.113	-.171	0.141	**-.443**	0.179	0.073	-.031	0.076	-.150	-.141	0.023	0.225	**1.000**

TABLE - 13

COCO field, 1986:
MEAN AND STD. DEVIATION OF DIFFERENT CHARACTERISTICS

CHR #	MEAN	S.D.
1. Salinity	12.041	8.018
2. Dissolved Oxygen	3.510	1.022
3. Temperature	28.188	2.540
4. Ammonia	6.865	2.962
5. Phosphate	3.030	0.950
6. Silicate	17.806	6.838
7. Nitrite	1.565	0.539
8. Nitrate	8.364	5.867
9. Primary Productivity	2793.159	1601.082
10. Chlorophyll 'a'	21.188	9.286

CORRELATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1.	**1.000**									
2.	**-.408**	**1.000**								
3.	**0.761**	-.046	**1.000**							
4.	**0.410**	0.094	**0.672**	**1.000**						
5.	-.354	**0.419**	0.093	0.215	1.000					
6.	-.197	-.142	-.148	-.201	0.185	1.000				
7.	-.355	0.315	-.187	0.215	0.236	-.329	1.000			
8.	-.159	-.170	-.124	-.044	-.053	**0.417**	-.075	1.000		
9.	-.258	**0.589**	-.289	0.002	-.031	-.272	**0.451**	0.122	1.000	
10.	0.165	0.131	0.331	**0.596**	0.079	-.366	**0.291**	0.356	**0.325**	1.000

was positively correlated with nitrate (r=0.41). Nitrite was positively correlated with primary productivity (r=0.45).

The results of these parameters during 1987 in the COCO field are presented as correlation matrix in Table - 14.

Salinity was negatively correlated with redox potential (r=-.86) and positively correlated with primary productivity (r=0.55). Dissolved oxygen was positively correlated with hydrogen-ion concentration (r=0.44), ammonia (r=0.44), nitrite (r=0.43) and nitrate (r=0.68) and negatively correlated with silicate (r=-.44). Hydrogen-ion concentration was negatively correlated with silicate (r=-.45). Redox potential was positively correlated with silicate (r=0.44) and negatively with primary productivity (r=-.69).

Ammonia was positively correlated with nitrite (r=0.84) and nitrate (r=0.41). Phosphate was positively correlated with nitrate (r=0.44). Silicate was negatively correlated with nitrate (r=-.49), primary productivity (r=-.72) and chlorophyll '<u>a</u>' (r=-.53). Nitrite was positively correlated with nitrate (r=0.48) and primary productivity (r=0.41). Nitrate was positively correlated with primary productivity (r=0.42) and cell count (r=0.40). Primary productivity was positively correlated with chlorophyll '<u>a</u>' (r=.48) and cell count (r=0.49). Chlorophyll '<u>a</u>' was positively correlated with cell count (r=0.51).

The results of these parameters during 1986 and 1987 in the POKKALI field are presented as correlation matrix in Table - 15.

TABLE - 14

COCO field, 1987:
MEAN AND STD. DEVIATION OF DIFFERENT CHARACTERISTICS

CHR #	MEAN	S.D.
1. Salinity	9.866	7.620
2. Dissolved Oxygen	2.346	0.988
3. Temperature	25.292	1.351
4. pH	7.457	0.282
5. Eh	202.125	57.145
6. Ammonia	10.812	5.567
7. Phosphate	3.687	1.411
8. Silicate	23.924	12.561
9. Nitrite	1.333	0.643
10. Nitrate	6.720	3.090
11. Primary Productivity	5945.303	5863.281
12. Chlorophyll 'a'	15.448	12.198
13. Cell count	3974.583	5511.054

CORRELATION MATRIX

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	**1.000**												
2.	0.110	**1.000**											
3.	-.404	0.021	**1.000**										
4.	0.226	**0.445**	-.234	**1.000**									
5.	**-.863**	-.332	0.258	-.238	**1.000**								
6.	-.014	**0.446**	0.034	0.295	-.247	**1.000**							
7.	-.378	0.332	-.063	0.077	0.212	0.257	**1.000**						
8.	-.284	**-.441**	-.259	**-.453**	**0.440**	-.375	0.056	**1.000**					
9.	0.122	**0.434**	-.077	0.332	-.307	**0.847**	0.097	-.293	**1.000**				
10.	0.089	**0.685**	-.016	0.319	-.347	**0.417**	**0.445**	**-.495**	**0.488**	**1.000**			
11.	**0.551**	0.338	0.266	0.365	**-.692**	0.318	-.200	**-.722**	0.411	0.427	**1.000**		
12.	0.290	-.027	0.052	0.266	-.213	0.075	-.006	**-.503**	0.043	0.326	0.482	**1.000**	
13.	0.271	-.067	0.066	0.179	-.205	0.083	0.001	-.386	0.314	0.405	0.498	0.511	**1.000**

TABLE - 15

POKKALI field, 1986 and 1987:
MEAN AND STD. DEVIATION OF DIFFERENT CHARACTERISTICS

CHR #	MEAN	S.D.
1. Salinity	20.841	2.803
2. Dissolved Oxygen	3.797	0.794
3. Temperature	27.375	3.387
4. Ammonia	7.398	3.376
5. Phosphate	2.876	0.706
6. Silicate	17.980	10.062
7. Nitrite	1.970	0.676
8. Nitrate	11.771	4.120
9. Primary Productivity	5738.795	5170.904
10. Chlorophyll '$\underline{a}$'	27.170	10.863

CORRELATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1.	1.000									
2.	0.402	1.000								
3.	0.513	0.569	1.000							
4.	-.021	0.074	0.058	1.000						
5.	0.194	-.066	0.236	0.430	1.000					
6.	0.220	0.185	-.089	0.442	-.048	1.000				
7.	-.391	-.083	0.005	0.315	0.302	-.396	1.000			
8.	-.158	-.037	-.522	0.027	-.469	0.186	-.292	1.000		
9.	-.535	-.535	-.251	0.102	0.575	-.454	0.683	-.297	1.000	
10.	-.181	0.062	0.480	-.016	0.238	-.422	0.537	-.578	0.344	1.000

Salinity was positively correlated with temperature (r=0.51) and negatively with primart productivity (r=-.53). Dissolved oxygen was positively correlated with temperature (r=0.56) and negatively with primary productivity (r--.50). Temperature was negatively correlated with nitrate (r=-.52) and positively with chlorophyll '<u>a</u>' (r=0.48). Phosphate was negatively correlated with nitrate (r=-.46) and positively with primary productivity (r=0.57). Silicate was negatively correlated with primary productivity (r=-.45). Nitrite was positively correlated with primary productivity (r=0.68) and chlorophyll '<u>a</u>' (r=0.53). Nitrate was negatively correlated with chlorophyll '<u>a</u>' (r=-.57).

After having obtained the results of the affinity of these parameters through correlation matrix, determination for primary productivity, chlorophyll '<u>a</u>' and cell count was studied using a multiple regression model and through selected parameters obtained after screening. Coefficient of correlation being an index of affinity, it could be taken as the degree of determination.

The determination for the parameter primary productivity during 1986 in the CIBA pond is presented in Table - 16. The derived coefficient of multiple regression for the selective paramters such as ammonia, silicate and nitrate on primary productivity was : R - SQUARE = 0.38 which indicate that only about 38% of the variation is accounted for.

The determination for the primary productivity parameter during 1987 in the CIBA pond is given in Table - 17. The coefficient of multiple regression (R) for the selective variable such as phosphate, silicate and nitrite on primary productivity was observed to be significant (R - SQUARE = 0.66).

The determination for the parameter primary productivity during 1986 in the COCO field is presented in Table - 18. The coefficient of multiple regression (R) for the selective variable such as salinity, dissolved oxygen, temperature, nitrite and nitrate on primary productivity was significant (R - SQUARE = 0.73).

The determination for the primary productivity parameter during 1987 in the COCO field is represented in Table - 19. The coefficient of multiple regression (R) for the selective variable such as temperature, redox potential, silicate and nitrite on primary productivity was observed to be significant (R - SQUARE = 0.80).

The determination for the primary productivity during the premonsoon season of 1986 and 1987 in the POKKALI field is given in Table - 20. The coefficient of multiple regression (R) for the relative variable such as salinity, dissolved oxygen, ammonia, phosphate and nitrite on primary productivity was significant (R - SQUARE = 0.95).

The determination for chlorophyll '<u>a</u>' concentration during 1986 in the CIBA pond is represented in Table - 21. The coefficient of multiple regression for relative variable such as

TABLE - 16

RESULTS OF MULTIPLE REGRESSION WITH RESPECT TO PRIMARY PRODUCTIVITY, CIBA POND, 1986.

RESULTS OF MULTIPLE REGRESSION

CO-EFS	VALUE	S.E.
B 1	-289.029	122.091
B 2	-137.682	46.279
B 3	66.712	39.414

A = 6832.59500

R-SQUARE = .3822738

CHAR #	MEAN	S.D.
1 Ammonia	4.324	2.947
2 Silicate	18.442	7.912
3 Nitrate	9.505	8.648
4 Primary Productivity	3677.522	1900.445

TABLE - 17

RESULTS OF MULTIPLE REGRESSION WITH RESPECT TO PRIMARY PRODUCTIVITY, CIBA POND , 1987.

RESULTS OF MULTIPLE REGRESSION

CO-EFS	VALUE	S.E.
B 1	501.576	180.521
B 2	-66.525	17.379
B 3	213.544	169.463

A = 4063.92500

R-SQUARE = .6617126

CHAR #	MEAN	S.D.
1 Ammonia	2.586	1.240
2 Silicate	27.668	14.651
3 Nitrate	1.579	1.527
4 Primary Productivity	3857.662	1689.417

TABLE - 18

RESULTS OF MULTIPLE REGRESSION WITH RESPECT TO PRIMARY PRODUCTIVITY. COCO field. 1986.

RESULTS OF MULTIPLE REGRESSION

CO-EFS	VALUE	S.E.
B 1	184.576	46.058
B 2	1374.863	243.487
B 3	-529.088	132.385
B 4	1104.721	394.375
B 5	93.240	35.035

A = 8150.92100

R-SQUARE = .7376117

CHAR #	MEAN	S.D.
1 Salinity	12.040	8.017
2 Dissolved Oxygen	3.509	1.021
3 Temperature	28.187	2.540
4 Nitrite	1.564	.538
5 Nitrate	6.363	5.667
6 Primary Productivity	2793.159	1601.082

TABLE - 19

RESULTS OF MULTIPLE REGRESSION WITH RESPECT TO PRIMARY PRODUCTIVITY, COCO field, 1987.

RESULTS OF MULTIPLE REGRESSION

CO-EFS	VALUE	S.E.
B 1	1502.283	511.308
B 2	-60.351	13.106
B 3	-152.238	60.191
B 4	1471.485	1001.990

A = %-18170.55000

R-SQUARE = .8008136

CHAR #		MEAN	S.D.
1	Temperature	25.291	1.350
2	Redox Potential	202.125	57.144
3	Silicate	23.923	12.561
4	Nitrite	1.332	.642
5	Primary Productivity	5945.303	5863.281

TABLE - 20

RESULTS OF MULTIPLE REGRESSION WITH RESPECT TO PRIMARY PRODUCTIVITY, POKKALI field, 1986 & 1987.

RESULTS OF MULTIPLE REGRESSION

CO-EFS	VALUE	S.E.
B 1	-767.691	140.916
B 2	%-1503.095	434.690
B 3	-446.659	102.653
B 4	4690.763	534.315
B 5	3062.603	547.985

A = %-11229.27000

R-SQUARE = .9525248

CHAR #	MEAN	S.D.
1 Salinity	20.841	2.802
2 Dissolved Oxygen	3.796	.794
3 Ammonia	7.398	3.375
4 Phosphate	2.875	.705
5 Nitrite	1.969	.676
6 Primary Productivity	5736.795	5170.904

TABLE - 21

RESULTS OF MULTIPLE REGRESSION WITH RESPECT TO CHLOROPHYLL 'a', CIBA POND, 1986.

RESULTS OF MULTIPLE REGRESSION

CO-EFS	VALUE	S.E.
B 1	4.597	2.307
B 2	8.466	3.279

A = 8.18317

R-SQUARE = .4618655

CHAR #	MEAN	S.D.
1 Phosphate	2.135	.843
2 Silicate	1.343	.593
3 Chlorophyl '*a*'	29.375	11.066

TABLE - 22

RESULTS OF MULTIPLE REGRESSION WITH RESPECT TO CHLOROPHYLL 'a', CIBA POND, 1987.

RESULTS OF MULTIPLE REGRESSION

CO-EFS	VALUE	S.E.
B 1	2.751	0.690
B 2	0.341	0.100
B 3	1.401	0.485
B 4	3.022	1.410
B 5	0.618	1.982

A = 101.27550

R-SQUARE = .5744502

CHAR #	MEAN	S.D.
1 Salinity	10.284	7.765
2 Redox Potential	208.666	56.329
3 Ammonia	8.089	6.103
4 Phosphate	2.586	1.240
5 Nitrite	1.579	1.527
6 Chlorophyll 'a'	18.318	10.999

TABLE - 23

RESULTS OF MULTIPLE REGRESSION WITH RESPECT TO CHLOROPHYLL 'a', COCO FIELD, 1986.

RESULTS OF MULTIPLE REGRESSION

CO-EFS	VALUE	S.E.
B 1	1.629	0.388
B 2	-0.689	0.185
B 3	0.934	0.211

A = 14.45795

R-SQUARE = .7056823

CHAR #	MEAN	S.D.
1 Ammonia	6.864	2.961
2 Silicate	17.806	6.838
3 Nitrate	8.363	5.867
4 Chlorophyll 'a'	21.190	9.283

TABLE = 24

RESULTS OF MULTIPLE REGRESSION WITH RESPECT TO CELL COUNTS, COCO FIELD, 1987.

RESULTS OF MULTIPLE REGRESSION

CO-EFS	VALUE	S.E.
B 1	%-3781.617	1151.299
B 2	-649.565	263.328
B 3	-188.611	76.485
B 4	6557.996	2469.469
B 5	995.475	391.308

A = 8950.07800

R-SQUARE = .6228953

CHAR #	MEAN	S.D.
1 Dissolved Oxygen	2.345	.988
2 Ammonia	10.812	5.567
3 Silicate	23.923	12.561
4 Nitrite	1.332	.642
5 Nitrate	6.720	3.089
6 Cell Count	3974.583	5511.054

phosphate and nitrate was : R - SQUARE = 0.46 which indicate that only about 46% of the variation is accounted for.

The determination for chlorophyll '<u>a</u>' concentration during 1987 in the CIBA pond is represented in Table - 22. The coefficient of multiple regression for relative variable such as salinity, redox potential ammonia, phosphate and nitrite was significant (R - SQUARE = 0.57).

The determination for chlorophyll '<u>a</u>' concentration during 1986 in the COCO field is given in Table - 23. The coefficient of multiple regression for the selective variable such as ammonia, silicate and nitrate was significant (R - SQUARE = 0.71).

The determination for chlorophyll '<u>a</u>' concentration during 1987 in the COCO field was formed to be not significant. The determination for cell count during 1987 in the CIBA pond was also formed to be not significant. However, the determination for cell count during 1987 in the COCO field is presented in Table _ 24. The coefficient of multiple regression for the selective variable such as dissolved oxygen, ammonia, silicate, nitrite and nitrate was significant (R - SQUARE = 0.62).

PART - III (E) : ASSESSMENT OF THE STATUS OF PRODUCTION

N.P : G.P. Ratio:

Calculated monthly ratio of net primary productivity to gross primary productivity for the three culture system during

TABLE - 25

Primary productivity (NP : GP ratio)
(Monthly mean values)

		CIBA pond	COCO field	POKKALI field
Jan.	1986	0.92	0.74	0.89
	1987	0.94	0.94	0.93
Feb.	1986	0.87	0.80	0.79
	1987	0.92	0.91	0.89
Mar.	1986	0.91	0.90	0.74
	1987	0.90	0.98	0.95
Apr.	1986	0.88	0.84	0.81
	1987	0.98	0.97	0.91
May	1986	0.95	0.90	0.91
	1987	0.95	0.96	0.98
Jun.	1986	0.88	0.80	
	1987	0.91	0.99	
Jul.	1986	0.69	0.70	
	1987	0.89	0.88	
Aug.	1986	0.91	0.84	
	1987	0.79	0.90	
Sep.	1986	0.92	0.87	
	1987	0.78	0.81	
Oct.	1986	0.78	0.58	
	1987	0.81	0.67	
Nov.	1986	0.72	0.67	
	1987	0.81	0.63	
Dec.	1986	0.79	0.63	
	1987	0.86	0.70	

TABLE - 26

Assimilation number
(Monthly mean values)

		CIBA pond	COCO field	POKKALI field
Jan.	1986	15.32	23.20	14.90
	1987	30.70	68.85	9.57
Feb.	1986	12.23	16.63	11.93
	1987	22.68	61.68	7.50
Mar.	1986	10.57	12.57	10.70
	1987	17.98	67.68	11.50
Apr.	1986	10.80	11.18	13.48
	1987	23.75	53.83	38.45
May	1986	8.43	8.35	12.48
	1987	14.44	28.17	28.75
Jun.	1986	9.09	10.59	
	1987	31.35	136.27	
Jul.	1986	15.50	30.79	
	1987	31.40	9.88	
Aug.	1986	18.00	14.50	
	1987	17.81	38.25	
Sep.	1986	21.52	9.50	
	1987	22.31	11.64	
Oct.	1986	11.40	21.40	
	1987	23.20	6.30	
Nov.	1986	17.20	21.75	
	1987	39.66	15.71	
Dec.	1986	28.78	30.94	
	1987	27.95	9.78	

1986 and 1987 are represented in Table - 25. The computed ratio (Monthly mean values) was found to range from 0.69 and 0.95 during 1986 and 0.78 and 0.98 during 1987 in the CIBA pond. In the COCO field calculated ratio ranged between 0.56 and 0.90 during 1986, and between 0.63 and 0.99 during 1987. The values ranged between 0.74 and 0.91 in 1986, and between 0.89 and 0.98 in 1987, during the premonsoon seasons in the POKKALI field.

Assimilation number:

Results of the calculated assimilation number (the ratio of carbon fixed/chlorophyll '*a*') during 1986 and 1987 in the three culture systems are presented in Table - 26.

In the CIBA pond the assimilation number varried between 8.43 and 26.76 during 1986, and between 14.44 and 39.86 during 1987. The some value were observed to range from 8.35 to 30.94 during 1986, and from 6.30 to 136.27 during 1987 in the COCO field. The same ratio varied between 10.70 and 14.90 in 1986, and between 7.50 and 38.45 in 1987 during the premonsoon season in the POKKALI field.

RATIO OF CHLOROPHYLL PIGMENTS

Measurement of other pigments such as chlorophyll '*b*', '*c*' and carotionoids was undertaken in the three culture systems. Observation made during 1986 and 1987 on the concentration of chlorophyll '*b*' are presented in Table - 27 chlorophyll '*c*' in Table - 28 and carotinoids in Table - 29.

TABLE - 27

Concentration of Chlorophyll 'a' (mg Chl/m^3)
(Monthly mean values)

		CIBA pond	COCO field	POKKALI field
Jan.	1986	0.39	1.16	0.67
	1987	1.53	1.97	3.51
Feb.	1986	1.23	0.29	0.64
	1987	1.31	1.65	2.64
Mar.	1986	1.29	1.29	1.41
	1987	3.44	3.03	2.19
Apr.	1986	1.47	3.71	0.27
	1987	2.08	3.41	0.27
May	1986	5.02	1.39	0.88
	1987	3.96	2.87	2.74
Jun.	1986	1.88	0.93	
	1987	1.22	1.07	
Jul.	1986	2.34	2.63	
	1987	2.33	6.58	
Aug.	1986	2.18	3.00	
	1987	3.37	1.53	
Sep.	1986	9.76	3.51	
	1987	3.55	1.73	
Oct.	1986	5.89	4.62	
	1987	3.67	3.66	
Nov.	1986	0.77	2.72	
	1987	6.28	5.92	
Dec.	1986	0.95	1.69	
	1987	5.22	3.84	

TABLE = 28

Concentration of Chlorophyll '*c*' (mg Chl/m^3)
(Monthly mean values)

		CIBA pond	COCO field	POKKALI field
Jan.	1986	2.13	1.20	0.55
	1987	0.60	0.39	0.41
Feb.	1986	2.07	1.06	0.97
	1987	2.00	2.91	2.29
Mar.	1986	1.45	1.52	4.68
	1987	2.41	2.67	1.70
Apr.	1986	4.02	2.41	5.06
	1987	5.05	3.07	2.49
May	1986	2.96	4.15	3.60
	1987	3.51	4.42	2.48
Jun.	1986	6.53	4.57	
	1987	2.09	3.79	
Jul.	1986	5.12	1.51	
	1987	5.33	3.06	
Aug.	1986	4.07	1.05	
	1987	1.45	1.27	
Sep.	1986	3.79	1.03	
	1987	3.14	1.09	
Oct.	1986	0.96	1.27	
	1987	3.14	1.70	
Nov.	1986	1.15	0.27	
	1987	0.48	0.41	
Dec.	1986	1.00	1.14	
	1987	4.73	2.23	

TABLE - 29

Concentration of Carotenoids (MSPU/m^3)
(Monthly mean values)

		CIBA pond	COCO field	POKKALI field
Jan.	1986	0.34	0.35	0.94
	1987	4.11	4.68	7.36
Feb.	1986	3.28	2.46	3.85
	1987	0.16	1.00	4.22
Mar.	1986	4.21	3.45	6.30
	1987	8.73	3.56	3.85
Apr.	1986	7.13	6.92	6.55
	1987	5.40	3.98	8.13
May	1986	8.83	8.47	7.89
	1987	2.41	5.44	4.93
Jun.	1986	7.31	4.64	
	1987	3.60	3.40	
Jul.	1986	8.47	4.04	
	1987	4.23	5.69	
Aug.	1986	6.33	4.59	
	1987	5.61	0.69	
Sep.	1986	7.45	7.27	
	1987	6.92	1.72	
Oct.	1986	4.62	4.89	
	1987	4.20	1.37	
Nov.	1986	3.07	2.84	
	1987	2.10	0.88	
Dec.	1986	3.64	0.97	
	1987	4.52	4.60	

TABLE - 30

Chlorophyll '*b*'/'*a*' ratio
(Monthly mean values)

		CIBA pond	COCO field	POKKALI field
Jan.	1986	0.01	0.11	0.03
	1987	0.20	0.26	0.25
Feb.	1986	0.05	0.01	0.02
	1987	0.13	0.22	0.16
Mar.	1986	0.04	0.06	0.04
	1987	0.13	0.16	0.35
Apr.	1986	0.04	0.12	0.00
	1987	0.06	0.15	0.13
May	1986	0.11	0.03	0.02
	1987	0.09	0.05	0.05
Jun.	1986	0.03	0.02	
	1987	0.10	0.10	
Jul.	1986	0.07	0.10	
	1987	0.12	0.47	
Aug.	1986	0.05	0.09	
	1987	0.20	0.33	
Sep.	1986	0.24	0.16	
	1987	0.21	0.23	
Oct.	1986	0.22	0.30	
	1987	0.17	0.21	
Nov.	1986	0.04	0.43	
	1987	0.69*	0.86**	
Dec.	1986	0.05	0.16	
	1987	0.42+	0.24	

* Mean value of bloom *Lynbya* included.
** Mean value of unidentified BGA included.
\+ Mean value of bloom *Microcystis* included.

TABLE - 31

Chlorophyll 'c'/'a' ratio
(Monthly mean values)

		CIBA pond	COCO field	POKKALI field
Jan.	1986	0.13	0.12	0.03
	1987	0.06	0.04	0.02
Feb.	1986	0.09	0.07	0.08
	1987	0.20	0.13	0.14
Mar.	1986	0.04	0.06	0.15
	1987	0.09	0.16	0.07
Apr.	1986	0.10	0.07	0.13
	1987	0.17	0.13	0.06
May	1986	0.06	0.11	0.09
	1987	0.16	0.10	0.11
Jun.	1986	0.14	0.13	
	1987	0.23	0.32	
Jul.	1986	0.16	0.05	
	1987	0.33	0.45	
Aug.	1986	0.05	0.03	
	1987	0.08	0.27	
Sep.	1986	0.09	0.05	
	1987	0.38	0.10	
Oct.	1986	0.03	0.02	
	1987	0.44*	0.14	
Nov.	1986	0.06	0.02	
	1987	0.04	0.05	
Dec.	1986	0.07	0.11	
	1987	0.38	0.13	

* Mean value of bloom *Peridinium* included.

TABLE - 32

Carotenoids/Chlorophyll '*a*' ratio
(Monthly mean values)

		CIBA pond	COCO field	POKKALI field
Jan.	1986	0.02	0.03	0.05
	1987	0.54	0.63	0.55
Feb.	1986	0.14	0.16	0.16
	1987	0.01	0.10	0.27
Mar.	1986	0.14	0.15	0.18
	1987	0.30	0.19	0.15
Apr.	1986	0.19	0.22	0.18
	1987	0.17	0.16	0.53
May	1986	0.19	0.23	0.21
	1987	0.05	0.12	0.11
Jun.	1986	0.16	0.13	
	1987	0.38	0.36	
Jul.	1986	0.27	0.36	
	1987	0.26	0.34	
Aug.	1986	0.16	0.14	
	1987	0.33	0.14	
Sep.	1986	0.19	0.27	
	1987	0.42	0.31	
Oct.	1986	0.18	0.32	
	1987	0.49*	0.10	
Nov.	1986	0.16	0.25	
	1987	0.22	0.13	
Dec.	1986	0.28	0.09	
	1987	0.36	0.26	

* Mean value of bloom *Peridinium* included.

The ratio of chlorophyll '<u>b</u>'/'<u>a</u>' during 1986 and 1987 is represented in Table - 30, chlorophyll '<u>c</u>'/'<u>a</u>' in Table - 31 and carotinoid/chlorophyll '<u>a</u>' in Table 32. In the present study chlorophyll '<u>a</u>' concentration always exceeded that of chlorophyll '<u>b</u>', '<u>c</u>' and carotinoids. The chlorophyll '<u>b</u>'/'<u>a</u>' ratio was found high in November 1987 in the CIBA pond is indicative of the occurrence of bloom of blue-green algae. Similar cases of high chlorophyll '<u>c</u>'/'<u>a</u>' ratio and carotinoids/chlorophyll '<u>a</u>' observed in the CIBA pond during October 1987 were due to the bloom of dinoflagellates.

CHAPTER - IV
ENRICHMENT EXPERIMENT

Results of enrichment experiment (*in vitro*) employing treatment with nitrate, phosphate, silicate and tracemetals, individually, and in combination using the water of CIBA pond during monsoon season of 1987 is presented in Table - 33. ANOVA technique was employed to test the significance of the effects of treatment. It was observed that addition of phosphorus and tracemetals individually resulted in a significance in the mean chlorophyll '*a*' values. The calculated '*F*' - value was significant at 5% level (Table - 34).

Results of enrichment experiment (*in situ*) employing treatment with nitrate, phosphate, silicate and tracemetals individually, and in combination in the CIBA pond during postmonsoon season of 1987 is presented in Table - 35. ANOVA technique was employed to test the significance of the effects of treatment. Addition of all nutrients including tracemetals resulted in a significant increase in the mean chlorophyll '*a*' values. The calculated '*F*' - value was observed to be highly significant at 1% level (Table - 36).

Results of enrichment experiment (*in situ*) employing treatment with nitrate, phosphate, silicate and tracemetals individually, and in combination, in the CIBA pond during premonsoon season of 1988 is presented in Table - 37. ANOVA technique was employed to test the significance of the effect of

TABLE = 33

Results of enrichment experiments - I
Chlorophyll 'a' concentration after enrichment in
CIBA pond* in August
(MONSOON SEASON)
(Chlorophyll a mg/m^3)

Date	Control	N	P	S	NPS	T	NPST
16.8.87	5.110	3.2520	6.057	4.4170	1.8800	0.0000	1.1000
17.8.87	1.1770	5.0770	2.796	10.2800	6.3310	0.5840	2.3380
18.8.87	1.1850	1.1000	0.000	0.4300	0.0650	0.4300	0.5800
19.8.87	0.0000	0.0100	0.030	1.8880	2.7980	0.592	0.4220
20.8.87	0.8440	0.0500	0.296	1.3120	5.925	0.5920	2.8040
21.8.87	0.1500	0.146	0.2310	0.0770	0.0040	1.7770	0.0770
22.8.87	0.1060	8.8870	3.5550	2.5450	1.1810	0.0000	0.3460

* Due to rain and concomitant land runoff, *in vitro* experiments were conducted.

N = Nitrogen, P = Phosphorus, S = Silica, T = Tracemetals

NPS = Nitrogen, Phosphorus and Silica

NPST = Nitrogen, Phosphorus, Silica and Tracemetals.

TABLE - 34

Anova Table of enrichment experiment - I

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
TREAT	6	34.854	5.809	1.28	N.S
REPLIC	6	81.950	13.658	3.01	SIG (5%)
ERROR	36	163.393	4.539		

REPLICATION MEAN COMPARISONS

MEAN COMPARISONS	REMARKS
R 1 -- R 2	N.S
R 1 -- R 3	SIG
R 1 -- R 4	N.S
R 1 -- R 5	N.S
R 1 -- R 6	SIG
R 1 -- R 7	N.S

TABLE - 35

Results of enrichment experiments - II
Chlorophyll 'a' concentration after enrichment in CIBA pond
(*in situ*) in December (POST MONSOON SEASON)
(Chlorophyll a mg/m^3)

Date	Control	N	P	S	NP	NS	PS	NPS	T	NPST
16.12.87	0.6948	1.1835	1.5310	3.2350	5.4470	2.2735	1.9530	2.2495	1.9520	2.3710
17.12.87	1.0655	1.5770	1.8655	4.5010	6.7110	7.2245	4.5800	5.0915	3.239	8.3690
18.12.87	1.6765	2.5060	2.2495	5.5240	8.1755	8.1370	5.0935	5.5280	4.4200	9.1600
19.12.87	2.1960	4.5010	2.7235	7.7745	8.4330	8.7295	5.7670	5.6870	5.0125	10.6985
20.12.87	2.1840	5.4510	5.6900	7.2205	11.2140	3.3970	7.4635	8.5675	6.1975	12.474
21.12.87	1.6075	6.5935	7.8980	8.1130	13.0685	4.5010	8.4905	9.1215	5.6050	13.1455
22.12.87	1.0655	7.8150	10.7410	8.4115	13.6610	5.6030	9.0825	10.2275	6.8710	14.8440

N = Nitrogen, P = Phosphorus, S = Silica, T = Tracemetals

NP = Nitrogen and Phosphorus

NS = Nitrogen and Silica

PS = Phosphorus and Silica

NPST = Nitrogen, Phosphorus, Silica and Tracemetals.

TABLE - 36

Anova Table of enrichment experiment - II

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
TREAT	9	399.319	44.369	16.15	HI.SIG(1%)
REPLIC	6	291.262	48.544	17.67	HI.SIG(1%)
ERROR	54	148.321	2.747		

TREATMENT MEAN COMPARISONS

MEAN COMPARISONS	REMARKS
T 1 -- T 2	SIG
T 1 -- T 3	SIG
T 1 -- T 4	SIG
T 1 -- T 5	SIG
T 1 -- T 6	SIG
T 1 -- T 7	SIG
T 1 -- T 8	SIG
T 1 -- T 9	SIG
T 1 -- T 10	SIG

TABLE - 37

Results of enrichment experiments - III
Chlorophyll 'a' concentration after enrichment in CIBA pond (*in situ*) in March (PRE MONSOON SEASON)
(Chlorophyll a mg/m^3)

Date	Control	N	P	S	NP	NS	PS	NPS	T	NPST
16.3.88	0.8480	1.3615	1.6580	5.5260	6.0410	2.2505	0.8475	0.6630	0.8095	1.6765
17.3.88	1.2620	1.4585	1.6585	7.0665	6.6710	7.4415	1.2180	0.9130	2.0550	2.5420
18.3.88	3.1665	2.6990	2.0015	7.7705	7.9195	8.1755	2.4710	1.6970	2.2700	2.7440
19.3.88	3.1110	2.6515	1.9510	6.8470	7.5425	9.3605	2.5870	2.1320	2.5125	3.0525
20.3.88	0.4145	2.3430	1.2765	0.5540	1.3170	1.2160	0.9700	1.2775	1.4605	1.3217
21.3.88	0.7905	5.4510	3.9085	2.8045	3.2390	3.5155	4.2075	11.2990	2.8045	14.3363
22.3.88	1.1060	7.1860	8.4135	6.1995	9.0040	4.5030	7.8960	10.1910	4.5010	16.4735
25.3.88	1.7760	NIL	0.2960	0.3555	0.2960	0.2960	0.2960	2.9625	NIL	1.7775
26.3.88	NIL	0.0075	0.0075	NIL	NIL	NIL	NIL	1.1850	NIL	0.5925
27.3.88	0.0590	NIL	0.0590	0.0590	0.0570	NIL	NIL	0.1185	NIL	0.1775
28.3.88	0.0130	0.2570	0.6120	0.2490	0.8425	0.5155	0.3645	0.5910	2.0425	2.4765
29.3.88	1.6365	5.8500	2.7445	1.6185	2.3905	0.8400	0.2165	1.1425	0.2565	5.7855
30.3.88	0.7315	2.2835	7.9030	3.2560	5.7120	2.8470	2.5890	9.5965	2.0125	16.8215
31.3.88	0.7765	5.8245	16.2325	8.9805	15.8670	5.0125	9.5905	10.3795	6.1955	18.1905

N = Nitrogen, P = Phosphorus, S - Silica, NP = Nitrogen and Phosphorus,

NS = Nitrogen and Silica, PS = Phosphorus and Silica,

NPS = Nitrogen, Phosphorus and Silica, T = Tracemetals,

NPST - Nitrogen, Phosphorus, Silica and Tracementals.

TABLE - 38

Anova Table of enrichment experiment - III

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
TREAT	9	272.326	30.258	4.28	HI.SIG(1%)
REPLIC	13	1079.915	83.070	11.76	HI.SIG(1%)
ERROR	117	826.274	7.062		

TREATMENT MEAN COMPARISONS

MEAN COMPARISONS	REMARKS
T 1 -- T 2	N.S
T 1 -- T 3	SIG
T 1 -- T 4	SIG
T 1 -- T 5	SIG
T 1 -- T 6	SIG
T 1 -- T 7	N.S
T 1 -- T 8	SIG
T 1 -- T 9	N.S
T 1 -- T 10	SIG

treament Addition of all nutrients including tracemetals resulted in a significant increase in the mean chlorophyll '_a_' values. The calculated '_F_' - value was highly significant at 1% level (Table - 38).

CHAPTER - V

DISCUSSION

The culture pond and connected field and canal system studied are mostly the extension of the estuarine and backwater systems, and are therefore subjected to wide variation in the environmental condition. In these culture systems which are dynamic ones, and in which the monsoon rains trigger changes from the marine conditions prevailing the during the premonsoon season to the freshwater condition during the monsoon period and with a gradual but progressive recovery of saline condition during postmonsoon months. It has been established that abiotic factors, particularly chemical characteristics of the environment exert profound influence on the growth and survival of aquatic organisms such as algae. Hence, in the present study, attention has been focused to elucidate the nature and extend of the physical-chemical environmental features, and their bearing on the primary productivity in the three selected tropical ecosystems, viz., a perennial prawn culture pond, canals among the coconut grove and a seasonal prawn - cum - paddy field at Cochin during 1986 and 1987.

Since the nutrients are the main sources for primary producers, special emphasis has been given to study the availability of nutrients both qualitatively and quantitatively in the culture ponds. Further enrichments were also conducted to analysis and understand the significant of the nutrients in the primary productivity.

Detailed description of environmental features and nutrient distribution in the Cochin backwater have been reported earlier. (Ramamirthan and Jayaraman, 1963; George and Krishnakartha, 1963; Desai and Krishnankutty, 1967; Qasim, 1969; Wellershaus, 1971; Qasim and Wyatt, 1972; Shynamma and Balakrishnan, 1973; Mohammed Salih, 1974; Balakrishnan and Shynamma, 1976; Lashmanan _et al_., 1982, 1987).

William, 1960; Zein - Eldin and Grifith, 1969; Vankataramaiah _et al_. 1974; Sreekumar Nair and Krishnankutty, 1975; Suseelan, 1978; Sankaranarayanan _et al_. 1982; Gopinathan _et al_. 1982; Nair _et al_. 1988, have stressed the importance of salinity and temperature in the survival and growth of prawns. The present observation clearly indicate that high salinity prevailed in the ecosystems during the premonsoon. Low salinity values recorded in the monsoon season was mainly due to the monsoon rains and the ensured in flow of water. The recovery of salinity was observed during the postmonsoon season in all the culture ponds during both the years. Towards the end of postmonsoon season, the salinity range observed in the ponds was in accordance with the required optima for the growth of prawns.

According to Suseelan (1978), the minimum survival level of oxygen content for _Penaeus indicus_ range between 1.49 ml/l and 3.80 ml/l among early jureniles and subadults. The dissolved oxygen content of water in all the ponds was mostly above 30% saturation level. However, relatively lower saturation values (3 ml/l) during postmonsoon period of 1987 in the CIBA pond and

COCO field were also observed when the ponds were of freshwater dominated.

In brackishwater aquaculture a regular exchange between tidal water and pond water is highly essential to maintain optimum temperature requirement by the organisms. The preferred temperature range of the medium for prawn culture was observed to be 28 - 32°C (Suseelan, 1978). Water temperature in all the ponds ranged between 27 - 34°C during different months of 1986 and 1987. Due to the prevalent nature of the habitats which is tropical variation in the temperature of water was observed to be narrow. However, the observed range was found to be within the optimum level for the growth of prawns.

During the present investigation, the observed range of pH was 7 and 8 indicating the alkaline nature of the environment. However, low pH value (7.0) recorded in the month of October in the ponds could be backtraced to the large scale influx and leaching activity during the monsoon months.

The oxidation reduction potential (Eh) exhibited a ranged of 130 to 270 MeV with an increasing trend from premonsoon season to the postmonsoon season. The observed values in the water did not evince a reducing condition as observed in the mud by Sankaranarayanan et al. (1982). Eh values were observed to be in the range of 47 to +06 in the prawn culture systems around Cochin earlier (Sugunan and Pillai, 1984).

Distribution of nutrients in the prawn culture ponds has been studied earlier (Sankaranarayanan et al., 1982; Gopinathan et al., 1982; Nair et al., 1988). During the present study, concentration of nutrients in different ponds was investigated. In the CIBA pond, the ammonia content was found to be higher during the premonsoon season with a gradual increasing trend subsequently. The observed tendency can be attributed to the fact that local matter and metabolites from the organisms get accumulated. If fluctuates highly and irregularly during the other seasons. Similer observation of high ammonia concentration in premonsoon season and fluctuation in other seasons were observed in the COCO field also. In the POKKALI field also the ammonia concentration was high during the premonsoon season.

Inorganic phosphate in the water showed a relatively high values (2 µg at/l) in most of the months. Highest values were recorded during monsoon season in all the ponds. However high values of inorganic phosphate were recorded in the postmonsoon season also in the COCO field. George and Krishnakartha (1963) and Qasim and Wyatt (1972) reported June and July as period of higher possible concentration in this estuary. The phosphates level showed a general increase during the SW monsoon period in the prawn culture fields (Sankaranarayanan et al., 1982). Results obtained during the present study agree with these results. High values of phosphate in water could be attributed to the common use of fertilizers in the situated fields adjusted to the culture ponds, and leaching activity during the monsoon months.

Gopinathan *et al*. (1974, 1984) observed the silicate values were found to be high during June - August in Cochin Backwaters. However, it was observed during the present study that there was no such high concentration of silicate confined to monsoon season but it was irregular throughout the year in the prawn culture ponds. The dissolved silicon showed wide range of values between 4 to 43 µg at/l in all the culture pond during different months. The chief source of silicate is from the sediment and soil of the ponds and presumed to be brought down by runoff. However the available silicats values ranged within the optimal level for phytoplankters.

Gopinathan *et al*. (1982) recorded the nitrite content of the water, in general was very low (1 µg at/l) in the prawn culture fields. Nitrite values in the CIBA pond varied between 1 and 5 µg at/l throughout years. Relatively high values were recorded during the monsoon period and low values recorded in the postmonsoon season. In the COCO field nitrite values ranged 1 µg at/l during the premonsoon seasons. High values were also recorded in the period monsoon. Distribution of nitrite in water in the postmonsoon was found to be irregular. In the POKKALI field nitrite concentration ranged 1 µg at/l during the period of observation. The distribution of nitrite suggest that the riverine inputs are more and a regenerative source exists within the culture system. Low values in the postmonsoon season were due to depletion of nitrites by phytoplankters.

Nitrate concentration ranged widely in the ecocystems during the period of study. In the CIBA pond, the values ranged between 4 - 12 µg at/l during the premonsoon season and a higher ranged of 5 to 26.8 µg at/l during the monsoon and a higher ranged of 5 to 26.8 µg at/l during the monsoon and relatively a lower ranged of 2 to 7 µg at/l during the postmonsoon. In the COCO field, the range in the concentration of nitrate was between 2.76 and 23.98 µg at/l with high concentration during monsoon period. In the POKKALI field higher range of 8 to 20 µg at/l of nitrate concentration was observed. The features are very similar to those observed for the nitrite distribution in the culture ponds. These results agree with those observed in the prawn culture field by Gopinathan et al. (1982) and Sankaranarayanan et al. (1982).

Primary production in the Cochin Backwater Area has been studied in general earlier (Qasim et al., 1969; Gopinathan, 1972, Qasim, 1973, 1979; Devassy and Bhattathiri, 1974; Joseph and Kunjikrishnan Pillai, 1975; Kumaran and Rao, 1975; Nair et al., 1975; Gopinathan et al.,1984), and extensive investigation on this aspect in the adjasent prawn culture fields are limited (Gopinathan et al., 1982; Gopalakrishnan et al., 1988). Even in these studied, and comprehensive attempt on the phytoplankton production in the different types of prawn culture systems are lacking. Hence, in the present investigation, an attempt has been made to determine the different productivity indices, and the relationship of different variables responsible for the phytoplankton production by statistical analysis.

Gopinathan et al. (1984) have observed two seasonal peaks of primary production, a primary one during monsoon season and a secondary peak during the postmonsoon period in the Cochin Bakwater. In the present study it was observed that the annual cycle of gross and net primary productivity showed two peaks during 1986 and 1987. Maximum primary productivity was recorded during April (Premonsoon season) and the secondary peak was observed during the postmonsoon period (September) in both CIBA pond and COCO field. In the POKKALI field maximum rate of primary production it was recorded in April. High rate of productivity has been recorded with the influx of inshore water into the culture ponds was relatively high. It was also observed that the low rate of productivity was due to low rate of replenishment by water or by the influx of freshwater. The present study substantiates the earlier observation that the culture ponds located at Narakkal in between Cochin and Azhikode bar mouth is relatively high productive ecosystem, (George et al., 1968; George, 1974; Pillai and George, 1974; Gopinathan et al., 1982). The advantage of the presence of two opening to the sea within a short distance through which there is a regular incursion of salinewater and also periodical enrichment from the run off from Periyar river and seasonality could be the causative factor for high rate of production. However, the higher values noticed during the premonsoon season in both COCO field and POKKALI field during 1987 presumably due to very lower level of water ($<$ 0.5m) and more light penetration and temperature as observed in the culture ponds. The observed seasonal peaks of primary productivity in culture ponds agree with the observation made by Gopinathan et al. (1984) in the Cochin culture.

Since chlorophyll '*a*' is one of the major indices of the standing crop of phytoplankton, the estimation of this pigment along with that of primary productivity is expected to give a general idea of variation in the magnitude of production. (Gopinathan *et al*., 1984). During this period of study, concentration of chlorophyll '*a*' always exceeded that of other pigments. Being a major constituents, distribution of chlorophyll '*a*' alone was computed and compared with that other productivity indices.

Maximum concentration of chlorophyll '*a*' values was recorded during the premonsoon season of the years in all the ponds. High chlorophyll concentration were usually observed with bloom of single species such as *Nitzschia closterium* and *Skeletonema costatum* during the premonsoon season (up to 45 mg chl/m^3). In general, the concentration of chlorophyll '*a*' was found to be high throughout the year in all the culture ponds (7 mg chl/m^3). Periodical development of bloom such as diatoms during premonsoon season, blue-green during monsoon and dinoflagellates in the postmonsoon, coupled with the abundance of nanoplankters contributed to relatively high concentration of chlorophyll '*a*' throughout seasons.

The results of enumeration of phytoplankton cells revealed that abundance of diatoms during the premonsoon season in all the ponds. Relatively low cell counts was recorded in the monsoon season. However, in the postmonsoon period, sporadic occurrence of dinoflagellates and blue-green algae were observed in CIBA pond, on account of the favourable condition such as low salinity, high nutrient concentration and moderate temperature. Abundance of diatoms during the premonsoon season in the indicative of the establishment of true marine environmental condition in the culture system. Qualitative and quantitative estimation of phytoplankters revealed that they were abandant in the POKKALI field, followed by CIBA pond and COCO field.

Statistical analyses of the data was attempted to elucidate the correlations and inter dependence of abiotic and biotic factors observed during the study. The hydrological factors and nutrients were reckoned as the independent variables and primary productivity indices as the dependent variables. The correlation coefficient between the independent variable and production indices were computed, and the variables which were found to be not significant deleted to determine standard regression coefficient for productivity indices viz., primary productivity chlorophyll '*a*' and numerical analysis of phytoplankters.

In the CIBA pond, during 1986, ammonia, silicate and nitrate gave significant multiple correlation coefficient. These variables gave coefficient of determination of 0.38. About 38% of the variation in primary productivity was explained by all these parameters. During 1987, phosphate, silicate and nitrate gave significant values and about 66% of the variation in primary productivity was explained by these factors.

In the COCO field during 1986, salinity, dissolved oxygen, temperature nitrite and nitrate showed significant multiple correlation. About 73% of the variation in primary productivity was explained. During 1987, temperature redox potential, silicate and nitrite gave a coefficient of determination of 0.800. These variables together contributed to 80% of the variation in primary productivity.

In the POKKALI field, salinity, dissolved oxygen, ammonia, phosphate, and silicate gave a multiple correlation coefficient of 0.95. These variables together contributed to 95% of the variation in primary productivity during the premonsoon of 1986 and 1987.

Fluctuation in the concentration of chlorophyll '_a_' was positively correlated to the distribution of phosphate and nitrate during 1986. These variables gave a coefficient of determination of 0.46. During 1987, salinity, redox potential, ammonia, phosphate and nitrate together explained about 57% of the variation in chlorophyll '_a_' production in the CIBA pond. During 1986, in the COCO field, ammonia, silicate and nitrate showed significant multiple correlation coefficient. These variables gave a coefficient of determination of 0.70.

Values of Cell counts in the CIBA pond was found to be not significant which imples that it is not dependent on the contributing variables. However, in 1987, in the COCO field, dissolved oxygen, ammonia, silicate, nitrite and nitrate together was responsible for 62% of the variation in cell counts.

From the standard regression coefficient it can be seen that the "contributing variables" evinced difference during different periods of the two years. Difference between culture ponds, was also evident from the data. The multiple regression analysis proved that these culture ponds were independent, and the contributing parameters also evinced variation. As opined by Gopinathan *et al*. (1984), the dynamic nature of these ecosystems coupled with its topographical features are responsible for such seasonal and spatial variation of the "variables".

The significance of nutrients based on data on primary productivity and chlorophyll '*a*' concentration was also attempted in this study. Ketchum *et al*. (1958) had put forward that the ratio of N.P: G.P. was indicative of the actual physiological states of phytoplankton population, which occur due to nutrients availability or deficiency. At times of nutrients deficiency the ratio would approach zero. In the present study the ratio was found to be within the range of 0.56 and 0.99 (Table - 25). These values agree with the abrivation of Qasim *et al*. (1969) for the Cochin backwater where N.P : G.P. ratio was found to be within the range of 0.55 and 0.75 and with that of the observed range of 0.40 to 0.90 by Vijayalakshmi, 1986 for the Vellar estuary. The observed values, during this present study signify that the available nutrients are rich in concentration in all the culture ponds.

Assimilation number (the ratio of carbon fixed/chlorophyll '*a*') were calculated based on data of primary productivity and concentration of chlorophyll '*a*' (mg C/mg Chl '*a*'). A nutrient relationship could be understood from the annual numerical value of assimilation number. Curl and Small (1965) suggested that assimilation ratio of 0-3 indicate nutrient depletion; ratio of 3-5 boderline nutrient deficiency and 5-12 indicate nutrient rich water. Radhakrishana et al. (1978) observed that the assimilation number in the north eastern Arabian Sea varied from 24 at the deepest station to 208 at the inshore station. At the offshore stations, the assimilation number averaged to 22 (range 11-34). In the present observation the annual numerical number between 8-136 in ponds in different seasons lend support to the fact that the culture system is rich in nutrient concentration. It is also observed that fluctuation in productivity rate was not only dependent on chlorophyll 'a' concentration but also due to other accessory pigments.

An attempt was made to assess the possible ratios among the estimated chlorophyll pigments and its biological significance. In the present study chlorophyll 'a' concentration always exceeded that of chlorophyll 'b', 'c' and carotenoids. However, in certain circumstances chlorophyll b/a ratio was found to be high during the concurrence of the development of bloom and the monsoonal rain (Table - 30). The blue-green algae Lynbya aeruginea bloomed in November 1987. The observed values of chlorophyll b/a which was 1.04 was indicated as monthly mean value of 0.69 in Table - 30 during November in the CIBA pond. In COCO field, the unidentified blue-green algal bloom was also accounted and presented as 0.86 (monthly mean value) during November. In the CIBA pond the observed ratio of 0.68 for the bloom Microcystis aeruginosa during December was presented the monthly mean value of 0.42 in Table - 30. In another instance, the ratio of chlorophyll 'c'/'a' was found to be pronounced concomitant development of dinoflagellates in the CIBA pond during October 1987 (Table - 31). The observed ratio of 0.82 of the bloom Peridinium pallidum was presented as the monthly mean value of 0.44 in Table - 31. The obtained ratio of Carotinoids/chlorophyll 'a' 0.49 in October also coincide with the bloom of dinoflagellates (Table - 32).

Studies on nutrient limitation shown that for marine coastal waters nitrogen is usually the most limiting nutrient for potential phytoplankton biomass formation (Burland et al., 1980, Nixon and Pilson, 1983; Caruco et al., 1987). For brackishwaters, phosphorus may play an important role, especially if freshwater inflow is high, as, for example, is the case in Trondhein fijord (Sakshaug and Myklestad, 1973), the inner part of Marseille Bay (Burland et al., 1980), Bothnian Bay, located at the northern part of the brackish Baltic Sea (Alasaarela, 1979), and Chesapeake Bay during winter (D'Elia et al., 1986).

An attempt was made during the present study to test which nutrient may limit potential biomass accumulation in the culture ponds. Statistical analysis (ANOVA technique) was conducted to examine the influence of nutrients, individually and in combination. Production was measured by means of chlorophyll 'a'.

In vitro experiment during monsoon season showed that phosphate and tracemetals individually gave significant values. The calculated F ratio is significant at 5% level. The high rate of utilization of phosphate by blue-green algae during monsoon season contributed to this significance. It supports the view that an increase in phytoplankton biomass through the growth of blue-green algae was due to the addition of phosphate to the samples (Graneli, 1979, 1984).

During *in situ* experiment carried out in the post monsoon period, all the nutrients including tracemetals gave high significant results. The calculated '*F*' value is highly significant at 1% level of significance. During premonsoon season also all the nutrients gave highly significant results at 1%.

Significance of treatment with nutrients during postmonsoon were presumably due to the concentration of nutrients relatively lesser than that of the premonsoon condition. Generally, an input of nutrients enhanced the concentration of the chlorophyll '*a*' to same extent, and response of phytoplankton to nutrients lead to growth are production. Similer results of obtained during the premonsoon season. Hence, it is concluded that enrichment of the culture ecosystems during the periods of active farming practise such as premonsoon and postmonsoon seasons would ensure enhanced production rate.

AN EVALUATION OF POTENTIAL YIELD AND CONCLUSION

Knowing the primary production and the quantitative transfer between trophic levels, the potential production of fish/prawn in an area - both first stage carnivores (Zooplankton feeders) and predators can be estimated.

Slobodkin (1961) indicated a value of ecological efficiency at about 10%. Shaefer (1965) considering the effect of ecological efficiencies ranging from 10 to 20% noted an order of magnitude of increase in the production of fish at the fifth trophical level. In general, the trophic levels included are- autotrophs and saprophages at the first trophic level, herbivorous organisms at the second trophic level, omnivorous organisms at the third trophic level, primary carnivores at the fourth level, secondary carnivores at the fifth level and tertiary carnivores at the sixth level (Petipa et al., 1970).

Ryther (1969) considered the number of trophic levels in three communities which may be described as of oceanic, continental shelf and upwelled. In these communities ecological efficiencies at each trophic level were assumed to be highest when governed largely by phytoplankton/herbivore associations and lowest for communities in these which were secondary and tertiary carnivores. Consequently a 10,15 and 20% efficiency was assigned to be oceanic, coastal and upwelling food chains respectively. From this Ryther estimated the potential fish production of 36,000,340 and 0.5 mg C/m^3/hr. for the upwelling, shelf and oceanic areas respectively.

Several attempts have been made to relate productivity parameters with that of potential yield or optimum sustainable yield (Subramanyam, 1959; Prasad and Nair, 1963; Nair et al., 1969; Prasad et al., 1979; 1970; Qasim et al., 1978). It has been postulated by Steeman Nielsen and Jensen (1957) that landings of commercial fish catch in intensely exploited water is about 0.4%

of the organic matter produced by the phytoplankton. However Nair and Pillai (1983) observed that a maximum sustainable yield of 0.2% would be a more realistic estimate for the EEZ of INDIA which would amount to just about 5 million tonnes of fish.

An attempt has been made to compute the potential fishery yield from primary production from the CIBA pond and that of COCO field and POKKALI field at Narakkal. Total primary production during the present study in the CIBA pond amounted to 5000 g C/m^3/year (5 kg. C/m^3/yr) in each year.

Since prawns are carnivores and they have been cultured in a closed system the energy conversion could be as high as 30% if not more. So it is postulated that a minimum yield of 20% is possible to be harvested at the third trophic level where the crustaceans occur in a closed system.

Total primary production during this study (biomass)	= 5 kg/m^3/yr.
Taking 30% ecological efficiency at the second trophic level for 0.6 ha (6000 m) pond	= $\frac{30}{100}$ x 5 x 6000
20% ecological efficiency at the third trophic level	= $\frac{20}{100}$ x 9000

∴ sustainable yield would be 1800 kg/0.6 ha./yr.
(3000 kg/ha./yr.)

It is possible to obtain a yield of 3000 kg. of prawn or fishes at the third trophic level from one ha. pond. Therefore the possibility of getting a quantum of harvest amounting 1800 kg. for 0.6 ha. pond is expected.

However in intensly stocked closed ecosystem as the CIBA pond exploited seasonaly a 0.4% yield in terms of carbon produced appear to be more reasonable. This would amount to 2000 kg. of prawns or fishes at this trophic level. Hence the possibility of getting a harvest of 1200 kg. for 0.6 ha. of the pond is within the possible limits.

In otherwords, since the culture practice is such that prawn larvae are stocked at a rate of 50,000/ha. and with a normal survival rate of 40% would result in a harvestable production of 200 kg. per crop (ie. 20000x10 g based on an average weight of each prawn). Maximum three harvests of 600 kg. is the average yield at present. Hence stocking can be made to utilize the available primary producers in full in the culture pond and increase production.

In this context it can therefore be concluded that it may be possible to increase the fish and prawn production by scientific planning and management of the existing prawn culture systems for which this document would form a scientific base.

SUMMARY

A knowledge of the biotic and abiotic factor influencing the cultivable species prawn is a prerequisite for the management of economically successful culture. A period of two years study during 1986 and 1987 has been made to investigate the existing prawn culture systems in the Cochin estuary at Narakkal. Three different prawn culture systems namely, CIBA pond, COCO field and POKKALI fied were selected which offered an excellent opportunity to study the different environmental conditions such as hydrography and nutrients and on the standing crop in terms of primary productivity, chlorophylls, and cell counts. A statistical analysis was conducted to examine the affinity of various hydrological and productivity parameters.

The present observation clearly indicate that the ponds are highly influenced by environmental factors like tide influence, seasonality, run off, agricultural and industrial activities etc. On the basis of the overview of these investigation salinity varied from 5-20%., dissolved oxygen from 3-5 ml/l, temperature from 28-33°C, pH from 7.5-8.0 and Eh from 130-250 mV are found to be favourable environmental conditions and conducive for culture practice.

The annual ranges in nutrient concentration clearly show the richness of water in the culture systems. Nutrients in general were high during monsoon season. Ammonia varied from 4-16 µg-at/l, phosphate from 1-3 µg-at/l, silicate from 7-40 µg-at/l,

niritefrom 1-5 µg-at/l and nitrate from 5-25 µg-at/l were accounted for.

The annual range of gross primary productivity ranged from 2000 to 15000 mg C/m^3/day, concentration of chlorophyll a from 7-45 mg $C/m^3$and the total cell counts clearly establish that these culture ponds are high productive systems.

Statistical analysis revealed that each culture system were independant. The contributing parameters also varied on account of the dynamic nature of the estuarine.

Enrichment of the culture ecosystems during the period of active operation such as premonsoon and postmonsoon ensured enhanced primary production.

A critical assessment of the primary productivity and its implication on the economic production of prawns in the culture pond was also included. These encouraging results of this research programme offer considerable scope for improvement through planned scientific methods.

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