STUDIES ON THE ECOLOGY AND PRODUCTIVITY OF SALINE LAGOON

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AUGUST 1985

Certificate

This is to certify that the thesis entitled "STUDIES ON THE ECOLOGY AND PRODUCTIVITY OF SALINE LAGOON" is the bonafide record of the work carried out by A. SILAS EBENEZAR under my guidance and supervision and that no part thereof has been presented for the award of any other Degree.

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Declaration

I hereby declare that this thesis entitled "STUDIES ON THE ECOLOGY AND PRODUCTIVITY OF SALINE LAGOON" has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.

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(A. SILAS EBENEZAR)

PREFACE

MARICULTURE dates back to 200 B.C. when the Japanese started the culturing of oysters. In Java, there were laws to protect milk fish farmers from fish poachers in 1400 A.D. In the past, development of mariculture was retarded by lack of scientific knowledge and because of other cheap and abundant sources of fish and land-grown food. Today, more than 50% of the world population depends on fish as a principal source of animal protein and people derive more than 50% of their daily animal protein requirements from fish in many countries(National Academy of Sciences,1977). Moreover, fish is second only to rice in the diet of low-income group of people of many nations such as India. It is nutritionally equivalent to meat in protein, high in essential minerals and low in saturated fats. Increased fishing efforts, advanced fish-finding and fish-catching devices,coupled with the lack of efficient management schemes have led to over-exploitation of many species of shell fishes and finfishes. The maximum sustainable harvest of the conventional species from the ocean is estimated to be only 100 million metric tonnes (Ryther,1975).

According to FAO(1978), in the early 1970s, the catch of fishes in the oceans seems to have reached a peak and levelled off. The recent events that have decreased the ocean fisheries are: the steep increase in fuel cost, increase in marine pollution and the concern over decrease in fishery production by countries that depend on fishing in foreign waters which was the aftermath of the declaration of the Exclusive Economic Zones by different nations. The total world fish production in 1977 amounted to 75.3 million tonnes which in 1983 was around 76.5 million tonnes. The demand for fish is growing rapidly throughout the world in par with the increasing population which is expected to touch the 7 billion mark by the end of this century from the level of approximately 4 billion of today. It is estimated that by the year 1985, this demand will reach about 107 million tonnes(Pillay,1973).

The population of India that was of the order of 684 million in 1981 is expected to touch the 850 million mark by 1991. With a population projection at a little over 1000 million by 2000A.D., and a demand on fish by 55% of the population at a rate of 30 g of fish per head per day, the country would need a minimum of 5.5 million tonnes of fish per annum, which is exclusive of the demand for industrial uses and exports. Thus the country's research and development programmes in fisheries sector should be geared to achieve this target by augmenting fish production by capture and culture fisheries. However, our major concern today is that for the last six years, India's marine fish production has been stagnating between 1.4 to 1.6 million tonnes. In order to make our planning credible and target achieveable, it is of paramount importance that top priority be given to aquaculture for achieving the production target by 2000A.D. In 1950, the development of fisheries was included under the integrated programme for production of subsidiary food for the nation. Aware of the importance of coastal aquaculture for augmenting fish production, the Central Marine Fisheries Research Institute launched research programmes in the early seventies to develop appropriate low cost technologies for the culture of marine and brackish water organisms. In 1975, world production by aquaculture was estimated to be over 6 million tonnes (Pillay, 1979), roughly 10% of the world fish production then, of which India produced 0.49 million tonnes of finfishes and 0.04 million tonnes of shrimps and prawns. It is expected to touch a total production of 12 million tonnes by the end of 1985.

Most of the present technologies which are in vogue in aquaculture in the developing countries are traditional in nature. Further increase in the production of finfishes and shellfishes through aquaculture could be achieved in two ways: one-by the utilisation of additional areas for aquaculture; and two - by the development and introduction of new culture technology and thereby increasing the production of organisms per unit area. Extension of aquaculture practices to enclosed bays and coastal lagoons necessitates extensive investigations on the environmental biology of the area in order to evaluate their potential for aquaculture.

A perusal of the literature shows that most of the earlier works on the ecology and productivity from the Indian waters have been confined to the estuarine ecosystems and contiguous neritic and oceanic water bodies. Although some information is available on certain aspects of the environmental parameters from the 'coastal lagoon ecosystem', there is hardly any indepth study on the ecological and productivity problems from "derlict saline lagoonal environment" in India .

In view of this, the candidate undertook a study on the subject "ecology and productivity" of a typical "coastal saline lagoon"(Pillaimadam lagoon) situated along the south-east coast of India for a period of two years(July, 1982 to June, 1984), and the results of the investigations are embodied in the present thesis entitled "Studies on the ecology and productivity of saline lagoon".

The thesis is presented in three sections. Section-I deals with '<u>Investigations on the ecology and productivity</u>', in which Chapter-1 contains "Introduction" to the problem, Chapter-2 presents the "Review of literature", Chapter-3 explains the "Material and methods" adopted, Chapter-4 construe "Results" of the work and Chapter-5 comprises the

"Discussion" on the results obtained. Section-II deals with the '<u>Studies on the nutrient enrichment</u>', of which Chapter-1 contains "Introduction" to the problem, Chapter-2 presents the "Review of literature", Chapter-3 explains the "Material and methods" followed, Chapter-4 comprises the "Results" obtained in the experiments and Chapter-5 presents the "Discussion" on the results obtained. A critique on the suitability of the Pillaimadom Lagoon for mariculture practice is presented in the last section(Section-III). Further, a detailed literature on the subject matter of the thesis is presented at the end.

The results of the investigations have considerably enhanced our knowledge on the physico-chemical, biological and productivity characteristics of the area studied. North-east monsoon exerts profound influence on the hydrology of the lagoon by initiating the sea water circulation with the opening of the barmouth, and with the inflow of freshwater consequent on the rainfall. With the advent of summer season, the lagoon becomes hypersaline and anoxic, making the environment non-endurable for the organisms. This results in the low rate of productivity in the lagoonal ecosystem. Based on the results of investigations conducted on the wind velocity, wind direction, pattern of surface currents, water and sediment quality, column and benthic productivity and results of experiments on nutrient enrichment, suggestions are presented for the perennial utilisation of Pillaimadam Lagoon for aquaculture practices.

I wish to express my deep sense of gratitude to Dr. E.G.Silas,D.Sc.,Director, Central Marine Fisheries Research Institute, Cochin, for providing me with an opportunity to carry out research work in the Centre of Advanced Studies in Mariculture, for the laboratory facilities extended and for his constant encouragement throughout the period of my study.

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SECTION-I

ECOLOGY AND PRODUCTIVITY

Chapter-1

INTRODUCTION

INTRODUCTION

MANY large expanses of relatively protected, shallow marine water exist along the coastal margins of the world's land masses and in some areas they are associated with coastal lagoons. Such coastal lagoons are commercially important in view of the fact that they support extensive fisheries and they are sites of a wide variety of changes in the environmental parameters. The coastal lagoon ecosystems are unique, mainly due to the peculiar conditions of their hydrodynamics and sedimentation. Due to the inflow of freshwater as well as due to the monsoonal impact, drastic changes take place in the ecosystems which in turn considerably influence the biological resources and organic production. Emery and Stevenson (1958) defined the coastal lagoons as "bodies of water, separated in most cases from the ocean by offshore bars or islands, of marine origin and are usually parallel to the coast line". Pritchard(1967) considered the coastal lagoons as "estuaries". According to Lankford(1977) a coastal lagoon is "a coastal zone depression below mean higher high water, having permanent or ephemeral communication with sea, but protected from the sea by some type of barrier". According to Zernov(1949), hypersaline lagoons are water bodies with a salinity range of 47-300‰. When a coastal lagoon becomes isolated from the sea and/or salinity values exceed 100‰, it is termed as "hypersaline" lagoon (Por,1972).

There are many coastal lagoons all along the coasts of U.S.A. The eastern coast of the Gulf of California is almost continuously bordered by extensive coastal lagoons. Ecological comparison of fifteen such representative lagoons with the open Gulf was attempted by Gilmartin and Revelante(1978). During the last eight years, there has been an increasing interest in developing mariculture in the coastal lagoons of the Baja California penninsula. In Mexico there are 125 coastal lagoons, with variable composition and salinity, since they are formed by the mixing of river and sea water (Lankford,1977). The evaporation of these lagoons causes further changes in their composition. Most of these coastal lagoons are very much in their natural state and basic ecological studies have not yet been made in many of these lagoons. Some of the hypersaline environments have received considerable attention in the eastern Mediterranean Area, Mediterranean coast of Turkey and South African Coast. The only hypersaline lagoons studied in the eastern Mediterranean are the Bardawil lagoon and the Great and Small Bitter lakes (Krumgalz et al.,1980). Limnologically, these lagoons are practically unknown. Only fragmentary information exists concerning the Bitter lakes of the Suez Canal (Fox,1929). There are more than 20 coastal lagoons around the Sinai Peninsula. The biology of saline lagoons on the Sinai Peninsula in the Red sea has been extensively investivated in recent years. The ecology of these lagoons is of special interest as they are subject to extremes of temperature and salinity. The Valli of Comacchio is a shallow coastal lagoon of the Po River delta, covering 10,000 ha and is utilised for extensive aquaculture (Colombo, 1972a). In the western Victoria there are 24 lakes ranging in salinity from 1-204‰. New Zealand has few coastal lagoons and the ecology of some was studied by Mitchell(1971).

Considerable attention has been paid in recent years to study the ecology and productivity of the estuarine and connected inshore waters around India in order to ascertain the productivity of these areas for the utility of aquaculture practises. Very little information is available on these aspects in the coastal lagoons which are characterised by high salinity. In India, along 6,100 kms of coastline, 0.612 million ha area has been used for aquaculture in 1977 and it is estimated that there are 2.73 million ha area which can be potentially used for aquaculture and this includes reservoirs, lakes, estuaries and coastal lagoons suitable for cage, pen and raft cultures (Rabanal,1977). In order to understand the suitability of such derelict saline lagoons for aquaculture practices, it is necessary to investigate their environment, nature of their fluctuations and the rate of productivity. With this in view, the investigations on the ecology and productivity of the coastal saline lagoon at Mandapam Peninsula along the south-east coast of India was taken up.

Investigations on the ecological parameters and their spatial and temporal variations in the lagoonal environment were conducted in order to estimate the variations of atmospheric temperature, water temperature, salinity, dissolved oxygen, pH soluble reactive phosphate, nitrate, nitrite, ammonia and sulphide. Organic production was estimated through out the course of study, whereas the assessment of the pattern of distribution of zooplankton was done for a monsoon period. Sediment samples collected were analysed for temperature, Eh, pH, organic carbon, total phosphorus, Kjeldahl nitrogen, grain size distribution and total sulphide. Qualitative and quantitative assay of benthic macrofauna was done. The sediment samples in the vertical profile were analysed for estimating the contents of organic carbon, total phosphorus, kjeldahl nitrogen and grain size. In order to understand the diel fluctuations due to tidal influx and fresh water inflow on the dissolved oxygen, salinity at the surface and bottom layers, soluble reactive phosphate, nitrate, nitrite and ammonia, a series of diurnal studies were undertaken in such a way so as to include the effects of pre-monsoon, monsoon and post-monsoon periods. Important coastal flora along the bank of the lagoon were identified.

The major set-back for the aquaculture practices in this coastal saline lagoon is the lack of water during summer. The impact of south-west monsoon in Palk Bay result in the decline of the sea level when compared to that of the lagoon floor. During the monsoon periods, due to poor agricultural practices in the Mandapam Peninsula, only lesser loading of nutrients input was observed. It is discussed that the lagoon may profitably be used for short-term culture practices with seasonal enrichment. Suggestions are made for perennial culture practice.

Chapter-2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Bayly(1970) investigated the macrobenthos of some saline lakes of south-east Australia. Armstrong and Schindler (1971) computed the total dissolved phosphorus, nitrate and reactive phosphate contents of three deep and two shallow Canadian lakes at the beginning and end of summer stagnation. Mitchell(1971) studied the seasonal distribution of phytoplankton, gross production, algal species composition, temperature, transparency, oxygen concentration, ionic solutes and pH for two & half years in the Tomahawk Lagoon, Lake Mahinerangi and Lake Waipori in New Zealand. Platt(1971) found annual variation in the primary productivity of St. Margaret's Bay, Nova Scotia and attributed it to the influence of the weather on hydrographic regime of the Bay. Malueg et al.(1972) studied the temperature, dissolved oxygen, pH, secchi disc measurement, nitrogen, phosphorus, carbon, major cations and phytoplankton distribution in an ultra-oligotrophic lake in Oregon, USA. Por(1972) has discussed on the hydrobiology of the highsaline waters of the Sinai Peninsula. He has discussed the benthic fauna and flora and attributed the poorer faunal diversity as due to the hypersaline condition. Schindler et al. (1972) investigated the seasonal variation of temperature, water transparency, pH, dissolved oxygen, reactive phosphate, nitrate, nitrite, ammonia, hydrogen sulphide, methane, primary productivity and phytoplankton in a small eutrophic lake at Minnesota over a period of several years.

Jorgensen and Fenchel(1974) studied the sulphur cycle of a marine sediment model system and estimated the maximum mean rate as about 80nMS/cm^3/day. Cammen(1975) analysed the core samples in a salt marsh sediment for organic carbon content. Glooschenko(1975) determined the correlation coefficients between primary production, phytoplankton biomass as chlorophyll a, temperature, forms of nitrogen, phosphorus and silicate in Lake Erie for eight months. Mitchell(1975) worked on the chloride, reactive phosphate, nitrate and ammonium concentration in the Tomahawk Lagoon, which is a small (9.6 ha), shallow (1 m) coastal lake in Otago, for a period of two years. O'Brein et al.(1975) investigated the primary productivity and nutrient limiting factors in the lakes and ponds of the Noatak River valley, Alaska. Pauly(1975) determined the salinity, temperature, influence of rainfall, exchange of water with the sea, rate of evaporation, dissolved oxygen, organic matter in the seston, primary productivity, macrofauna and the fisheries of a small shallow West-African coastal lagoon for about one year.

Geddes(1976) recorded the seasonal changes in the physical, chemical and biological aspects of 16 ephemeral saline lakes in western Victoria. Aston and Hewitt(1977) determined the total phosphorus and organic carbon contents of the sediments in the polluted coastal environment at Walton backwaters, England. Berner(1977) studied the release of nutrients by microbial activity in the anoxic sediments of Long Island Sound and presented stoichiometric models. Cohen *et al.* (1977) investigated on the temperature, salinity, pH, Eh, dissolved oxygen and hydrogen sulphide in a coastal hypersaline desert lake. Cohen *et al.*(1977) worked on the occurence of sulphur phototrophic bacteria, their distribution in relation to hydrogen sulphide concentration and light intensities and the primary production of the Solar Lake. Jorgensen and Cohen(1977) observed the sulphur cycle of the benthic cyanobacterial mats in the coastal hypersaline Solar lake and found only 1.5%o of the sulphide produced is trapped within the sediment in reduced form and the remaining 998.5%o diffuses to the surface where it is oxidised. Kufel and Kufel(1977) analysed the organic matter, calcium, total and exchangeable phosphorus, lead, molybdenum and copper in the vertical profiles of the littoral sediments of the Polish lakes, Inulec and Majcz Wielki. Rosenberg(1977)studied the number of species, abundance and biomass of the benthic macrofaunal communities in different strata in the sediments and the seasonal variation in the fjords of Sweden. Bagander and Niemisto(1978) evaluated the use of reduction-oxidation measurements for characterising the sediments in the Baltic Sea and the Gulf of Bothnia. Barnes(1978) studied the variation in the paragnath number of *Nereis diversicolor* in relation to sediment type and salinity regime at eight sites in north Norfolk and at six sites situated in the Severn Estuary, England. Edwards(1978) investigated the temperature, salinity, diel cycle of dissolved oxygen, visibility, wind circulation, primary production and benthic infauna and epifauna of the Huizache Caimanero coastal lagoon complex in Mexico. Gilmartin and Revelante(1978) carried out investigations on the temperature variation, nitrate and phosphate concentration, primary productivity and tidal exchange of the fifteen representative lagoons and compared them with the open Gulf during the season of lowest upwelling, highest temperature and at the end of the low rainfall season. Hansen et al.(1978) analysed the mechanism of the hydrogen sulphide release from a small, shallow, anoxic-sedimented Aggersund Area in Limfjorden and a small lagoon Kalo Vig in the coastal area of Denmark. Holm(1978) constructed the community structure of a tropical marine lagoon in the upper Florida Keys. Jones et al.(1978) investigated the lagoon profiles and tides, air and water temperature fluctuation, salinity variation, faunal diversity and zooplankton biomass and diel variation of a high saline lagoon, Dawhat-as-Sayh in Saudi Arabia.

Fee(1979) found a relationship between lake morphometry and primary productivity and related the eutrophication to the concentration of algae in the Experimental Lake Area, northwestern Ontario. Crawford et al.(1979) studied the nutrient levels, plant pigments, oxygen balance and phytoplankton populations over a period of two years in the brakish-water Swanpool lagoon, Falmouth. Mitchell and Burns(1979) evaluated the oxygen consumption for two eutrophic New Zealand lakes using a simple 2 layer model, from the estimates of net changes in oxygen, phytoplankton photosynthesis, inflow and outflow, eddy diffusion and changes in the depth of the thermocline. Rashid and Reinson(1979) found a correlation between the nitrogen, organic carbon and the particle size of the estuarine sediments in Miramichi estuary, Canada. Reshkin and Knauer(1979) investigated the light dependence of phosphate uptake by phytoplankton in natural assemblages at Monterey Bay, California. The relationship observed approximates the Michaelis-Menten kinetic function commonly used in algal nutrient uptake studies. Rosenfeld(1979a) observed from the sediment cores of Long Island Sound, Florida Bay and Pettaquamscutt river, Rhode Island and from the laboratory experiments that the ammonia produced by the decomposition of organic nitrogen compounds in anoxic sediments can accumulate in the pore water, diffuse out of the sediments into the overlying water column or be adsorbed onto the sediments. Amino acids, bound in peptides or proteins, or both are the predominant form of organic nitrogen in the nearshore anoxic sediments and the organic nitrogen is preferentially utilised relative to organic carbon during early diagenesis (Rosenfeld, 1979b).

Krom and Berner (1980) worked on the adsorption of phosphate in anoxic marine sediments of Long Island Sound. Krumgalz _et al._(1980) determined the annual salinity variation, pH and dissolved oxygen fluctuation in a natural hypersaline Bardawil lagoon in Sinai. Lemasson _et al._(1980) studied the inorganic phosphate uptake in the brakish tropical Ebric lagoon along the Ivory Coast. Lara-Lara *et al.*(1980) estimated the sea level, current velocity, temperature, salinity, oxygen, inorganic phosphate, chlorophyll *a*, seston and its organic and inorganic fractions, phytoplankton species abundance, particulate organic carbon and nitrogen and primary productivity in a shallow Mexican coastal lagoon. Rosenberg(1980) reviewed the number of species, their abundance, biomass and macrobenthic faunal composition reactions to the oxygen deficiency due to organic enrichment and/or geomorphological conditions in ten fjords and estuaries in northern Europe. Welsh(1980) estimated the relative magnitudes of nutrient activity and diel cycle of nutrients of the marsh-mudflat ecosystems of Branford River Estuary on the north shore of Long Island Sound. Youngbluth(1980) worked on the daily, seasonal and annual fluctuation among zooplankton biomass and densities in the unpolluted tropical embayment of Jobos Bay, Puerto Rico.

Mitchell and Burnes(1981) studied the seasonal and vertical changes in major ions, conductivity, pH, reactive phosphorus, chlorophyll *a* concentration and nutrient sources for about two years in two New Zealand lakes. van der Loeff *et al.* (1981) analysed the sediment water exchange of nitrate, silica, ammonia, phosphate and oxygen on the tidal flats in the Ems-Dollard estuary.

Callender and Hammond(1982) investigated on the C:N ratio, macro-invertebrate population including polychaete worms, molluscs and amphipods, sulphide, organic carbon, nitrogen and phosphorus, N:P ratio and the average benthic flux across the sediment-water interface in the Potomac river estuary. Ceccherelli and Ferrari(1982) estimated the annual and seasonal variations of zooplankton abundance in a shallow-water lagoon of 10,000 ha, the Valli Comacchio, utilized for extensive aquaculture. Fernandez _et al._(1982) studied the faunal density and composition of hypersaline waters of a Mexican lagoon. Fisher et al.(1982_a_) worked on the phosphate, nitrate and ammonium regeneration from the sediment, in three north Carolina estuaries. They (1982_b_) also determined the carbon and nitrogen photosynthetic productivity by the plankton community in these three estuaries. McCarthy _et al._(1982) analysed the uptake of ammonium, nitrate and Urea-N by microplankton of the Kinneret Lake over a period of two years. Millan-Nunez _et al._(1982) determined the sea level, salinity, temperature, nitrate, nitrite, phosphate, silicate, chlorophylls _a_, _b_, and _c_ and their phaeophytins, phytoplankton abundance and phytoplankton productivity at three interior locations of Bahia San Quintin coastal lagoon (Mexico) by sampling once in every two hours for ten days in the summer period. Nedwell(1982) experimented on the exchange of nitrate and the products of bacterial nitrate reduction between seawater and sediment in a salt marsh and found that the rate of removal of nitrate from water column increased with the steady state concentrations of nitrate. Parker(1982) studied the redox-potential, organic matter, grain-size and benthic fauna of the sediments of a semi-enclosed marine Bay, the Belfast Lough.

Comin et al.(1983) analysed the depth, temperature, salinity, dissolved oxygen, soluble reactive phosphate, nitrate, nitrite and the phytoplankton density at two stations in a shallow lake (50 cm - 170 cm depth) in Spain for a span of one year. Devol(1983) based on his findings of studies at the Saanich inlet sediments, indicated that the anaerobic methane oxidation was occuring at the base of the sulphate reduction zone. Farfan and Alvarez-Borrego(1983) investigated on the nitrate, nitrite, ammonia, particulate organic carbon and particulate organic nitrogen at the mouth of a coastal lagoon along the Baja California coast to predict the variability and fluxes of nitrogen and organic carbon. Kaufmann et al.(1983) determined the alkalinity and calcium carbonate solubility of the hypersaline surface Mediterranean sea water, off the Tel Aviv Coast. Timms(1983) analysed the macrobenthic communities of 24 lakes having a salinity range of 1 to 204‰ and discovered 27 species of macro-invertebrates at Western Victoria, Australia. Wafar et al.(1983) worked on the seasonal changes in the concentration of nitrite, nitrate, reactive phosphate, N:P ratio, ammonium and primary production in a permanently well-mixed temperate coastal waters in the Morlaix Bay for a period of two years.

Jayaraman(1954) investigated on the seasonal variations in the temperature, salinity, dissolved oxygen, meteorological condition, concentration of soluble reactive phosphate, nitrate, nitrite, ammonia and silicate of the coastal waters of the Palk Bay and inshore waters of the Gulf of Mannar. Prasad(1954, 1956) analysed the plankton of the inshore waters off Mandapam.

Nair(1970) determined the primary productivity in the Palk Bay.

In 1980, UNESCO undertook global survey on the coastal lagoon research. This survey assets the coastal water research in India at Parangipettai Killai, Pichavaram, Cochin Backwater, Vembanad Lake, Mandoui, Cumbarjua Canal and Zuary Estuarine system, Veli Lake, Kadinamkulam Lake, Anjuthengu Lake, Edava-Nadayara Lake, Paravoor Lake, Ashtamudi Lake, Vembanad Lake, Kayamkulam Lake, Kodungalloor Kayal, Glasea Lagoon and Kavarthi Lagoon by different institutions. But, the ecosystem of the Pillaimadam Lagoon is quite different from that of the above mentioned places which are categorised as mangroove, lake, estuary and backwater.

Panikkar(1952) discussed the possibilities of fish and prawn culture in the Pillaimadam Lagoon. Pillai(1954a) investigated some of the factors controlling algal production in Pillaimadam Lagoon. He(1954b) cultured a halophilic blue-green alga, *Phormidium tenue*(Menegh), collected from the Pillaimadam Lagoon to find its growth requirements. Pillai(1955) investigated the ionic composition of blue-green algae at Pillaimadam Lagoon. Pillai(1956) investigated on the pH, organic matter, total nitrogen, total and interstitial phosphorus, water soluble constituents like chloride, sulphate, calcium, nitrate and iron and the grain-size of the bottom mud collected from two stations in the Pillaimadam lagoon at Mandapam peninsula. Tampi(1959) reported on the surface temperature, dissolved oxygen salinity, pH, phosphate, phytoplankters, zooplankters, and other faunistic components such as coelenterates, annelids, crustaceans, molluscs, fishes and prawns of the Pillaimadam Lagoon. He also studied the fishing methods employed by the local fishermen and the economics of the fishery of this area. Tampi(1960) reviewed the results of marine fish culture experiments(*Chanos chanos*) in Mandapam and the possible means of increasing the fish yield. Tampi(1967) discussed the utilisation of Pillaimadam Lagoon for mariculture practice. He(1969)had discussed the general physical and chemical characteristics of the Pillaimadam lagoon and brought to light some of the inherent draw backs which affect the biological productivity in this area. Mohan(1983*a*,*b* and *c*) briefly discussed the hydrological condition of the Pillaimadam Lagoon while presenting the results of *Chanos chanos* culture experiments conducted in Pillaimadam lagoon in three fish pens of 0.25 ha each. He had presented a brief note on temperature, dissolved oxygen and salinity of the Pillaimadam water at the fish pen sites.

Chapter-3

MATERIAL AND METHODS

MATERIAL AND METHODS

3.1 Description of the Lagoon:

Pillaimadam lagoon, between 09° 17' N to 09° 17' 48" N and 79° 5' E to 79° 8' 24" E, which extends over 300 ha, is situated along the Palk Bay coast of Mandapam peninsula (Plate: 1-1 to 1-3). Along the east-west direction it is 5 kms long and the north-south direction 0.2 to 1.0 km broad. This lagoon, though on the whole is known as Pillaimadam lagoon, has three separate names for three zones. The first zone extends from the fresh water inlet to the western side and is called Pillaimadam. The second zone occupying the area from the freshwater inlet to the bar mouth is called Theedai and the third zone located from the bar mouth to the eastern side is called Munaikkadu. The deepest area during monsoon season hardly exceeds 1.5 m deep.

3.2 Location of stations:

Six stations were selected for regular sampling, of which one was at the Palk Bay (Plate: 1-4). Station-I was located in the Pillaimadam zone and station-II at the commencement of the Theedai zone where the freshwater inflow is felt. Station-III was located in the middle of the Theedai zone and station-IV was fixed at the end of Theedai zone where the bar mouth exists. Station-V was in the middle of the Munaikkadu zone. The station in the Palk Bay was fixed in the inshore area at 1.5 m depth in between stations-III and IV.

PLATE 1-1

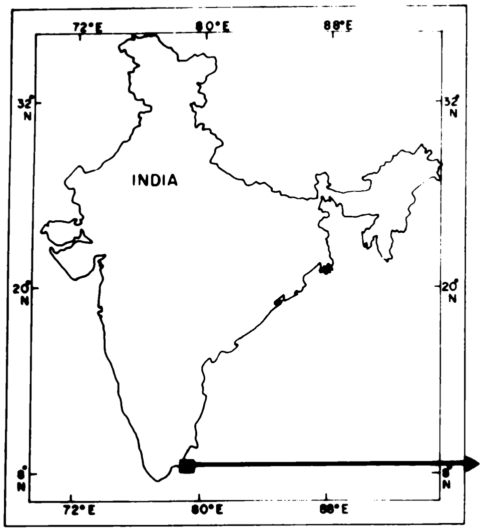


PLATE 1-2

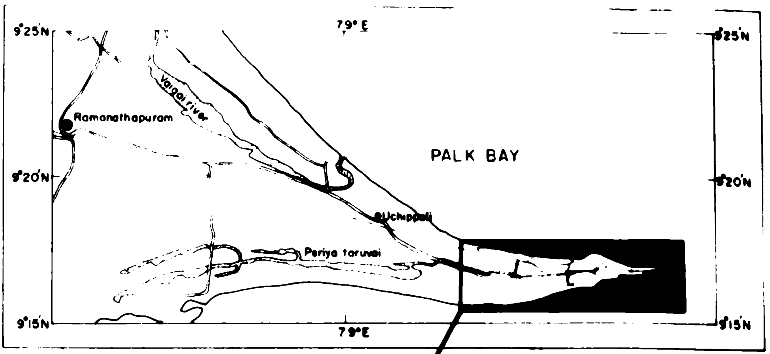


PLATE 1-3

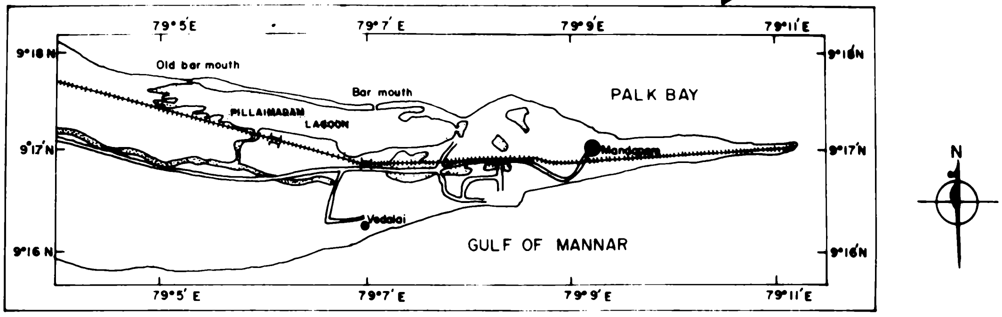


PLATE 1-4

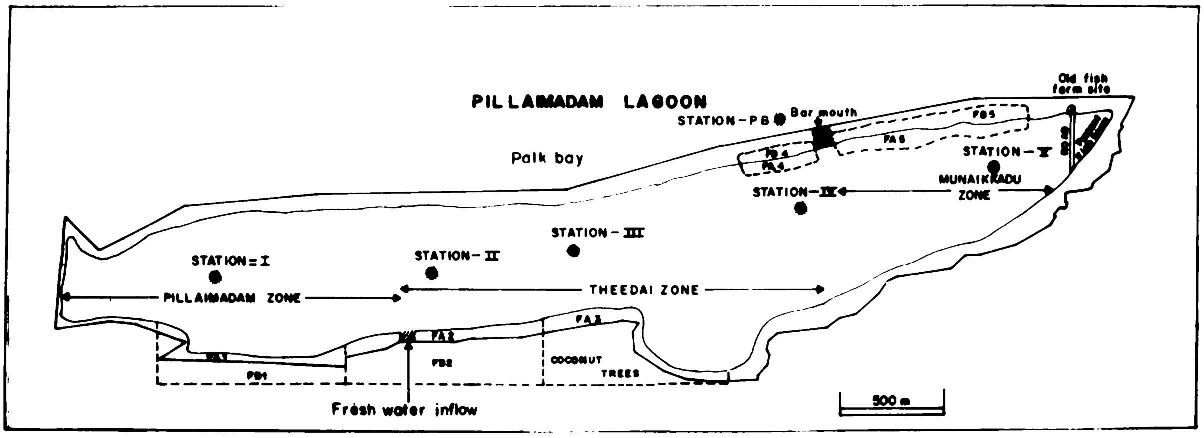
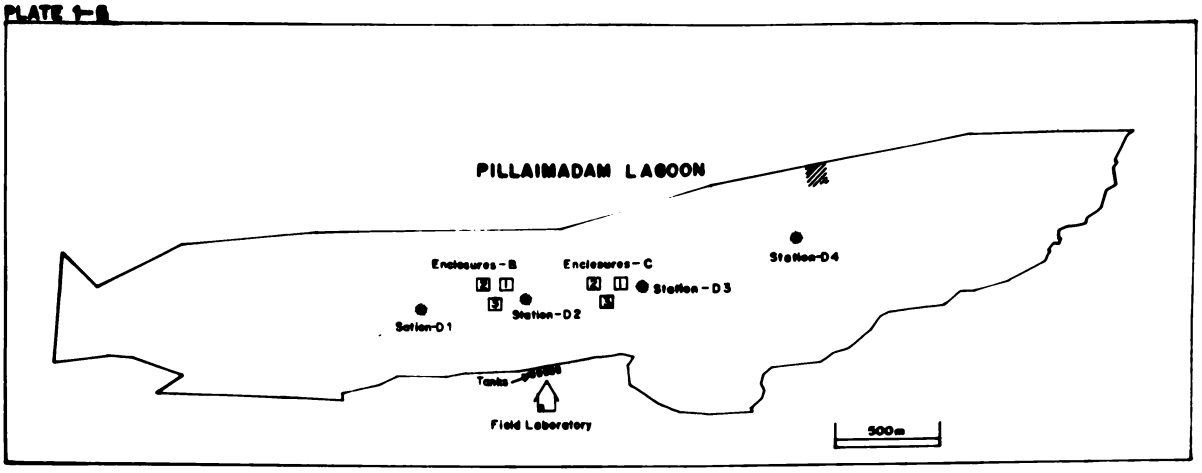


PLATE 1-5



3.3 Sampling frequency:

Regular weekly sampling was conducted from all these stations. Samples for estimating hydrology and nutrients were collected weekly, whereas estimation of primary productivity and analyses of sediment were carried out fortnightly. During the collection, a set of ready made kits was taken to the field depending on the nature of collection (Plate:2-1). Starting from the first station at 0070 h, sampling was done at every successive hour from the other stations. For the convenience of covering the distance in the minimum period, the station in the Palk Bay was sampled after station-III. Thus the usual time of sampling was from 0070 h to 1300 h. During the monsoon period when the lagoon was filled with water, a fibre glass boat with an OAL of 9 feet was used for sampling. However, the time and the course of sampling were always the same.

3.4 Air temperature:

Using 0-50°C high precision thermometer, the air temperature was recorded just prior to the collection of water samples. The thermometer was kept in inverted position while recording the temperature.

3.5 Water temperature:

The thermometer that was used for recording air temperature, was used for measuring water temperature. As the lagoon is usually shallow, the thermometer was inserted in the water column upto 5 cm and the temperature was recorded. While

Plate 2-1 View of a field sampling.

Plate 2-2 Improvised instruments (From Left to Right):

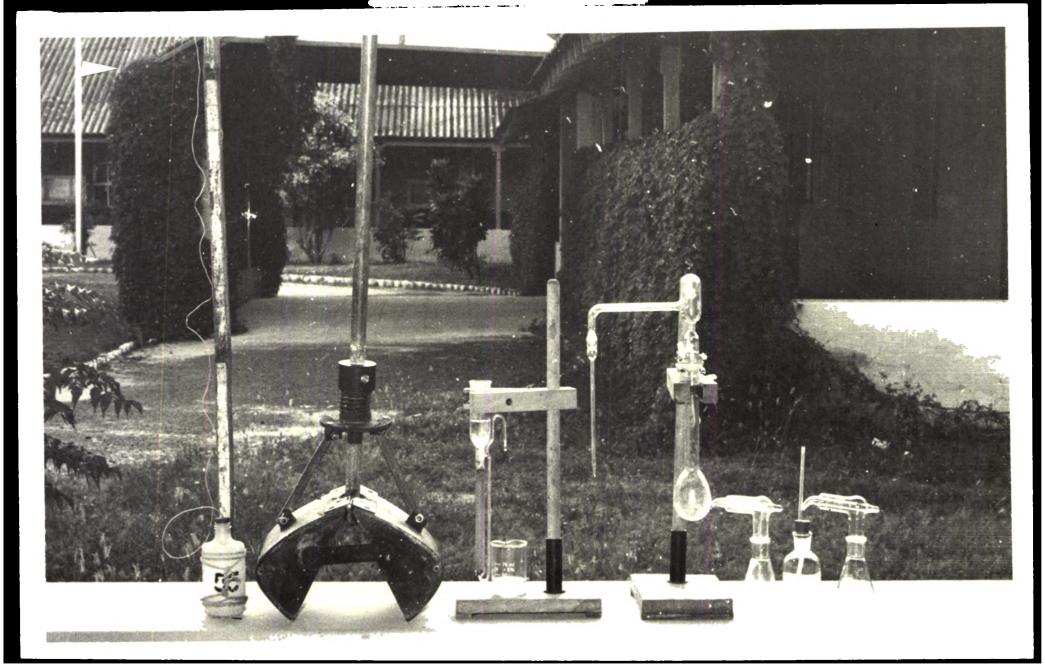
1. Bottom salinity sampler
2. Grab
3. Reduction column
4. Distillation apparatus

5 & 7. Automatic 1 ml pipettes for measuring Winkler solutions at the field.

6. Oxygen sampler

Plate 2-1

Plate 2-2



using the boat, water was drawn in a plastic bucket and the temperature was immediately recorded.

3.6 Dissolved Oxygen:

125 ml 'Corning' reagent bottles with BOD stoppers were used for collection of samples for dissolved oxygen estimation. Three replicates were taken. As shown in the Plate:2-2, an oxygen sampler was designed to draw unagitated water. The sampler used was two-holed rubber cork, with a tube inserted from the base of the stopper and ending above the water column and another tube arising from the top of the stopper and ending just above the bottom of the bottle. Before sampling, the bottles were washed twice with the ambient water and the sampler was fitted in. Dipping the bottle at 5 cm depth and taking caution to avoid the entry of air bubble through the action of the waves, the bottle was filled through the tube, while the air found its way to the atmosphere through the exit tube. An indicative sound ensured the completion of filing and the sampler was removed by keeping the bottle inside the water. Using the BOD stopper, the bottle was stoppered inside the water without trapping any air bubble.

Using the automatic pipette shown in Plate:2-2, one ml of Winkler A and one ml of Winkler B was added immediately after removing the bottle from inside the water. After securing the stopper without trapping any air bubble, the precipitate was dispersed uniformly throughout the bottle by shaking. The fixed samples were kept in a covered rack to prevent evaporation.

Traditional Winkler Method with Aside modification was used to determine the dissolved oxygen content (FAO, 1975). The outline of the method is as follows:

The precipitate was dissolved in the laboratory using 1 ml of 1+1 sulphuric acid. The solution was titrated against sodium thiosulphate solution. Starch was used to note the end point and the sodium thiosulphate solution was standardised during every set of titration using 0.005 N potassium iodate. Mean value of the three titrations was taken for calculation. Then the dissolved oxygen concentration was calculated using the formula:

$$O_2 ml/l = \frac{a.N.22393}{4.(V-2)}$$

Where,

a = volume of the thiosulphate consumed in ml
N = normality of the thiosulphate solution
V = volume of the Winkler bottle in ml

All the reagents used in the analyses were prepared with double distilled water, distilled from all-glass distillation apparatus. The chemicals were of analytically pure quality.

3.7 Salinity:

Samples were collected in 200 ml polyethylene narrow mouth bottles at 5 cm below the water surface. Before drawing the samples, the bottles were washed twice with the surrounding water. Collected samples were preserved in an ice box till these were titrated in the laboratory.

Salinity was determined by the classical Mohr' titration method (Stickland and Parson, 1968). The outline of the method is as follows:

10 ml of the water sample was titrated against the silver nitrate solution with potassium chromate as indicator. Care was taken to arrive at the exact end point colouration in all the samples and the standardisation titration. Silver nitrate solution was standardised during every set of titration using the standard sea water supplied by the Oceanography Institute, Copenhagen. Each sample was titrated thrice and the mean value was taken.

3.8 pH:

pH was determined using Elico pH meter model LI-10T. The samples collected for the determination of salinity were used for pH determination before salinity was determined. After taking the pH meter reading, the *in situ* pH was calculated using the formula (Gieskes, 1969):

$$pH_{\text{in situ}} = pH_{\text{measured}} + 0.0118\ (t_2 - t_1)$$

Where,

t_1 = temperature *in situ*

t_2 = measurement temperature

3.9 Depth:

Water depth was measured at constant points near the poles erected at each station. A scientific scale of 1 m long was used to measure the depth and the mean value of the ebb and tide of the wave was taken.

3.10 Nutrients:

Water samples for nutrient analyses were collected in three 500 ml narrow-mouthed polyethylene bottles, washed twice by the ambient water, at 5 cm depth from the surface. The bottles were preserved in an ice box till the analyses were carried out. Using a ECIL senior spectrophotometer model GS865D with a wavelength range of 200-930 nm, intensities of the colours developed in all the analyses were measured. Values represent the means of triplicate analyses.

3.10.1 Soluble reactive phosphate:

Following the method described by Murphy and Riley(1962) the soluble reactive phosphate was estimated (FAO,1975). The outline of the method is presented below:

The acid-molybdate solution was prepared by mixing 200 ml of 9.1 N sulphuric acid with 45 ml of 0.073 M ammonium heptamolybdate solution and then adding 5 ml of 0.1 M potassium antimonyltartrate solution. From each sample two 25 ml subsamples were separately taken, of which one was regarded as the sample and the other was turbidity blank. To each of the subsample, 0.7 ml of the acidmolybdate solution was added and to the sample 0.7 ml of 0.4 M ascorbic acid solution was also added. After five minutes the sample was measured against its turbidity blank in the spectrophotometer at 882 nm.

3.10.2 Nitrate:

Using cadmium reduction column, nitrate was estimated

(Solyom and Carlberg,1975). Nitrate is reduced to nitrite almost quantitatively by amalgamated cadmium column (Plate:2-2). The nitrite is then determined according to the classical Griess's reaction. The outline of the method followed is presented below (FAO, 1975):

75 ml of the sample was run through the amalgamated cadmium column. First 10 ml of the sample flowing through the column was discarded and the next 10 ml used to wash the flasks. Then 50 ml was collected in two flasks of 25 ml each. To 25 ml of the reduced sample and the blank sample, 0.5 ml sulphanilamide reagent prepared by dissolving 8 g of sulphanilamide in a mixture of 80 ml concentrated hydrochloric acid and 420 ml of water was added. After not less than 3 min and not longer than 8 min, 0.5 ml of N-(1-naphthyl)-ethylenediamine solution prepared by dissolving 0.8 g in water and diluted to 500 ml was added to the sample. The absorbance was measured against the blank in the spectrophotometer at 545 nm.

3.10.3 Nitrite:

Nitrite was determined by the Azo Dye Method(Bendschneider and Robinson,1952). The determination of nitrite is based in the classical Griess's reaction, in which the nitrification at pH 1.5-2.0 is diazotised with sulphanilamide, resulting in a diazo compound, which in turn is coupled with N-(1-naphthyl)-ethylenediamine to form a highly coloured azo dye with an absorption maxima at 545 nm that is measured colorimetrically.

The methodology used was the same as for the determination of nitrate after reducing the sample through the amalgamated cadmium reduction column (FAO, 1975).

3.10.4 Ammonia:

Ammonia was determined following the phenol-hypochlorite method (Solorzano,1969). The following methodology was employed in the analysis. To 50 ml of the sample and blank, 2 ml of phenol solution prepared by dissolving 10 g of phenol in 100 ml of methanol and 2 ml of 0.5% sodium nitroprusside were added. To the sample, 5 ml of oxidizing reagent prepared by mixing 100 ml of 100 g trisodium citrate and 5 g of sodium hydroxide dissolved in 500 ml of water and 25 ml of sodium hypochlorite solution which was above 1.5 N was also added. The developed colour was read colorimetrically at 640 nm.

3.11 Hydrogen sulphide:

The method by which sulphide was determined, is based on the following principle: the acidified sample is allowed to react with dimethyl p-phenylene diamine, with ferric-ions as catalyst. A complex oxidation and substitution takes place resulting in the quantitative incorporation of any sulphide-sulphur present, into a heterocyclic dye called methylene blue. The absorption of light by the sample is measured against the blank at 670 nm(Carlberg,1975).

125 ml 'Corning' reagent bottles were used with BOD stoppers to draw unagitated bottom samples. The oxygen sampler was fitted into the bottle and a long rubber tube was inserted on

the top of the outer stem. By closing the other hole of the rubber stopper with a finger and the rubber tube above the water column, the bottle was taken to a small pit escavated near the pole. By keeping the bottle mouth in par with the level of the bottom water, the finger was removed. The water thus obtained was usdd to wash the bottle and then the bottle was filled with the bottom water. The air that was left in the bottle while it was getting filled, thus found its way outside through the long rubber tube without getting mixed up with the sample. Then the sampler was removed and the bottle was stoppered tightly at the bottom itself. Using long-tipped automatic pipettes, 1 ml of N, N-dimethyl p-phenylene diamine dihydrochloride prepared by dissolving 1 g in about 6 N hydrochloric acid to 500 ml, and 1 ml of ferric chloride prepared by dissolving 8 g in about 6 N hydrochloric acid to 500 ml, were added to the sample and the bottle was stoppered avoiding air bubbles getting in. The sample was shaken well and the blue colour that developed was read in the laboratory against the blank. The colour intensity was constant for atleast 24 h.

3.12 Sediment analyses:

A grab of 225 cm^2 gape and 15 cm high was used to collect the sediment samples. As soon as the grab sediment was taken out of the water column, sediment sample was filled in a 100 ml wide mouth polyethylene bottle with minimum aeration and closed air-tight. The rest of the sediment was taken in a trough for macrobenthic analysis. In the second bite, a small quantity of sediment was taken in a wide-mouthed 50 ml polyethylene bottle as quickly as possible and 0.5 ml of 2 N zinc acetate solution was added. The bottle was shaken well after closing, and these samples were preserved in the ice box.

3.12.1 Temperature:

In the third bite, as soon as the grab was removed from the water surface, a thermometer of 0-50°C precision was inserted immediately in the sediment and the reading was recorded.

3.12.2 pH:

The pH of the sediment was determined using Elico pH meter Model LI-10T.

3.12.3 Eh:

The Eh of the sediment was estimated using the same Elico pH meter but with a platinum electrode.

3.12.4 Organic carbon:

The method of Walkley and Black(1934) was used to determine the organic carbon content of the sediment. In this method, hot chromic acid was used to oxidise any organic carbon present and the excess acid not reduced by the organic matter was determined volumetrically with ferrous salt. The outline of the procedure is presented below (Holme and McIntyre,1971; FAO,1975):

The sediment sample which was dried in the oven at 110°C for 24 h was ground in an agate mortar and then passed through a

0.2 mm brass sieve. To a known amount of powdered sample, 10 ml of 1 N potassium dichromate solution and 20 ml of concentrated sulphuric acid containing 1.25 g of silver nitrate for every 100 ml of acid were added and swirled. It was kept in a water bath for 30 min, cooled and 200 ml of water was added. Then, 10 ml of concentrated phosphoric acid and 1 ml of diphenylamine prepared by dissolving 0.5 g diphenylamine in a mixture of 20 ml distilled water and 100 ml of concentrated sulphuric acid were added. The sample was back titrated with 0.5 N ferrous sulphate solution which was prepared by dissolving 139 g of ferrous sulphate in water, adding 7.5 ml of concentrated sulphuric acid and then diluting to 1 litre. The change ffom blue colour to sharp brilliant green colour confirmed the end point.

The results were calculated from the equation:

$$\text{Percent C} = \frac{3.951}{g}\left(1-\frac{T}{S}\right)$$

Where,

g = sample weight in grammes
S = ml ferrous solution, standardisation blank titration
T = ml ferrous solution, sample titration;

3.12.5 Total phosphorus:

Total phosphorus was determined by prolonged nitric-perchloric acid hot digestion. This brings all phosphorus into solution except that held in resistant silicate lattice structural sites. The outline of the method is as follows (FAO, 1975):

Sediment samples were dried in oven at 110°C for 24 h. 0.5 g of sediment which was dried at 110°C and powdered was taken in a 100 ml Kjeldahl flask and, 3 small acid-washed glass beads, 2 ml of concentrated nitric acid and 2 ml of concentrated perchloric acid were added. The sediment sample was then heated to dry. After cooling, sulphuric acid prepared by diluting 50 ml concentrated sulphuric acid to 1000 ml was added to the sediment. It was then boiled slowly for 10 min. After cooling, the solution was filtered using moistened Whatman 42 filter paper into a 250 ml volumetric flask and diluted to 250 ml. To 5 ml of this solution, 25 ml of water, 5 drops of 0.4 M ascorbic acid and 1 ml of sulphuric acid-ammonium molybdate solution (prepared as for the soluble reactive phosphate estimate of water) were added. After 5 minutes the absorbance was measured by spectrophotometer at 882 nm against distilled water. The results were calculated from the equation;

$$x = \frac{a.1}{b}$$

Where,

x = total concentration of phosphorus in μg/g
a = values obtained from the curve, in μg/0.5 g
b = sample weight in g.

3.12.6 Kjeldahl nitrogen:

The nitrogen compounds in the mud are converted to ammonium sulphate by sulphuric acid digestion. Then the ammonia is released and distilled off from the salt and determined as indophenol blue method (FAO, 1975) as follows:

The sediment sample was dried at 100°C for 24 h and then powdered. 0.1 g of powdered sample was taken in a 100 ml

Kjeldahl flask and then 15 ml of water, 3 small glass beads, 4 ml concentrated sulphuric acid and 1 ml of 0.1 M copper sulphate solution were added and heated for 30 minutes after the white smoke ceased. It was then cooled and 25 ml of water was added. Subsequently 20 ml of 10 N sodium hydroxide was added and distilled in a receiver containing 1 ml of 0.1 M sulphuric acid. Receiver was cooled and diluted to 25 ml.

To 2 ml of this solution, 2 ml of sodium phenate solution [(a) 62.5 g phenol dissolved in 20 ml acetone and diluted to 100 ml with methanol; (b) 27.5 g sodium hydroxide dissolved in water and diluted to 100 ml. By mixing 1 part of (a), 1 part of (b) and 2 parts of water, sodium phenate solution was prepared] and 2 ml of sodium hypochlorite reagent, prepared by adding 1 ml of 0.625 mgMn/l manganous sulphate which contained 0.9 g active chlorine and then diluting to 100 ml, were added. It was then diluted to 25 ml and the absorbance was measured after 45 minutes at 625 nm against distilled water. The results were calculated using the equation:

$$X = \frac{a.25.100}{2.b}$$

Where,

a = % HN_3-N
a = mg NH_3-N/25 ml, obtained from the standard curve
b = amount of sample, mg
25/2 = dilution factor.

3.12.7 Total Sulphide:

The sulphide estimation was done following the standard method (Standard Methods,1971), the principle of the method being sulphides are stripped off from the acidified sample with an inert gas and collected in zinc acetate solution. Excess iodine solution was added to the zinc sulphide suspension which react with the sulphide under acidic conditions. Thiosulphate is used to measure unreacted iodine to indicate the quantity of iodine consumed by sulphide. The outline of the method followed is presented below:

The sediment samples fixed with zinc acetate were weighed and transferred to 1 l reagent bottle, and 500 ml of distilled water was added to it. 5 ml 2 N zinc acetate and 95 ml distilled water were added into each of two 250 ml gas wash bottles. The 1 l reagent bottle and the gas wash bottles were connected in series using rubber tube. The sample was acidified with 10 ml of concentrated sulphuric acid and carbon-di-oxide gas was passed through the sample till there was no more smell of sulphide from the exit stem of the second gas wash bottle. 15 ml and 5 ml of 0.025 N iodine solution were added to the first and second gas wash bottles respectively to react with the collected sulphide. 2.5 ml concentrated hydrochloric acid was added to each bottle, stoppered and shaken well. The contents of both bottles were transferred to a 500 ml conical flask and back-titrated with 0.025 N sodium thiosulphate titrant, using starch solution as indicator. A blank was run on the reagents.

The results were calculated as follows:

$$S = \frac{(\text{ml iodine} - \text{ml sodium thiosulphate}) \times 400}{g}$$

Where,

S = total sulphide in ug/g wet wt.

ml iodine = total volume of iodine added in both gas wash bottles.

ml sodium thiosulphate = volume of sodium thiosulphate solution consumed for the titration.

g = wet weight of sample in grammes.

3.13 Primary production:

Primary productivity was estimated fortnightly by Light and Dark Bottle technique. As the lagoon is shallow, carbon-14 technique was not carried out since the organic debris was expected to interfere during the analysis. 125 ml 'Corning' reagent bottles with BOD stoppers were used. The dissolved oxygen values were taken for the initial bottle. Three replicates of the 'light' and 'dark' bottles were used. 125 ml 'Corning' reagent bottles coated twice with black paint and then wrapped with Aluminium foil were used as 'dark' bottles.

After filling the bottles following the precautions taken in the case for estimating dissolved oxygen, the light bottles were hung at the same depth from the poles . The dark bottles were tied in black rexin bags and hung along with the light bottles. Next day at the same time, the light and dark bottles were fixed in the field using Winkler A and B solutions and brought to the laboratory for further analysis. The difference between the light and dark bottles was taken as gross production whereas that of the light and the initial bottles was taken as net production. The calculation was done as follows(Strickland and Parsons,1968):

$$\text{Gross production, mgC/m}^3\text{/d} = \frac{605.f.(V_{(LB)}-V_{(DB)})}{PQ}$$

$$\text{Net production, mgC/m}^3\text{/d} = \frac{605.f.(V_{(LB)}-V_{(IB)})}{PQ}$$

Where,

f = 'f' factor determined through sodium thiosulphate standardisation.

$V_{(LB)}$, $V_{(DB)}$ and $V_{(IB)}$ = Sodium thiosulphate titre values obtained from the titrations of light, dark and initial bottles respectively.

PQ = photosynthetic quotient, here taken as 1.2

3.14 <u>Zooplankton distribution</u>:

The attempt to filter a known quantity of water was not found to be fruitful. The distribution and abundance of zooplankters zooplankters was estimated for one monsoon season only during 1983-84. Collection was made by using a 9 foot fibre glass boat to which an outboard YAMAHA engine of 8 horse power was fitted. Zooplankton sampling was done in the area adjacent to Station-III since that place is deeper than the rest of the stations. As the lagoon is too shallow to have a long rope attached to the net and to prevent the effect of agitation by the outboard engine, the net was held firmly in hand at the side of the boat ensuring total immersion of the rim of the net in the water column during towing.

Zooplankton samples were collected with a cylinder-cone shaped nylon net with a mouth diameter of 0.5 m and mesh size of 202 µm. The duration of each tow was 10 minutes and the speed of the boat was kept constant at 2.5 knots/h. Samples were taken at 1900 h, 2400 h and 0500 h with fortnightly intervals. During November, only one set of collection could be made and in December sampling was not conducted in the second half because of the cyclonic weather.

After each tow, before the net was removed from the water, it was thoroughly washed with the lagoon water. Samples were preserved in buffered 4% formalin. The total volume of water filtered ranged from 140–160 m^3. In the text, the number of zooplankters are expressed as the number per 150 m^3 of water filtered. Within 24 h after the samples were collected, the pH of the formalin solution was checked and adjusted to 7.6. Standing crop of zooplankton was estimated by volumetric method. Sub-samples were counted from each sample and organisms were recorded in broad taxonomic categories.

3.15 Benthic macrofauna:

A hand operated grab of 225 cm^2 gape and 15 cm high was used to collect the mud samples. At each station, for each sampling, the grab was operated five times thereby covering an area of 0.1125 m^2. The sediment sample was brought to the shore where it was sieved through 0.5 mm sieve. Sieved samples were preserved in 5% buffered formalin to which 1 g of rose bengal per litre was added. In the laboratory, the animals were sorted out by hand picking, and identified (Fauvel,1953). The results are presented for 1 m^2.

3.16 Grain size analysis:

Grain size analysis was done during pre-monsoon, monsoon and post-monsoon periods for two years in the upper layer of the sediment following "the sieving and pipette analysis" method to analyse the sand, silt and clay proportion (Holmes and McIntyre, 1971). The outline of the method is as follows:

Sediment sample necessary to produce 10-25 g of silt and clay fraction was dried in the oven at 100°C for 24 h. This sediment was then transferred to an one litre beaker with 250 ml of 6% hydrogen peroxide. It was left in this condition over night and then heated gently on a water bath. Small quantities of hydrogen peroxide was added till there was no further reaction. The contents of the beaker were washed thoroughly under gentle suction with distilled water onto a Whatman No.50 filter paper in a Buchner funnel. The sediment was then washed from the filter paper into a beaker using a jet of 200-300 ml distilled water and a camel-hair brush. 10 ml of sodium hexametaphosphate solution (6.2 g/l) was added to this, stirred for 15 minutes and left to soak overnight.

The sediment was then stirred again for 15 minutes and then transferred to the 62 µ sieve placed in a flat-bottomed white basin. Care was taken to see that there was no increase in the volume of distilled water within the basin used to sieve to 1 litre. Sediment was wet sieved by agitating and puddling. The sieve and its contents were transferred to a drying oven at 100°C. The dried 62 µ sieve was thoroughly agitated over a large sheet of white glazed paper and the material passed through was transferred to the suspension of silt and clay in the basin.

The dispersed silt clay fraction in the basin was transferred to an one litre stoppered cylinder with distilled water to make a suspension of exactly 1 litre. This analysis was done at 20°C room temperature. The sediment was suspended by vigorously shaking the cylinder for uniform dispersion, then placed upright and a stop-watch was started. Using a 20 ml pipette, sample was taken at a depth of exactly 10 cm below the surface of the suspension after an exact lapse of 2 hours and 2 minutes and the material in the pipette was subsequently dried at 100°C and weighed.

The material that remained on the 62 µ sieve was regarded as the sand fraction. The size of material retained by the pipette was less than 3.9 µ and it was considered as clay. Silt fraction (62-3.9 µ) was then determined by calculation.

3.17 Core sample analyses:

Core samples analyses were done once in two months. Organic carbon, total phosphorus and Kjeldhal nitrogen analyses were done following the procedures for regular analyses. Analysis for grain size distribution was done once during May-June 1984.

10 cm diameter G.I. pipe was plunged to a depth of 0.5 m and then a pit was escavated surrounding the pipe. By

inserting the hand at the bottom of the pipe and subsequently closing it, the pipe was taken out and the bottom was tied with thick polyethylene sheet. In the laboratory the core sample was carefully removed using a long tube to which a 10 cm circular metal plate was welded at one end to push the sample evenly from the upper end.

3.18 Diurnal study:

Four stations were selected to study the diurnal variations in the dissolved oxygen, surface and bottom salinities, soluble reactive phosphate, nitrate, nitrite and ammonia. These four stations were located in the Theedai zone. Stations D1, D2 and D4 were identical to the regular sampling stations number II, III and IV respectively, whereas station D3 was situated in between stations III and IV of the regular sampling stations (Plate:1-5). The study was undertaken depending on the lunar cycle-full moon/new moon and also to cover three seasons, viz., pre-monsoon, monsoon and post-monsoon. The sampling was done from 0900 h of one day to 0600 h of the successive day at every three hours.

A thatched field laboratory situated on the bank of the lagoon was used for sampling. All the four stations were sampled at the same time by four persons. During day time waving of flag and petromax light during night were used as indicators to start the sampling. Each person was provided with three 125 ml 'Corning' reagent bottles, Winkler A and B in automatic pipettes, oxygen samplers, one 125 ml polyethylene narrow mouthed salinity bottle, three 500 ml polyethylene narrow mouthed nutrient bottles and one bottom water sampler in an ice box.

The samples for dissolved oxygen were taken in three bottles following the usual precautions and using the oxygen sampler. Oxygen in the sample was fixed with Winkler A and B. The salinity and nutrient samples were then taken at 5 cm below the surface of water. The bottom water sampler consists of a 250 ml narrow mouth polyethylene bottle tied to a bamboo stick. A rubber stopper with a nylon thread was hung in the stick (Plate:2-2). Using the rubber stopper, the bottle was closed and the bamboo stem was dipped to the bottom. Then the stopper was plugged off and the water that entered was used for washing. Again the same procedure was repeated to obtain the bottom water. The rubber stopper was re-fitted after finishing the sampling and the bottle was preserved in the ice box.

Dissolved oxygen and salinity samples were analysed in the field laboratory itself by following Winkler method and Mohr' titration method respectively. Nutrient samples were preserved in big plastic drums with ice till it was taken to the laboratory for the analyses of soluble reactive phosphate, nitrate, nitrite and ammonia. The procedures followed to determine the nutrients were the same as for the regular analyses.

3.19 Coastal flora:

To distinguish between the near shore flora and terrestrial flora, different zones were demarcated where floral distribution was high. Based on this, FA1, FA2, FA3, FA4 and FA5 represent near shore zones, whereas FB1, FB2, FB3 and FB5 zones represent terrestrial zones (Plate:1-4). FB4 zone was trodden by Fishermen and a coconut groove exists there as wall. Hence, this zone was not accounted for in the study. The flora occurring more abundantly were collected and identified following Gamble(1935).

3.20 Statistical analyses:

All the statistical analyses were carried out according to Snedecor and Cochran(1967). Mean and standard deviations were calculated for all the parameters, monthwise. Correlation between all the ecological and productivity parameters were computed and the correlation matrices for all the stations are given in the tables and discussed.

RESULTS

The period of observation extended from July 1982 to June 1984. In order to present the data, the period from July 1982 to June 1983 has been considered as the 'first year' and that from July 1983 to June 1984 as the 'second year'.

For graphical presentation of the data, plots are suggested. This was found necessary to avoid the overlapping of the various parameter plots. However, sampling was done during the period indicated for the different parameter. Therefore, in the figures, the plots represented in the different time blocks (months or days or hours) pertain to the results obtained during the respective period (Fig.1-1 to 10-4; 13-1 to 17-8 and 18-1 to 23-15).

Graphs (Fig.1-1 to 10-4) were drawn using monthly mean values. The vertical line at each mean point indicates the standard deviation on either side of the mean.

4.1 Meteorology:

The Mandapam peninsula is generally regarded as a dry place as summer is usually felt severely in this area. High average maximum temperature was recorded between July 1982 to October 1983 and February 1984 to June 1984. Average monthly minimum temperature also followed the same pattern. Minimum temperature was felt from November 1982 to February 1983 and

December 1983 to March 1984 (Fig.1-1). The average monthly humidity was high during the monsoon period, recording values between 77 to 87%, whereas it was low during the summer season when the values ranged between 71 to 76% (Fig.1-2).

With regard to the rainfall, there was a significant difference between the monsoons of 1982 and 1983. In 1982, the rains started in the latter half of September and ceased in the first fortnight of December. But, for the 1983-84 period, the monsoon rains started during December 1983, and extended upto April 1984. The total rainfall in the monsoon period of 1982 was 922.5 mm with a peak in November(447.6 mm) and the total rainfall in the monsoon period of 1983 was 1346.7 mm, with a peak in December(652.9 mm)(Fig.1-3).

South-west monsoon winds blew till August 1982 with a high average speed of 15 kms/hr in June and subsequently north-east monsoon gained strength. The north-east monsoon period existed from September 1982 to February 1983 but was weak towards the end. The high average wind speed of 21 kms/hr was recorded in December. From March 1983 to October 1983, south-west monsoon winds prevailed in this area with a maximum speed of 15 kms/hr in September. From November 1983 to March 1984 north-east monsoon was felt and the highest average wind speed was recorded in December(19 kms/hr). From April 1984 to June 1984, south-west monsoon prevailed over the area and the average wind speed was 22 kms/hr in June 1984(Fig.1-4).

METEOROLOGICAL DATA

Fig. 1-1 Distribution of minimum and maximum monthly average air temperature.

Fig. 1-2 Distribution of relative humidity.

Fig. 1-3 Distribution of monthly total rainfall

Fig. 1-4 Distribution of monthly average wind speed and wind direction.

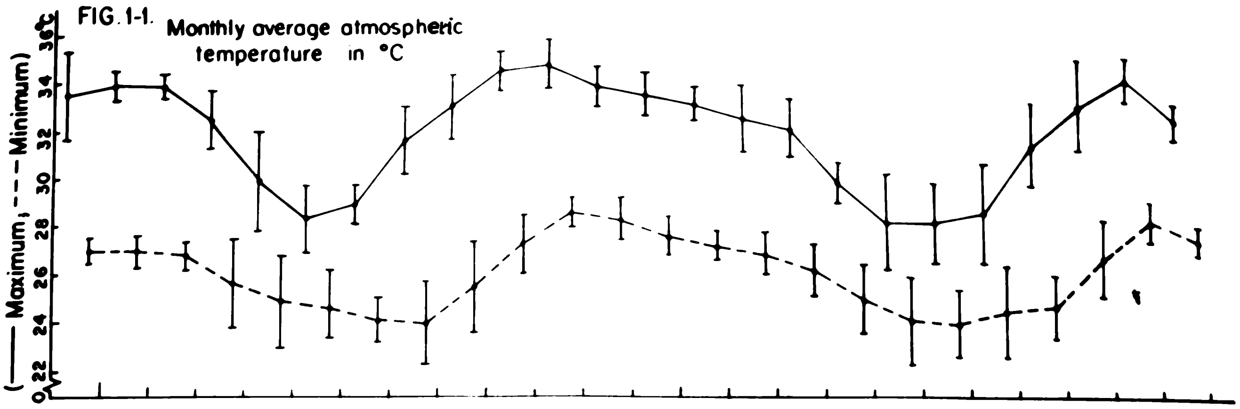


FIG. 1-1. Monthly average atmospheric temperature in °C

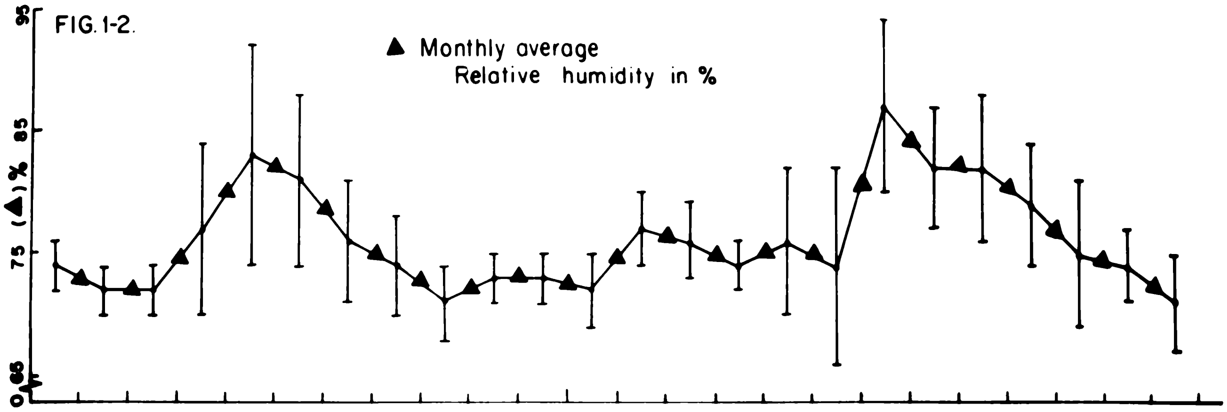


FIG. 1-2.
▲ Monthly average Relative humidity in %

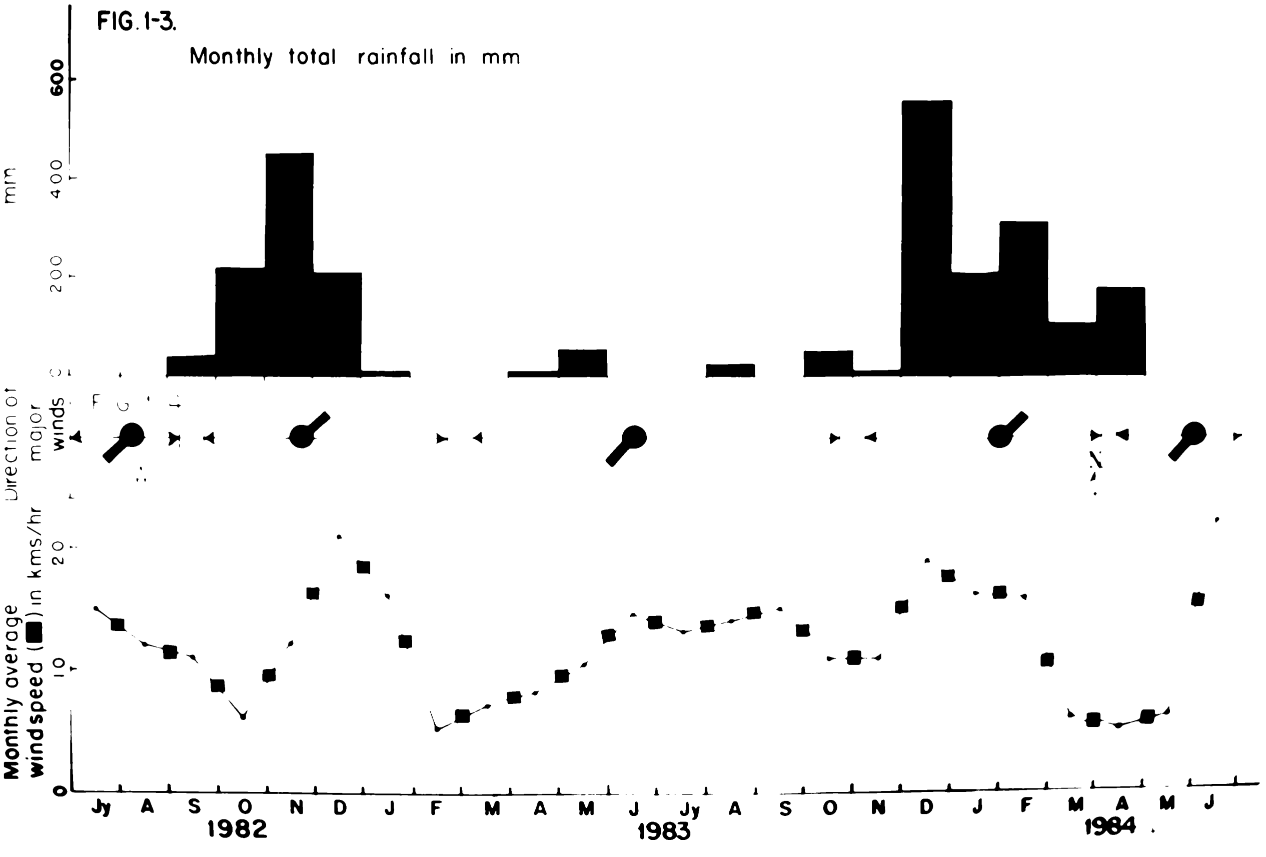


FIG. 1-3.
Monthly total rainfall in mm

Chapter-4

RESULTS

In the first year, bar mouth opened during the last week of September 1982 and got closed in the middle of February 1983. Freshwater inflow was felt from December 1982 to April 1983. In the second year, bar mouth opened during the first week of October 1983 and got closed at the end of May, 1984. Freshwater inflow was felt from December 1983 to April 1984.

4.2 Station-I:

4.2.1 First year (October 1982 to February 1983):

4.2.1.1 Hydrography and Sedimentology:

Water was present in this station from October to February. Maximum water level was observed in October(48 cm) followed by a steady decrease and the minimum level was observed in February(6 cm) (Fig.2-1). The air temperature recorded was 27.9°C in October which registered a sharp fall in November(24.9°C) and gradually increased to 27.3°C in February (Fig.2-1). The water temperature followed the same pattern as that of the air temperature with the maximum value recorded in October(26.5°C). Relatively low values were observed in November(23.8°C) and December(23.1°C) and the water temperature gradually increased to 25.7°C in February (Fig.2-1). Dissolved oxygen content was high in October(4.68 ml/l), and in November maximum value was recorded (4.79 ml/l). Oxygen content dropped sharply in January(2.51 ml/l)and maintained a more or less similar concentration in February(2.59 ml/l)(Fig.2-2). In October, the salinity value recorded was 12.8‰ and subsequently a fall was noticed in November(10.0‰) after which a steady but steep increase was noted which attained its maximum in February (74.3‰)(Fig.2-2).

STATION - I

Fig. 2-1	Distribution of air temperature, water temperature and depth.
Fig. 2-2	Distribution of oxygen, salinity and hydrogen sulphide
Fig. 2-3	Distribution of soluble reactive phosphate, nitrate, ammonia and nitrite
Fig. 2-4	Distribution of the rates of gross primary production, net primary production and pH.

FIG. 2-1

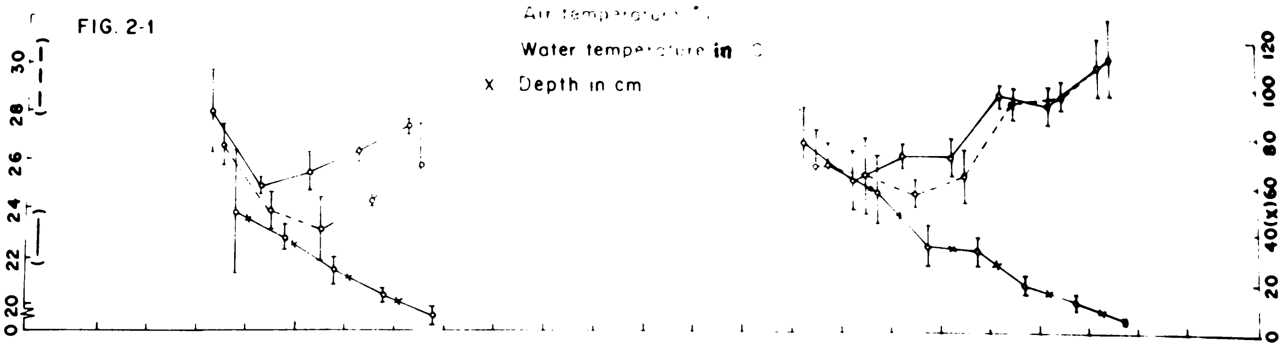


FIG. 2-2

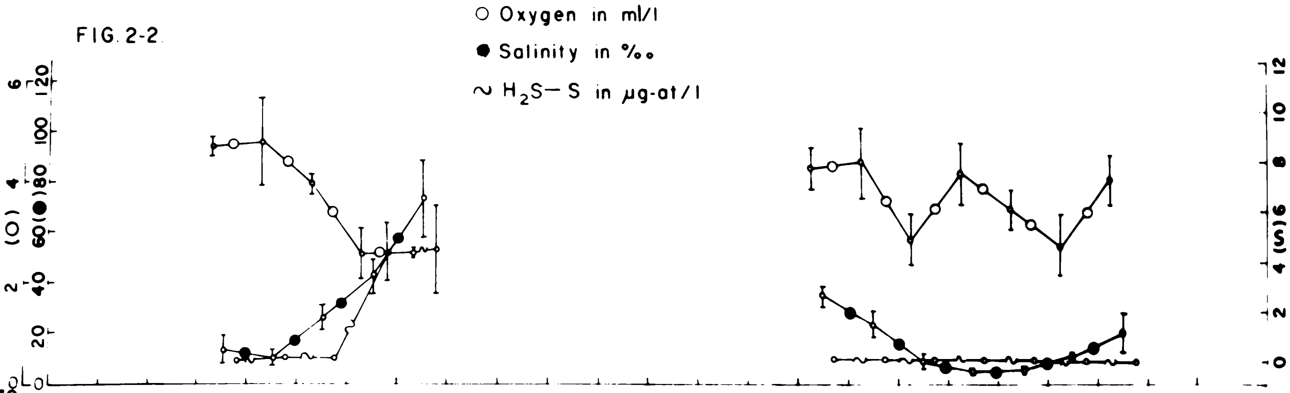


FIG. 2-3.

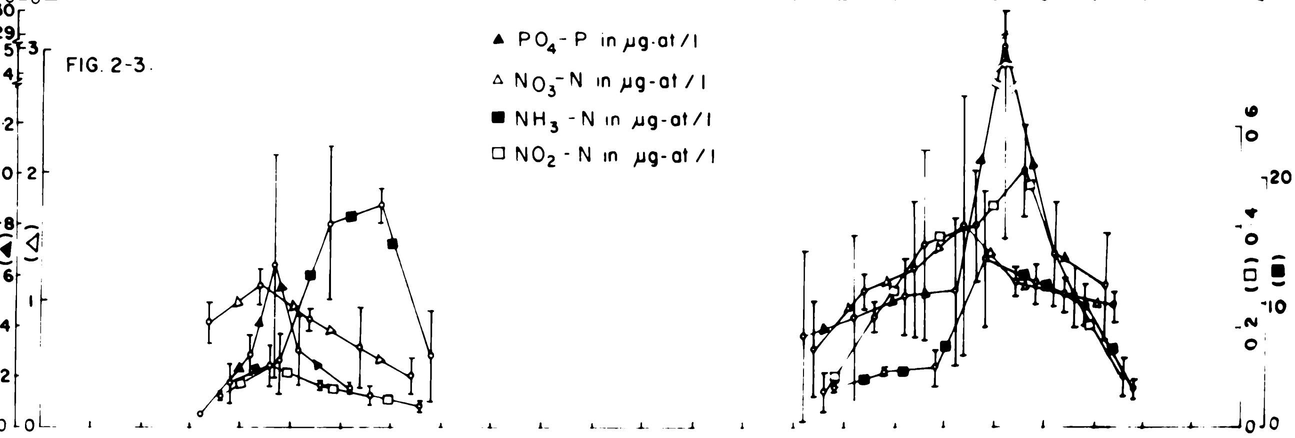
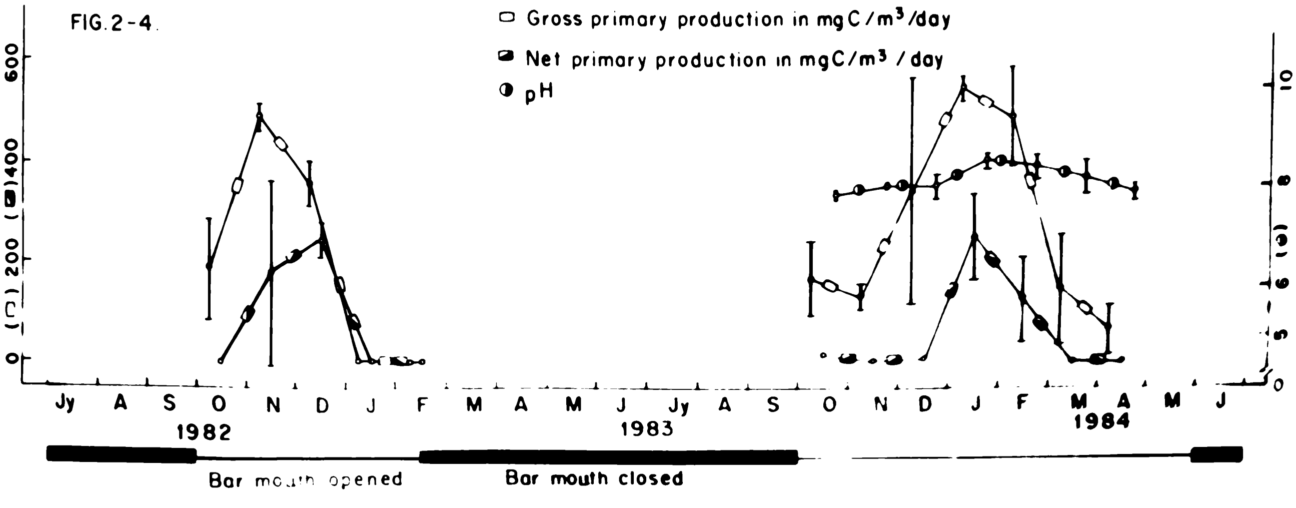


FIG. 2-4.



Soluble reactive phosphate content was at its peak in December(0.63 µg-at PO_4-P/l). A sharp increase in its value was recorded from October(0.05 µg-at PO_4-P/l) to November(0.20 µg-at PO_4-P/l), and a steep decline was observed till February(0.15 µg-at PO_4-P/l)(Fig.2-3). Nitrate concentration was at its peak in November(1.10 µg-at NO_3-N/l). It started declining steadily, and arrived at the minimum level in February(0.39 µg-at NO_3-N/l) (Fig.2-3). Nitrite concentration showed a similar pattern as that of the nitrate. From October(0.06 µg-at NO_2-N/l) to November(0.12 µg-at NO_2-N/l) a sharp rise was noted, which was followed by a constant and gradual decrease upto February(0.04 µg-at NO_2-N/l)(Fig.2-3). Ammonia concentration recorded an increase from November(5.02 µg-at NH_3-N/l) to December(15.85 µg-at NH_3-N/l), which was followed by a peak in January(17.30 µg-at NH_3-N/l). Subsequently, the ammonia concentration in the water declined in February(5.53 µg-at NH_3-N/l)(Fig.2-3). No trace of hydrogen sulphide content in the water could be observed from October to December. It was recorded only in January(4.16 µg-at H_2S-S/l) and February(4.38 µg-at H_2S-S/l)(Fig.2-2).

Temperature of the sediment decreased sharply from October (25.8°C) to November(23.1°C) and subsequently its values increased constantly till February(26.2°C)(Fig.4-1). There was a steep increase in the organic carbon content of the sediment from October(0.36% dry wt) to November(0.55% dry wt) which was followed by a gradual decrease upto February(0.38% dry wt) (Fig.4-2). Total phosphorus content of the sediment showed sharp increase from October(65.1 μg/g dry wt) to November(295.4 μg/g dry wt)(Fig.4-2). From the undetectable level of Kjeldahl nitrogen in October, a sudden increase was noted in November (0.230% NH_3-N dry wt) which was followed by a fairly sharp decrease until February(0.056% NH_3-N dry wt)(Fig.4-2). The total sulphide content of the sediment decreased sharply from October(26.4 μg/g wet wt) to November(4.4 μg/g wet wt). A steep increase in its value was noticed from December(5.2 μg/g wet wt) to January(22.0 μg/g wet wt) and maximum concentration was recorded in February(33.3 μg/g wet wt)(Fig.4-1).

4.2.1.2. Productivity:

Gross primary production rate was estimated in October, November and December with values at 183.7 mgC/m^3/day, 481.7 mgC/m^3/day and 354.6 mgC/m^3/day respectively. During January and February no gross production was observed (Fig.2-4). Net primary production rate was noticed in November(173.0 mgC/m^3/day) and December(237.5 mgC/m^3/day)(Fig.2-4)

4.2.2 Second year (October 1983 to April 1984):

4.2.2.1 Hydrography and sedimentology:

In Station-I, water flooded in October and this condition persisted till April. The maximum level recorded was in October (68 cm), and subsequently a decreasing trend was noticed. Fairly constant water level persisted at this station in December and January and then it declined rapidly to minimum level(5 cm) in April (Fig.2-1). The air temperature fluctuated between 24.0

& 27.0°C during the period October to January and the minimum value was recorded in November(25.2°C). From November, a sharp increase was noted upto February(28.7°C) which was followed by a gradual increase till April(29.9°C)(Fig.2-1). Water temperature also followed the same pattern as that of air temperature. Between October and January it fluctuated between 24.0 & 27.0°C with a minimum value in December(24.7°C). A steep rise was noticed in February(28.4°C) and the value gradually increased till April (30.3°C)(Fig.2-1). There was an uneven fluctuation in the distribution of dissolved oxygen content of the water. The initial concentration of 4.29 ml/l in October reached the primary maximum in November(4.42 ml/l), and subsequently low value was observed in December(2.89 ml/l). A sharp increase in oxygen value was noticed in January(4.20 ml/l), which was followed by a gradual decrease in its concentration till March(2.83 ml/l). This was succeeded by a steep increase in April when a concentration of 4.12 ml/l was recorded (Fig.2-2). Salinity values declined gradually from October(34.0‰) onwards and recorded the minimum value in January(6.2‰). Fairly constant increase in its value was noticed till April(20.0‰)(Fig.2-2). The pH of water steadily increased from October(7.79) and the maximum value was recorded in January(8.49) and then a gradual decline was observed till April(7.90)(Fig.2-4).

Soluble reactive phosphate values showed gradual increase from October(0.36 μg-at PO_4-P/l) to January(0.54 μg-at PO_4-P/l). In February, an abrupt increase in its value was recorded(15.07 μg-at PO_4-P/l). There was a steady decrease in the phosphate content in the months of March(0.69 µg-at PO_4-P/l) and April (0.56 µg-at PO_4-P/l)(Fig.2-3). Nitrate content increased sharply from October(0.62 µg-at NO_3-N/l) till January(1.60 µg-at NO_3-N/l) with wide fluctuations. Afterwards it started declining gradually till April(0.95 µg-at NO_3-N/l) (Fig.2-3). From October(0.07 µg-at NO_2-N/l) to November(0.22 µg-at NO_2-N/l), there was a moderate increase in the nitrite concentration and this was followed by a gradual increase through December(0.36 µg-at NO_2-N/l) and January(0.40 µg-at NO_2-N/l) to arrive at the maximum in February(0.51 µg-at NO_2-N/l). Subsequently, there was a sharp decrease in the nitrite concentration in March(0.26 µg-at NO_2-N/l) (Fig.2-3). From October to December, ammonia concentration was found to fluctuate between 3.00 & 5.00 µg-at NH_3-N/l. An abrupt increase in its concentration was observed in January(13.44 µg-at NH_3-N/l) followed by a gradual decrease through February(11.37 µg-at NH_3-N/l) and March(9.77 µg-at NH_3-N/l) with a further steep drop in April (2.95 µg-at NH_3-N/l)(Fig.2-3). There was no trace of hydrogen sulphide in the water during this year (Fig.2-2).

From October(28.5°C) to November(25.1°C), there was a fall in the temperature of the sediment. In December(25.6°C) and January(24.8°C) fluctuation in temperature values was recorded. This was followed by a sudden increase in February (28.8°C) and the values recorded a rising trend upto April (30.2°C)(Fig.4-1). The pH of sediment increased from October (7.15) to November(7.99) and this was followed by a gradual and moderate decrease upto April(7.17)(Fig.4-1). Eh values of the sediment sharply increased from October(-235 mV) to November (-54 mV). After December(-59 mV), Eh values decreased continuously and was relatively constant in April(-271 mV) (Fig.4-1).

The organic carbon content values showed a primary maximum in November(0.48% dry wt) followed by a slight decrease in January(0.42% dry wt). Subsequently, in February the organic carbon content evinced a value of 0.65% dry wt which declined sharply in March(0.39% dry wt)(Fig.4-2). Total phosphorus content of the sediment increased steadily from October(60.5 µg/g dry wt) to November(251.6 µg/g dry wt). After registering a decline in December(238.9 µg/g dry wt) and January(153.1 µg/g dry wt), it recorded an increase in February (351.6 µg/g dry wt) which was followed by a sudden fall in March(120.9 µg/g dry wt)(Fig.4-2). The level of Kjeldahl nitrogen was very meagre in October, but in November it recorded a value of 0.148% NH_3-N dry wt. Subsequently, the values declined in December(0.064% NH_3-N dry wt) and January(0.053% NH_3-N dry wt). Its distribution indicated a rise in February(0.163% NH_3-N dry wt), after which a sudden fall in its value in March(0.060% NH_3-N dry wt) was observed (Fig.4-2). The total sulphide content of the sediment decreased from a concentration of 28.6 µg/g wet weight in October, to zero level in November and December. From January(6.3 µg/g wet wt) onwards a steady increase was noted, and in April a value of 24.9 µg/g wet wt was recorded(Fig. 4-1).

4.2.2.2 Productivity:

Gross production values in October and November were 168.2 mgC/m^3/day and 126.5 mgC/m^3/day respectively. It recorded an increase in December(336.7 mgC/m^3/day)(Fig.2-4). After attaining a peak in January(542.4 mgC/m^3/day) the values declined gradually in February(486.7 mgC/m^3/day), March(141.5 mgC/m^3/day) and April (64.5 mgC/m^3/day). Net primary production rate was observed in January at 248.7 mgC/m^3/day and in February at 122.2 mgC/m^3/day (Fig.2-4).

4.3 Station-II:

4.3.1 First year (September 1982 to April 1983):

4.3.1.1 Hydrography and sedimentology:

In Station-II, although water was present in September, the water level reached its maximum only in November(64 cm) followed by a gradual decline till April(10 cm)(Fig.3-1). Air temperature showed insignificant variation during September and October and subsequently its values declined in December (25.4°C), after which a steady increase was noted till April (30.2°C)(Fig.3-1). Water temperature evinced the same fluctuation as that of the air temperature, and the values gradually decreased from October(27.6°C) to January(23.9°C) and subsequently increased rapidly till April(29.0°C)(Fig.3-1). Dissolved oxygen content was low in September(1.91 ml/l) and a sharp increase was recorded in October(3.16 ml/l) and

STATION - II

Fig. 3-1 Distribution of air temperature, water temperature and depth.

Fig. 3-2 Distribution of oxygen, salinity and hydrogen sulphide

Fig. 3-3 Distribution of soluble reactive phosphate, nitrate, ammonia and nitrite

Fig. 3-4 Distribution of the rates of gross primary production, net primary production and pH.

FIG. 3-1

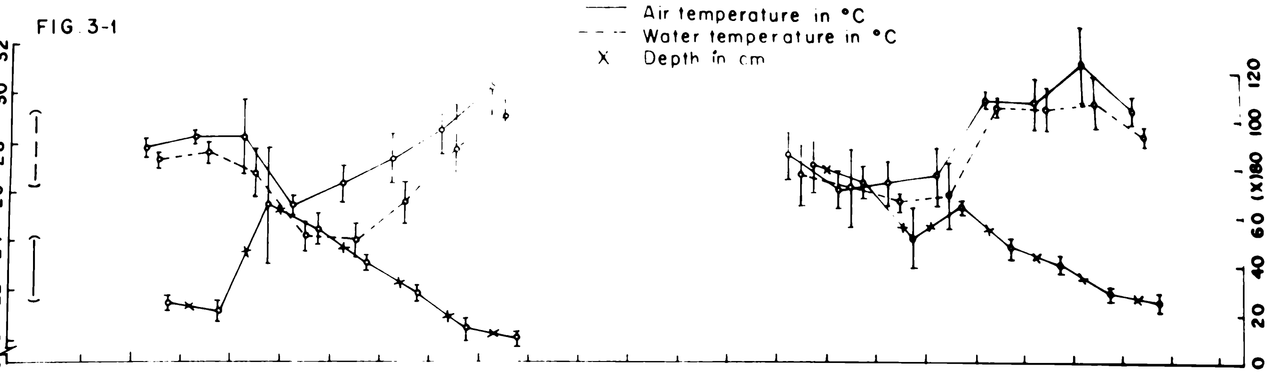


FIG. 3-2

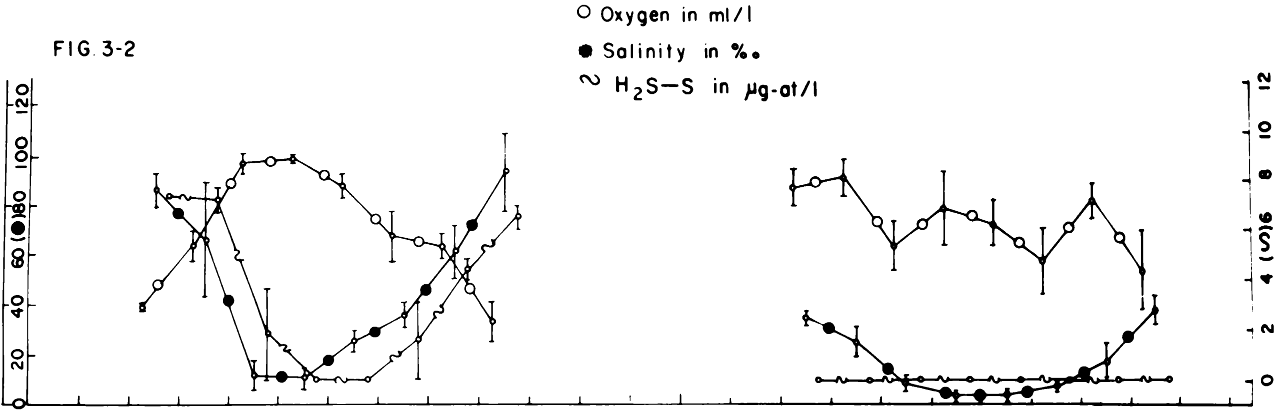


FIG. 3-3

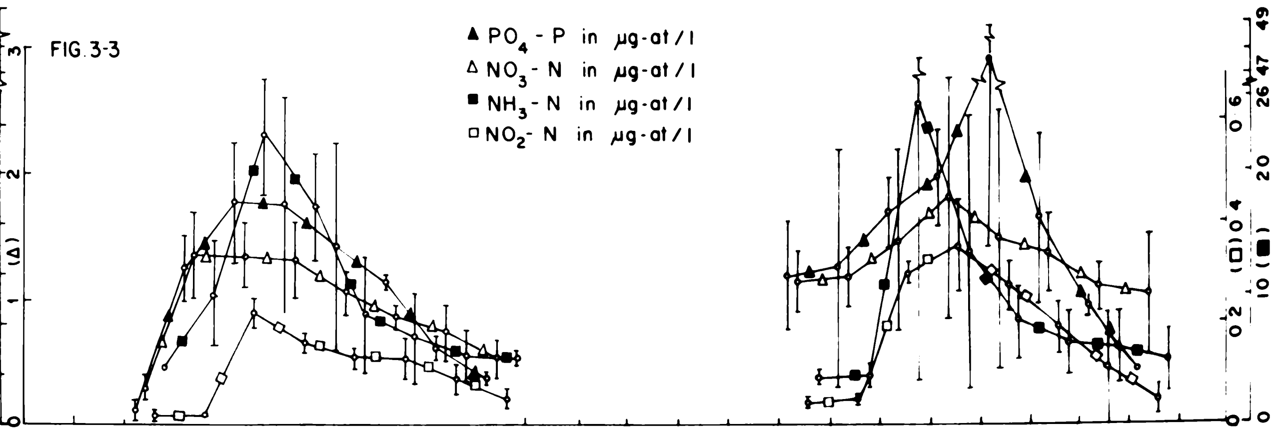
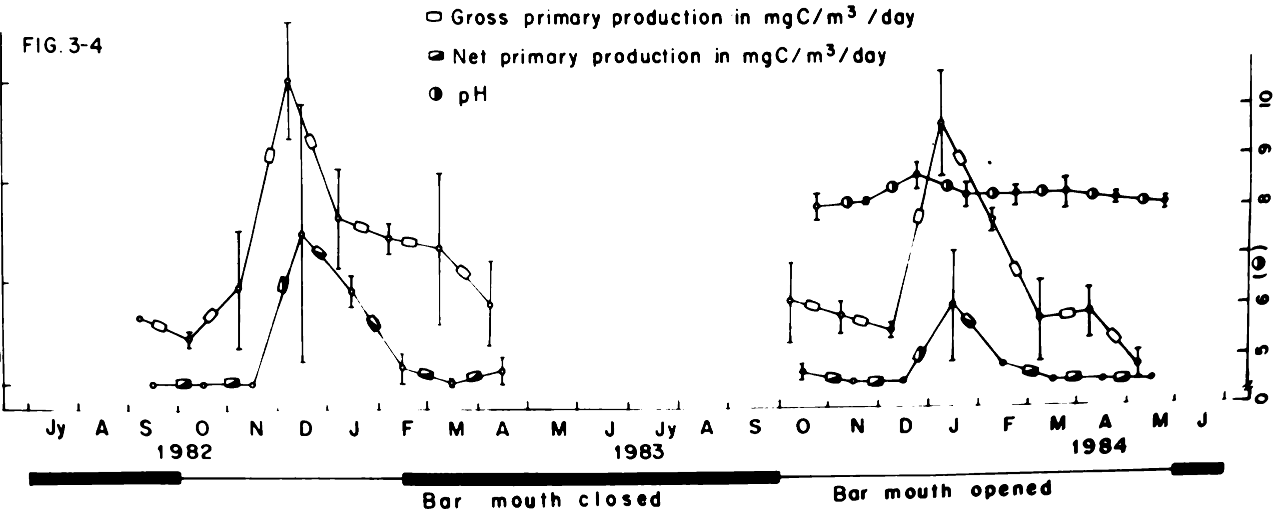


FIG. 3-4



November(4.82 ml/l). In December, the oxygen content of the water was as high as 4.91 ml/l which gradually decreased in March(3.15 ml/l). In April, oxygen content was low(1.67 ml/l) (Fig.3-2). Salinity showed high value in September(86.4‰) and as the monsoon advanced its values dropped and in November it was 12.2‰. From December onwards a steady and rapid increase in its values was noticed till April(92.5‰)(Fig.3-2).

Soluble reactive phosphate concentration was low in September(0.07 µg-at PO_4-P/l) and a sharp rise in its value was observed in October(0.62 µg-at PO_4-P/l) subsequent to which there was high fluctuation in its value. The primary maximum was recorded in January(0.87 µg-at PO_4-P/l). Later, the soluble reactive phosphate concentration gradually declined till April (0.18 µg-at PO_4-P/l)(Fig.3-3). Nitrate concentration was low in September(0.30 µg-at NO_3-N/l) followed by a steep increase in October(1.33 µg-at NO_3-N/l). Till January, the concentration of nitrate mostly varied from 1.00 to 1.50 µg-at NO_3-N/l . Subsequently, the value gradually declined to 0.51 µg-at NO_3-N/l in April(Fig.3-3). The distribution of nitrite concentration showed the same trend as that of nitrate. An abrupt increase in its concentration was recorded from October(0.02 µg-at NO_2-N/l) to November(0.22 µg-at NO_2-N/l) after which a gradual decline was observed till April(0.05 µg-at NO_2-N/l)(Fig.3-3). The concentration of Ammonia was 4.37 µg-at NH_3-N/l in September, which showed an increased value of 22.66 µg-at NH_3-N/l in November. A fairly constant concentration was maintained in December(17.10 µg-at NH_3-N/l) which declined gradually till

April(5.09 µg-at NH_3-N/1)(Fig.3-3). Hydrogen sulphide was present in the water in September(7.41 µg-at H_2S-S/1) and subsequently it was recorded only in February(1.58 µg-at H_2S-S/1). The sulphide content gradually increased till April(6.48 µg-at H_2S-S/1)(Fig. 3-2).

From September(28.7°C), the temperature of the sediment gradually declined till December(23.4 °C) and subsequently a steady increase was noted till April(29.6°C)(Fig.4-3). Organic carbon content of sediment increased from October(0.11% dry wt) to November(0.31% dry wt) and then a rapid increase was noted in December(1.05% dry wt) which was followed by a gradual decrease till April(0.27% dry wt)(Fig.4-4). The total phosphorus content was low in October(42.9 µg/g dry wt) and November(9.10 µg/g dry wt) and high in December(319.8 µg/g dry wt). A gradual decrease in its value was noted from December upto March(158.4 µg/g dry wt). This was followed by an abrupt fall in April(48.4 µg/g dry wt)(Fig.4-4). Detectable level of Kjeldahl nitrogen was present from November to March. The peak value of Kjeldahl nitrogen recorded in December(0.190% NH_3-N dry wt) was preceded by low value in November(0.057% NH_3-N dry wt). Its concentration slowly decreased from January(0.099% NH_3-N dry wt) upto March (0.068% NH_3-N dry wt)(Fig. 4-4). Total sulphide content of the sediment fluctuated between 56.0 & 70.0 µg/g wet wt during the period September to November with a peak in October(69.6 µg/g wet wt). The total sulphide concentration was low in December (16.2 µg/g wet wt) and increased steadily till April(56.2 µg/g wet wt)(Fig.4-3).

STATION - I

Fig. 4-1 Distribution of temperature, total sulphide, pH and Eh of the sediment.

Fig. 4-2 Distribution of organic carbon, total phosphorus and Kjeldahl nitrogen contents of the sediment.

STATION - II

Fig. 4-3 Distribution of temperature, total sulphide, pH and Eh of the sediment.

Fig. 4-4 Distribution of organic carbon, total phosphorus and Kjeldahl nitrogen contents of the sediment.

FIG 4-1

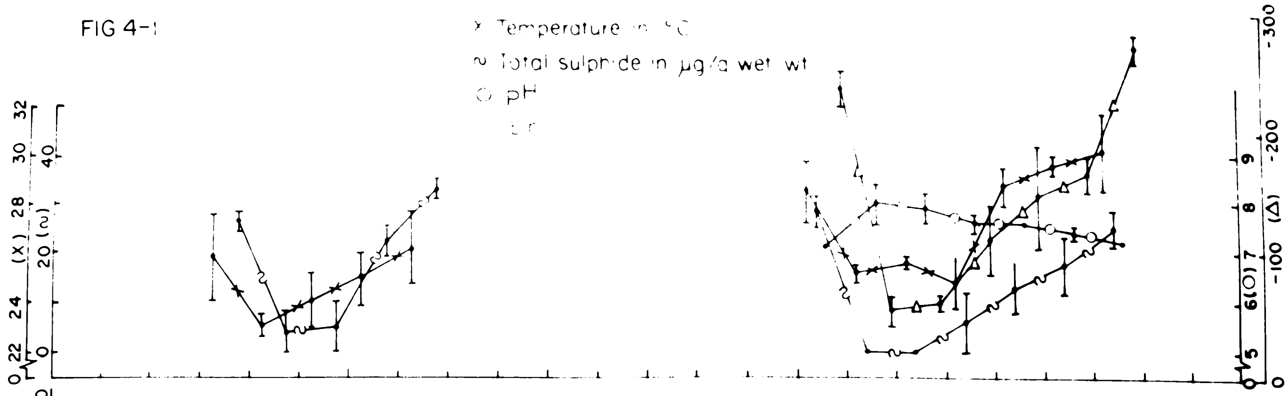


FIG 4-2

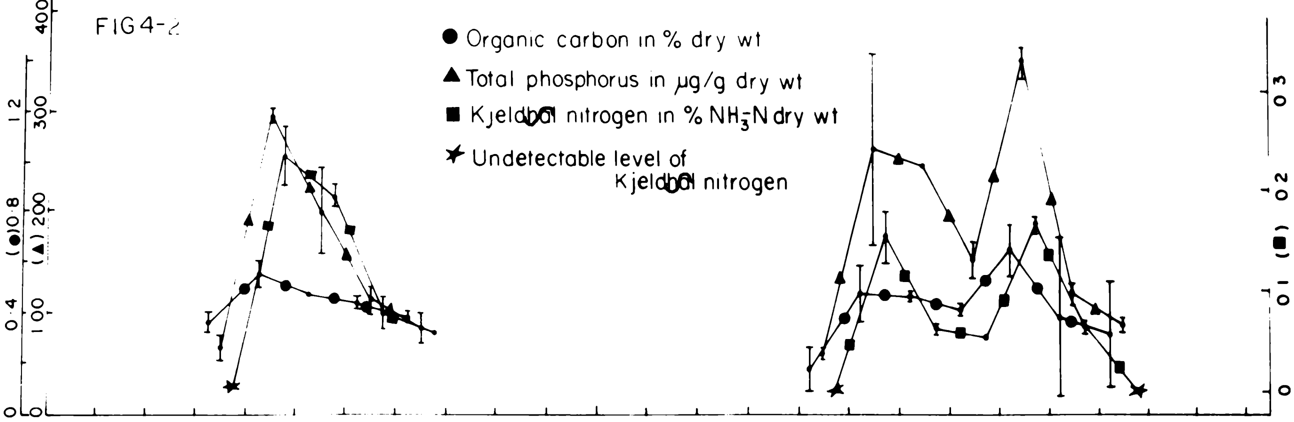


FIG 4-3

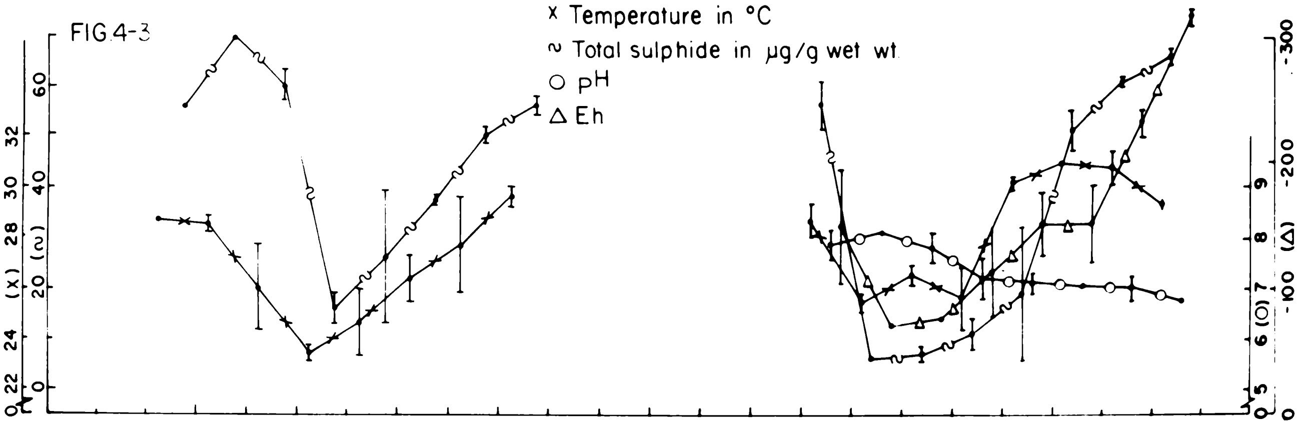
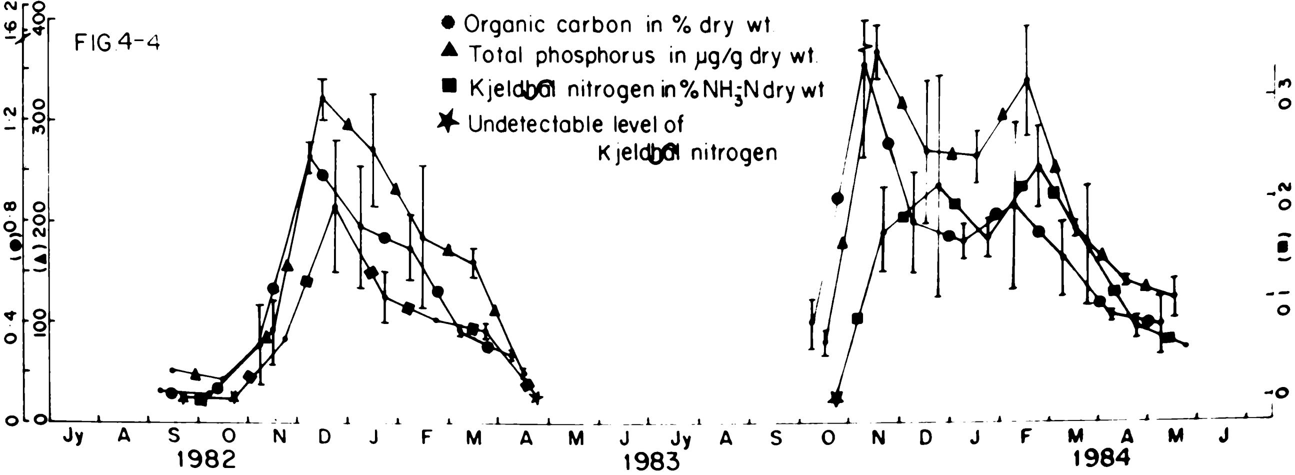


FIG 4-4



4.3.1.2 Productivity:

Gross primary production rate was low in September (128.6 mgC/m^3/day) and October(98.1 mgC/m^3/day) and it reached a peak in December(601.7 mgC/m^3/day), after which a gradual decline was noted till April(270.0 mgC/m^3/day)(Fig.3-4). No net primary production was recorded from September to November but in December the rate was at 298.7 mgC/m^3/day. This peak in net primary production rate gradually declined in March, and in April the value recorded was 23.8 mgC/m^3/day(Fig.3-4).

4.3.2 Second year (October 1983 to May 1984):

4.3.2.1 Hydrography and sedimentology:

Water flooded this station in October with a maximum level of 80 cm, and started declining slowly till January(63 cm). Afterwards a steady decrease was noticed till May(25 cm)(Fig.3-1). Minimum air temperature was recorded in November(26.0°C). The overall trend showed an drratic pattern. The maximum level was recorded in April(31.3°C)(Fig.3-1). The pattern of distribution of water temperature was almost similar to that of the air temperature. From October(26.6°C), there was a gradual decrease and the minimum was observed in December(25.5°C). From December, a gradual increase in its values was noticed upto April(29.7°C) after which a slight fall was observed in May(28.3°C)(Fig.3-1). There was an uneven fluctuation in the distribution of dissolved oxygen. Dissolved oxygen concentration recorded maximum value in November(4.55 ml/l) and minimum in May(2.66 ml/l). However, oxygen level throughout the period of study almost always fluctuated between 3.00 & 4.50 ml/l (Fig.3-2). The value of salinity was almost the same as that of the Palk Bay in October (34.8‰) and started declining steadily upto February(3.9‰) as a consequence of the freshwater inflow. Subsequently, a gradual increase in the salinity values was noticed upto May(38.2‰) (Fig.3-2). The pH of water exhibited alkaline condition in October(7.97), the values of which increased gradually to attain 8.56 in December. Later, gradual decrease in pH with mild fluctuation was noticed till May(7.99)(Fig.3-4).

Soluble reactive phosphate concentration started increasing from October(0.58 µg-at PO_4-P/l) to January(0.97 µg-at PO_4-P/l) and the peak value was registered in February(15.49 µg-at PO_4-P/l). From March(0.81 µg-at PO_4-P/l) onwards the soluble reactive phosphate concentration gradually decreased to 0.21 µg-at PO_4-P/l in May (Fig.3-3). Throughout the period, the concentration of nitrate usually ranged from 1.00 to 2.00 µg-at NO_3-N/l with a peak in January(1.78 µg-at NO_3-N/l) to be followed by a steady decline to reach the minimum concentration in May(1.02 µg-at NO_3-N/l)(Fig.3-3). There was a sudden increase in nitrite concentration in December(0.30 µg-at NO_2-N/l) in comparison to its value in November(0.05 µg-at NO_2-N/l). There was a slight increase in its value in January(0.35 µg-at NO_2-N/l) followed by a steady decline upto May(0.05 µg-at NO_2-N/l) (Fig.3-3). Ammonia concentration evinced an increase from November(3.79 µg-at NH_3-N/l) to December(25.39 µg-at NH_3-N/l) which then decreased gradually till May(4.91 μg-at NH_3-N/l) (Fig.3-3). There was absolutely no trace of hydrogen sulphide content in the water during the period of observation(Fig.3-2).

The temperature of sediment recorded 28.7°C in October which decreased suddenly to 25.4°C in November and then maintained a fairly steady trend till January(25.6°C). A sharp rise was felt in February(30.2°C) followed by a gradual increase in March(30.9°C), with a slight but steady decline till May(29.3°C) (Fig.4-3). The pH of sediment increased from October(7.85) to November(8.11), to be followed by a relatively mild decrease upto May(6.77)(Fig.4-3). The Eh of the sediment increased from October(-148 mV) to November(-70 mV) to be followed by a constant but sharp decrease till May(-336 mV)(Fig.4-3).

Sharp increase in the value of the organic carbon content of the sediment was noticed from October(0.40% dry wt) to November(1.42% dry wt) which then declined in December(0.80% dry wt) and fluctuated between 0.70 and 1.00% dry weight till February. From March(0.66% dry wt) onwards a downward trend in its value was noticed upto May(0.39% dry wt)(Fig.4-4). Total phosphorus content displayed a primary maximum in November(368.6 μg/g dry wt). After recording a slight decline, its value in Bebruary was 339.3 μg/g dry wt. Subsequently, a sudden decline occurred in March(195.0 μg/g dry wt) which was followed by a gradual decrease upto May(125.1 μg/g dry wt)(Fig.4-4). Except in October, the Kjeldahl nitrogen was detected in all the other months. Maximum concentration was recorded in February(0.235% NH_3-N dry wt). However, the values fluctuated between 0.150 and 0.200% NH_3-N dry wt till March(0.156% NH_3-N dry wt) to be followed by a steep decrease till May(0.053% NH_3-N dry wt) (Fig.4-4). Total sulphide concentration of the sediment showed a sharp decrease from October(56.2 µg/g wet wt) to November (6.25 µg/g wet wt) and then fluctuated between 6.0 and 14.0 µg/g wet wt till January. After registering a moderately high value in February(19.1 µg/g wet wt), the total sulphide level in the sediment increased during the rest of the period and the peak value was recorded in May(66.7 µg/g wet wt)(Fig.4-3).

.3.2.2 Productivity:

Gross primary production rate was at its peak in January (514.6mgC/m^3/day) which was preceded by low values from October (155.8 mgC/m^3/day) to December(96.3 mgC/m^3/day) and succeeded by sharp and steady decline till May(27.9 mgC/m^3/day)(Fig.3-4). Except for the values of 16.2, 145.8 and 30.8 mgC/m^3/day in October, January and February respectively, no net primary production could be recorded mainly due to the high rate of dark assimilation (Fig.3-4).

4.4 Station-III:

1.4.1 First year (July 1982 to June 1983):

1.1.1. Hydrography and sedimentology:

The level of water gradually increased from August(20 cm) to October(35 cm) and attained its maximum in November(77 cm), after which a steady decrease was noted till April(12 cm). From April to June, water level showed variation from 10 to 17 cm (Fig.5-1). Temperature of the air fluctuated between 29.0 and 30.0°C from July to October and subsequently declined to minimum in December(26.0°C). This was followed by a gradual increase in the air temperature till March(29.4°C) and it varied between 29.0 and 32.0°C till June with a peak in May(31.0°C) (Fig.5-1). The temperature of water followed the same trend as that of the temperature of air with minimum values recorded in December(24.7°C) and January(24.3°C). Between July and October and March and June, the water temperature fluctuated between 28.0 and 31.0°C(Fig.5-1). A decrease in dissolved oxygen content was noticed from July(2.54 ml/l) to September(2.09 ml/l) after which a steep increase was observed till November(5.00 ml/l). From December(5.13 ml/l) onwards, a steady decline was observed in the oxygen concentration till May(1.71 ml/l)(Fig.5-2). High saline condition was noticed from July(72.1‰) to October (58.7‰) with a peak in August(102.1‰). In November(20.6‰), an abrupt shift to brakish water condition was observed, and this condition existed through December(13.9‰) and January(26.0‰). A sharp increase to hypersaline condition was observed till June(110.4‰)(Fig.5-2).

Soluble reactive phosphate content of water varied between 0.15 and 0.35 μg-at PO_4-P/l from July to October and the values evinced an increasing trend till January(0.83 μg-at PO_4-P/l) after which a gradual decrease in its values was noticed

STATION - IV

Fig. 5-1 Distribution of air temperature, water temperature and depth

Fig. 5-2 Distribution of oxygen, salinity and hydrogen sulphide

Fig. 5-3 Distribution of soluble reactive phosphate, nitrate, ammonia and nitrite

Fig. 5-4 Distribution of the rates of gross primary production, net primary production and pH.

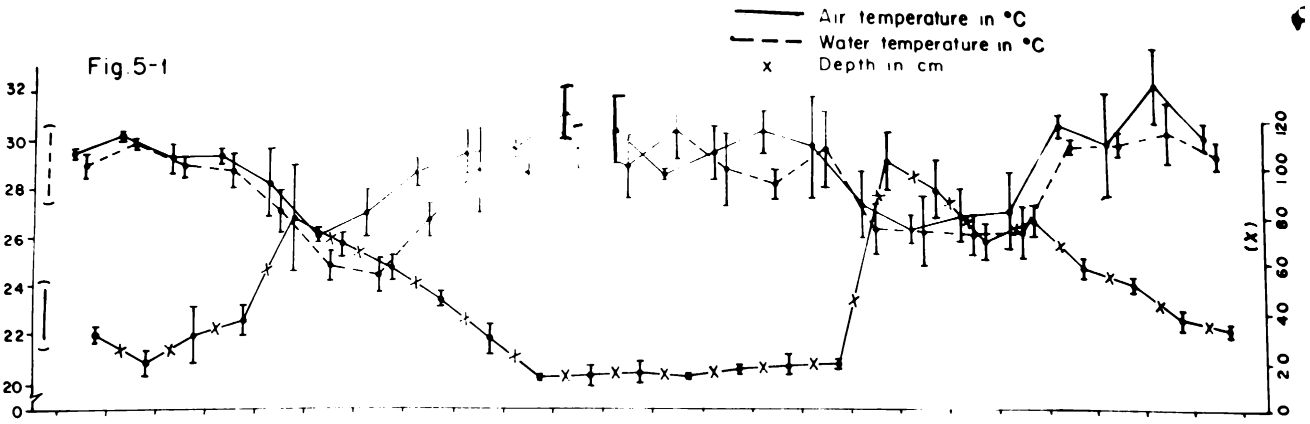


Fig. 5-1

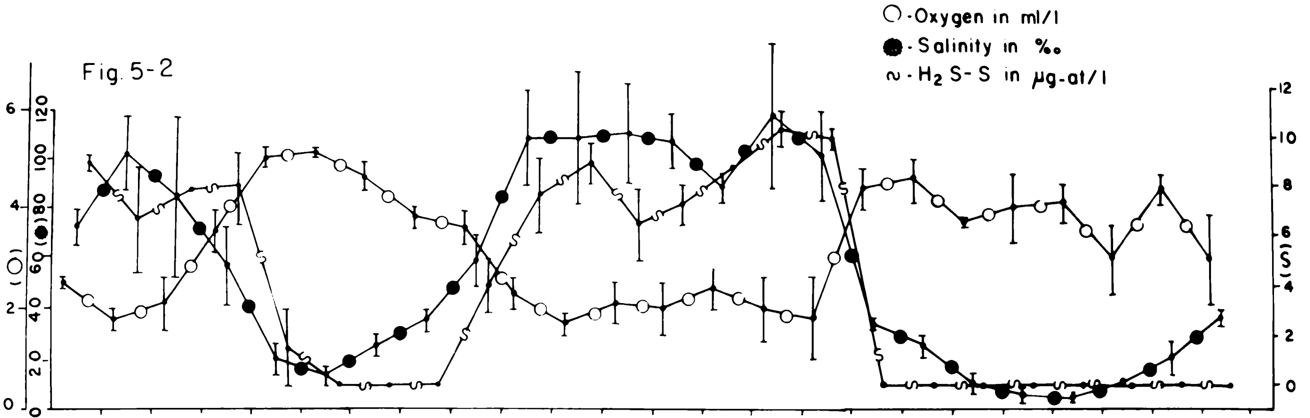


Fig. 5-2

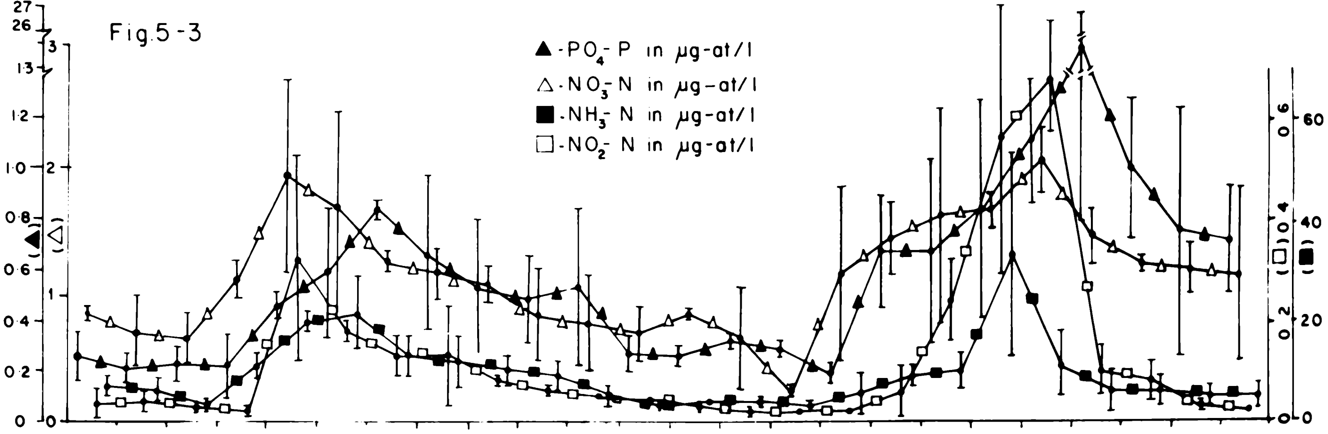


Fig. 5-3

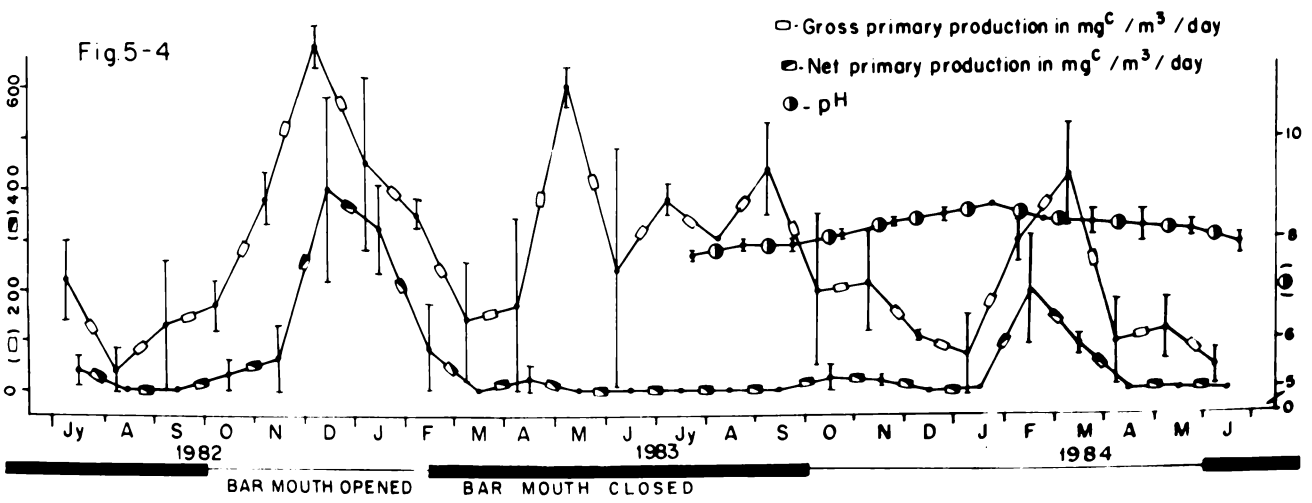


Fig. 5-4

till June(0.27 µg-at PO_4-P/l)(Fig.5-3). The nitrate content of water recorded low concentration (0.50 to 1.00 µg-at NO_3-N/l) from July to September and it increased in October(1.12 µg-at NO_3-N/l) to reach its peak in November(1.94 µg-at NO_3-N/l). A gradual decrease in its value was observed till July(0.69 µg-at NO_3-N/l)(Fig.5-3). Nitrite content followed the same trend as that of nitrate. Low values were recorded in the nitrite concentration (0.02 to 0.05 µg-at NO_2-N/l) from July to October. It attained its peak in November(0.32 µg-at NO_2-N/l) and the values gradually decreased from December(0.18 µg-at NO_2-N/l) to June(0.04 µg-at NO_2-N/l)(Fig.5-3). Low ammonia concentration in water(2.00 to 9.00 µg-at NH_3-N/l) was recorded from July to September followed by a sharp increase in October(11.03 µg-at NH_3-N/l). Gradual increase in its content was noticed upto December(21.59 µg-at NH_3-N/l) after which a sharp decline was observed in January(12.93 µg-at NH_3-N/l), and subsequently it decreased to 3.36 µg-at NH_3-N/l in June(Fig.5-3). Hydrogen sulphide content of water fluctuated from 4.00 to 9.00 µg-at H_2S-S/l between July and October. In November(1.45 µg-at H_2S-S/l) it declined sharply and no trace of sulphide was recorded till February. In March(3.94 µg-at H_2S-S/l), hydrogen sulphide content was again traced and mild increase in its values was noticed till June(5.30 µg-at H_2S-S/l)(Fig.5-2).

Temperature of the sediment was high from July(30.4°C) to October(29.6°C) with its peak in August(31.4°C) and the value decreased to 23.8°C in December. A gradual increase in its value was recorded from January(25.8°C) to April(30.6°C) and in June the value recorded was 29.5°C(Fig.7-1). Organic carbon content of the sediment varied from 0.10 to 0.30% dry wt from July to September. A sharp increase was noticed in October (0.57% dry wt) and the peak value was observed in December (0.95% dry wt) which decreased to 0.29% dry wt in June(Fig.7-2). Low total phosphorus content of sediment (20.0 to 65.0 µg/g dry wt) was recorded from July to September after which the value evinced a sharp increase in October(214.5 µg/g dry wt). From November(324.7 µg/g dry wt), the total phosphorus concentration of sediment started declining gradually till June(46.8 µg/g dry wt)(Fig.7-2). Detectable level of Kjeldahl nitrogen of sediment was found only from October(0.060% NH_3-N dry wt) to March(0.050% NH_3-N dry wt). Its peak was observed in November(0.290% NH_3-N dry wt) after which a gradual decrease occurred although a rise in its value was noticed in February(0.120% NH_3-N dry wt)(Fig.7-2). Total sulphide content of sediment gradually increased from July (88.2 µg/g wet wt) to September(93.4 µg/g wet wt) with a moderate decrease in October(73.4 µg/g wet wt) after which its values dropped in November(38.9 µg/g wet wt). From the minimum recorded value in December(15.4 µg/g wet wt), the total sulphide concentration of sediment steadily increased till June(86.0 µg/g wet wt)(Fig.7-1).

4.4.1.2 Productivity:

Relatively low values of gross primary production rate (upto 300.0 mgC/m^3/day) was observed from July to October with minimum production rate recorded in August(42.9 mgC/m^3/day). A moderate rise in its value was noticed in November(377.3 mgC/m^3/day) with the primary maximum in December(680.0 mgC/m^3/day) after which a gradual decline in its values was observed till March(140.1 mgC/m^3/day). Secondary maximum was recorded in May (598.2 mgC/m^3/day) which declined in June(244.2 mgC/m^3/day) (Fig.5-4). Very low net primary production (Upto 125.0 mgC/m^3/day) was noticed from July to November. December(393.1 mgC/m^3/day) and January(323.3 mgC/m^3/day) were characterised by moderate net primary production rates. From February to June the net production was low (Upto 160.0 mgC/m^3/day)(Fig.5-4).

4.4.2 Second year (July 1983 to June 1983):

4.4.2.1. Hydrography and Sedimentology:

The level of water fluctuated from 12 to 20 cm between July and October and attained its maximum in November(101 cm). It oscillated between 60 and 100 cm between December and February followed by a gradual decrease till June(32 cm)(Fig. 5-1). The temperature of air fluctuated between 28.0 and 31.0°C till October after which a sharp decrease was noticed upto December(25.3°C) followed by a gradual rise till February (27.1°C). From March(30.7°C), the values increased rapidly and attained a value of 32.4°C in May(Fig.5-1). The fluctuation in the temperature of water resembled that of the temperature of air. Between July and October and March and June, the temperature of water varied between 27.0 and 31.5°C. Minimum values were recorded from November(26.3°C) to February(26.2°C)

(Fig.5-1). Dissolved oxygen content of water ranged between 1.00 and 2.50 ml/l from July to October. A sharp rise in its concentration was observed in November(4.42 ml/l) followed by a peak value recorded in December(4.55 ml/l). Oxygen level fluctuated between 3.00 and 4.75 ml/l between January and May, followed by a sudden decrease in June(2.95 ml/l)(Fig.5-2). Hypersaline condition existed from July(106.8‰) to October (101.2‰) and recorded a maximum in September(116.5‰). Salinity values evinced a decreasing trend from November(34.0‰), and dropped to its minimum in February(5.9‰) and March(5.1‰) after which a rapid increase was observed till June(37.3‰) (Fig.5-2). The pH value recorded in July was 7.73 which increased to 7.78 in September after which a rapid increase was noticed from October(8.12) to January(8.70). Subsequently, gradual decrease in its value was observed till June(7.93) (Fig.5-4).

Low levels of soluble reactive phosphate content was recorded from July to October(0.15 to 0.35 µg-at PO_4-P/l) after which an increase was noticed in its value in November(0.67 µg-at PO_4-P/l) and then a gradual increase till February(1.11 µg-at PO_4-P/l). In March(13.76 µg-at PO_4-P/l), an abrupt increase was observed which declined sharply in April(1.00 µg-at PO_4-P/l) and then a gradual decrease was noted till June(0.71 µg-at PO_4-P/l)(Fig.5-3). Low nitrate concentration was recorded from July to September(0.20 to 0.90 µg-at NO_3-N/l). Gradual increase in its value was observed till February(2.05 µg-at NO_3-N/l) after which it steadily decreased till June(1.16 µg-at NO_3-N/l) (Fig.5-3). Low nitrite concentration was recorded from July to October(0.010 to 0.035 µg-at NO_2-N/l), after which it increased sharply till January(0.560 µg-at NO_2-N/l) and attained its peak in February(0.680 µg-at NO_2-N/l). The value was low in March(0.100 µg-at NO_2-N/l) and subsequently a decrease was noted till June(0.020 µg-at NO_2-N/l)(Fig.5-3). Low ammonia concentration of water(2.50 to 5.00 µg-at NH_3-N/l) was noticed from July to September after which a gradual rise was observed till December(10.16 µg-at NH_3-N/l). After reaching its peak in January(33.08 µg-at NH_3-N/l), the ammonia concentration gradually decreased from February(11.20 µg-at NH_3-N/l) to June(4.81 µg-at NH_3-N/l)(Fig.5-3). The hydrogen sulphide content of water was traced from July(7.09 µg-at H_2S-S/l) to October(9.77 µg-at H_2S-S/l) with its peak in September(10.16 µg-at H_2S-S/l). During the remaining months, hydrogen sulphide content could not be detected in the water(Fig.5-2).

The temperature of sediment fluctuated between 28.0 and 32.0°C from July to November, after which a sharp decrease was observed in December(25.9°C). From January(27.2°C), a gradual increase was noticed upto June(30.1°C)(Fig.7-1). pH of the sediment recorded a value of 6.93 in October and its values varied between 6.93 and 7.50 from July to October. The alkalinity increased in the sediment till December(8.15) and subsequently a gradual decrease was noticed in its values from January(7.95) to April(7.75). A moderate decrease in its value was observed upto June(7.08)(Fig.7-1). The Eh of the sediment was very low (-295 to -320 mV) between July and October after which an increasing trend was noticed in November(-154 mV) and December (-82 mV). From January(-83 mV) onwards a steady decrease was observed till June(-291 mV)(Fig.7-1).

Low level(0.15 to 0.25% dry wt) of organic carbon content of the sediment was recorded from July to October, followed by a steep increase in November(0.55% dry wt). It attained its peak in December(0.79% dry wt) after which a gradual decrease was observed till February(0.57% dry wt). Secondary maximum was recorded in March(0.69% dry wt) followed by a gradual decrease till June(0.46% dry wt)(Fig.7-2). Total phosphorus content of sediment was very low from July to October(30.0 to 60.9 μg/g dry wt). An increase in its value in November(146.3 μg/g dry wt) was followed by the primary maximum in December (306.2 μg/g dry wt). After a decrease, the secondary maximum was recorded in March(304.2 μg/g dry wt) which was followed by a rapid decline in April(129.3 μg/g dry wt) and a gradual decrease till June(89.7μg/g dry wt)(Fig.7-2). Detectable level of Kjeldahl nitrogen in the sediment was present only from November(0.055% NH_3-N dry wt) onwards. Primary maximum was recorded in December(0.409% NH_3-N dry wt) after which a steady decrease was observed till February(0.195% NH_3-N dry wt). Secondary maximum was recorded in March(0.295% NH_3-N dry wt) followed by a sharp decline in its values in April(0.080% NH_3-N/l dry wt) and thereafter a gradual decrease till June

(0.053% NH_3-N dry wt)(Fig.7-2). Total sulphide content of sediment varied between 85.0 & 95.0 ug/g wet wt from July to October and subsequently the values decreased rapidly till December(20.0 ug/g wet wt). A moderate decrease was noticed upto February(11.5 ug/g wet wt) after which a steady increase was recorded till June(68.4 ug/g wet wt)(Fig.7-2).

4.4.2.2 Productivity:

Moderate gross primary production rate was observed from July(377.3 mgC/m^3/day) to September(437.7 mgC/m^3/day) after which a decrease in the rate of primary production was noticed from October(197.3 mgC/m^3/day) to February(295.9 mgC/m^3/day). It attained its peak in March(426.7 mgC/m^3/day) with a sharp decrease in the subsequent months till June(45.0 mgC/m^3/day) (Fig.5-4). Except in October(25.7 mgC/m^3/day), November(22.9 mgC/m^3/day), February(197.2 mgC/m^3/day) and March(90.1 mgC/m^3/day), no net production rate was observed as the dark assimilation rates were found to be very high (Fig.5-4).

4.5 Station-IV:

4.5.1 First year(September 1982 to April 1983):

4.5.1.1 Hydrography and sedimentology:

The depth of water at this station ranged from 27 cm (September) to 11 cm (April). The maximum level recorded was 67 cm (November) after which a gradual but steady decrease was noted in the water level till April (11 cm)(Fig.6-1). After October(31.5°C), the temperature of air decreased

STATION - IV

Fig. 6-1 Distribution of air temperature, water temperature and depth.

Fig. 6-2 Distribution of oxygen, salinity and hydrogen sulphide.

Fig. 6-3 Distribution of soluble reactive phosphate, nitrate, ammonia and nitrite

Fig. 6-4 Distribution of the rates of gross primary production, net primary production and pH.

FIG 6-1

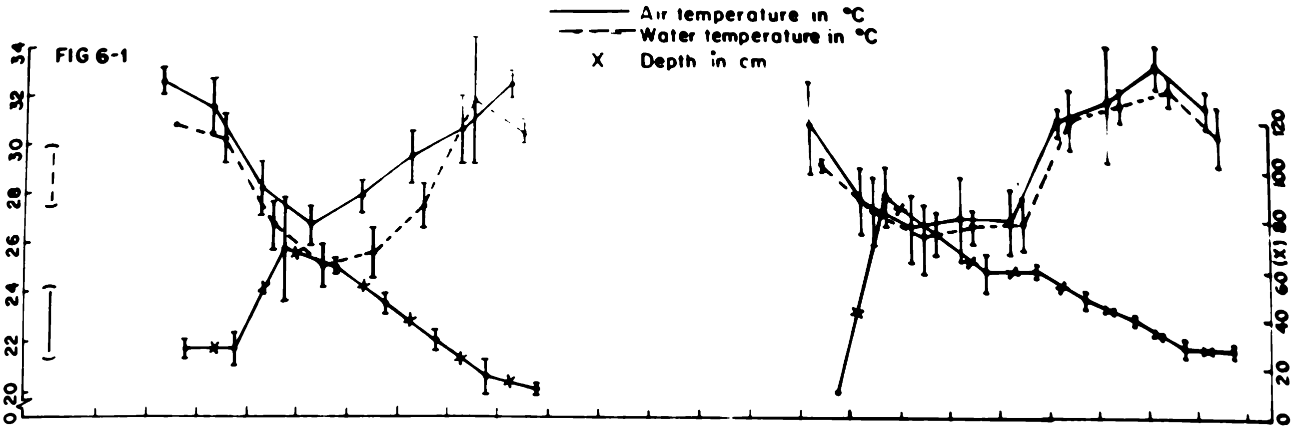


FIG 6-2

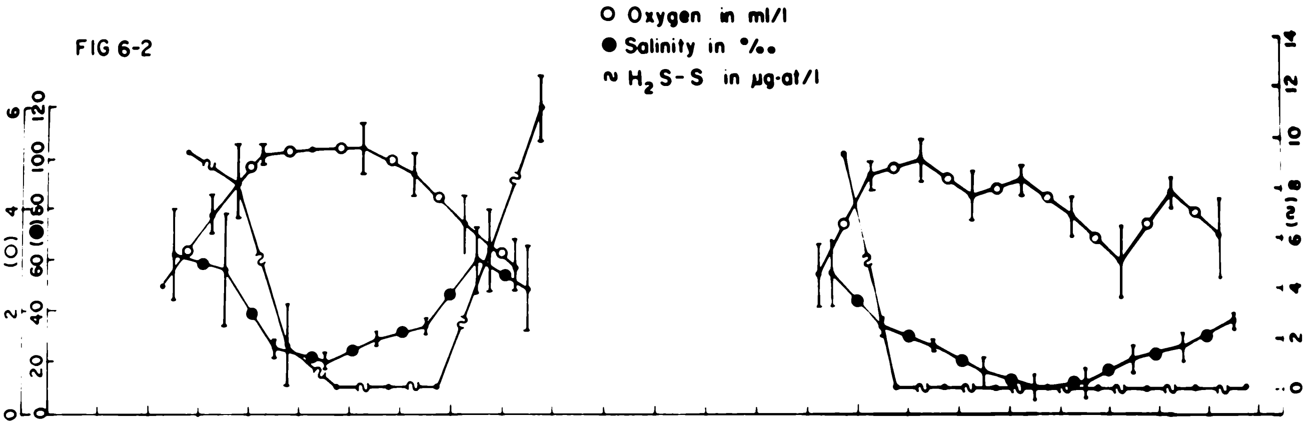


FIG 6-3

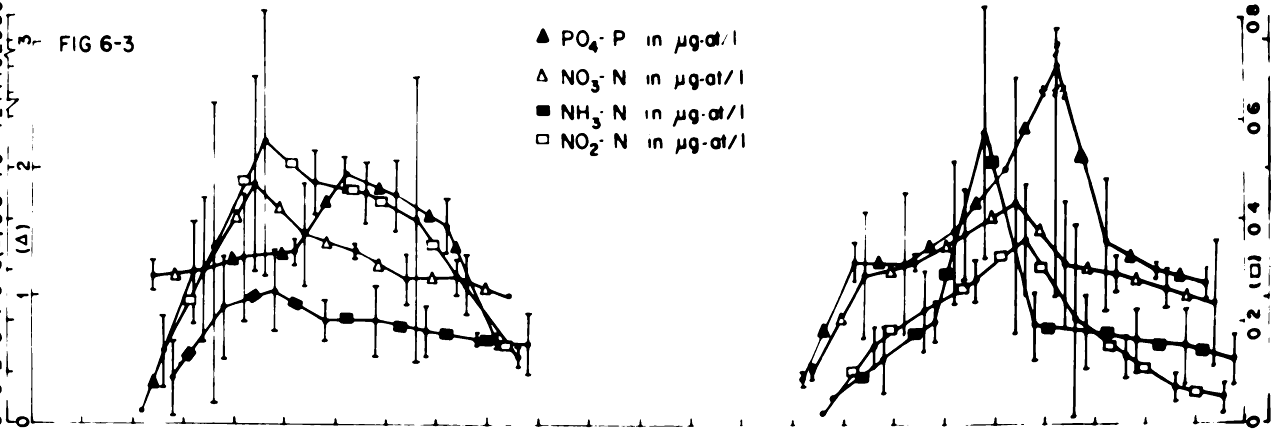
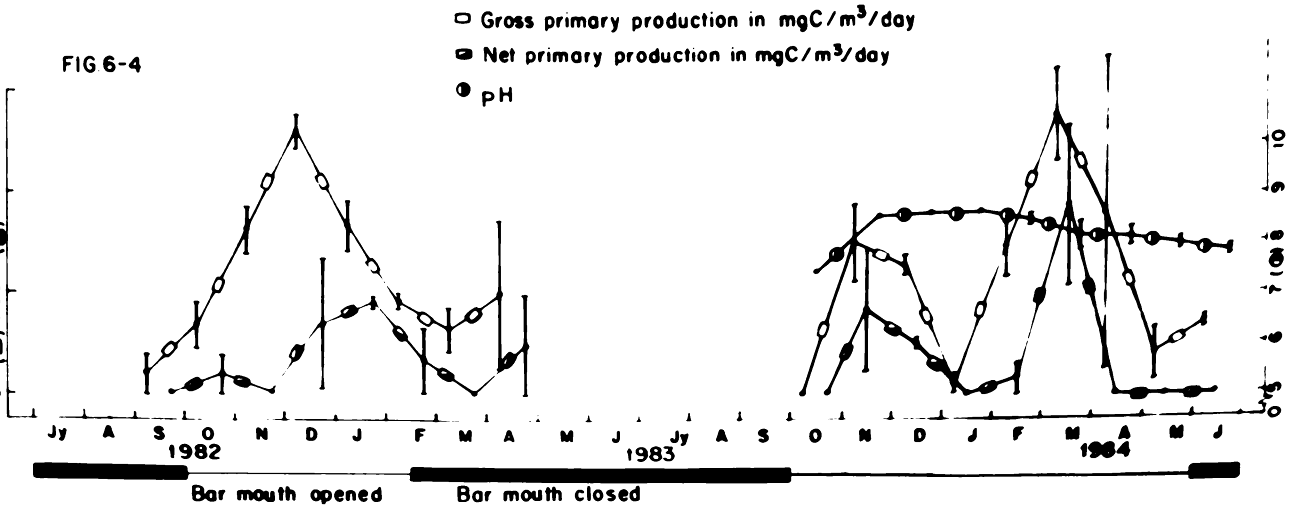


FIG 6-4



steadily upto December(26.7°C) and then gradually rose till April(32.3°C)(Fig.6-1). The temperature of water followed the same trend as that of the air temperature except in March (31.7°C) when it was recorded to be higher than the air temperature. The temperature of water sharply decreased from October(30.2°C) to November(26.7°C) with the minimum values recorded in December(25.0°C) after which a gradual rise was recorded till March(Fig.6-1). The dissolved oxygen content increased sharply from September(2.53 ml/l) to November(5.08 ml/l) and maintained a fairly steady concentration upto January (5.15 ml/l), after which a steady and gradual decrease was noticed till April(2.9 ml/l)(Fig.6-2). Salinity values declined sharply from October(55.7‰) to November(25.4‰) and the minimum was recorded in December(20.1‰). Subsequently, a steady increase was observed with its peak in March(60.0‰) (Fig.6-2).

The soluble reactive phosphate content of water showed a steep increase from September(0.05 µg/at PO_4-P/l) to October (0.59 µg-at PO_4-P/l) after which there was a gradual increase upto December(0.67 µg-at PO_4-P/l), followed by another rise in January(0.97 µg-at PO_4-P/l). Steady decline in its values was noticed till March(0.77 µg-at PO_4-P/l) with an abrupt fall in April(0.32 µg-at PO_4-P/l)(Fig.6-3). Nitrate content registered a peak in November(1.85 µg/at NO_3-N/l) after which a gradual and steady decrease was noticed till April(0.99 µg-at NO_3-N/l) (Fig.6-3). Nitrite concentration followed the same trend as that of the nitrate content and a sharp increase was recorded from September(0.19 µg-at NO_2-N/l) to November(0.55 µg-at NO_2-N/l) followed by a gradual decrease till April(0.13 µg-at NO_2-N/l)(Fig.6-3). From September(3.58 µg-at NH_3-N/l) to October (8.95 µg-at NH_3-N/l) a sudden rise was observed in the ammonia content of the water which was followdd by its peak in November (10.42 µg-at NH_3-N/l). A moderately sharp fall was registered in December(8.01 µg-at NH_3-N/l), after which ammonia content mildly decreased till April(6.22 µg-at NH_3-N/l)(Fig.6-3). The sulphide content of water sharply declined from October(8.11 µg-at H_2S-S/l) to November(1.58 µg-at H_2S-S/l). From December to January, there was no trace of hydrogen sulphide in the water. During March and April the hydrogen sulphide concentration in water were 5.39 and 11.14 µg-at H_2S-S/l respectively(Fig.6-2).

The temperature of the sediment declined rapidly from October(31.7°C) to December(23.8°C) after which a sharp increase was observed till March(31.4°C)(Fig.7-3). A steep increase was noticed in the organic carbon content of the sediment from September(0.17% dry wt) to October(0.41% dry wt). It reached its peak in November(0.75% dry wt) after which a steady and gradual decrease was noted till April(0.37% dry wt) (Fig.7-4). Total phosphorus content of sediment increased sharply from October(69.0 µg/g dry wt) to November(241.8 µg/g dry wt) after which a steady and gradual decrease was recorded till April(73.1 µg/g dry wt)(Fig.7-4). Undetectable level of Kjeldahl nitrogen of the sediment was found in September,

STATION - III

Fig. 7-1 Distribution of temperature, total sulphide pH and Eh of the sediment.

Fig. 7-2 Distribution of organic carbon, total phosphorus and Kjeldahl nitrogen contents of the sediment.

STATION - IV

Fig. 7-3 Distribution of temperature, total sulphide, pH and Eh of the sediment.

Fig. 7-4 Distribution of organic carbon, total phosphorus and Kjeldahl nitrogen contents of the sediment.

FIG 7-1

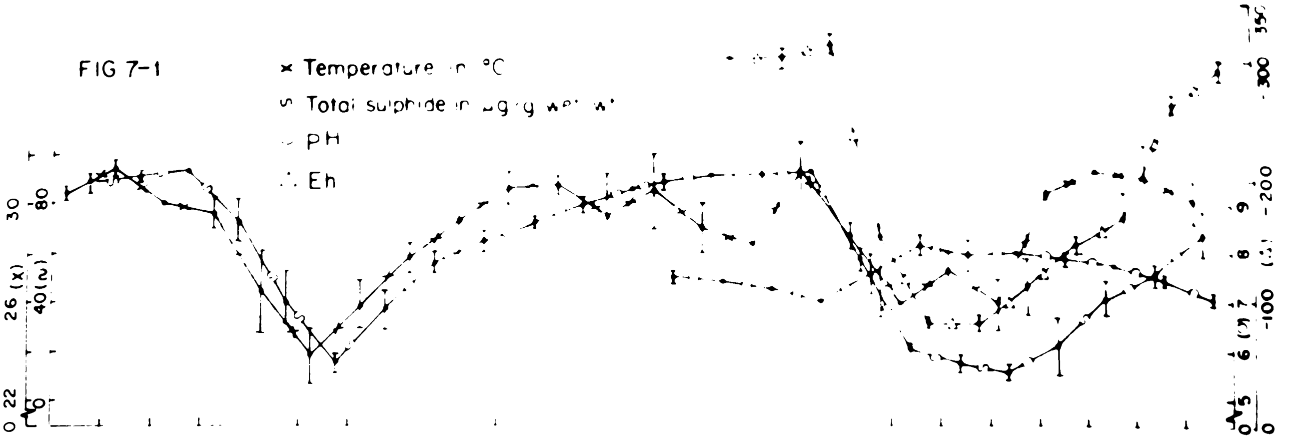


FIG 7-2

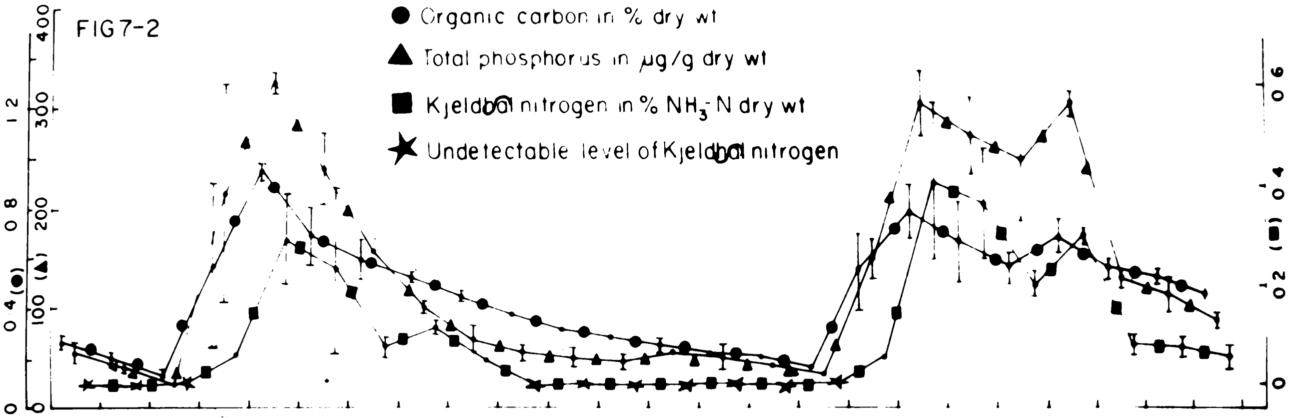


FIG 7-3

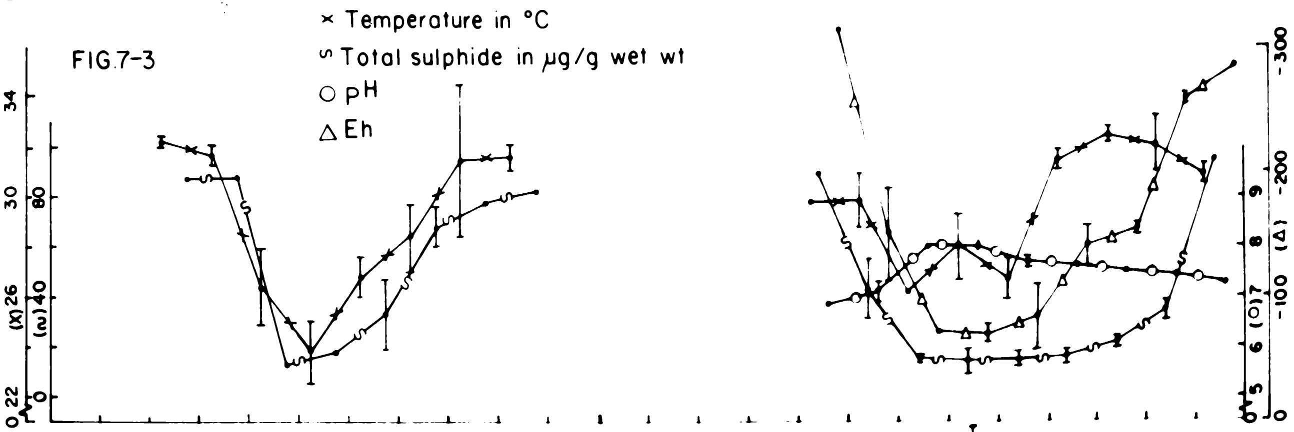
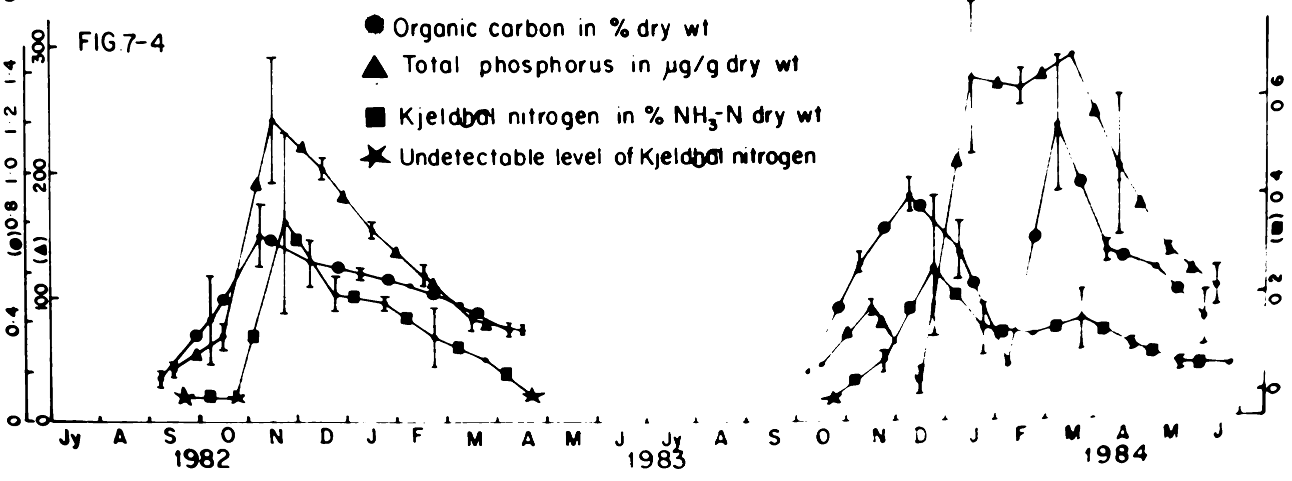


FIG 7-4



October and April. The Kjeldahl nitrogen content of the sediment attained its peak in November(0.35% NH_3-N dry wt) after which it gradually decreased till March(0.079% NH_3-N dry wt)(Fig.7-4). The total sulphide content of the sediment sharply decreased from October(87.1 μg/g wet wt) to November(13.45 μg/g wet wt). From December(17.5 μg/g wet wt) onwards a sharp increase in its concentration was noticed till April(82.0 μg/g wet wt)(Fig.7-3).

4.5.1.2 Productivity:

Gross primary production rate sharply increased from September(38.6 mgC/m^3/day) to December(520.3 mgC/m^3/day) and subsequently decreased till March(126.5 mgC/m^3/day), after which a slight increase was recorded in April(193.1 mgC/m^3/day) (Fig.6-4). Net primary production rate recorded low values upto December after which it reached its peak in January (199.7 mgC/m^3/day). Low net primary production values were recorded in February(64.3 mgC/m^3/day) and April(96.5 mgC/m^3/day) mainly due to the high rate of dark assimilation (Fig.6-4).

4.5.2 Second year (October 1983 to June 1984):

4.5.2.1 Hydrography and sedimentology:

The level of water at this station in October was 11 cm after which flooding occured in November(89 cm). A fairly moderate level of water was maintained from December(74 cm) to February(59 cm) and subsequently it started declining gradually till June(27 cm)(Fig.6-1). Air temperature registered a sudden fall from October(30.7°C) to November(27.7°C) and low air temperature values were recorded till February(26.9°C). A steep rise was observed in March(30.9°C) after which a gradual increase was noted upto May(33.2°C) with a slight fall in June (31.4°C)(Fig.6-1). The pattern of distribution of the temperature of water closely resembled that of the air temperature. From October(29.1°C) it started declining till December(26.2°C) and then maintained a fairly low range till February(26.8°C). A sudden rise in water temperature was recorded in March(31.0°C) which was followed by a steady increase through May(32.2°C) with a slight fall in June(30.3°C)(Fig.6-1). There was a sharp increase in the dissolved oxygen content from October(2.72 ml/l) to November(4.73 ml/l) with its peak in December(5.01 ml/l), after which a gradual decrease was noticed till April(2.97 ml/l). A sharp rise was observed in May(4.42 ml/l) before reaching 3.51 ml/l oxygen concentration in June(Fig.6-2). Salinity values showed declining trend from October(54.7‰) to February(9.8‰), after which a gradual increase was recorded till June(36.6‰) (Fig.6-2). The pH of water always evinced an alkaline range. A sharp rise was observed from October(7.42) to November(8.54) in the pH of water. A slight increase was noticed till January (8.64) after which a gradual decline occurred till June(7.86) (Fig.6-4).

Soluble reactive phosphare content showed a sharp increase from October(0.17 µg-at PO_4-P/l) to November(0.63 µg-at PO_4-P/l) after which a gradual increase was recorded till February(0.99 µg-at PO_4-P/l). An abrupt rise was noticed in March(14.98 µg-at

PO_4-P/l) followed by a sudden fall in April(0.70 μg-at PO_4-P/l) with gradual decrease upto June(0.55 μg-at PO_4-P/l)(Fig.6-3). The nitrate concentration registered a sharp increase from October(0.39 μg-at NO_3-N/l) to November(1.15 μg-at NO_3-N/l) after which a gradual increase was observed till February(1.72 μg-at NO_3-N/l). There was a fall in its value in March(1.24 μg-at NO_3-N/l) after which the nitrate concentration gradually decreased till June(0.93 μg-at NO_3-N/l)(Fig.6-3). The nitrite content followed the same trend as that of the nitrate concentration. There was a sharp increase in its concentration from October(0.02 μg-at NO_2-N/l) to November(0.15 μg-at NO_2-N/l) which was followed by gradual and steady increase till February (0.36 μg-at NO_2-N/l). A sharp decline in the nitrite content was noticed till May(0.07 μg-at NO_2-N/l)(Fig.6-3). Ammonia content of water increased sharply from December(7.98 μg-at NH_3-N/l) to January(22.76 μg-at NH_3-N/l). The abrupt fall in its concentration noticed in February(7.74 μg-at NH_3-N/l) was followed by a steady decrease till June(4.85 μg-at NH_3-N/l)(Fig.6-3). Hydrogen sulphide concentration in water could be detected only in October(9.16 μg-at H_2S-S/l)(Fig.6-2).

The temperature of sediment decreased sharply from November(29.8°C) to December(26.2°C). A steep rise was noticed from February(26.7°C) to March(31.3°C) after which a gradual increase was observed till May(32.1°C)(Fig.7-3). The pH of the sediment showed alkaline condition except in October(6.84). The alkalinity of the sediment reached its peak in December(8.00).

after which a gradual and constant decrease in alkalinity was observed till June(7.32)(Fig.7-3). The Eh of the sediment increased sharply from October(-313 mV) to December(-73 mV). Fairly high level of Eh was maintained till February(-84 mV) after which a steady and rapid decrease was observed till June (-28 mV)(Fig.7-3).

The organic carbon content of the sediment sharply increased from October(0.20% dry wt) to December(0.91% dry wt) after which an abrupt decrease was observed till February(0.20% dry wt). The peak organic carbon content observed in March (1.19% dry wt) was followed by a sharp decline till June(0.40% dry wt)(Fig.7-4). There was an abrupt increase in the total phosphorus content of the sediment from October(45.8 µg/g dry wt) to December(302.3 µg/g dry wt) after which it decreased steadily till February(268.1 µg/g dry wt). An increase in its concentration noticed in March(293.6 µg/g dry wt) was followed by a sharp decrease till June(105.3 µg/g dry wt)(Fig.7-4). The Kjeldahl nitrogen content of the sediment increased sharply from November(0.070% NH_3-N dry wt) to December(0.260% NH_3-N dry wt) after which a steady decline was observed till June(0.055% NH_3-N dry wt) with a slight rise in March(0.150% NH_3-N dry wt) (Fig.7-4). The total sulphide content of the sediment sharply declined from October(88.6 µg/g wet wt) to December(14.5 µg/g wet wt). From March(16.1 µg/g wet wt) onwards a steady increase was noticed with its peak in June(95.5 µg/g wet wt)(Fig.7-3).

.5.2.2 Productivity:

Gross primary production rate was 298.7 mgC/m^3/day in November and 253.0 mgC/m^3/day in December. After a sudden decrease in January(21.5 mgC/m^3/day) its values registered a sharp increase and reached its peak in March(555.5 mgC/m^3/day). Subsequently, an abrupt decrease was observed till May(80.0 mgC/m^3/day) with a slight rise in June(137.2 mgC/m^3/day) (Fig.6-4). Net primary production was observed only in November, December, February and March with values at 165.8, 98.6, 32.2 and 373.1 mgC/m^3/day respectively as the dark assimilation rates were relatively high in other months(Fig.6-4).

4.6 Station-V:

4.6.1 First year (October 1982 to February 1983):

.6.1.1 Hydrography and sedimentology:

This station was flooded with water in October(55 cm) after which the water level receded rapidly till February(11 cm) (Fig.8-1). There was a slight drop in air temperature from October(28.8°C) to November(27.8°C) after which a steady and steep increase in its values was recorded till February(33.2°C) (Fig.8-1). The temperature of water followed the same pattern as that of the air temperature. Mild decline was recorded from October(26.9°C) to November(25.8°C), which was followed by a steady increase till February(34.0°C). In February the water temperature was found to be higher than the air temperature (Fig.8-1). The dissolved oxygen content was fairly constant

STATION-V

Fig. 8-1	Distribution of air temperature, water temperature and depth.
Fig. 8-2	Distribution of oxygen, salinity and hydrogen sulphide.
Fig. 8-3	Distribution of soluble reactive phosphate, nitrate, ammonia and nitrate.
Fig. 8-4	Distribution of the rates of gross primary production, net primary production and pH.

FIG. 8-1

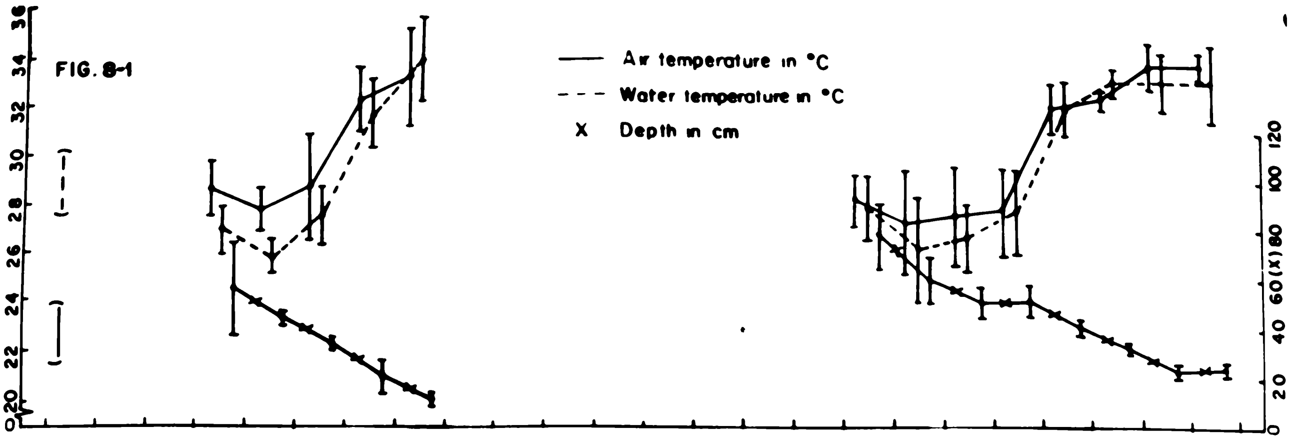


FIG. 8-2

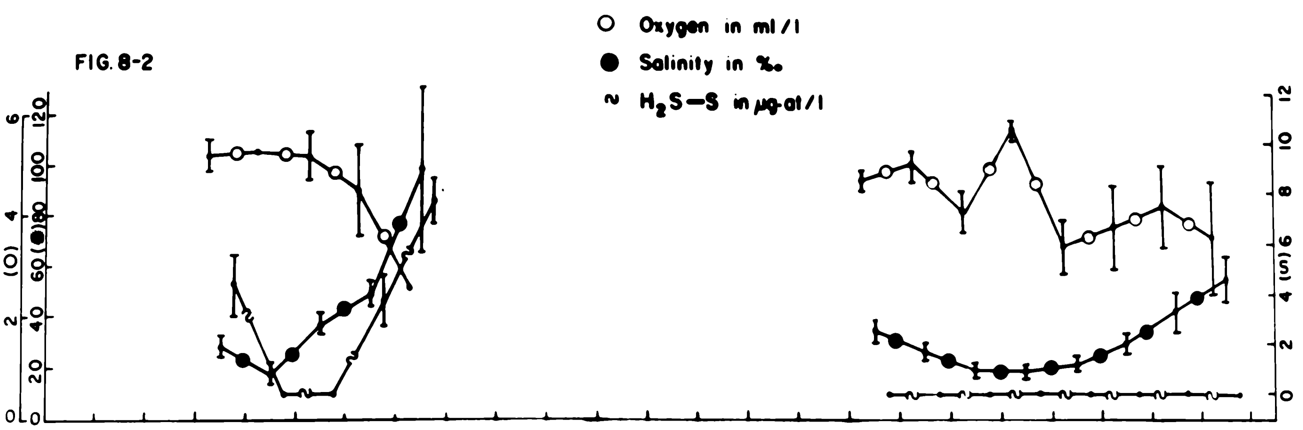


FIG. 8-3

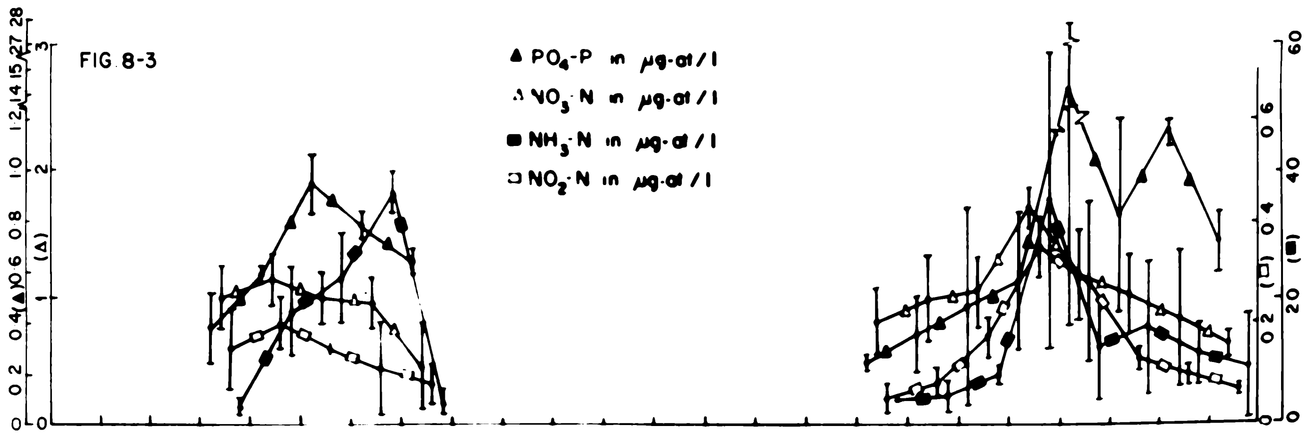
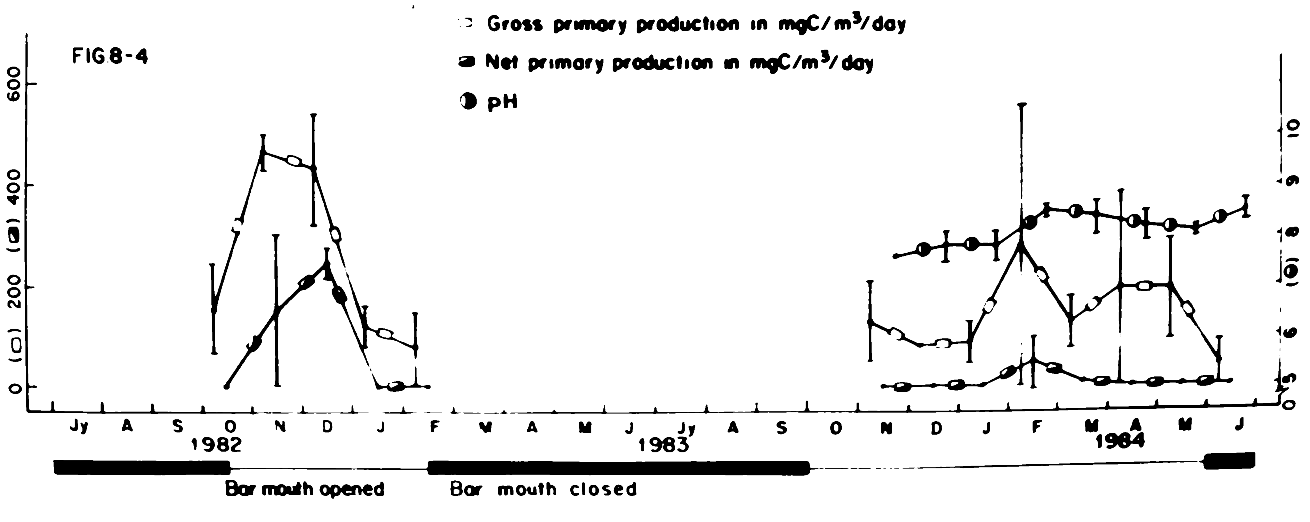


FIG 8-4



from October(5.19 ml/l) to December(5.18 ml/l) with its peak in November(5.26 ml/l). Steep decrease was noticed from January (4.45 ml/l) to February(2.58 ml/l)(Fig.8-2). Salinity showed its minimum value of 18.3‰ in November which was preceded by 29.2‰ in October. This was followed by a steady and steep increase till February(99.43‰)(Fig.8-2).

Soluble reactive phosphate content of water steadily increased from October(0.38 µg-at PO_4-P/l) to December(0.94 µg-at PO_4-P/l) after which a gradual decline was recorded till February(0.64 µg-at PO_4-P/l)(Fig.8-3). Nitrate content reached its peak from October(1.00 µg-at NO_3-N/l) to November(1.13 µg-at NI_3-N/l) which was followed by a gradual decline till January(0.96 µg-at NO_3-N/l) and a drop in February(0.45 µg-at NO_3-N/l)(Fig.8-3). Nitrite concentration followed the same trend of fluctuation as that of the nitrate concentration. From October(0.150 µg-at NO_2-N/l) to November(0.200 µg-at NO_2-N/l) nitrite concentration reached its peak, after which a steady and gradual decline was noticed till February(0.080 µg-at NO_2-N/l)(Fig.8-3). Ammonia concentration increased abruptly from October(2.80 µg-at NH_3-N/l) to January(36.10 µg-at NH_3-N/l) after which its concentration decreased to 3.30 µg-at NH_3-N/l in February(Fig.8-3). The total sulphide content of water was present only in October(4.25 µg-at H_2S-S/l), January(3.74 µg-at H_2S-S/l) and February(7.61 µg-at H_2S-S/l)(Fig.8-2).

The temperature of sediment decreased from October(26.5°C) to November(24.8°C), after which a sharp increase was noticed till

January(32.2°C)(Fig.10-1). Organic carbon content of sediment was at its peak in October(1.57% dry wt) followed by a gradual decline till February(0.98% dry wt)(Fig.10-2). The total phosphorus content of sediment attained its peak from October (133.6 μg/g dry wt) to November(326.6 μg/g dry wt), after which a gradual decrease was observed till February(168.6 μg/g dry wt) (Fig.10-2). Kjeldahl nitrogen content was at its peak from October(0.060% NH_3-N dry wt) to November(0.118% NH_3-N dry wt) after which a gradual decline was noticed till February(0.073% NH_3-N dry wt)(Fig.10-2). The total sulphide content of sediment decreased from October(86.8 μg/g wet wt) to November (72.8 μg/g wet wt), which was followed by a steady increase till February(85.9 μg/g wet wt)(Fig.10-1).

4.6.1.2 Productivity:

Gross primary production rate was at its peak from October(152.2 mgC/m^3/day) to November(464.5 mgC/m^3/day). After December(428.9 mgC/m^3/day), a sudden decrease was registered in January(115.8 mgC/m^3/day)(Fig.8-4). Net primary production was recorded in November(150.0 mgC/m^3/day) and December(244.1 mgC/m^3/day)(Fig.8-4).

4.6.2 Second year: (November 1983 to June 1984):

4.6.2.1 Hydrography and sedimentology:

Water level was high in this station in November(77 cm) after which decrease was noticed in December(49 cm). Till February, water level fluctuated between 45 and 55 cm, which was followed by a steady decrease till May(23 cm) and it maintained almost the same level in June(24 cm)(Fig.8-1). The temperature of air decreased from November(28.1°C) to December(27.2°C) and remained almost constant till February (27.8°C) after which a steady but sharp increase was noticed till June(33.8°C)(Fig.8-1). Water temperature followed the same pattern as that of the air temperature, usually registering values lower than the air temperature. Moderately sharp decline was noticed from November(27.8°C) to December(26.1°C) after which a steady increase was recorded (Fig.8-1). Dissolved oxygen content varied widely in this year. Oxygen content fluctuated between 4.08 and 4.99 ml/l from November to January with its peak in February(5.69 ml/l). A sharp decrease was observed in March(3.38 ml/l) followed by a gradual increase till May(4.15 ml/l) after which a decline occurred in June(3.59 ml/l) (Fig.8-2). Salinity gradually decreased from November(35.2‰) to January(19.0‰), after which a gradual increase was noticed from February(19.3‰) to June(56.4‰)(Fig.8-2). The pH of water gradually increased from November(7.55) to January(7.81) followed by a sharp increase in February(8.53). A slight decrease was noticed till May(8.1) after which a value of 8.5 was recorded in June(Fig.8-4).

Soluble reactive phosphate content of water gradually increased from November(0.24 µg-at PO_4-P/l) to February(0.56 µg-at PO_4-P/l). The peak was recorded in March(14.10 µg-at PO_4-P/l). It reached the concentration of 0.72 µg-at PO_4-P/l in June(Fig.8-3). Nitrate concentration gradually increased from November(0.80 µg-at NO_3-N/l) to February(1.69 µg-at NO_3-N/l), after which a steady decrease was noticed till June (0.63 µg-at NO_3-N/l)(Fig.8-3). Nitrite content followed the same trend as that of the nitrate. Nitrite sharply increased from December(0.08 µg-at NO_2-N/l) to February(0.35 µg-at NO_2-N/l) after which a gradual decrease was observed till June(0.07 µg-at NO_2-N/l)(Fig.8-3). Ammonia content gradually increased from November(3.70 µg-at NH_3-N/l) to January(7.50 µg-at NH_3-N/l), which was succeeded by a sharp rise in February(35.0 µg-at NH_3-N/l). There was a moderate increase in its values from March(11.70 µg-at NH_3-N/l) to April(14.20 µg-at NH_3-N/l) which was succeeded by a gradual decrease till June(8.80 µg-at NH_3-N/l)(Fig.8-3). No trace of hydrogen sulphide content of water was recorded for this period in this year(Fig.8-2).

The temperature of sediment sharply declined from November(29.7°C) to December(25.9°C). From February(27.1°C) to March(30.7°C), a steep rise was recorded which was followed by a gradual increase till June(33.5°C)(Fig.10-1). The pH of the sediment was at its peak from November(7.60) to December (7.78), after which a gradual decrease was noticed till April (7.25). The sediment showed neutral value of pH in May(7.0), whereas in June(6.9) it was acidic (Fig.10-1). The Eh of the sediment moderately increased from November(-243 mV) to December(-182 mV). From January(-185 mV) onwards a steady and steep decrease in its values was recorded till June(-372 mV) (Fig-10.1).

The organic carbon content of the sediment increased sharply from November(1.18% dry wt) to December(2.33% dry wt) after which a decline was observed till February(1.30% dry wt). In March(2.62% dry wt) its peak was observed, followed by a rapid decline in April(1.21% dry wt)(Fig.10-2). Total phosphorus content of the sediment increased sharply from November(114.1 μg/g dry wt) to December(307.1 μg/g dry wt) followed by a steady decrease till February(210.3 μg/g dry wt). In March(350.5 μg/g dry wt) its peak was recorded after which a sharp decrease was noticed in April(159.0 μg/g dry wt) followed by smooth decline till June(119.9 μg/g dry wt)(Fig.10-2). The Kjeldahl nitrogen content of sediment increased sharply from November(0.073% NH_3-N dry wt) to December(0.186% NH_3-N dry wt). It was at its peak from February(0.170% NH_3-N dry wt) to March (0.264% NH_3-N dry wt) after which a sharp decrease was observed till June(0.087% NH_3-N dry wt)(Fig.10-2). The total sulphide content of sediment sharply decreased from November(95.5 μg/g wet wt) to December(41.3 μg/g wet wt) after which a gradual increase was noticed till June(88.0 μg/g wet wt)(Fig.10-1).

4.6.2.2 Productivity:

Gross primary production rate fluctuated between 77.9 to 128.0 mgC/m^3/day from November to January. In February it was at its peak (276.6 mgC/m^3/day), after which a gradual decrease was recorded till June(42.9 mgC/m^3/day)(Fig.8-4). During February(49.3 mgC/m^3/day) and March(6.4 mgC/m^3/day) low net primary production rate was recorded (Fig.8-4).

4.7 Correlation:

In order to evaluate the nature of relationship between different parameters studied under ecology and productivity of the environment, the data were analysed for estimating the correlation coefficient('r') values. The results obtained at Station-I to V are presented in Tables-1 to 5. In the ensuing account, the roman numerals I to V given in brackets indicate the station number, and the arabic numerals 1 and 2 succeeding the roman numerals denote the years in which the correlations were worked out (1982-'83 and 1983-'84).

4.7.1 Stations-I to V (Tables 1 to 5):

The level of water was negatively correlated with the temperature of air (I.2.r=-0.70; II.1.r=-0.61; II.2.r=-0.66; III.1.r=-0.76; IV.1.r=-0.79; V.1.r=-0.75; V.2.r=-0.73), the temperature of water (I.2.r=-0.69; II.1.r=-0.63; III.1.r=-0.75; III.2.r=-0.62; IV.1.r=-0.76; V.1.r=-0.83; V.2.r =-0.75), Salinity (I.1.r=-0.72; II.1.r=-0.80; III.1.r=-0.88; III.2.r= -0.67; IV.1.r=-0.69; IV.2.r=-0.63; V.1.r=-0.71), the hydrogen sulphide content of water (I.1.r=-0.62; II.1.r=-0.68; II.1.r= -0.69; III.2.r=-0.72; IV.1.r=-0.71; IV.2.r=-0.68), the temperature of sediment (II.1.r=-0.71; II.2.r=-0.65; III.1.r= -0.74; IV.1.r=-0.74; V.1.r=-0.79; V.2.r=-0.64) and the sulphide content of sediment (III.1.r=-0.71; III.2.r=-0.64; IV.1.r= -0.84) and showed a positive correlation with the dissolved oxygen content (I.1.r=0.76; II.1.r=0.81; III.1.r=0.89; III.2.r=0.73; IV.1.r=0.77; IV.2.r=0.69; V.1.r=0.72) and the Eh

Table-1; Correlation matrix of ecological and productivity parameters at Station-I

1983-84

	A.temp	W.temp	Oxy	Sal	PO_4	NO_3	NO_2	NH_3	Depth	WpH	Gross	Net	S.temp	SEh	OrgC	SPO_4	Kj.N	S.Sul	SpH	
		0.86	-0.27	-0.15	0.23	-0.24	-0.12	0.03	-0.70	-0.01	-0.18	-0.20	0.81	-0.69	-0.07	-0.19	-0.14	0.62	-0.48	A.temp
			-0.14	-0.06	0.21	-0.15	-0.17	-0.07	-0.69	-0.10	-0.24	-0.07	0.89	-0.68	-0.06	-0.16	-0.03	0.58	-0.45	W.temp
A.temp				0.49	-0.18	-0.19	-0.33	-0.05	0.44	-0.25	-0.20	-0.04	-0.16	-0.28	-0.35	-0.35	0.02	0.30	-0.22	Oxy
W.temp	0.72				-0.23	-0.47	-0.70	-0.55	0.54	-0.66	-0.53	-0.44	0.23	-0.41	-0.65	-0.51	-0.11	0.49	-0.33	Sal
Oxy	-0.25	-0.06				-0	0.25	-0.01	-0.22	0.13	0.16	0.42	0.27	-0.16	0.24	0.40	0.39	0.05	-0.01	PO_4
Sal	0.32	0.28	-0.86				0.71	0.18	-0.16	0.37	0.45	0.57	-0.17	0.36	0.37	0.23	0.07	-0.44	0.48	NO_3
PO_4	-0.32	-0.25	-0.03	-0.02				0.55	-0.22	0.63	0.66	0.47	-0.21	0.46	0.68	0.55	0.35	-0.42	0.51	NO_2
NO_3	-0.56	-0.39	0.78	-0.80	0.18				-0.21	0.83	0.61	0.50	-0.38	0.18	0.20	0	-0.08	-0.12	0.07	NH_3
NO_2	-0.61	-0.39	0.57	-0.58	0.15	0.85				-0.30	-0.06	-0.14	-0.45	0.24	-0.26	-0.03	0.12	-0.11	0.21	Depth
NH_3	-0.25	-0.38	-0.47	0.77	0.71	-0.08	-0.06				0.80	0.60	-0.42	0.30	0.48	0.29	0.21	-0.26	0.20	WpH
Depth	-0.23	-0.03	0.76	-0.72	0.16	0.58	0.36	-0.32				0.60	-0.36	0.32	0.49	0.40	0.21	0.29	0.27	Gross
W.Sul	0.22	0.38	-0.90	0.89	-0.09	-0.82	-0.71	0.12	-0.62				-0.20	0.10	0.18	0.16	0.04	-0.20	0.07	Net
Gross	-0.66	-0.66	0.70	-0.67	0.39	0.89	0.91	0.10	0.45	-0.73				-0.78	0.30	-0.31	-0.10	0.78	-0.57	S.temp
Net	-0.31	-0.58	0.15	-0.19	0.53	0.37	0.38	0.47	-0.03	-0.33	0.63				-0.62	0.64	0.39	-0.95	0.82	SEh
S.temp	0.80	0.90	-0.37	0.54	-0.18	-0.74	-0.82	-0.17	-0.43	0.50	-0.74	-0.35				0.91	0.73	-0.60	0.64	OrgC
OrgC	-0.85	-0.66	0.30	-0.3	0.47	0.67	0.90	0.16	0.15	-0.37	0.76	0.36	-0.78				0.85	-0.62	0.71	SPO_4
SPO_4	-0.72	-0.72	0.45	-0.46	0.28	0.69	0.90	-0.06	0.12	-0.49	0.82	0.39	-0.79	0.91				-0.32	0.54	Kj.N
Kj.N	-0.69	-0.64	0.50	-0.47	0.45	0.68	0.88	0.02	0.11	-0.56	0.86	0.51	-0.68	0.89	0.96				-0.80	S.Sul
S.Sul	0.68	0.73	-0.53	0.61	-0.42	-0.76	-0.91	-0.16	-0.26	0.64	-0.93	-0.65	0.76	-0.86	-0.91	-0.95				SpH
	A.temp	W.temp	Oxy	Sal	PO_4	NO_3	NO_2	NH_3	Depth	W.Sul	Gross	Net	S.temp	OrgC	SPO_4	Kj.N	S.Sul			

1982-83

Abbreviations:

A.temp = Temperature of air
W.temp = Temperature of water
Oxy = Dissolved oxygen content
Sal = Salinity
PO_4 = Soluble reactive phosphate
NO_3 = Nitrate
NO_2 = Nitrite
NH_3 = Ammonia
Depth = Water depth
W. Sul = Sulphide content of water
WpH = pH of the water
Gross = Gross primary production
Net = Net primary production
S. Temp = Temperature of the Sediment
SEh = Eh of the Sediment
OrgC = Organic Carbon content of the Sediment
SPO_4 = Total phosphorus of the sediment
Kj.N = Sediment Kjeldahl nitrogen
S. Sul = Sediment Total Sulphide
SpH = pH of the sediment.

Table-2: Correlation matrix of ecological and productivity parameters at Station-II

1983-'84

	A.temp	W.temp	Oxy	Sal	PO_4	NO_3	NO_2	NH_3	Depth	WpH	Gross	Net	S.temp	SEh	OrgC	SPO_4	KJ.N	S.Sul	SpH	
		0.84	-0.22	-0.05	0.17	-0.25	-0.14	-0.12	-0.66	-0.22	-0.02	-0.02	0.53	-0.47	-0.30	-0.24	-0.26	0.47	-0.64	A.temp
			-0.29	-0.10	0.23	-0.19	-0.18	-0.17	-0.58	-0.21	0	-0.02	0.41	-0.38	-0.04	-0.06	0.06	0.27	-0.61	W.temp
A.temp				0.12	0.07	0.11	0.24	-0.10	0.52	0.29	0.12	-0.06	-0.14	0.27	0.19	0	-0.04	-0.13	0.37	Oxy
W.temp	0.86				-0.23	-0.31	-0.83	-0.37	0.11	-0.53	-0.55	-0.33	0.14	-0.69	-0.44	-0.62	-0.50	0.59	-0.15	Sal
Oxy	-0.67	-0.67				0.46	0.27	-0.04	-0.09	-0.07	0.21	0.06	0.22	0.14	0.34	0.42	0.30	-0.30	0.01	PO_4
Sal	0.66	0.73	-0.92				0.54	-0.04	0.04	0.13	0.27	0.01	0.18	0.39	0.29	0.37	0.21	-0.35	0.15	NO_3
PO_4	-0.47	-0.55	0.74	-0.72				0.44	-0.03	0.58	0.58	0.41	-0.08	0.58	0.27	0.49	0.35	-0.56	0.12	NO_2
NO_3	-0.48	-0.50	0.70	-0.69	0.77				0.04	0.69	0.41	0.09	-0.28	0.39	0.01	0.13	0	-0.44	0.08	NH_3
NO_2	-0.49	-0.60	0.80	-0.84	0.64	0.57				-0.04	0.31	0.22	-0.65	0.56	0.25	0.13	0.17	-0.57	0.66	Depth
NH_3	-0.26	-0.33	0.69	-0.67	0.77	0.69	0.66				0.32	0.03	-0.23	0.53	0.19	0.40	0.35	-0.50	0.24	WpH
Depth	-0.61	-0.63	0.81	-0.80	0.70	0.66	0.82	0.72				0.83	-0.30	0.44	0.13	0.26	0.07	-0.47	0.11	Gross
W.Sul	0.72	0.79	-0.79	0.81	-0.36	0.57	-0.85	-0.37	-0.68				-0.20	0.28	0.06	0.17	0.04	-0.31	0.09	Net
Gross	-0.62	-0.80	0.52	-0.53	0.46	0.46	0.48	0.37	-0.36	-0.71				-0.48	-0.40	-0.37	-0.30	0.70	-0.52	S.temp
Net	-0.35	-0.62	-0.39	-0.36	0.57	0.27	0.29	0.20	0.19	-0.55	0.74				0.68	0.69	0.60	-0.72	0.78	SEh
S.temp	0.81	0.93	-0.76	0.80	-0.66	-0.74	-0.77	-0.56	-0.71	0.84	-0.78	-0.58				0.89	0.90	-0.66	0.63	OrgC
OrgC	-0.69	-0.77	0.58	-0.60	0.35	0.48	0.61	0.30	0.40	-0.84	0.81	0.67	-0.84				0.85	-0.73	0.49	SPO_4
SPO_4	-0.77	-0.82	0.64	-0.63	0.50	0.45	0.57	0.29	0.36	-0.84	0.85	0.67	-0.85	0.95				-0.65	0.52	KJ.N
KJ.N	-0.65	-0.59	0.51	-0.52	0.63	0.49	0.44	0.47	0.37	-0.59	0.63	0.46	-0.73	0.82	0.80				-0.51	S.Sul
S.Sul	0.61	0.74	-0.47	0.50	-0.39	-0.30	-0.48	-0.18	-0.26	0.76	-0.86	-0.69	0.77	-0.96	-0.93	-0.75				SpH
	A.temp	W.temp	Oxy	Sal	PO_4	NO_3	NO_2	NH_3	Depth	W.Sul	Gross	Net	S.temp	OrgC	SPO_4	KJ.N	S.Sul			

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Abbreviations:

Same as in Table-1.

Table-3: Correlation matrix of ecological and productivity parameters at Station-III

1983-'84

	A.temp	W.temp	Oxy	Sal	PO_4	NO_3	NO_2	NH_3	Depth	WpH	W.Sul	Gross	Net	S.temp	SEh	OrgC	SPO_4	KJ.N	S.Sul	SpH
A.temp		0.72	-0.20	0.12	0.16	-0.39	-0.48	-0.41	-0.54	-0.33	0.18	0.08	0.03	0.39	-0.45	-0.32	-0.36	-0.46	0.28	-0.35
W.temp			-0.34	0.20	0.12	-0.32	-0.50	-0.44	-0.62	-0.46	0.22	0.18	-0.11	0.42	-0.48	-0.29	-0.36	-0.35	0.33	-0.26
Oxy				-0.76	0.19	0.34	0.30	0.20	0.73	0.55	-0.74	-0.16	0.09	-0.13	0.57	0.63	0.50	0.25	-0.62	0.48
Sal					-0.24	-0.51	-0.47	-0.33	-0.67	-0.67	0.94	0.29	-0.32	0.14	-0.74	-0.78	-0.73	-0.40	0.85	-0.55
PO_4						0.08	-0.06	-0.07	0.07	0.26	-0.19	0.13	0.17	0.11	0.19	0.31	0.37	0.18	-0.33	0.26
NO_3							0.37	0.35	0.53	0.41	-0.49	-0.11	0.23	-0.24	0.48	0.32	0.40	0.09	-0.54	0.12
NO_2								0.44	0.46	0.57	-0.40	-0.04	0.56	-0.60	0.71	0.54	0.63	0.66	-0.70	0.63
NH_3									0.36	0.86	-0.35	-0.06	0.04	-0.44	0.60	0.50	0.60	0.70	-0.54	0.48
Depth										0.70	-0.72	-0.20	0.29	-0.38	-0.70	0.58	0.60	0.37	-0.64	0.44
WpH											-0.59	-0.24	0.14	-0.11	0.64	0.59	0.68	0.58	-0.63	0.52
M.Sul												0.43	-0.20	0.06	-0.65	-0.75	-0.64	-0.35	0.76	-0.44
Gross													0.35	-0.19	-0.22	-0.38	-0.12	-0.10	0.19	-0.09
Net														-0.33	0.28	0.08	0.22	0	-0.40	0.19
S.temp															-0.58	-0.41	-0.55	-0.48	-0.48	-0.54
SEh																-0.88	0.91	-0.62	-0.93	-0.87
OrgC																	0.90	0.72	-0.88	0.84
SPO_4																		0.75	-0.92	0.85
KJ.N																			-0.60	0.74
S.Sul																				-0.80
SpH																				

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	A.temp	W.temp	Oxy	Sal	PO_4	NO_3	NO_2	NH_3	Depth	W.Sul	Gross	Net	S.temp	OrgC	SPO_4	KJ.N	S.Sul
A.temp																	
W.temp	0.86																
Oxy	-0.80	-0.80															
Sal	0.71	0.74	-0.92														
PO_4	-0.41	-0.55	0.43	-0.35													
NO_3	-0.59	-0.52	0.68	-0.53	0.40												
NO_2	-0.57	-0.54	0.64	-0.55	0.35	0.70											
NH_3	-0.58	-0.58	0.78	-0.65	0.44	0.68	0.59										
Depth	-0.76	-0.75	0.89	-0.88	0.30	0.71	0.78	0.68									
M.Sul	0.75	0.79	-0.72	0.73	-0.45	-0.51	-0.60	-0.47	-0.69								
Gross	-0.55	-0.53	0.48	-0.50	0.32	0.52	0.48	0.38	0.56	-0.51							
Net	-0.77	-0.80	0.68	-0.59	0.62	0.47	0.63	0.56	0.65	-0.65	0.62						
S.temp	0.85	0.82	-0.82	0.72	-0.45	-0.69	-0.64	-0.58	-0.74	0.78	-0.53	-0.74					
OrgC	-0.65	-0.70	0.82	-0.71	0.41	0.56	0.85	0.77	0.81	-0.66	0.54	0.54	-0.70				
SPO_4	-0.70	-0.69	0.86	-0.74	0.33	0.59	0.87	0.82	0.90	-0.58	0.53	0.58	-0.68	0.94			
KJ.N	-0.56	-0.51	0.57	-0.51	0.04	0.28	0.52	0.55	0.64	-0.45	0.46	0.34	-0.57	0.72	0.77		
S.Sul	0.79	0.85	0.79	0.71	-0.57	-0.62	-0.63	-0.67	-0.71	0.80	-0.64	-0.81	0.87	-0.74	-0.69	-0.57	

Abbreviations:

Same as in Table-1.

Table-4; Correlation matrix of ecological and productivity parameters at Station-IV.

1983-'84

	A.temp	W.temp	Oxy	Sal	PO_4	NO_3	NO_2	NH_3	Depth	WpH	W.Sul	Gross	Net	S.temp	SEh	OrgC	SPO_4	Kj.N	S.Sul	SpH
A.temp		0.82	-0.39	0.26	0.12	-0.13	-0.49	-0.34	-0.59	-0.57	0.27	0	-0.03	0.58	-0.64	-0.24	-0.50	-0.57	0.43	-0.48
W.temp			-0.38	0.17	0.17	-0.14	-0.43	-0.27	-0.51	-0.49	0.18	0	-0.04	0.73	-0.48	-0.18	-0.27	-0.45	0.28	-0.29
Oxy				-0.65	0	0.30	0.46	0.33	0.69	0.67	-0.51	0	0.23	-0.35	0.51	0.37	0.28	0.32	-0.51	0.33
Sal					-0.18	-0.41	-0.53	-0.36	-0.63	-0.58	0.83	-0.10	-0.24	0.34	-0.68	-0.72	-0.69	-0.83	0.78	-0.61
PO_4						0.31	0.37	0.08	0.05	0.16	-0.15	0.26	0.25	0.10	0.17	0.57	0.29	0.30	-0.24	0.17
NO_3							0.74	0.36	0.39	0.52	-0.45	0.03	0.01	-0.12	0.38	0.27	0.33	0.15	-0.37	0.40
NO_2								0.50	0.58	0.74	-0.44	0.20	0.16	-0.29	0.64	0.54	0.56	0.44	-0.58	0.55
NH_3									0.26	0.74	-0.32	-0.25	-0.09	-0.30	0.51	0.33	0.56	0.34	-0.50	0.59
Depth										0.82	-0.68	0.14	0.34	-0.54	0.67	0.50	0.49	0.55	-0.59	0.44
WpH											0.62	-0.01	0.11	-0.37	0.73	-0.54	0.60	0.51	-0.31	-0.39
W.Sul												-0.04	-0.18	0.26	-0.54	-0.62	-0.59	-0.37	0.65	-0.60
Gross													0.63	-0.19	0.11	0.34	0.15	0.05	-0.09	-0.08
Net														-0.36	0.17	0.41	0.17	0.17	-0.13	-0.03
S.temp															-0.53	-0.34	-0.47	-0.50	0.38	-0.43
SEh																0.74	0.84	0.65	-0.93	0.80
OrgC																	0.85	0.66	-0.83	0.70
SPO_4																		0.73	-0.87	0.91
Kj.N																			-0.62	0.70
S.Sul																				-0.82
SpH																				

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	A.temp	W.temp	Oxy	Sal	PO_4	NO_3	NO_2	NH_3	Depth	W.Sul	Gross	Net	S.temp	OrgC	SPO_4	Kj.N	S.Sul
A.temp																	
W.temp	0.84																
Oxy	-0.85	-0.75															
Sal	0.74	0.71	-0.81														
PO_4	-0.69	-0.50	0.79	-0.62													
NO_3	-0.40	-0.33	0.49	-0.47	0.30												
NO_2	-0.60	-0.51	0.65	-0.60	0.57	0.82											
NH_3	-0.49	-0.46	0.61	-0.63	0.58	0.33	0.60										
Depth	-0.79	-0.76	0.77	-0.69	0.50	0.47	0.59	0.59									
W.Sul	0.79	0.76	-0.82	0.65	-0.69	-0.36	-0.46	-0.41	-0.71								
Gross	-0.65	-0.73	0.57	-0.46	0.37	0.54	0.54	0.21	0.59	-0.58							
Net	-0.27	-0.43	0.40	-0.30	0.41	0.04	0.17	0.17	0.16	-0.37	0.54						
S.temp	0.80	0.93	-0.66	0.65	-0.50	-0.38	-0.43	-0.37	-0.74	0:75	-0.70	-0.31					
OrgC	-0.86	-0.70	0.83	-0.68	0.79	0.47	0.64	0.73	0.77	-0.75	0.62	0.33	-0.70				
SPO_4	-0.80	-0.82	0.77	-0.67	0.59	0.47	0.59	0.61	0.91	-0.74	0.67	0.22	-0.84	0.89			
Kj.N	-0.78	-0.72	0.66	-0.55	0.53	0.21	0.40	0.60	0.91	-0.65	0.49	0.14	-0.73	0.79	0.92		
S.Sul	0.82	0.84	-0.76	0.66	-0.50	-0.59	-0.66	-0.52	-0.84	0.74	-0.76	-0.30	0.85	-0.80	-0.94	-0.81	

Abbreviations:

Same as in Table-1.

Table-5: Correlation matrix of ecological and productivity parameters at Station-V.

1983-'84

A.temp	W.temp	Oxy	Sal	PO$_4$	NO$_3$	NO$_2$	NH$_3$	Depth	WpH	Gross	Net	S.temp	SEh	OrgC	SPO$_4$	Kj.N	S.Sal	SpH	
	0.87	-0.40	0.55	0.32	-0.22	-0.09	0	-0.73	0.34	-0.21	-0.41	0.87	-0.83	-0.37	-0.33	-0.23	0.43	-0.77	A.temp
		-0.50	0.52	0.28	-0.29	-0.08	-0.06	-0.75	0.33	-0.07	-0.26	0.86	-0.83	-0.31	-0.30	-0.14	0.38	-0.71	W.temp
			-0.36	-0.29	0.30	0.07	0.20	0.47	-0.01	0.27	0.50	-0.36	0.37	-0.26	-0.12	-0.14	-0.09	0.37	Oxy
				-0.04	-0.44	-0.47	-0.24	-0.83	-0.20	-0.18	-0.34	0.62	-0.74	-0.55	-0.62	-0.62	0.71	-0.79	Sal
					0.37	0.59	0.10	0.18	0.35	0.43	-0.08	0.13	-0.16	0.20	0.22	0.17	-0.02	-0.06	PO$_4$
						0.76	0.54	0.16	0.48	0.61	0.48	-0.37	0.25	0.17	0.35	0.30	-0.23	0.34	NO$_3$
							0.52	-0.05	0.61	0.71	0.54	-0.19	0.13	0.16	0.32	0.36	-0.30	0.26	NO$_2$
								-0.07	0.67	0.75	0.74	0.02	0	-0.05	0.05	0.12	-0.10	0.05	NH$_3$
									-0.36	0.02	0.03	-0.64	0.67	0.17	0.14	-0.04	-0.01	0.72	Depth
										0.47	0.47	0.07	[illegible]	-0.02	0.11	0.21	-0.29	-0.13	WpH
											0.70	-0.07	0.03	-0.06	0.03	0.11	-0.02	0.14	Gross
												-0.21	0.24	-0.06	0.06	0.18	-0.20	0.30	Net
													-0.81	-0.52	-0.52	-0.38	-0.68	-0.73	S.temp
														0.56	0.53	0.38	-0.63	0.90	SEh
															0.91	0.85	-0.72	0.54	OrgC
																0.93	-0.78	0.63	SPO$_4$
																	-0.73	0.30	Kj.N
																		0.57	S.Sul
																			SpH

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	A.temp	W.temp	Oxy	Sal	PO$_4$	NO$_3$	NO$_2$	NH$_3$	Depth	W.Sul	Gross	Net	S.temp	OrgC	SPO$_4$	Kj.N	S.Sul
A.temp																	
W.temp	0.83																
Oxy	-0.66	-0.81															
Sal	0.71	0.87	-0.82														
PO$_4$	0.06	0.17	-0.04	0.13													
NO$_3$	-0.36	-0.73	0.80	-0.81	0.10												
NO$_2$	-0.34	-0.63	0.61	-0.58	0.01	0.83											
NH$_3$	0.01	-0.01	0.32	-0.25	0.63	0.43	0.13										
Depth	-0.75	-0.83	0.72	-0.71	-0.34	0.65	0.63	-0.19									
W.Sul	0.44	0.68	-0.77	0.67	-0.48	-0.66	-0.60	-0.32	-0.41								
Gross	-0.43	-0.71	0.60	-0.65	0.30	0.49	0.42	0.11	0.33	-0.83							
Net	-0.23	-0.49	0.40	-0.40	0.33	0.37	0.36	0.12	0.09	-0.74	0.81						
S.temp	0.77	0.94	-0.75	0.66	0.23	-0.72	-0.62	0.20	-0.79	0.66	-0.74	-0.43					
OrgC	-0.36	-0.36	0.33	-0.41	0.17	0.51	0.57	0.29	0.06	-0.61	0.64	0.77	-0.41				
SPO$_4$	-0.28	-0.45	0.39	-0.45	0.48	0.35	0.38	0.30	-0.01	-0.81	0.88	0.88	-0.45	0.83			
Kj.N	-0.35	-0.43	0.39	-0.50	0.44	0.30	0.33	0.29	0.03	-0.76	0.82	0.58	-0.52	0.66	0.89		
S.Sul	0.47	0.48	-0.42	0.49	-0.30	-0.60	-0.67	-0.31	-0.20	0.72	-0.77	-0.79	0.52	-0.96	-0.88	-0.75	

Abbreviations:

Same as in Table-1.

of sediment (III.2.r=0.70; IV.2.r=0.67; V.2.r=0.67).

The temperature of water was positively correlated with the temperature of air(I.1.r=0.72; I.2.r=0.86; II.1.r=0.86; II.2.r=0.84; III.1.r=0.86; III.2.r=0.72; IV.1.r=0.84; IV.2.r =0.82; V.1.r=0.83; V.2.r=0.87), temperature of sediment (I.2.r= 0.90; I.2.r=0.89; II.1.r=0.95; III.1.r=0.82; IV.1.r=0.95; IV.2. r=0.73; V.1.r=0.94; V.2.r=0.86), salinity (II.1.r=0.73; III.1.r= 0.74; IV.1.r=0.71; V.1.r=0.87), the hydrogen sulphide content of water (II.1.r=0.79; III.1.r=0.79; IV.1.r=0.76; V.1.r=0.68) and the sulphide content of sediment (I.1.r=0.73; II.1.r=0.74; III.1. r=0.85; IV.1.r=0.84) and negatively correlated with the dissolved oxygen content (II.1.r=-0.67; III.1.r=-0.80; IV.1.r=-0.75; V.1.r= -0.81); Gross primary production (I.1.r=-0.66; II.1.r=-0.80; IV.1.r=-0.73; V.1.r.=-0.71) and net primary production(II.1.r= -0.62; II.r.1=-0.80).

Dissolved oxygen content was negatively correlated with the salinity (I.1.r=-0.86; II.1.r=-0.92; III.1.r=-0.92; II.2.r= -0.76; IV.1.r=-0.81; IV.2.r=-0.65; V.1.r=-0.81), the hydrogen sulphide content of water (I.1.r=-0.90; II.1.r=-0.79; III.1.r= -0.72; III.2.r=-0.74; IV.1.r=-0.82; V.1.r=-0.77), the temperature of sediment (II.1.r=-0.76; III.1.r=-0.82; IV.1.r= -0.66; V.1.r=-0.75) and the total sulphide content of sediment (III.1.r=-0.79; III.2.r=-0.62; IV.1.r=-0.76).

Salinity showed positive correlation with the temperature of air (II.1.r=0.66; III.1.r=0.71; IV.1.r=0.74; V.1.r=0.71), the temperature of sediment (II.1.r=0.80; III.1.r=0.72; IV.1.r=0.65; V.1.r.=0.86; V.2.r=0.62), the hydrogen sulphide content of water (I.1.r=0.89; II.1.r=0.81; III.1.r=0.73; III.2.r=0.94; IV.1.r=0.65; IV.2.r=0.83; V.1.r=0.67) and the total sulphide content of sediment (I.1.r=0.61; III.1.r=0.71; III.2.r=0.85; IV.1.r=0.66; IV.2.r=0. 81; V.2.r=0.71).

The pH of the water was positively correlated with the ammonia (I.2.r=0.83; II.2.r=0.69; III.2.r=0.86; IV.2.r=0.74; V.2.r=0.67) and the Eh of the sediment (III.2r=0.64; IV.2.r=0.75) and negatively with the sulphide content of sediment (III.2.r=-0.63; IV.2.r=-0.71).

Nitrate concentration was positively related to nitrite (I.1.r=0.85; I.2.r=0.71; III.1.r=0.70; IV.1.r=0.82; IV.2.r=0.74; V.1.r=0.83; V.2.r=0.72). Nitrite content was negatively related to the hydrogen sulphide content of water (I.1.r=-0.71; II.1.r=-0.85; III.1.r=-0.60; IV.1.r=-0.60) and the total sulphide content of sediment (I.1.r=-0.91; III.1.r=-0.63; III.2.r=-0.70; IV.1.r=-0.66; V.1.r=-0.67).

The hydrogen sulphide content of water was positively correlated with the total sulphide of sediment (I.1.r=0.64; II.1.r=0.76; III.1.r=0.80; III.2.r=0.76; IV.1.r=0.74; IV.2.r=0.64; V.1.r=0.72) and negatively with the gross primary production (I.1.r=-0.73; II.1.r=-0.71; V.1.r=-0.83) and net primary production (III.1.r=-0.65; V.1.r=-0.74).

The temperature of sediment was positively correlated with the temperature of air(I.1.r=0.80; I.2.r=0.81; II.1.r=0.81; III.1.r=0.85 IV.1.r=0.80; V.1.r=0.77; V.2.r=0.87) and total sulphide content of sediment (I.1.r=0.76; I.2.r=0.78; II.1.r=0.77; II.2.r=0.70; III.1.r=0.87; IV.1.r=0.85; V.2.r=0.68).

The Eh of the sediment was positively correlated with the pH of the sediment (I.2.r=0.82; II.2.r=0.78; III.2.r=0.87; IV.2.r= 0.80; V.2.r=0.90) and negatively with the total sulphide content of sediment (I.2.r=-0.95; II.2.r=-0.72; III.2.r=-0.93; IV.2.r= -0.93; V.2.r=-0.63).

The organic carbon content of sediment was positively correlated with the total phosphorus of sediment (I.1.r=0.91; I.2.r=0.91; II.1.r=0.95; II.2.r=0.89; III.1.r=0.94; III.2.r=0.90; IV.1.r=0.89; IV.2.r=0.85; V.1.r=0.83; V.2.r=0.91) and the Kjeldahl nitrogen content of sediment (I.1.r=0.89; I.2.r=0.75; II.1.r=0.82; II.2.r=0.90; III.1.r=0.72; III.2.r=0.72; IV.1.r= 0.79; IV.2.r.=0.66; V.1.r=0.66; V.2.r=0.85) and negatively correlated with the total sulphide content of sediment (I.1.r= -0.86; I.2.r=-0.60; II.1.r=-0.96; II.2.r=0.66; III.1.r=-0.74; III.2.r=-0.88; IV.1.r=-0.80; IV.2.r.=-0.83; V.1.r=-0.96; V.2.r=-0.72).

The total phosphorus content of sediment was positively correlated with the Kjeldahl nitrogen content of sediment (I.1.r =0.96 ;1.2.r=0.85; II.1.r=0.80; II.2.r=0.85; III.1.r=0.77; III.2.r=0.75; IV.1.r=0.92; IV.2.r=0.73; V.1.r=0.89; V.2.r=0.93) and negatively with the total sulphide content of sediment

(I.1.r=-0.91; 1.2.r=-0.62; II.1.r=-0.93; II.2.r=-0.75; III.1.r=-0.69; III.2.r=-0.92; IV.1.r=-0.94; IV.2.r=-0.87; V.1.r=-0.88; V.2.r=-0.78).

Kjeldahl nitrogen content of the sediment was negatively correlated with the total sulphide content of sediment(I.1.r=-0.95; II.1.r=-0.75; II.2.r=-0.65; III.2.r=-0.60; IV.1.r=-0.81; IV.2.r=-0.62; V.1.r=-0.75; V.2.r=-0.73).

The total sulphide content of the sediment was negatively correlated with the pH of the sediment (I.2.r=-0.80; III.2.r=-0.80; IV.2.r=-0.82).

Gross primary production was positively correlated with the net primary production (I.1.r=0.63; I.2.r=0.60; II.1.r=0.74; II.2.r=0.83; III.1.r=0.62; IV.2.r=0.63; V.1.r=0.81; V.2.r=0.70). Net primary production was negatively correlated with the total sulphide content of sediment (I.1.r=-0.65; II.1.r=-0.69; III.1.r=-0.81; V.1.r=-0.79).

4.8 Station-PB:

4.8.1 First year:(July 1982 to June 1983):

4.8.1.1 Hydrography and sedimentology:

The temperature of air varied between 30°C and 32.0°C from July to October after which there was a drop in temperature till December(26.6°C). This was followed by a steady and steep increase till March(31.8°C) and the temperature values were between 31.0 and 32.0°C for the period April to June(Fig.9-1).

STATION - PALK BAY

Fig. 9-1 Distribution of air temperature, water temperature and depth.

Fig. 9-2 Distribution of oxygen, salinity and hydrogen sulphide.

Fig. 9-3 Distribution of soluble reactive phosphate, nitrate, ammonia and nitrite

Fig. 9-4 Distribution of the rates of gross primary production, net primary production and pH.

FIG 9-1

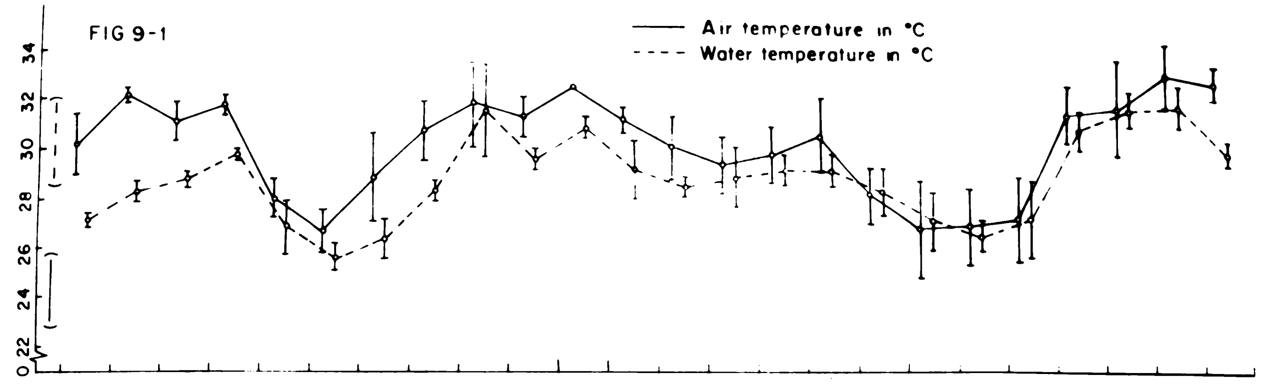


FIG 9-2

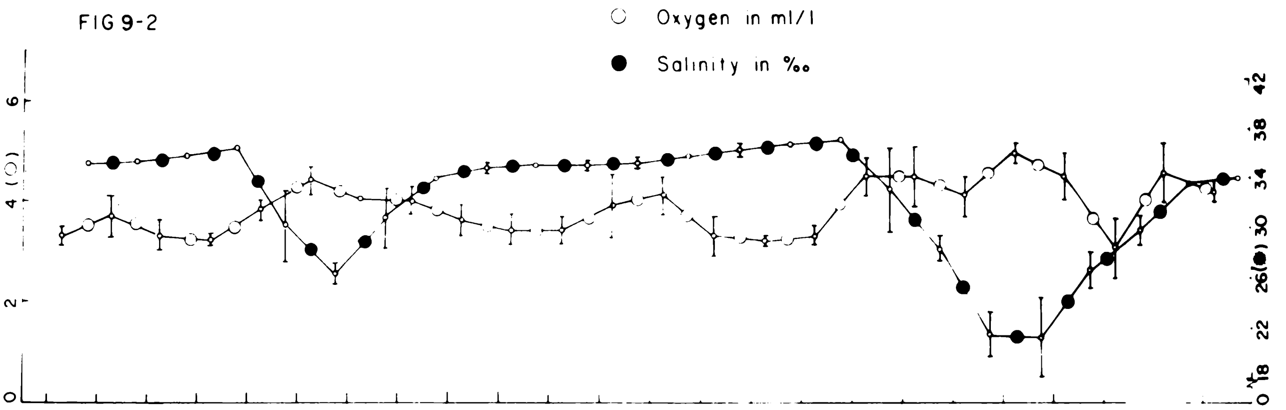


FIG 9-3

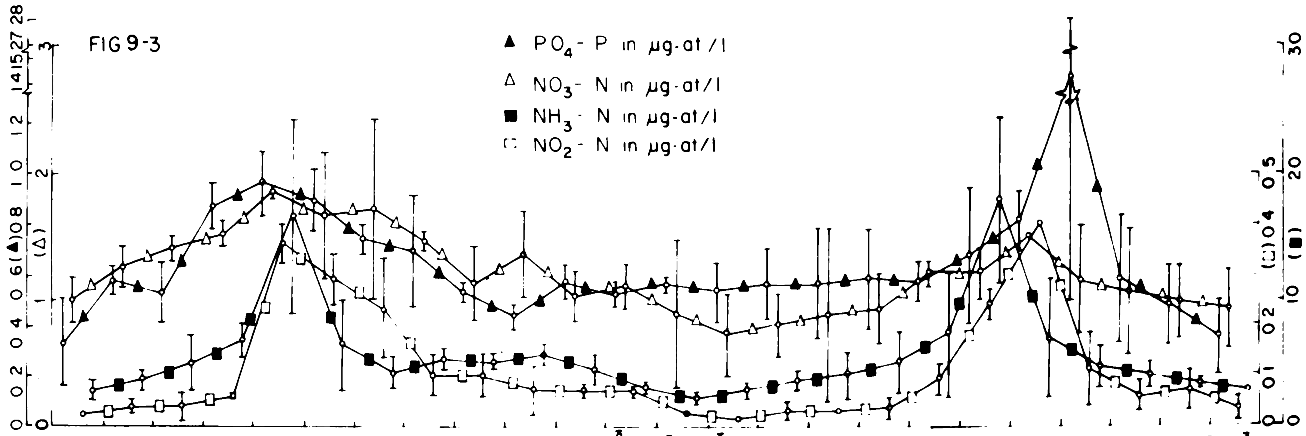
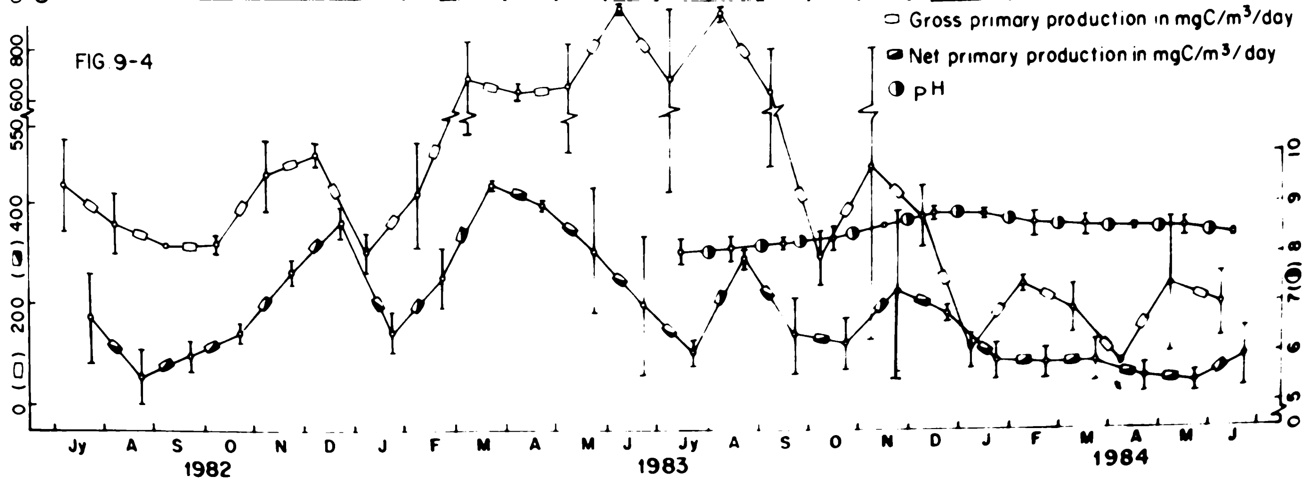


FIG 9-4



The temperature of water closely followed the pattern of distribution of the air temperature. Gradual increase was noticed from July(27.1°C) to October(29.8°C) after which a rapid decline was recorded till December(25.5°C) followed by a steady increase till March(31.6°C). Water temperature was found to vary from 29.2°C (April) to 30.9°C (June)(Fig.9-1). Dissolved oxygen content of water varied between 3.16 & 3.70 ml/l from July to October, after which an increase was noticed till December(4.37 ml/l) and a gradual decrease was observed from January(3.99 ml/l)to May(3.43 ml/l)(Fig.9-2). Salinity values increased from July(35.0‰) to October(36.2‰), after which a sharp decline was noticed till December(26.2‰), followed by a gradual increase upto March(34.6‰)(Fig.9-2).

Soluble reactive phosphate content of water increased from July(0.33 µg-at PO_4-P/l) to November(0.96 µg-at PO_4P/l), after which a gradual decrease was noticed till April(0.43 µg-at PO_4-P/l)(Fig.9-3). Nitrate content of water steadily increased from July(1.01 µg-at NO_3-N/l) to November(1.84 µg-at NO_3-N/l), after which a gradual decrease was recorded till June(1.10 µg -at NO_3-N/l)(Fig.9-3). The variation in the nitrite concentration in water was almost similar to that of the nitrate. A sharp increase in its values was noticed from October(0.060 µg-at NO_2-N/l) to November(0.36 µg-at NO_2-N/l), followed by a gradual decrease till April(0.070 µg-at NO_2-N/l)(Fig.9-3). The ammonia concentration gradually increased from July(2.79 µg-at NH_3-N/l) to October(6.39 µg-at NH_3-N/l) and recorded a maximum in November(16.72 µg-at NH_3-N/l). A sharp decline was noticed in its concentration in December(6.45 µg-at NH_3-N/l) after which the ammonia concentration in the water varied between 3.04 and 5.74 µg-at NH_3-N/l till June(Fig.9-3).

The temperature of sediment gradually increased from July(28.0°C) to September(30.6°C). A steep decrease in its value was recorded from October(30.5°C) to December(23.8°C) after which a steady increase was noticed till March(31.4°C). Subsequently, a slight decrease was observed till June(29.7°C) (Fig.10-3). The organic carbon content of sediment varied between 0.06 and 0.07% dry wt from July to October, which was followed by its peak in November(0.09% dry wt). A gradual decrease in the organic carbon content of sediment was recorded till March(0.05% dry wt) after which its value rose slightly in April(0.07% dry wt), which was further followed by a decrease in June(0.05% dry wt)(Fig.10-4). The total phosphorus content of sediment varied between 80.0 and 103.8 µg/g dry wt from July to October after which it was at its peak in November(193.1 µg/g dry wt). A gradual decrease in its value was observed from December(192.1 µg/g dry wt) to March(60.5 µg/g dry wt).From 92.6 µg/g dry wt concentration in April the total phosphorus content of the sediment decreased to 54.6 µg/g dry wt in May and 75.1 µg/g dry wt in June(Fig.10-4). Detectable level of Kjeldahl nitrogen content of sediment was observed in July(0.055% NH_3-N dry wt) and September(0.058% NH_3-N dry wt). From the undetectable level of Kjeldahl nitrogen in October, it recorded a peak value in November (0.073% NH_3-N dry wt) after which a gradual decrease was observed till February(0.058% NH_3-N dry wt)(Fig.10-4).

4.8.1.2 Productivity:

The gross primary production rate gradually decreased from July(436.4 mgC/m^3/day) to October(313.1 mgC/m^3/day), followed by a moderate increase till December(494.6 mgC/m^3/day). A sharp increase was observed from January(301.8 mgC/m^3/day) to June(962.7 mgC/m^3/day)(Fig.9-4). Net primary production rate followed the same trend as that of the gross production rate. Investigations showed that after a decrease from July(169.7 mgC/m^3/day) to August(55.8 mgC/m^3/day), its values recorded a gradual increase till December(360.2 mgC/m^3/day). From January(139.4 mgC/m^3/day), the net production rate gradually increased till March(437.4 mgC/m^3/day) and afterwards a sharp decline was noticed from April(396.6 mgC/m^3/day) to June(193.0 mgC/m^3/day)(Fig.9-4).

4.8.2 Second year(July 1983 to June 1984):

4.8.2.1 Hydrography and sedimentology:

The temperature of air varied from 29.4 to 30.6°C between July and October after which a gradual decrease was noticed till December(26.8°C). A noticeable increase was observed from February(27.2°C) to March(31.5°C) followed by a gradual increase till June(32.8°C)(Fig.9-1). Water temperature followed the same trend as that of the air temperature. A slight increase was observed from July(28.5°C) to October(29.2°C) after which it gradually decreased till January(26.5°C). A rapid increase in its values was observed from February(27.2°C) to April(31.8°C) (Fig.9-1). The dissolved oxygen content of water decreased from July(4.15 ml/l) to August(3.28 ml/l). Low oxygen level was maintained till October(3.26 ml/l) which was followed by a sharp increase in November(4.52 ml/l). After recording relatively high concentration in February(5.05 ml/l), the dissolved oxygen content widely fluctuated between 3.14 and 4.62 ml/l till June(Fig.9-2). Salinity values increased from July(35.7‰) to October(36.7‰), after which a steep decrease in its value was noticed till February(21.3‰) followed by a steady and sharp increase till May (33.6‰)(Fig.9-2). The pH of water increased from July(7.53) to January(8.33) and subsequently, a gradual decrease was recorded till June(7.85)(Fig.9-4).

Soluble reactive phosphate content of water ranged from 0.53 to 0.58 µg-at PO_4-P/l from July to December, after which a gradual increase was recorded till February(0.81 µg-at PO_4-P/l). An abrupt increase in its concentration was noticed in March (14.33 µg-at PO_4-P/l) followed by a sharp decrease in April (0.58 µg-at PO_4-P/l). Afterwards a gradual decrease was observed till June(0.35 µg-at PO_4-P/l)(Fig.9-3). Nitrate content of water gradually increased from August(0.73 µg-at NO_3-N/l) to February(1.50 µg-at NO_3-N/l), followed by a steady decline till June(0.93 µg-at NO_3-N/l)(Fig.9-3). Nitrite content of water showed a distribution pattern similar to that of the nitrate. A sharp increase was recorded from November(0.035 μg-at NO_2-N/l) to February(0.400 μg-at NO_2-N/l), after which a sharp decline was noticed in March(0.110 μg-at NO_2-N/l) followed by a gradual decrease till June(0.040 μg-at NO_2-N/l) (Fig.9-3). The ammonia concentration in water gradually increased from July(2.17 μg-at NH_3-N/l) to December(7.18 μg-at NH_3-N/l) and recorded a peak in January(17.84 μg-at NH_3-N/l). After a sharp decline in February(6.39 μg-at NH_3-N/l), the ammonia content of water gradually decreased till June(2.76 μg-at NH_3-N/l)(Fig.9-3).

The temperature of sediment recorded an increase from July(28.8°C) to November(29.1°C). After registering a sharp decrease in December(26.4°C), a slight increase was noted till February(27.8°C). Temperature of the sediment was relatively high in March(31.5°C) followed by a gradual increase till May (32.0°C)(Fig.10-3). The pH of the sediment gradually increased from September(7.20) to December(7.70) and fluctuated between 7.50 and 7.70 till March. After recording a decline in April (7.17), the pH value increased to 7.45 in May(Fig.10-3). The Eh of the sediment varied from -42.5 to +23 mV during the period of observation. Eh value was relatively higher in October(+23 mV), whereas the lowest value was recorded in December(-43 mV). From January to June, the Eh values fluctuated between -5 mV and -25 mV (Fig.10-3).

The organic carbon content of the sediment varied between 0.05 and 0.08% dry wt from July to November and peak value was recorded in December(0.13% dry wt). After January(0.11% dry wt) and February(0.10), a mild rise was observed in March(0.12% dry wt), after which it varied between 0.08 and 0.10% dry wt till June(Fig.10-4). The total phosphorus of sediment fluctuated from 56.5 to 1273. ug/g dry wt between July and November. The primary peak in its concentration was observed in December(300.3 ug/g dry wt) followed by a sharp decline in January(179.4 ug/g dry wt). Secondary peak was recorded in March(276.9 ug/g dry wt). A sharp fall in its concentration was noticed in April(102.4 ug/g dry wt) followed by a slight increase till June(132.1 ug/g dry wt)(Fig.10-4). The Kjeldahl nitrogen concentration of sediment was in the undetectable range from July to October and in June. An increase in its concentration was noticed from November(0.055% NH_3-N dry wt) to December(0.142% NH_3-N dry wt), after which a steady decrease was noticed till February(0.091% NH_3-N dry wt). After registering relatively high value in March(0.140% NH_3-N dry wt), the Kjeldahl nitrogen content of sediment decreased sharply in April(0.057% NH_3-N dry wt) (Fig.10-4).

4.8.2.2 Productivity:

The gross primary production rate was relatively high during July(694.6 mgC/m^3/day) and August(943.4 mgC/m^3/day), after which a sharp fall was recorded till October(289.4 mgC/m^3/day). After recording a moderately high value in November(467.4 mgC/m^3/day), the gross primary production rate gradually declined to 105.1 mgC/m^3/day in January. Between February and June, its

STATION - V

Fig. 10-1 Distribution of temperature, total sulphide, pH and Eh of the sediment.

Fig. 10-2 Distribution of organic carbon, total phosphorus and Kjeldahl nitrogen contents of the sediment.

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Fig. 10-3 Distribution of temperature, total sulphide, pH and Eh of the sediment.

Fig. 10-4 Distribution of organic carbon, total phosphorus and Kjeldahl nitrogen contents of the sediment.

FIG 10-1

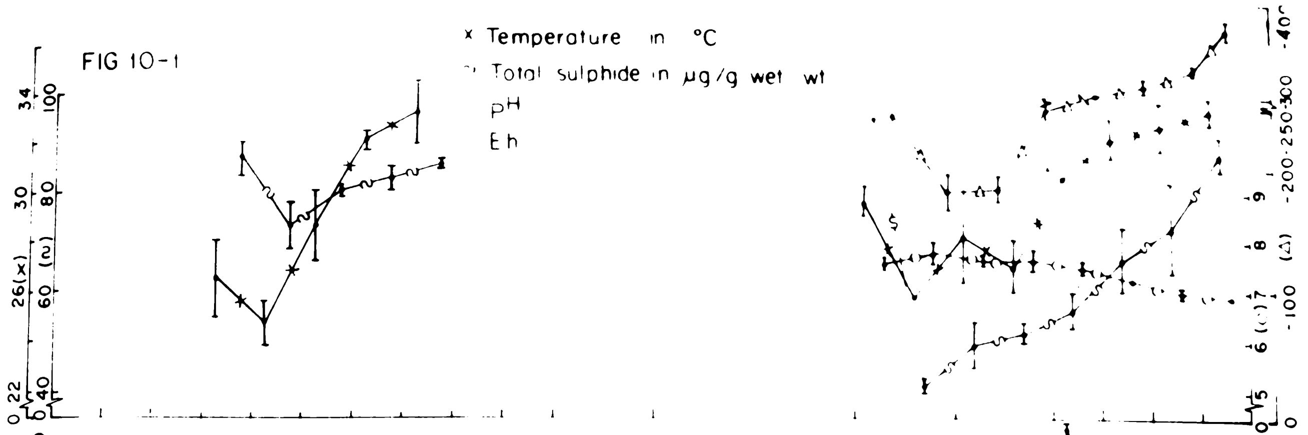


FIG 10-2

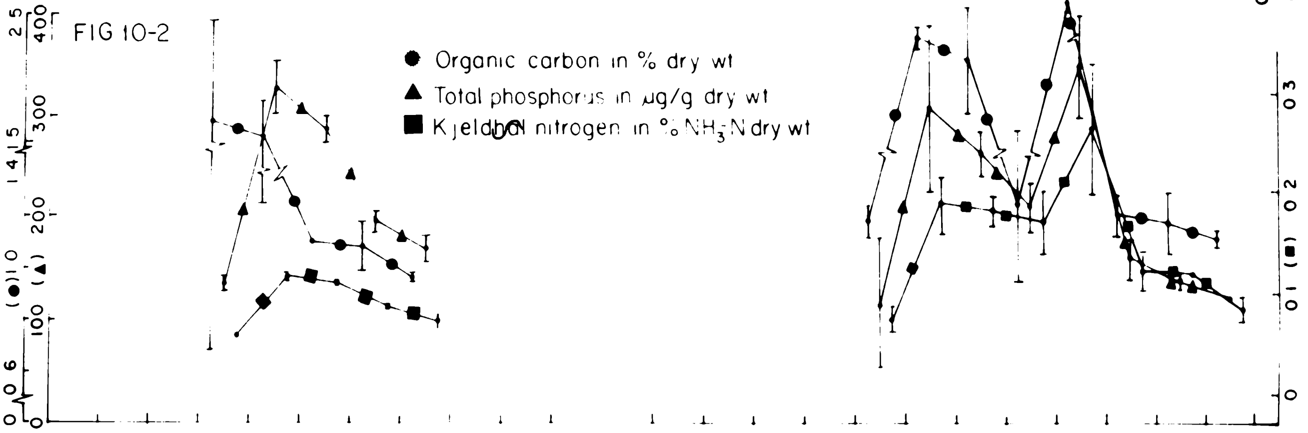


FIG 10-3

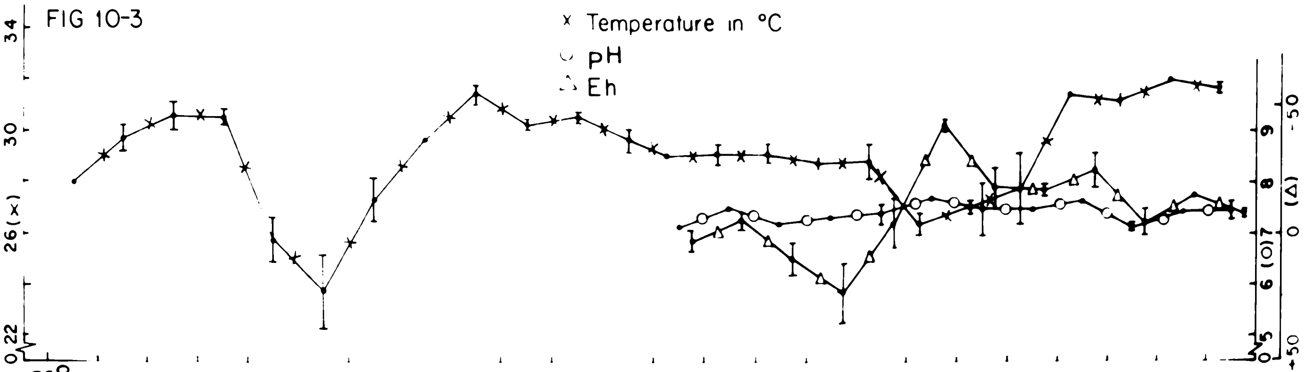
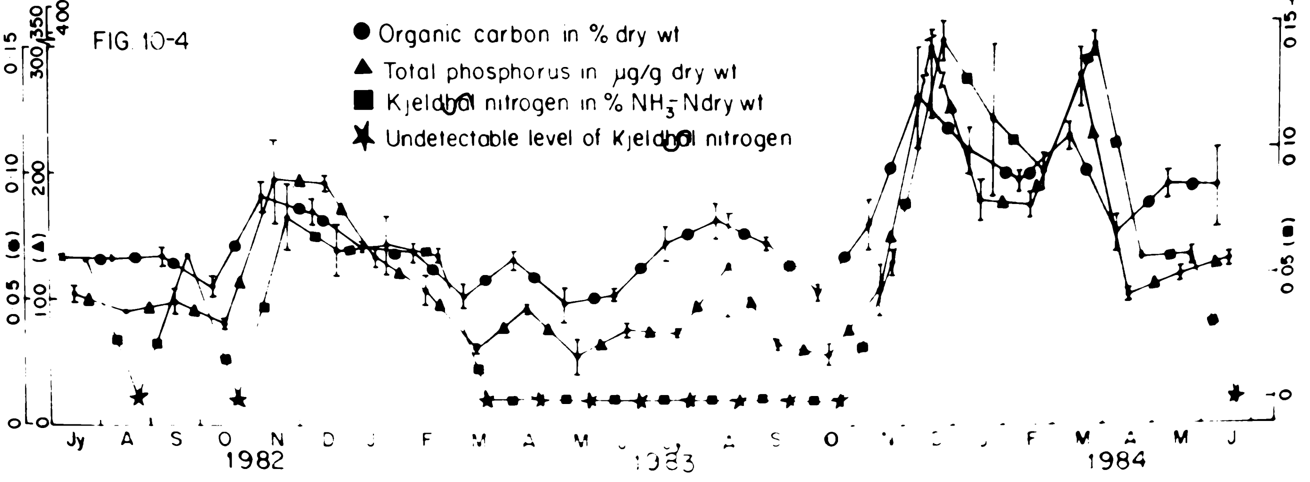


FIG 10-4



values varied from 79.3 to 244.4 mgC/m^3/day (Fig.9-4). The net primary production rate was relatively high from July (100.8 mgC/m^3/day) to August(290.6 mgC/m^3/day) after which a decrease in its values was noticed till October(120.1 mgC/m^3/day). After registering a secondary maximum in November (224.4 mgC/m^3/day), the net production rate gradually decreased till May(41.5 mgC/m^3/day) followed by a slight rise in June (92.2 mgC/m^3/day)(Fig.9-4).

4.9 Correlation (Table-6):

In the following account, the arabic numerals 1 and 2 given in brackets denote the years in which the correlations were worked out (1982-83 and 1983-84).

The temperature of air was positively correlated with the temperature of water (1.r=0.75; 2.r=0.85) and the temperature of sediment (1.r=0.76; 2.r=0.70). The temperature of water was positively correlated with the temperature of sediment (1.r=0.82; 2.r=0.76). Nitrate content was positively correlated with the nitrite (2.r=0.64). Eh of the sediment was negatively correlated with the pH of the sediment(2.r=-0.69). The organic carbon content of the sediment was positively correlated with the total phosphorus (1.r = 0.95; 2.r=0.91) and Kjeldahl nitrogen(1.r=0.74; 2.r=0.86) contents of sediment. The total phosphorus content of sediment was positively correlated with the Kjeldahl nitrogen content of the sediment(1.r =0.77; 2.r=0.92). Ammonia content was positively correlated with the pH of water(2.r=0.92).

Table-6: Correlation matrix of ecological and productivity parameters at Palk Bay Station

1983-'84

	A.temp	W.temp	Oxy	Sal	PO_4	NO_3	NO_2	NH_3	WpH	Gross	Net	S.temp	SEh	OrgC	SPO_4	Kj.N	SpH
A.temp		0.85	0.13	0.45	0.21	-0.30	-0.43	-0.36	-0.31	-0.01	-0.05	0.70	0.27	-0.36	-0.34	-0.36	-0.29
W.temp			0.17	0.38	0.22	-0.16	-0.40	-0.42	-0.16	-0.10	-0.07	0.76	0.18	-0.27	-0.18	-0.27	-0.20
Oxy				-0.16	0.73	-0.07	-0.04	-0.05	-0.02	-0.22	-0.14	-0.16	-0.20	0.21	0.05	0.15	0.10
Sal					-0.12	-0.46	-0.80	-0.62	-0.67	0.51	0.28	0.45	0.66	-0.61	-0.57	-0.67	-0.41
PO_4						-0.13	-0.14	-0.05	0.01	-0.15	-0.14	0.20	-0.10	0.18	0.29	0.34	0.14
NO_3							0.64	0.16	0.36	-0.24	-0.29	-0.22	-0.02	0.13	-0.01	0.09	-0.26
NO_2								0.47	0.45	-0.33	-0.23	-0.44	-0.28	0.35	0.22	0.33	0.02
NH_3									0.92	-0.20	0.04	-0.44	-0.23	0.31	0.23	0.41	0.05
WpH										-0.44	0	-0.35	-0.36	0.47	0.49	0.64	0.08
Gross											0.36	-0.20	0.29	-0.34	-0.34	-0.30	-0.24
Net												-0.23	0.15	-0.21	-0.05	-0.08	-0.25
S.temp													0.20	-0.18	-0.21	-0.31	-0.11
SEh														-0.85	-0.83	-0.74	-0.69
OrgC															0.91	0.86	0.50
SPO_4																0.92	0.56
Kj.N																	0.34
SpH																	

1982-'83

	A.temp	W.temp	Oxy	Sal	PO_4	NO_3	NO_2	NH_3	Gross	Net	S.temp	OrgC	SPO_4	Kj.N
A.temp														
W.temp	0.75													
Oxy	-0.45	-0.39												
Sal	0.77	0.70	-0.59											
PO_4	-0.47	-0.32	0.24	-0.50										
NO_3	-0.32	-0.42	0.30	-0.44	0.44									
NO_2	-0.45	-0.30	0.37	-0.45	0.39	0.53								
NH_3	-0.34	-0.24	0.16	-0.42	0.41	0.42	0.49							
Gross	0.33	0.36	0.11	0.07	-0.26	-0.28	-0.13	-0.03						
Net	-0.12	0.23	0.12	-0.34	0.04	0	0.07	0.23	0.55					
S.temp	0.76	0.82	-0.44	0.88	-0.30	-0.11	-0.22	-0.20	0.14	-0.09				
OrgC	-0.70	-0.69	0.40	-0.75	0.38	0.17	0.19	0.37	-0.44	-0.07	-0.82			
SPO_4	-0.82	-0.78	0.47	-0.90	0.47	0.24	0.32	0.39	-0.32	0.04	-0.92	0.95		
Kj.N	-0.70	-0.58	0.20	-0.74	0.41	-0.17	-0.16	0.06	-0.24	0.12	-0.75	0.74	0.77	

Abbreviations:

Same as in Table-1.

4.10 Studies on the distribution pattern of Zooplankton:

During the monsoon of 1982 attempts were made to filter a known quantity of water to study the zooplankton distribution in the lagoon, but the method was not successful. In the monsoon period of 1983, a zooplankton net with mouth diameter of 0.5 m was employed to make the collections. Details of the method of collection have been presented in the section "material and methods". The plankton collections were minutes duration and the water filtered was estimated as 150 m^3. The sea water flooded the lagoon in the first half of November, 1983 and hence collections could be made only from the latter half of November. Due to the cyclonic weather conditions, no collection was made during the second fortnight of December. Operation of the boat for collection became impossible since water receded from the lagoon after the first fortnight of March, 1984.

Zooplankton collected were grouped under broad taxonomic categories. In the following text, number indicated in brackets represents number of different zooplankton taxa per 150 m^3 of water filtered. The roman numerals presented adjacent to the month of collection indicate the fortnight of that particular month. The results of observations are presented in Table-7.

Coelenterates(60 Nos) appeared in the sample in November-II 1900 h collection, but in December-I all the samplings showed the presence of coelenterates(200 Nos, 100 Nos and 400 Nos at

Table-7: Variation in the numerical abandance of zooplankters during the period November 1983 to March 1984 (in Nos / 150 m^3 of water)

Month & year	November 1983			December 1983			January 1984						February 1984						March 1984		
Fortnight in every month		II			I			I			II			I			II			I	
Time of sampling (in hours)	1900	2400	0000	1900	2400	0500	1900	2400	0500	1900	2400	0500	1900	2400	0500	1900	2400	0500	1900	2400	0500
Volume of zooplankton (in ml)	11·5	18·5	12·1	21·8	26·2	10·5	7·9	9·0	8·4	9·0	19·5	7·2	19·0	16·1	16·2	11·3	41·0▲	15·8	61·0▲	89·2▲	80·7▲
Coelenterates	50	—	—	200	100	400	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cladocerans	—	—	200	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ostracods	—	—	—	—	—	—	250	100	65	—	—	—	—	—	—	—	—	—	—	—	—
Copepods	6250	15700	15600	5000	12000	400	11500	36400	23500	58250	357500	27875	27500	35875	29200	1625	6750	3900	207750	277500	200500
Cumaceans	100	400	20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Amphipods	—	200	100	200	100	—	—	300	200	1250	2750	125	250	125	125	250	—	—	250000	305750	22500
Isopods	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
Mysids	900	1500	650	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other decapod larvae	75	13	110	1300	700	2100	67	1400	1850	500	257	875	—	130	60	125	750	250	27	61	—
Lucifer	300	10	100	—	—	—	—	200	125	100	—	—	250	—	—	—	—	—	—	—	—
Chaetognaths	580	200	—	—	200	100	500	500	250	250	1500	—	—	—	—	—	—	—	—	—	—
Polychaetes	—	—	—	—	—	—	—	200	9000	—	—	—	—	—	—	125	—	—	125	300	375
Lamellibranchs	—	200	2100	—	—	—	500	11000	9000	—	—	125	—	—	—	125	—	—	—	—	—
Heteropods	1500	4750	100	100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pteropods	100	200	25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gastropods	—	—	400	100	100	—	—	2000	585	—	250	—	750	375	250	—	—	—	—	—	—
Appendicularians	125	100	100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fish eggs	700	2400	2500	—	400	300	1500	1000	925	—	—	125	—	—	—	125	250	100	—	—	—
Fish larvae	65	200	310	100	—	—	3	110	80	2	—	—	—	1	—	—	—	—	10	11	10
Copepod nauplii	—	200	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fish scales	—	—	400	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Copepod eggs	—	—	—	300	600	750	1500	1600	1500	750	1250	300	1000	1550	990	1750	2800	1200	—	—	—
Ophiopleuteus larvae	500	200	100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Insect larvae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1125	32200	20375

▲ Samples contained large quantities of debris.

at 1900, 2400 and 0500 hrs respectively). Cladocerans(200 Nos) were recorded only in the 0500 h collection in November-II. Ostracods were recorded only in January-I(250 Nos, 100 Nos and 65 Nos at 1900, 2400 and 0500 hrs respectively). Copepods(400 Nos to 3,57,500 Nos) were present in the collections throughout the period. Collections made at 2400 h always contained maximum concentration of Copepod population. High density of copepods was observed in the collections made in January-II and March-I (27875 Nos to 3,57,500 Nos). A decrease in copepod population was observed in December-I and February-II(400 Nos to 12,000 Nos). Cumaceans(100 Nos, 400 Nos and 20 Nos at 1900, 2400 and 0500 hrs respectively) were present in the collection made in November-II. Amphipods ranged from 100 Nos to 2750 Nos/ 150m^3 of water filtered from November-II to February-II. The Highest density of amphipods(2,50,000 Nos, 3,05,750 Nos and 22,500 Nos at 1900 h, 2400 h and 0500 h respectively) was recorded in March-I. Isopods were rare and were observed in the collections made in February-I(2 Nos) at 24 h. Mysidaceans (900 Nos, 1500 Nos and 650 Nos at 1900, 2400 and 0500 hrs respectively) were encountered in the collection only in November-II, recording high density in the collection made at 24 h. Decapod larvae ranged from 13 Nos to 2100 Nos/150m^3 of water filtered throughout the period, and their density was relatively high in December-I. Lucifers were observed in November-II(300 Nos, 10 Nos and 100 Nos at 1900, 2400 and 0500 hrs respectively), January-I(200 Nos and 125 Nos at 2400 and and 0500 hrs respectively), January-II(100 Nos at 1900 h) and

February-I(250 Nos at 1900 h). Chaetognaths were abundant till January-II(100 Nos to 1500 Nos). Polychaetes were present in the collections made in January-I(200 Nos at 2400 h), February-II(125 at 1900 h) and in March-I(125 Nos, 300 Nos and 375 Nos at 1900, 2400 and 0500 hrs respectively). Lamellibranchiates were observed in the samples in November-II(200 Nos and 2100 Nos at 2400 and 0500 hrs respectively), January-I(500 Nos, 11000 Nos and 9000 Nos at 1900, 2400 and 0500 hrs respectively), January-II(125 Nos at 0500 h) and February-II(125 Nos at 1900 h). Heteropods were encountered in the samples in November-II (1500, 4750 and 100 at 1900, 2400 and 0500 hrs respectively) and December-I(100 at 1900 h). Peteropodes were recorded only in November-II(100 Nos, 200 Nos and 25 Nos at 1900, 2400 and 0500 Hrs respectively). The presence of gastropods was observed till February-I and their distribution was irregular. When present, their number ranged between 100 Nos and 2,000 Nos/150 m^3 of water filtered and their abundance in the lagoon was observed in January-I(2000 Nos at 2400 h). Appendicularians were found only in the sample made in November-II(125 Nos, 100 Nos and 100 Nos at 1900, 2400 and 0500 hrs respectively). Fish eggs were noticed till February-II, and their distribution was irregular. When present, their number ranged from 100 Nos to 2500 Nos/150 m^3 of water filtered. High density was recorded in November-II(700 Nos, 2400 Nos and 2500 Nos at 1900, 2400 and 0500 hrs respectively). Fish larvae were encountered in fairly good quantities in November-II(65 Nos, 200 Nos and 310 Nos at 1900, 2400 and 0500 hrs respectively) after which its occurrence in the lagoon was sporadic. Copepod nauplii were observed in November-II (200 Nos at 2400 h). Fish scales were found in the collections made in November-II (400 Nos at 0500 h). Copepod eggs were recorded from December-I to February-II and when present, their number ranged between 300 Nos and 2800 Nos/150m^3 of water filtered. Maximum concentration of copepod eggs was seen in February-II (1750 Nos, 2800 Nos and 1200 Nos at 1900, 2400 and 0500 hrs respectively). Copepod eggs were absent in the collections in November-II and March-I. Ophiopleuteus larvae occurred only in November-II (500 Nos, 200 Nos and 100 Nos at 1900, 2400 and 0500 hrs respectively). Insect larvae were present in maximum numbers in the samples made in March-I (1125 Nos, 32,200 Nos and 20,375 Nos at 1900, 2400 and 0050 hrs respectively) (Table-7).

4.11 Benthic macrofauna:

In order to study the qualitative and quantitative nature of the distribution of macrobenthos a series of collections were made and analysed once in a fortnight during the period July, 1982 to June, 1984. Large amount of empty shells of *Carithedia fluviatilis* was observed at Station-V. Moderate concentration of the shells was recorded at Stations-II, III and IV, whereas they were scanty at Station-I. Shells of *Meretrix costa*, *Mactra cuneata*, *Cardium setosum*, *Cardita bicolor* and *Umbonium vestiarium* were frequently met with at Theedai zone and rarely at Pillaimadam and Munaikkadu zones.

As the macrobenthos were present only during a particular period, the quantitative data was not summarised on a monthly basis. In the ensuing account, the roman numerals indicated after each month denotes the week of collection in that particular month. The results of analysis are presented in Figs. 11-1 to 12.7. As the sampling from the Palk Bay was made more or less throughout the period of study, the monthly mean values were used to represent the faunal abundance at this station. Due to the rough nature of the sea, samples could not be collected from the Palk Bay during December, 1983 and February, 1984.

4.11.1 Station-I(Fig.11-1 and 11-2):

Bivalve spat was observed at this station during the first year from January-III(18 Nos/m^2) and a gradual increase in their concentration was noticed till February-III(108 Nos/m^2), followed by a sharp rise in March-I(351 Nos/m^2). Afterwards, the bivalve spat was not represented in the collection during the rest of the year.

In the following year, *Chironomus* sp. appeared in December-I(1917 Nos/m^2) and recorded a peak in March-II(2754 Nos/m^2). After March-IV(1719 Nos/m^2) a sharp decrease was recorded in its concentration till April-IV(81 Nos/m^2). The occurrence of bivalve spat was highest in December-III(54 Nos/m^2). *Perinereis* sp., was recorded in December-I(18 Nos/m^2) and from March-IV(18 Nos/m^2) to April-IV(9 Nos/m^2). *Pulliella armata* occurred in the sample in February-IV(396 Nos/m^2) and

STATION - I

Fig. 11-1 Quantitative distribution of macrobenthos during the first year.

Fig. 11-2 Quantitative distribution of macrobenthos during the second year.

STATION - II

Fig. 11-3 Quantitative distribution of macrobenthos during the first year.

Fig. 11-4 Quantitative distribution of macrobenthos during the second year.

STATION - III

Fig. 11-5 Quantitative distribution of macrobenthos during the first year

Fig. 11-6 Quantitative distribution of macrobenthos during the second year.

FIG. 11-1

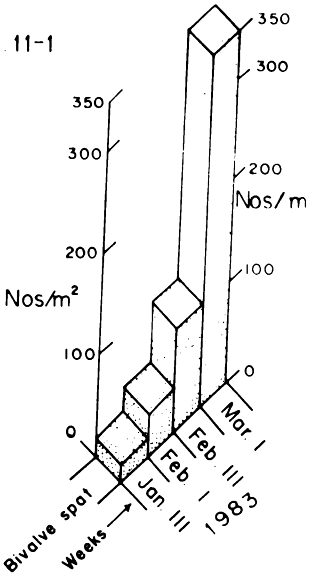


FIG. 11-2

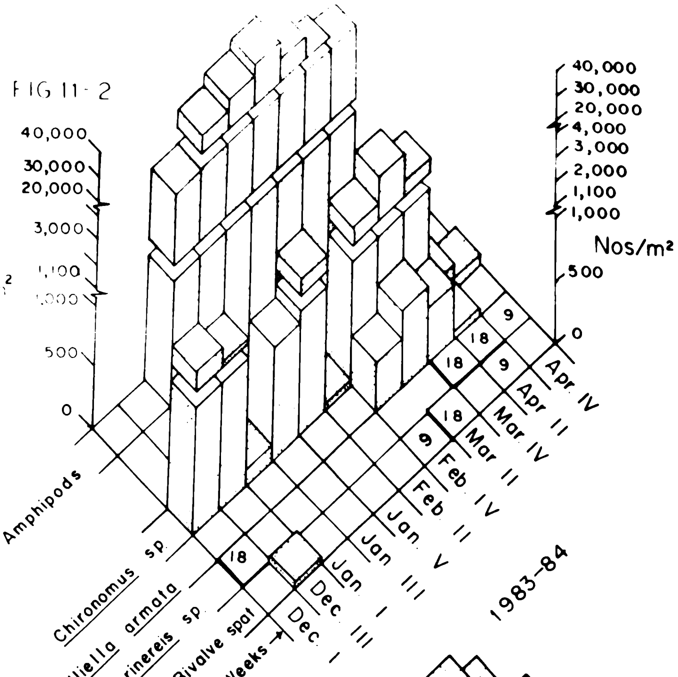


FIG. 11-3

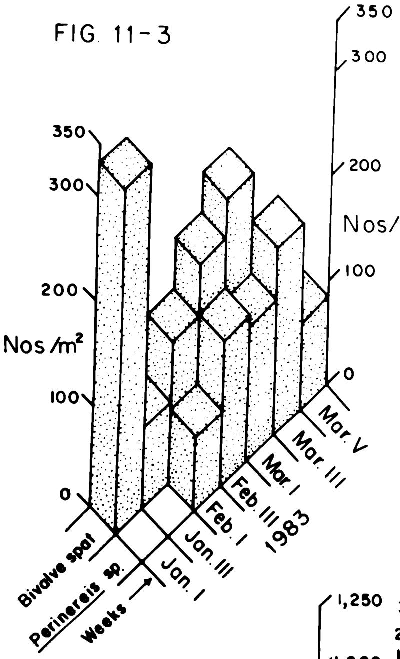


FIG. 11-4

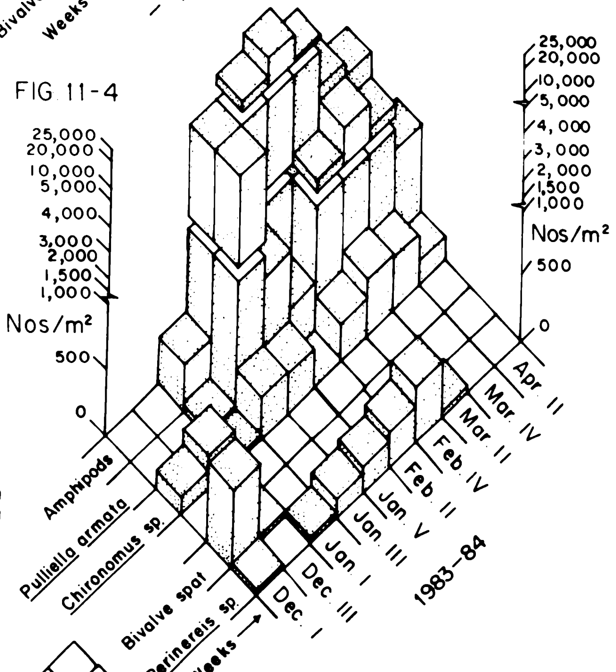


FIG. 11-5

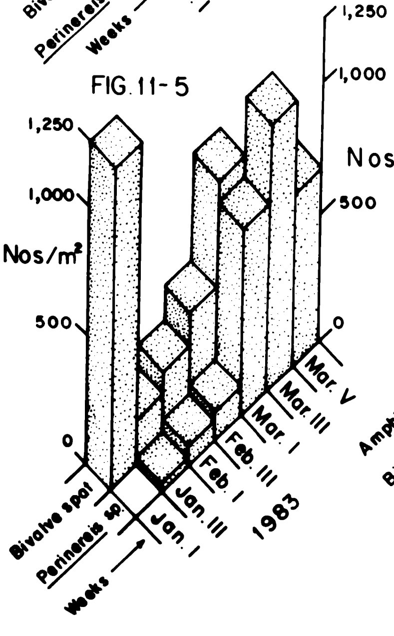
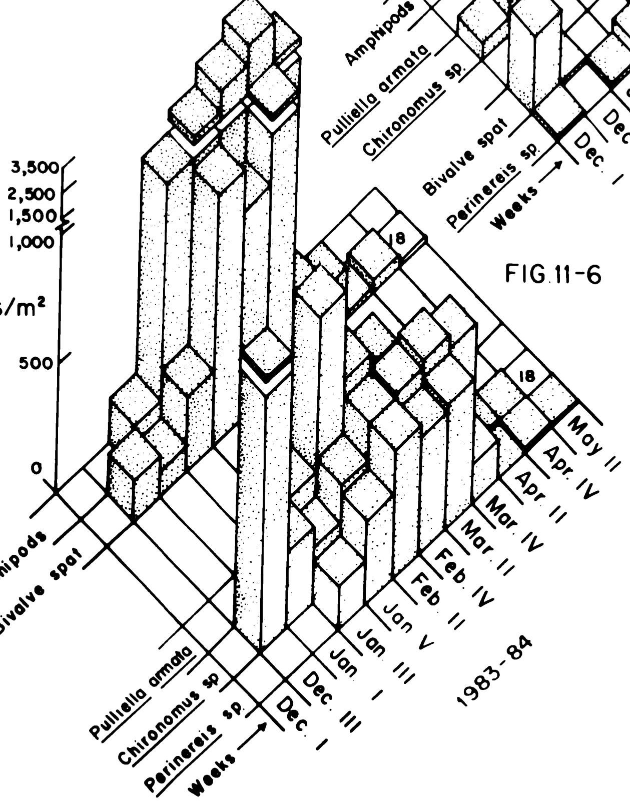


FIG. 11-6



after recording a peak in March-IV(639 Nos/m^2) a sharp decline in its concentration was observed till April-II(72 Nos/m^2). Amphipods were observed in the sample in January-I(3852 Nos/m^2), after which a sharp increase in their number was found in January-III(27,801 Nos/m^2). A gradual increase was observed in their concentration till February-II(37,305 Nos/m^2) which was followed by steady and sharp decline till March-IV(3,996 Nos/m^2).

4.11.2 Station-II(Fig.11-3 and 11-4):

Bivalve spats were observed at this station in the first year in January-I(333 Nos/m^2) with a sharp decrease in January-III(81 Nos/m^2), after which a gradual increase was noticed in their concentration till March-I(225 Nos/m^2). *Perinereis* sp. was recorded in February-I(72 Nos/m^2) and an increase in its number was observed till March-III(180 Nos/m^2) after which its concentration dwindled in March-V(81 Nos/m^2).

In the following year, *Chironomus* sp. appeared in the sample in December-I(135 Nos/m^2) and after evincing fluctuation in its occurrence, it recorded a peak in March-II(450 Nos/m^2). Subsequently, a steady decline in its number occurred till April-II(189 Nos/m^2). Bivalve spats recorded a peak in their occurrence in December-I(612 Nos/m^2) and afterwards their number steeply decreased in December-III(45 Nos/m^2). *Perinereis* sp. appeared in the sample in December-I(36 Nos/m^2). From January-I (36 Nos/m^2) onwards a gradual increase in its number was noticed in the sample and it recorded a peak in February-IV(414 Nos/m^2). Its number dwindled in March-II(45 Nos/m^2) and subsequently, it was not observed in the samples. *Pulliella armata* appeared in the samples in January-I(54 Nos/m^2) and an abrupt increase in its concentration was noticed in January-III(4995 Nos/m^2) followed by sharp decrease till February-II(396 Nos/m^2). A sharp increase in its number was recorded in February-IV(1854 Nos/m^2) and after recording a secondary peak in March-II(2961 Nos/m^2) its number dwindled sharply till April-II(837 Nos/m^2). Amphipods were present in the sample in January-I(351 Nos/m^2) and after recording a peak in February-II(21195 Nos/m^2), their number decreased sharply till March-IV(3006 Nos/m^2).

4.11.3 *Station-III*(Fig.11-5 and 11-6):

Bivalve spats appeared in the sample in January-I(1251 Nos/m^2) and after recording a sharp fall in January-III(189 Nos/m^2), a gradual and steady increase in their concentration was noticed till March-I(810 Nos/m^2). *Perinereis* sp. was first recorded in January-III(27 Nos/m^2) and its number gradually increased upto February-III(126 Nos/m^2). After recording a maximum in March-III(1035 Nos/m^2), its number dwindled in March-V(675 Nos/m^2).

In the following year, *Chironomus* sp.appeared in the sample in December-III(1629 Nos/m^3) and subsequently a sharp decrease in its number was noticed till January-III(225 Nos/m^2) which was followed by a gradual increase till March-II(549

Nos/m^2). A sharp decline in its concentration was noticed from March-IV(498 Nos/m^2) to May-II(18 Nos/m^2). Bivalve spats appeared in December-III(153 Nos/m^2) and after recording a peak in February-IV(1638 Nos/m^2) their number dwindled sharply in March-II(261 Nos/m^2) which was followed by a gradual decline till May-II(18 Nos/m^2). Perinereis sp. was first observed in January-III(171 Nos/m^2) and its occurrence was at its peak in February-II(504 Nos/m^2). A steep decline in its population was noticed from March-II(486 Nos/m^2) to May-II(36 Nos/m^2). Pulliella armata was observed in January-III(315 Nos/m^2) and after recording a maximum occurrence in January-V(909 Nos/m^2), a gradual decline in its number was observed till February-IV (522 Nos/m^2). Amphipods were present in the sample in January-I(171 Nos/m^2) and a steep increase in their number was observed till February-IV(3402 Nos/m^2). Their number dwindled in March-II(1530 Nos/m^2) and they were absent in the subsequent samples.

4.11.4 Station-IV(Fig.12-1 and 12-2):

Bivalve spats appeared in the sample in January-I(585 Nos/m^2) during the first year. From January-III(27 Nos/m^2) onwards a steep increase in their populations was noticed and their peak occurrence was recorded in March-I(1062 Nos/m^2). Perinereis sp. was recorded in January-III(18 Nos/m^2) which was followed by a steady and sharp increase till March-III(1296 Nos/m^2). After March-V(729 Nos/m^2), it was absent in the samples.

STATION - IV

Fig. 12-1	Quantitative distribution of macrobenthos during the first year.
Fig. 12-2	Quantitative distribution of macrobenthos during the second year.

STATION - V

Fig. 12-3	Quantitative distribution of macrobenthos during the first year.
Fig. 12-4	Quantitative distribution of macrobenthos during the second year.

STATION - PALK BAY

Fig. 12-5 & 12-6	Quantitative distribution of macrobenthos during the first year.
Fig. 12-7	Quantitative distribution of macrobenthos during the second year.

FIG 12-1

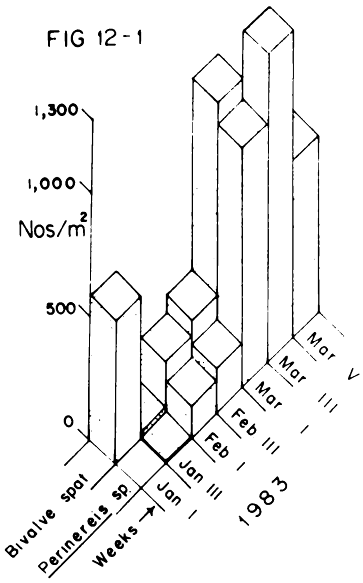


FIG 12 2

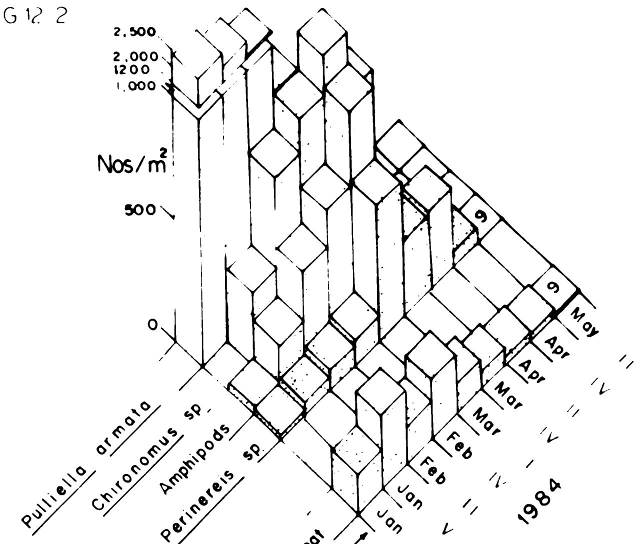


FIG 12-3

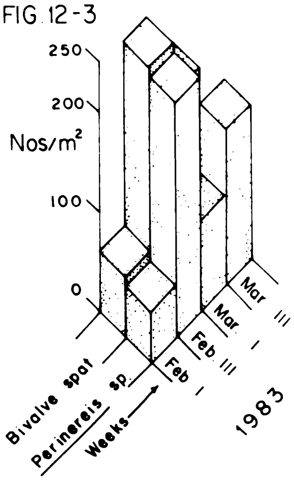


FIG 12-4

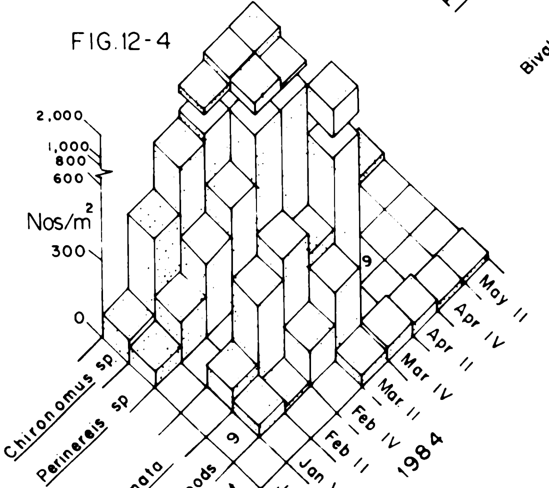


FIG 12-5

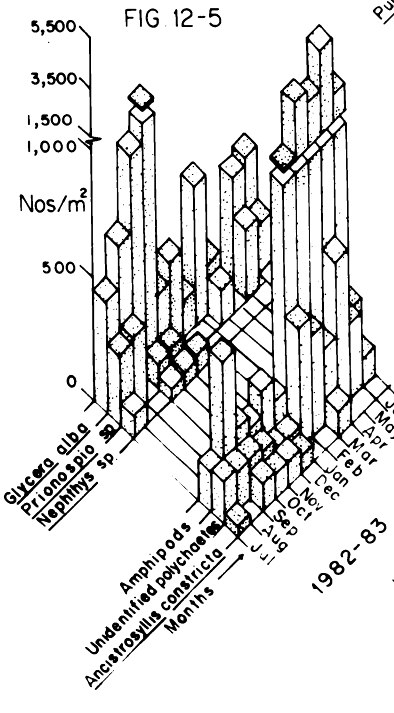


FIG 12-6

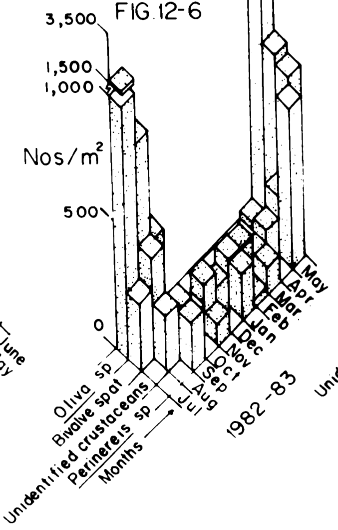
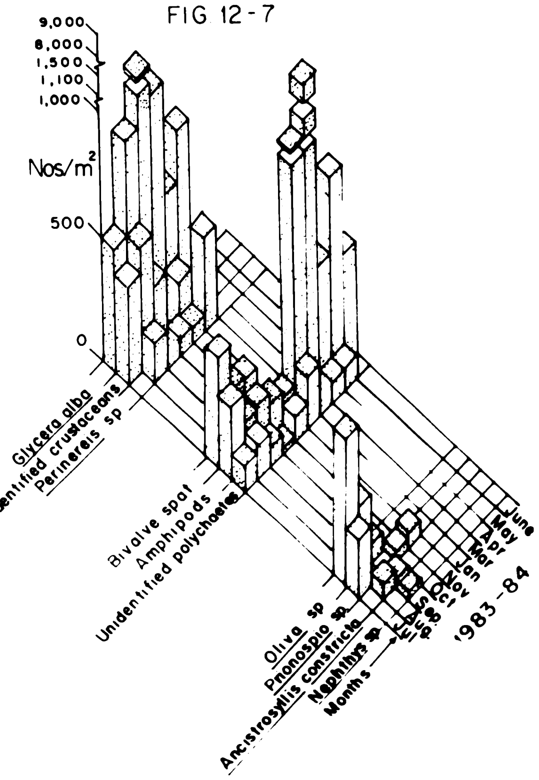


FIG 12-7



In the second year, *Chironomus* sp. was recorded in January-V(288 Nos/m^2) and since then a steady and sharp increase was noticed in its concentration till March-II(963 Nos/m^2). Its number dwindled in March-IV(801 Nos/m^2) and subsequently, it was absent in the samples. The bivalve spats were observed in the samples in January-III(153 Nos/m^2) and they recorded a peak occurrence in January-V(297 Nos/m^2) after which their population gradually declined till May-II(9 Nos/m^2). *Perinereis* sp. was present at this station in January-III(18 Nos/m^2). Its number gradually increased and attained a peak in March-II(558 Nos/m^2), after which a sharp decrease was noticed till May-II(9 Nos/m^2). The population of *Pulliella armata* was at its maximum in January-III(2439 Nos/m^2) and a gradual decline in its number was noticed till February-IV(819 Nos/m^2). Amphipods appeared in the sample in January-III(36 Nos/m^2) and a sharp increase in their number was recorded till March-II(837 Nos/m^2). Their population dwindled in March-IV(378 Nos/m^2) and subsequently they were not recorded in the samples.

4.11.5 Station-V(Fig.12-3 and 12-4):

Bivalve spats appeared for the first time in the sample in February-I(63 Nos/m^2) during the first year and their population was at its maximum in February-III(241 Nos/m^2). Their number decreased in March-I(198 Nos/m^2) and they were absent in the samples since then. *Perinereis* sp. was present in February-I (54 Nos/m^2) and it recorded a peak in occurrence in February-III(234 Nos/m^2). After a fall in number in March-I(90 Nos/m^2), an increase in its population was noticed in March-III(153 Nos/m^2).

In the second year, *Chironomus* sp. was recorded in January-III(90 Nos/m^2) and its number sharply increased till March-IV(1305 Nos/m^2), after which it was not recorded in the samples. Bivalve spats appeared in the sample in March-II (45 Nos/m^2) and an increase in its number was recorded in March-IV(63 Nos/m^2). Later it dwindled till May-II(18 Nos/m^2) and subsequently it was absent in the samples. *Perinereis* sp. was recorded in January-III(81 Nos/m^2) and its population increased sharply from February-IV(396 Nos/m^2) to March-II (1062 Nos/m^2). After March-IV(891 Nos/m^2), this species was recorded only in May-II(18 Nos/m^2). *Pulliella armata* was observed in the samples in January-V(90 Nos/m^2) and it recorded a peak in March-IV(1926 Nos/m^2). It was recorded in fewer number in April-II(9 Nos/m^2) and afterwards was absent in the samples. Amphipods were poorly represented in the samples in January-III(9 Nos/m^2) and maximum number was recorded in March-II(261 Nos/m^2) during the period of observation.

Station-PB(Fig.12-5 to 12-7):

First year (1982-83):

The population of *Glycera alba* gradually increased from July(441 Nos/m^2) and maximum was recorded in October(1611 Nos/m^2). From November to July its concentration in the samples fluctuated between 54 to 549 Nos/m^2. *Prionospio* sp.occurred sporadically in the samples and maximum number was recorded in August(306 Nos/m^2). *Nephthys* sp. ranged between 54 Nos/m^2 (October) and 81 Nos/m^2(July) during the period of observation. Amphipods fluctuated between 162 Nos/m^2 and 549 Nos/m^2 from July to December, after which a sharp increase in their number was noticed till April(4,869 Nos/m^2). Subsequently, their number gradually declined till June(252 Nos/m^2). *Ancistrosyllis constricta* varied between 45 Nos/m^2 and 117 Nos/m^2 from July to December except in August when it was not recorded. After December, it was recorded only in March(108 Nos/m^2). *Oliva* sp. occurred in July(1,557 Nos/m^2), August(801 Nos/m^2), September(369 Nos/m^2), May(27 Nos/m^3) and June(954 Nos/m^2). Bivalve spats occured in July(261 Nos/m^2), August(396 Nos/m^2) and June(684 Nos/m^2). Unidentified Crustaceans were recorded during the period of observation and when present, their population varied between 99 Nos/m^2(March) and 657 Nos/m^2(June). *Perinereis* sp. varied between 27 Nos/m^2(February) and 189 Nos/m^2 (September) when present and recorded a peak in May(630 Nos/m^2). Unidentified polycheats varied between 81 Nos/m^2(November) and 594 Nos/m^2 (April).

Second year(1983-84):

Glycera alba gradually increased in the samples from July(495 Nos/m^2) to September(1260 Nos/m^2) and subsequently declined till November(504 Nos/m^2). In January, 702 Nos/m^2 was recorded after which it was not found in the samples. *Perinereis* sp. was found only in August(162 Nos/m^2), October(72 Nos/m^2), November(72 Nos/m^2) and January(369 Nos/m^2). Bivalve spats were present in July(450 Nos/m^2), August(279 Nos/m^2) and September(261 Nos/m^2). *Oliva* sp. spats were recorded in July (612 Nos/m^2), August(279 Nos/m^2) and September(63 Nos/m^2). *Prionospio* sp. was observed in the samples in July(243 Nos/m^2), October(36 Nos/m^2) and November(54 Nos/m^2). *Ancistrosyllis constricta* was recorded in August(63 Nos/m^2) and September(27 Nos/m^2). *Nephthys* sp. occurred only in September(27 Nos/m^2). Unidentified Crustaceans were recorded in July(396 Nos/m^2), August(486 Nos/m^2), September(288 Nos/m^2) and November(198 Nos/m^2). The population of Amphipods ranged between 126 and 297 Nos/m^2 from July to November, after which a rapid increase in their number was noticed till March(8838 Nos/m^2) followed by a sharp decrease in April(495 Nos/m^2). Unidentified polycheats were recorded during the period of observation except in March and June. When present, it ranged from 18 Nos/m^2 (October) to 207 Nos/m^2(January).

4.12 Studies on the grain-size distribution:

Grain size analysis was done for the pre-monsoon, monsoon and post-monsoon periods of 1982-'83 and 1983-'84. The data obtained from the analysis of the core-samples of the upper layers in March-April, 1984 is also incorporated in the text for possible comparison. Core samples were collected and analysed from the five stations inside the lagoon, and no sampling was made from the station located in the Palk Bay.

The results of the analysis is presented in Table-8.

At Station-I, the sediment was sandy in nature(78.3 to 93.9%). The silt content sharply increased in the post monsoon period of 1982-'83(January-February,1983=10.8%). The increase of silt content in the sediment was gradual from November-December,1983(5.3%) to March-April,1984(12.4%). The percentage contribution of clay in the sediment showed little increase from November-December,1983(6.5%) to January-February,1984(9.5%).

At station-II, the sediment was predominantly sandy mud in nature. A sharp increase in the silt content was noticed in the sediment from September-October,1982(2.9%) to November-December,1982(26.3%), after which a moderate decrease was observed in January-February, 1983(14.1%). There was a sharp increase in the silt content from November-December,1983(3.6%) to January-February,1984(29.8%).

At Station-III, the sediment was a mixed nature with sand and mud. Moderate increase was recorded in the silt content from September-October,1982(3.7%) to November-December,1982 (8.8%) followed by a slight increase in January-February,1983 (9.9%). Clay content was relatively high in November-December, 1983(14.9%). Gradual increase was noticed in the silt content from September-October,1983(3.2%) to March-April,1984(14.2%). During this period, the percentage contribution of clay in the sediment varied from 12.1 to 15.6%.

Table-9: Distribution of grain-size
(in percentage)

Stations	I			II			III		
Particles	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay
Month & Year									
Sep - Oct '82	No water			93.4	2.9	3.7	84.4	3.7	11.9
Nov - Dec '82	93.9	1.2	4.9	71.4	26.3	2.3	76.3	8.8	14.9
Jan - Feb '83	84.3	10.8	4.9	82.2	14.1	3.7	80.8	9.9	9.3
Sep - Oct '83	No water			No water			81.6	3.2	15.2
Nov - Dec '83	89.2	5.3	6.5	88.1	3.6	8.3	80.9	5.7	13.4
Jan - Feb '84	81.2	9.3	9.5	68.2	29.8	2.0	72.5	11.9	15.6
*Mar - Apr '84	78.3	12.4	9.3	80.2	13.4	6.4	73.7	14.2	12.1

Stations	IV			V		
Particles	Sand	Silt	Clay	Sand	Silt	Clay
Month & Year						
Sep - Oct '82	77.2	8.2	14.6	No water		
Nov - Dec '82	65.6	17.5	16.9	16.1	4.8	79.1
Jan - Feb '83	69.9	9.6	20.5	18.4	6.5	75.1
Sept- Oct '83	No water			No water		
Nov - Dec '83	74.6	10.8	14.6	17.6	6.2	76.2
Jan - Feb '84	70.3	18.9	10.7	21.3	6.1	72.6
*Mar - Apr '84	74.2	15.4	10.4	18.8	2.1	79.1

* Data obtained from the upper layers of the grain-size analysis for the core-sample.

At station-IV, the characteristics of the sediment was similar to that at station-III, and was composed of sand and mud. The silt content sharply increased from September-October,1982(8.2%) to Nov.-Dec.,1982(17.5%) followed by a decrease in its content in January-February,1983(9.6%). During this period, the clay content evinced a gradual increase from 14.6 to 20.5%. In the second year, the silt content showed an increase in January-February,1984(18.9%) after which a slight decrease was noticed in March-April,1984(15.4%). The clay content during this period constantly showed a decreasing trend and the values dropped from 14.6% to 10.4%.

At station-V, the sediment was highly clayey in nature. A slight increase was noticed in the silt content from November-December,1982(4.8%) to January-February,1983(6.5%). The proportion of sand in the sediment was relatively high during January-February,1984(21.3%). The silt content sharply decreased from January-February,1984(6.1%) to March-April,1984 (2.1%). The clay content was comparatively high in the sediment in March-April,1984(79.1%).

4.13 Studies on the vertical profile of sediment:

This study was undertaken once in two months and the sampling for the estimation of chemical composition of the sediment in vertical profile was made only if water was present at the station. Regular samples were collected at those stations from where data were collected to estimate other ecological and productivity parameters. In this study, no sampling has been made from the station situated in the Palk Bay. Sediment samples were collected and analysed upto 50 cm depth. In the ensuing text, the letters U, M and L presented in brackets denote the upper, middle and lower layers respectively. The results of analyses are presented in Table-9.

4.13.1 Station-I:

Upto 5 cm, the sediment was dark greyish. From 5 cm to 10 cm the sediment was light greyish. From 10 cm and below, it was cream yellowish.

.13.1.1 First year (1982-'83):

Superficial layer showed high nutrient content. Organic carbon content showed relatively high values in all the layers in January-February(U-0.50; M-0.24 and L-0.21% dry wt). Total phosphorus also recorded relatively high concentration in the sediments(U-156.0, M-146.3 and L-54.6 µg/g dry wt). From the undetectable level of Kjeldahl nitrogen in the middle layer in November-December period, there was trace of Kjeldahl nitrogen in January-February(M-0.050% NH_3-N dry wt) period. Undetectable level of Kjeldahl nitrogen was found in the lower layer.

.13.1.2 Second year(1983-'84):

Organic carbon and total phosphorus contents of sediment increased from November-December(Organic carbon; U-0.15, M-0.14

Table _ 9 Chemical composition and grain-size distribution of the sediments in vertical profile

Stations →		I			II			III			IV			V		
Parameters → Month & year ↓		Or C	TP	Kj.N	Or.C	TP	Kj.N	Or C	TP	Kj.N	Or C	TP	Kj.N	Or C	TP	Kj.N
	U							0·25	47·8	N D						
Jul – Aug 1982	M		N W			N W		0·20	32·5	N D		N W			N.W	
	L							0·16	26·1	N D						
	U				0·12	97·5	N D	0·18	45·7	N D	0·25	140·2	N.D			
Sep – Oct 1982	M		N W		0·10	48·8	N.D	0·16	29·6	N D	0·18	68·2	N.D		N.W	
	L				—	—	—	0·10	17·8	N D	0·15	58·5	N.D			
	U	0·45	97·5	0·07	1·08	296·4	0·21	0·89	321·8	0·55	0·68	243·8	0·51	1·25	226·2	0·14
Nov – Dec 1982	M	0·16	28·5	N D	0·93	165·8	0·16	0·62	212·6	0·37	0·45	152·0	0·38	1·09	140·4	0·10
	L	0·12	19·2	N D	—	—	—	0·41	97·5	0·26	0·46	98·6	0·20	0·82	102·4	0·09
	U	0·50	156·0	0·07	0·69	212·6	0·10	0·52	109·2	0·07	0·56	148·9	0·18	1·24	237·9	0·15
Jan – Feb 1983	M	0·24	146·3	0·05	0·57	159·2	0·08	0·44	94·8	0·05	0·49	91·1	0·10	1·18	156·0	0·09
	L	0·21	54·6	N.D	—	—	—	0·38	73·0	N.D	0·25	87·8	0·06	0·99	102·6	0·08
	U				0·34	158·5	N D	0·44	83·6	0·05	0·52	97·5	0·07			
Mar – Apr 1983	M		N.W		0·27	123·4	N.D	0·30	59·5	N.D	0·42	62·9	N.D		N.W	
	L				—	—	—	0·22	27·3	N.D	0·21	49·3	N.D			
	U							0·27	60·5	N.D						
May – Jun 1983	M		N.W			N.W		0·17	48·0	N.D		N.W			N.W	
	L							0·12	17·3	N.D						
	U							0·22	67·8	N.D						
Jul – Aug 1983	M		N.W			N W		0·18	58·5	N.D		N.W			N.W	
	L							0·15	37·1	N.D						
	U							0·20	58·3	N.D						
Sep – Oct 1983	M		N.W			N.W		0·15	39·0	N.D		N.W			N W	
	L							0·12	22·4	N.D						
	U	0·15	66·3	N.D	0·67	194·6	0·10	0·89	298·9	0·58	0·73	192·4	0·26	2·66	291·1	0·16
Nov – Dec 1983	M	0·14	23·4	N.D	0·40	23·6	0·05	0·57	190·2	0·35	0·41	93·6	0·14	1·82	146·3	0·10
	L	0·09	19·5	N.D	—	—	—	0·39	105·8	0·19	0·28	87·8	0·05	1·69	108·3	0·08
	U	0·54	132·6	0·08	0·94	213·1	0·14	0·49	209·2	0·09	0·77	243·8	0·11	1·98	226·2	0·20
Jan – Feb 1984	M	0·32	113·1	0·06	0·87	136·5	0·11	0·38	146·3	0·08	0·64	204·8	0·10	1·20	191·1	0·15
	L	0·22	45·7	N.D	—	—	—	0·24	100·9	0·06	0·52	122·9	0·08	1·14	146·3	0·10
	U	0·57	204·0	0·16	0·61	191·1	0·12	0·62	226·2	0·14	0·86	234·0	0·14	2·19	265·8	0·16
Mar – Apr 1984	M	0·25	146·3	0·10	0·36	160·9	0·06	0·52	159·9	0·10	0·32	185·3	0·11	2·01	195·0	0·10
	L	0·22	93·9	0·06	—	—	—	0·34	126·8	0·07	0·29	98·0	0·08	1·30	109·0	0·09
	U							0·54	98·9	0·07	0·50	151·0	0·07	1·71	190·0	0·11
May – Jun 1984	M		N.W			N W		0·41	72·6	0·05	0·36	102·0	0·05	1·41	146·3	0·09
	L							0·26	60·0	N D	0·25	91·1	N.D	1·16	87·8	0·06

Particles →		Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay
	U	78·3	12·4	9·3	80·2	13·4	6·4	73·7	14·2	12·1	74·2	15·4	10·4	18·8	2·1	79·1
Mar – Apr 1984	M	90·2	4·1	5·7	69·3	10·6	20·1	80·5	12·3	7·2	76·6	8·8	14·6	30·6	3·6	65·8
	L	95·4	2·6	2·0	—	—	—	87·7	9·5	2·8	84·2	8·6	7·2	41·6	2·4	56·0

Abbreviations:

Or.C = Organic carbon in % dry wt
TP = Total phosphorus in µg/g dry wt.
Kj.N = Kjeldhal nitrogen in % NH_3 – N dry wt
N.W = No water
Sand, silt and clay proportions in %

N D = Not detected
U = Upper layer
M = Middle layer
L = Lower layer

and L-0.09% dry wt and Total phosphorus; S-66.3, M-23.4 and L-19.5 µg/g dry wt) to January-February(organic carbon; S-0.54, M-0.32 and L-0.22% dry wt and Total phosphorus; S-132.6, M-113.1 and L-45.7 µg/g dry wt) in all the three layers. Middle and lower layers showed decreased organic carbon content but the concentration of total phosphorus content at middle layer was moderate. From the undetectable level of Kjeldahl nitrogen, a gradual increase in its concentration was noticed in all the layers till March-April(S-0.16, M-0.10 and L-0.06% NH$_3$-N dry wt). Superficial layer showed more silt content(12.4%) than the other layers, but the lower layer had relatively high proportion of sand(95.4%).

4.13.2 Station-II:

Upto 15 cm the sediment was black and muddy. Below 15 cm, the sediment was black and clayey. Only two layers could be differentiated in this station.

.13.2.1 First Year(1982-'83):

Sharp increase was noticed in the organic carbon, total phosphorus and Kjeldahl nitrogen contents of the sediments in both the layers from September-October(Organic carbon; S-0.12 and M-0.10% dry wt; Total phosphorus; S-97.5 and M-48.8 µg/g dry wt and the Kjeldahl nitrogen level was in the undetectable range in both layers) to November-December(Organic carbon; S-1.08 and M-0.93% dry wt; Total phosphorus; S-296.4 and M-165.8 µg/g dry wt and Kjeldahl nitrogen; S-0.21 and M-0.16%

NH_3-N dry wt). Subsequently, a steady decline was observed till March-April(Organic carbon; U-0.34 and M-0.27% dry wt; Total phosphorus; U-158.5 and M-123.4 µg/g dry wt and Kjeldāhl nitrogen level was undetectable in both the layers).

4.13.2.2 Second year(1983-'84):

Moderate increase was observed in the organic carbon, total phosphorus and Kjeldāhl nitrogen contents of the upper layer and a sharp increase in the lower from November-December(Organic carbon; U-0.67 and M-0.40% dry wt; Total phosphorus; U-194.6 and M-23.6 µg/g dry wt and Kjeldāhl nitrogen; U-0.10 and M-0.05% NH_3-N dry wt) to January-February(Organic carbon; U-0.94 and M-0.87% dry wt; Total phosphorus; U-213.1 and M-136.5 µg/g dry wt and Kjeldāhl nitrogen; U-0.14 and M-0.11% NH_3-N dry wt). A decline was observed in the organic carbon, total phosphorus and Kjeldāhl nitrogen content of the sediment in March-April(Organic carbon; U-0.61 and M-0.36% dry wt; Total phosphorus; U-191.1 and M-160.9 µg/g dry wt and Kjeldāhl nitrogen; U-0.12 and M-0.06% NH_3-N dry wt).

The superficial layer contained more silt(14.3%) than clay(6.4%), whereas the proportion of clay(20.1%) in the lower layer was relatively high.

4.13.3 Station-III

Upto 5 cm, the sediment was dark greyish with fine grains. From 5 to 21 cm, the soil was moderately greyish with coarse grains. Below 21 cm, it was light greyish and sandy.

4.13.3.1 First year(1982-'83);

The organic carbon and total phosphorus contents of the sediment showed a mild decrease in all the three layers from July-August(Organic carbon; U-0.25, M-0.20 and L-0.16% dry wt and Total phosphorus; U-47.8, M-32.5 and L-26.1 μg/g dry wt) to September-October(Organic carbon; U-0.18, M-0.16 and L-0.10% dry wt and Total phosphorus; U-45.7, M-29.6 and L-17.8 μg/g dry wt). Kjeldahl nitrogen level was undetectable during this season. A sharp increase was noticed in the organic carbon, total phosphorus and Kjeldahl nitrogen contents of the sediment in November-December(Organic carbon; U-0.89, M-0.62 and L-0.41% dry wt, Total phosphorus, U-321.8, M-212.6 and L-97.5 μg/g dry wt and Kjeldahl nitrogen; U-0.55, M-0.37 and L-0.26% NH_3-N dry wt) after which a steep decrease in value of all these parameters was noticed in all the three layers till May-June(Organic carbon; U-0.27, M-0.17 and L-0.12% dry wt; Total phosphorus; U-60.5, M-48.0 and L-17.3 μg/g dry wt and Kjeldahl nitrogen was in undetectable range in all the layers).

4.13.3.2 Second year(1983-'84):

A steep increase was observed in the organic carbon, total phosphorus and Kjeldahl nitrogen contents of sediment in November-December(Organic carbon; U-0.89, M-0.57 and L-0.39% dry wt, Total phosphorus; U-298.9, M-190.2 and L-105.8 μg/g dry wt and Kjeldahl nitrogen; U-0.58, M-0.35 and L-0.19% NH_3-N dry wt) in all the layers. After recording a moderate decrease in January-February(Organic carbon; U-0.49, M-0.38 and L-0.24%

dry wt; Total phosphorus; U-209.2, M-146.3 and L-100.9 µg/g dry wt and Kjeldahl nitrogen; U-0.09, M-0.08 and L-0.06% NH_3-N dry wt) in all the parameters in three layers, an increase in their concentration in the sediment was recorded in March-April(Organic carbon; U-0.62, M-0.52 and L-0.34% dry wt; Total phosphorus; U-226.2, M-159.9 and L-126.8 µg/g dry wt and Kjeldahl nitrogen; U-0.14, M-0.10 and L-0.07% NH_3-N dry wt). This was followed by a sharp decrease in the organic carbon, total phosphorus and Kjeldahl nitrogen contents in all the layers in May-June(Organic carbon; U-0.54 and M-0.41 and L-0.26% dry wt; Total phosphorus; U-98.9, M-72.6 and L-60.0 µg/g dry wt and Kjeldahl nitrogen; U-0.07, M-0.05 and L-undetectable).

The grain size analysis showed relatively more silt-clay content in the upper two layers(U-silt 14.2% and clay 12.1% and M-silt 12.3% and clay 7.2%), whereas the proportion of sand in the lower layer was comparatively high(87.7%).

4.13.4 Station-IV:

Upto 13 cm, the sediment was greyish and fine grained. From 13 to 31 cm, the sediment was coarse grain. Below 31 cm, the sediment was light grey and sandy.

13.4.1 First Year(1982-'83):

A sharp increase in the organic carbon, total phosphorus and Kjeldahl nitrogen contents in all the three layers was observed from September-October(Organic carbon; U-0.25, M-0.18 and L-0.15% dry wt; Total phosphorus; U-140.2, M-68.2 and

and L-58.5 µg/g dry wt and Kjeldāhl nitrogen was in undetectable level in all the layers) to November-December(Organic carbon; U-0.68, M-0.45 and L-0.46% dry wt; Total phosphorus; U-243.8, M-152.0 and L-98.6 µg/g dry wt and Kjeldāhl nitrogen; U-0.51, M-0.38 and L-0.20% NH_3-N dry wt). A gradual decrease was observed in the organic carbon content of sediment in all the layers till March-April(U-0.52, M-0.42 and L-0.21% dry wt), whereas total phosphorus and Kjeldāhl nitrogen contents decreased sharply till March-April(Total phosphorus; U-97.5, M-62.9 and L-49.3 µg/g dry wt and Kjeldāhl nitrogen; U-0.07% NH_3-N dry wt and undetectable quantity in M and L layers).

4.13.4.2 Second year(1983-'84):

Gradual increase in the organic carbon content was noticed in the upper layer of the sediment from November-December(0.73% dry wt) to March-April(0.86% dry wt). Middle and lower layers also showed increased proportion of organic carbon content in January-February(M-0.64 and L-0.52% dry wt) but the values declined in March-April(M-0.32 and L-0.29% dry wt). Total phosphorus concentration moderately increased in the upper and lower layers, but sharply in the middle layer from November-December(U-192.4, M-93.6 and L-87.8 µg/g dry wt) to January-February(U-243.8, M-204.8 and L-122.9 µg/g dry wt). Total phosphorus concentration recorded a mild decrease in March-April(U-234.0, M-185.3 and L-98.0 µg/g dry wt) in all the layers. The level of Kjeldāhl nitrogen content decreased in the upper two layers from November-December(U-0.26 and M-0.14%

NH_3-N dry wt) to January-February(U-0.11 and M-0.10% NH_3-N dry wt), whereas its concentration in the lower layers showed a mild increase (0.05 to 0.08% NH_3-N dry wt). Sharp decline was observed in the organic carbon, total phosphorus and Kjeldahl nitrogen contents in May-June(Organic carbon; U-0.50, M-0.36 and L-0-25% dry wt, Total phosphorus; U-151.0, M-102.0 and L-91.1 µg/g dry wt and Kjeldahl nitrogen; U-0.07, M-0.05% NH_3-N dry wt and L-not detected).

The grain size analysis showed high content of silt (15.4%) in the upper layer, high clay content(14.6%) in the middle layer and high sand content(84.2%) in the lower layer.

4.13.5 Station-V:

Upto 22 cm, the sediment was light greyish and clayey. From 22 to 36 cm, the sediment was light greyish, more clayey and less sandy. Below 36 cm, the sediment was light greyish, less clayey and more sandy.

4.13.5.1 First year(1982-'83):

A slight increase was noticed in the total phosphorus content of the sediment from November-December(U-226.2 and M-140.4 µg/g dry wt) to January-February(U-237.9 and M-156.0 µg/g dry wt) in the upper and middle layers. Kjeldahl nitrogen content showed a very slight increase in the upper layer(0.14 to 0.15% NH_3-N dry wt) and a decrease in the lower two layers(M-0.10 to 0.09 and L-0.09 to 0.08% NH_4-N dry wt) from November-December to January-February, whereas organic carbon displayed mild increase in the middle and lower layers (M-1.09 to 1.18 and L-0.82 to 0.99% dry wt).

4.13.5.2 Second year(1983-'84):

The decrease in the organic carbon content of the sediments in all the three layers was recorded from November-December(U-2.66, M-1.82 and L-1.69% dry wt) to January-February (U-1.98, M-1.20 and L-1.14% dry wt). An increase was observed in the Kjeldahl nitrogen content(U-0.16, M-0.10 and L-0.08 to U-0.20, M-0.15 and L-0.10% NH_4-N dry wt) of the three layers. Total phosphorus content slightly decreased in the upper layer (294.1 to 226.2 µg/g dry wt) but moderately increased in the lower two layers(M-146.3 and L-108.3 to M-191.1 and L-146.3 µg/g dry wt). A mild increase was noted in the organic carbon content of the sediment in March-April in the upper(2.19% dry wt) and lower (1.30% dry wt) layers whereas moderate increase in its concentration was recorded in the middle layer(2.01% dry wt). Total phosphorus content showed a slight increase in the upper two layers (U-265.8 and M-195.0 µg/g dry wt) but decrease in the lower layer (109.0 µg/g dry wt). Kjeldahl nitrogen content decreased moderately in all the layers(U-0.16, M-0.10 and L-0.09% NH_3-N dry wt). In May-June, organic carbon, total phosphorus and Kjeldahl nitrogen contents of sediment in all the layers showed moderate decrease(Organic carbon; U-1.17, M-1.41 and L-1.16% dry wt; Total phosphorus; U-190.0, M-146.3 and L-87.8 µg/g dry wt and Kjeldahl nitrogen; U-0.11, M-0.09 and L-0.06% NH_3-N dry wt).

The grain size analysis indicated a high clay content in the upper(79.1%) and middle(65.8%) layers but the proportion of sand content(41.8%) in the lower layer was relatively more.

4.14 Diurnal study:

Studies on the diel periodicity of hydrological parameters was undertaken in order to assess their nature of fluctuation during the pre-monsoon, monsoon and post-monsoon seasons. Four locations were selected for sampling in the Theedai zone(Plate-1-5) and they were designated as Station-D1, D2, D3 and D4 respectively starting from the area of freshwater influence to the bar mouth. During pre-monsoon period water was present only at stations-D2 and D3 and hence diurnal observations during this period was undertaken at these two stations only. At all the stations, samples were collected for the analysis of dissolved oxygen content and concentration of nutrients from the surface, whereas for salinity estimation collections were made from both surface and bottom layers.

4.14.1 Pre-monsoon period:

4.14.1.1 New moon phase:

14.1.1.1 Station-D2 (Figs.13-1 and 13-2):

Dissolved oxygen(Range: 1.03 to 4.43 ml/l) recorded maximum value at 1500 h followed by a sharp decrease till 0300h. Oxygen

STATION - D2

Fig. 13-1	Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the pre-monsoon period(New moon phase)
Fig. 13-2	Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the pre-monsoon period (New moon phase)

STATION - D3

Fig. 13-3	Results of observations on diurnal variation of dissolved oxygen surface and bottom salinity during the pre-monsoon period(New moon phase)
Fig. 13-4	Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the pre-monsoon period (New moon phase)

STATION - D2

Fig. 13-5	Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the pre-monsoon period(Fullmoon phase)
Fig. 13-6	Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the pre-monsoon period (Full moon phase)

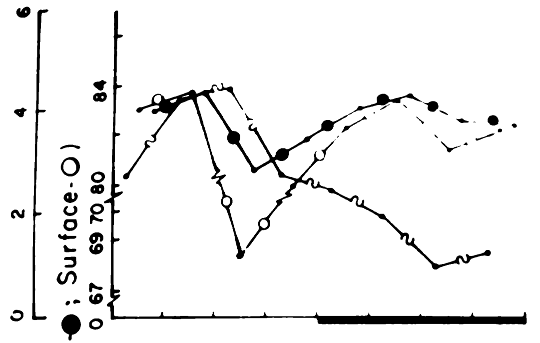
STATION - D3

Fig. 13-7	Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the pre-monsoon period(Full moon phase)
Fig. 13-8	Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the pre-monsoon period (Full moon phase)

FIG 13-1

NEW MOON

FIG 13 2



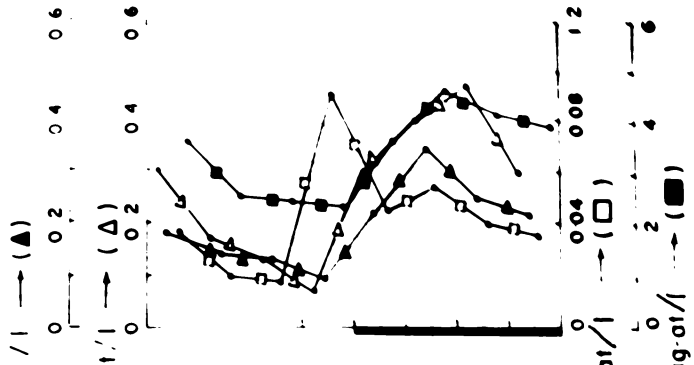


FIG 13-3

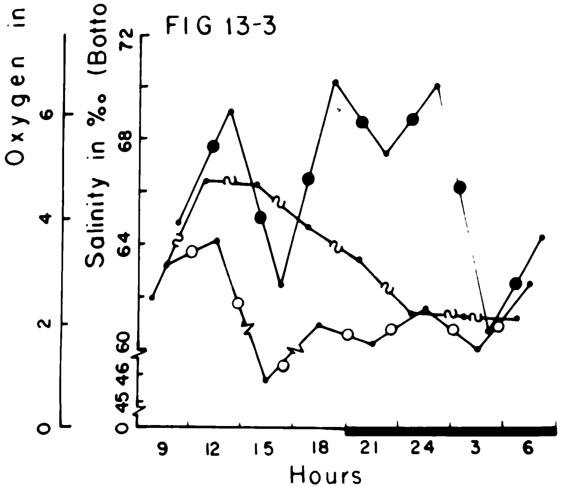
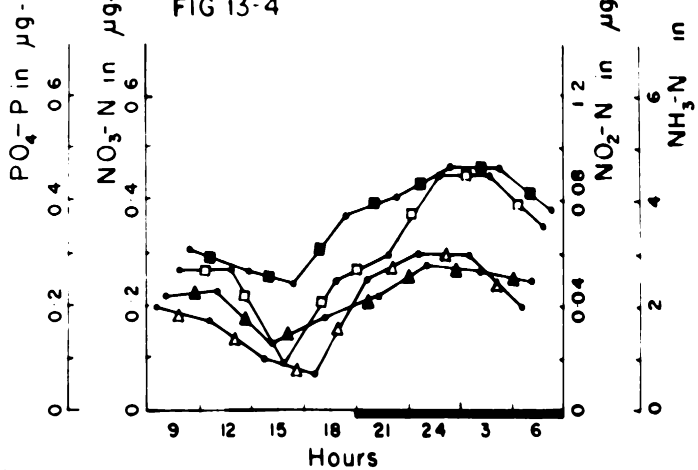
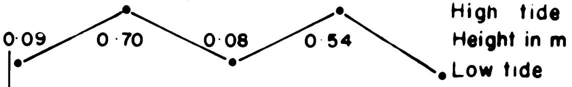


FIG 13-4





FULL MOON

FIG. 13-5

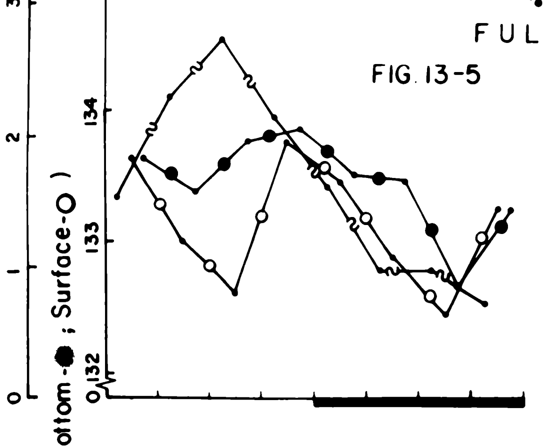


FIG.13-6

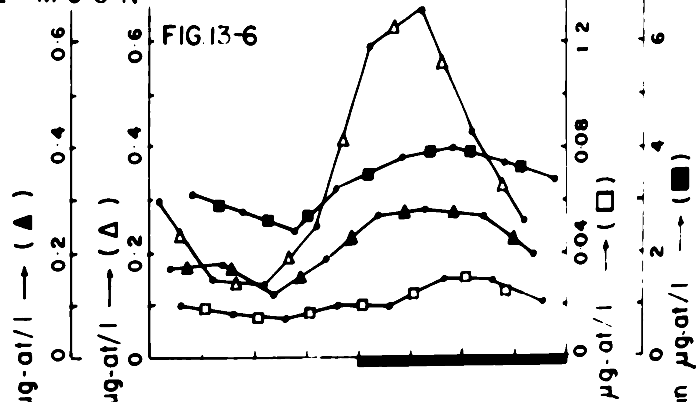


FIG 13-7

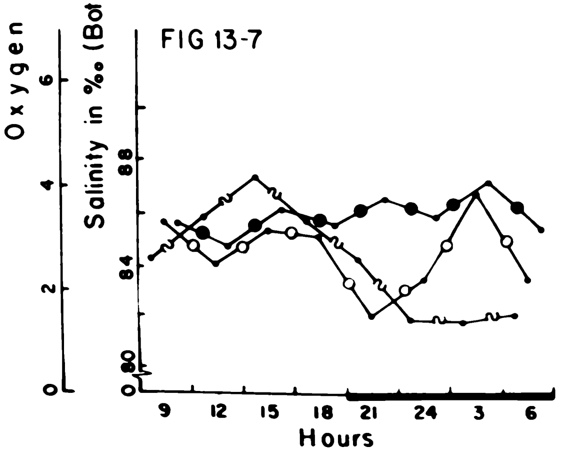
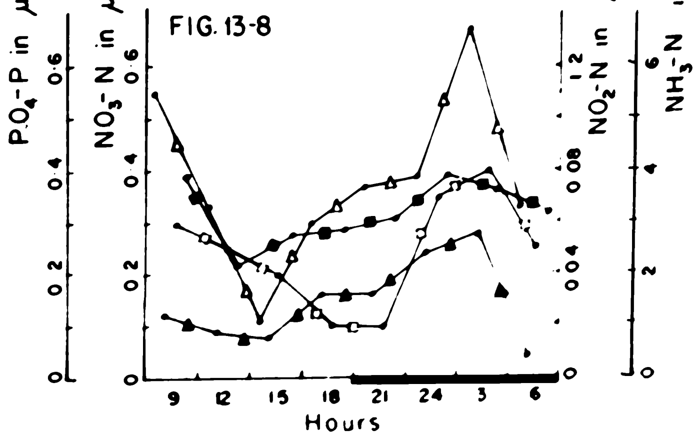
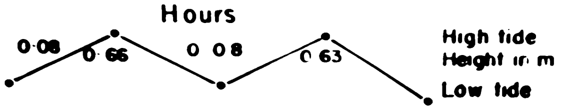


FIG. 13-8





content was high during the day time. Salinity at the bottom layer was either equal to or more than the salinity at surface. There was a sharp decrease in the surface salinity from 83.7% at 1200 h to 68.4% at 1500 h. Soluble reactive phosphate (Range:0.07 to 0.47 µg-at PO_4-P/l), nitrate(Range:0.12 to 0.34 µg-at NO_3-N/l) and ammonia(Range:2.29 to 4.58 µg-at NH_3-N/l) concentrations at the surface layer gradually decreased from 0600 h and minimum was observed at 1800 h, followed by a steady increase as the night advanced. Maximum concentration of nitrate and ammonia was observed at 2400 h whereas that of the soluble reactive phosphate was observed at 0300 h. Nitrite (Range:0.018 to 0.090 µg-at NO_2-N/l) concentration recorded a minimum at 1500 h followed by a sharp increase at 1800 h after which its values decreased gradually.

14.1.1.2 Station-D1 (Figs. 13-3 and 13-4):

The dissolved oxygen content at the surface stratum(Range: 2.07 to 4.70 ml/l) was maximum at 1200 h followed by a steep decline till 0600 h. In the level of surface salinity a sharp fall was observed at 1500 h(45.8‰). Salinity of the bottom water(Range:60.7 to 70.1‰) always showed higher values than the surface salinity. A slight decrease was noted in the bottom salinity from 1800 h(70.1‰) to 21.00h(67.4‰) and again at 0300 h(60.7‰). Soluble reactive phosphate(Range:0.13 to 9.28 µg-at PO_4-P/l), nitrite(Range:0.020 to 0.090 µg-at NO_2-N/l) and ammonia(Range:2.44 to 4.58 µg-at NH_3-N/l) concentrations at the surface stratum decreased from 0600 h to 1500 h after which their concentrations increased in the surface stratum upto 2400 h. Nitrate(Range:0.07 to 0.30 µg-at NO_3-N/l) content was minimum at 1800 h and maximum at 2400 h.

4.14.1.2 Full moon phase:

.14.1.2.1 Station-D2(Figs.13-5 and 13-6):

A peak in dissolved oxygen content at the surface(Range: 0.74 to 2.72 ml/l) was observed at 1200 h after which a gradual decrease was recorded till 0600 h. Salinity showed very slight variations. Soluble reactive phosphate(Range:0.12 to 0.29 µg-at PO_4-P/l), nitrate(Range:0.14 to 0.66 µg-at NO_3-N/l), nitrite(Range:0.015 to 0.030 µg-at NO_2-N/l) and ammonia(Range: 2.40 to 3.97 µg-at NH_3-N/l) concentrations were low at 1500 h and their values increased sharply at 2400 h. A distinct increase was noticed in the nitrate concentration from 1500 to 2400 h.

.1.2.2 Station-D3(Figs.13-7 and 13-8):

Dissolved oxygen(Range:1.40 to 4.24 ml/l) content of the surface layer sharply increased from 0900 h to 1500 h followed by a steep decrease upto 2400 h. Surface salinity ranged from 81.9 to 86.8% and a sharp decrease was observed in its concentration at 2100 h. Salinity of the bottom layer fluctuated between 84.8% and 87.1% without any definite trend. Soluble reactive phosphate(Range:0.08 to 0.28 µg-at PO_4-Pl/) and nitrate(Range:0.10 to 0.67 µg-at NO_3-N/l) concentrations were minimum at 1500 h and subsequently, their values increased sharply and attained a maximum at 0300 h. Nitrite content (Range:0.020 to 0.080 µg-at NO_2-N/l) recorded minimum value at 1800 h followed by a steady increase upto 0300 h. Ammonia (Range:2.25 to 3.90 µg-at NH_3-N/l) content at the surface layer was minimum at 1200 h followed by an increase to reach its maximum concentration at 2400 h. Sharp fluctuation was observed in the concentration of nitrate.

4.14.2 Monsoon period:

.14.2.1 New moon phase:

4.2.1.1 Station-D1(Figs.14-1 and 14-2):

Dissolved oxygen(Range:4.06 to 5.08 ml/l) was at its peak at 1500 h and the minimum value was recorded at 0300 h with a slight increase at 2400 h(4.28 ml/l). Surface salinity was either lesser than or equal to the salinity at the bottom layer. A slight increase was noticed in the salinity values during night hours. Surface salinity ranged between 34.6 and 36.5‰, whereas salinity at the bottom layer fluctuated from 34.9 to 36.9‰. Soluble reactive phosphate(Range:0.14 to 0.64 µg-at PO_4-P/l), nitrate(Range:0.64 to 1.32 µg-at NO_3-N/l), nitrite (Range:0.09 to 0.26 µg-at NO_2-N/l) and ammonia(Range:1.80 to 3.82 µg-at NH_3-N/l) contents at the surface layer gradually increased from 0900 h to 1500 h, and the maximum concentration was recorded at 2400 h. Soluble reactive phosphate evinced

STATION - D1

Fig. 14-1	Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the monsoon period(New moon phase)
Fig. 14-2	Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the monsoon period(New moon phase)

STATION - D2

Fig. 14-3	Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the monsoon period(New moon phase)
Fig. 14-4	Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the monsoon period(New moon phase)

STATION - D3

Fig. 14-5	Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the monsoon period(New moon phase)
Fig. 14-6	Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the monsoon period(New moon phase)

STATION - D4

Fig. 14-7	Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the monsoon period(New moon phase)
Fig. 14-8	Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the monsoon period(New moon phase)

NEW MOON

FIG 14·1

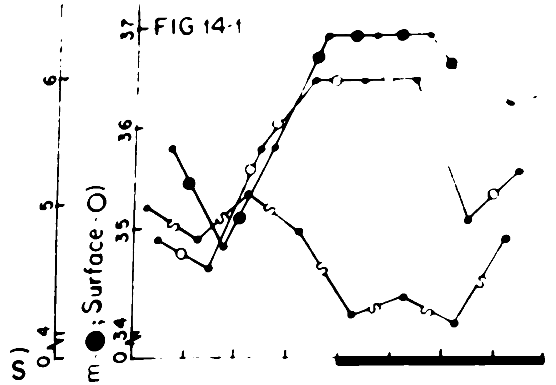


FIG 14·2

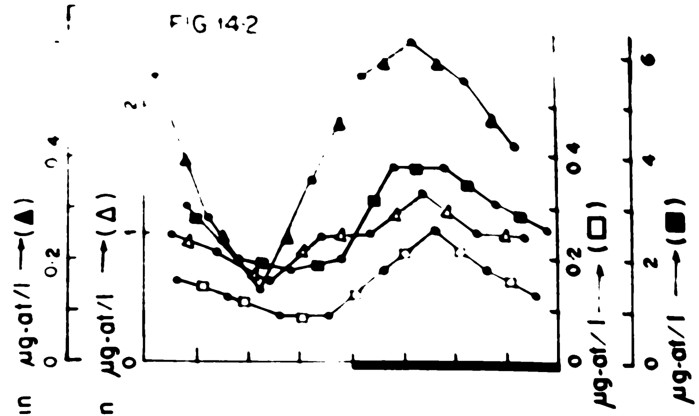
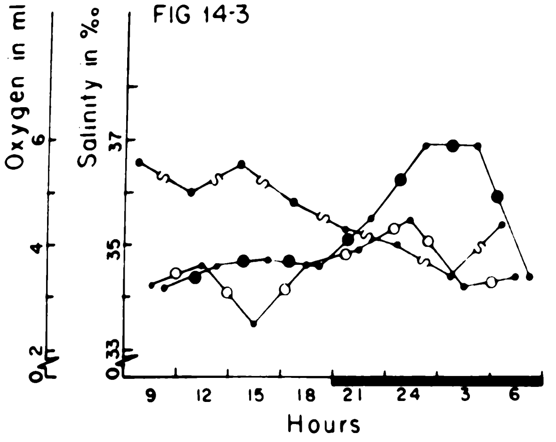
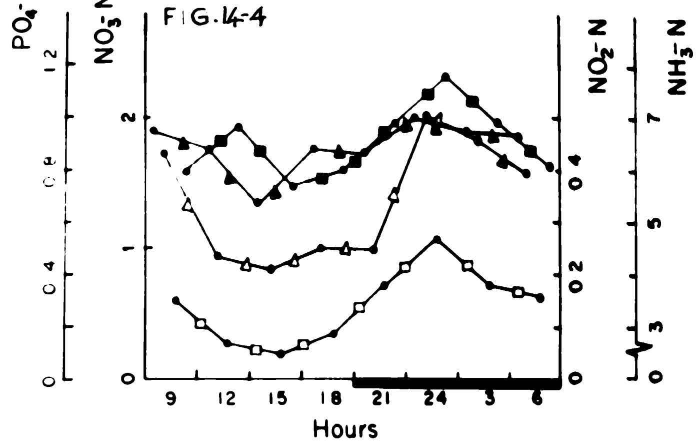


FIG 14·3



FIG·14·4



NEW MOON

FIG 14·5

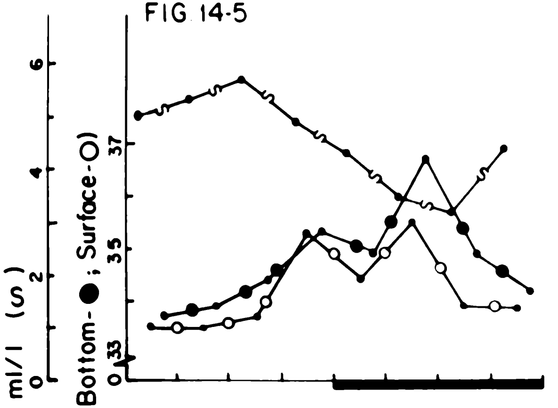


FIG 14·6

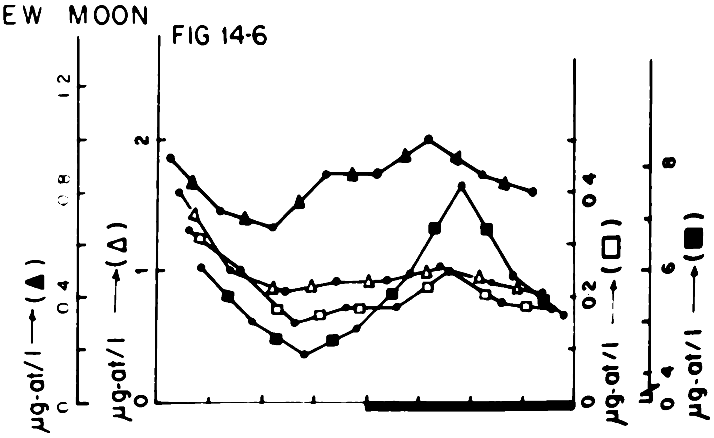
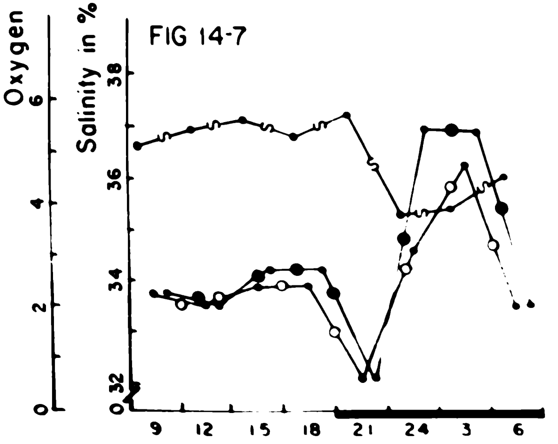


FIG 14·7



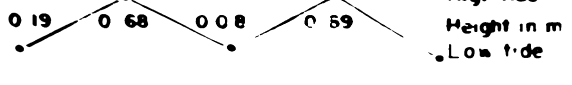
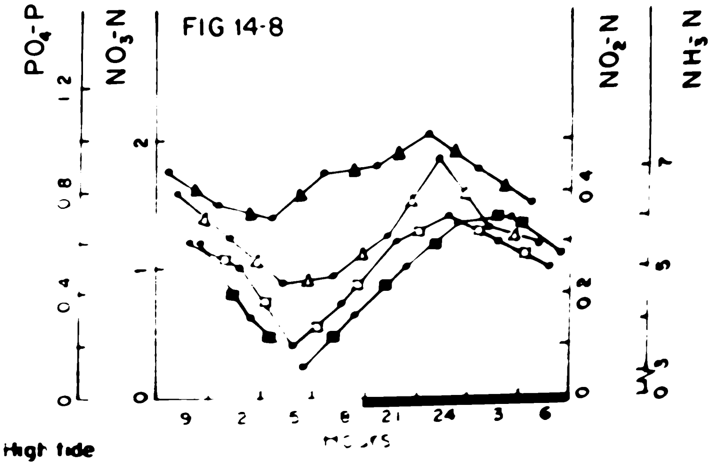


FIG 14·8



wide fluctuation during the period of observation.

4.2.1.2 Station-D2(Figs.14-3 and 14-4):

Dissolved oxygen concentration at the surface stratum was high during the day time and it gradually decreased from 1500 h (5.5 ml/1) to 0300 h(3.36 ml/1). A slight increase in the salinity was observed at 2400 h (surface -35.54‰; bottom -36.93‰). Surface salinity varied from 33.47% to 35.54‰ and bottom salinity from 34.16‰ to 36.93‰. Soluble reactive phosphate (Range:0.67 to 1.00 µg-at PO_4-P/l), nitrate(Range:0.85 to 2.04 µg-at NO_3-N/l), nitrite(Range:0.055 to 0.270 µg-at NO_2-N/l) and ammonia(Range:5.67 to 7.82 µg-at NH_3-N/l) concentrations at the surface were minimum at 1500 h, but gradually increased till 2400 h. Nitrate increase was sharp from 2100 h to 2400 h.

4.2.1.3 Station-D3(Figs.14-5 and 14-6

Dissolved oxygen content of the surface layer gradually increased from 0900 h(5.03 ml/l) to 1500 h(5.68 ml/l) and then constantly decreased till 0300 h(3.17 ml/l). Salinity showed a peak value at 2400 h(Surface-35.54‰ and bottom-36.7‰) but the ranges(Surface-33.47% to 35.54‰ and bottom-33.7‰ to 36.7‰) were very narrow. Soluble reactive phosphate(Range:0.67 to 1.00 µg-at PO_4-P/l), nitrate(Range: 0.82 to 1.60 µg-at NO_3-N/l), nitrite(Range:0.150 to 0.334 µg-at NO_2-N/l) and ammonia(Range: 4.41 to 7.64 µg-at NH_3-N/l) concentrations at the surface were minimum at 1500 h. Soluble reactive phosphate and ammonia recorded maximum values at 2400 h whereas the values of nitrate and nitrite were relatively high at 0900 h.

14.2.1.4 Station-D4(Figs.14-7 and 14-8):

Dissolved oxygen content of the surface layer was high from 0900 h to 2100 h(5.11 to 5.65 ml/l). A sharp decline was noticed at 2400 h(3.75 ml/l) and values increased to 4.47 ml/l at 0600 h. Salinity values at surface and bottom layers were usually the same and the maximum difference was observed at 2400 h(surface-35.08‰ and botton-36.93‰). A steep increase in salinity value was noticed from 2100 h to 2400 h and subsequently the values declined at 0600 h. Soluble reactive phosphate(Range:0.70 to 1.20 µg-at PO_4-P/l), nitrate(Range:0.88 to 1.86µg-at NO_3-N/l), nitrite(Range: 0.100 to 0.350 µg-at NO_1-N/l) and ammonia(Range:3.10 to 5.98 µg-at NH_3-N/l) contents at the surface gradually decreased from 0900 h to 1500 h and subsequently a rise was noticed in their concentration till 2400 h.

4.14.2.2 Full moon phase:

14.2.2.1 Station-D1(Figs.15-1 and 15-2):

Dissolved oxygen content(Range:3.80 to 5.10 ml/l) was maximum at the surface layer at 1200 and 1500 hrs, after which a sharp decrease was observed at 1800 h(4.08 ml/l) followed by a gradual decrease to minimum at 0300 h. Surface salinity ranged between 35.52 and 35.56‰ and salinity at the bottom layer between 35.52 and 36.56‰. Fluctuations in salinity at the surface and bottom layers showed more or

STATION - D1

Fig. 15-1 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the monsoon period(Full moon phase)

Fig. 15-2 Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the monsoon period (Full moon phase)

STATION - D2

Fig. 15-3 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the monsoon period(Full moon phase)

Fig. 15-4 Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the monsoon period(Full moon phase)

STATION - D3

Fig. 15-5 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the monsoon period(Full moon phase)

Fig. 15-6 Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the monsoon period. (Full moon phase)

STATION - D4

Fig. 15-7 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the monsoon period(Full moon phase)

Fig. 15-8 Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the monsoon period (Full moon phase)

FULL MOON

FIG 15.1

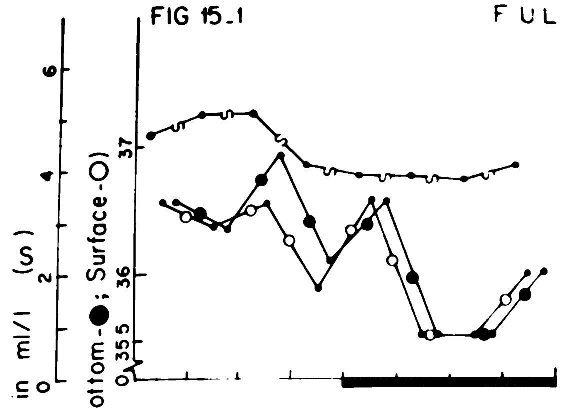


FIG 15.2

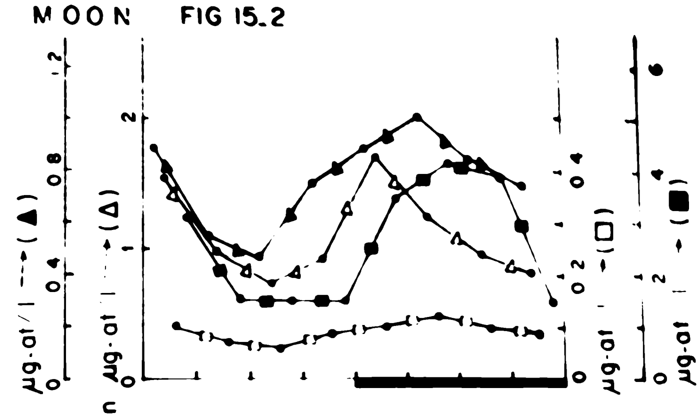


FIG.15-3

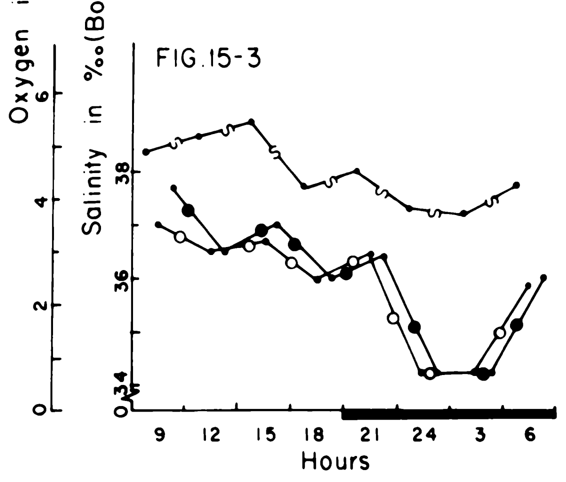
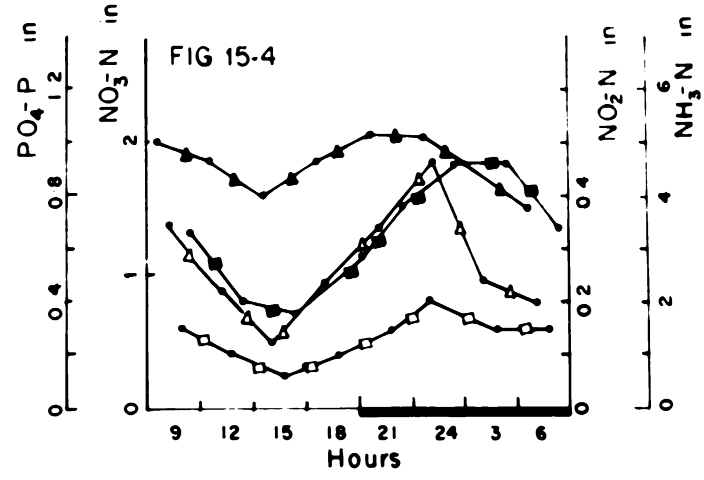


FIG 15-4



FULL MOON

FIG.15-5

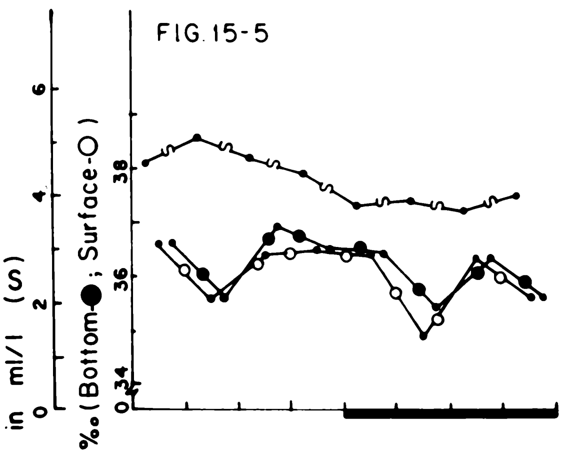


FIG.15-6

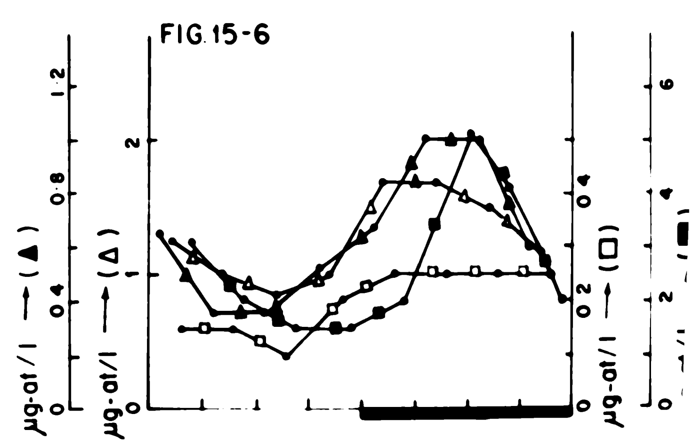


FIG.15-7

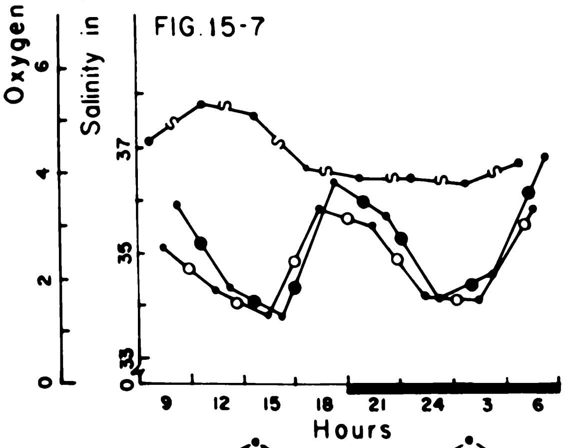
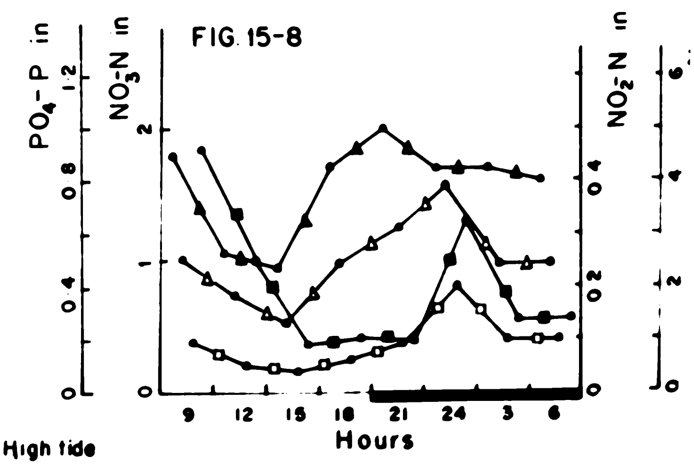
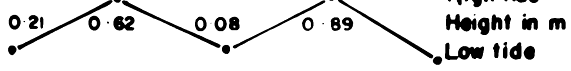


FIG.15-8





less the same trend. Soluble reactive phosphate(Range:0.47 to 1.04 µg-at PO_4-P/l), Nitrate(Range:0.74 to 1.72 µg-at NO_3-N/l), Nitrite(Range:0.060 to 0.120 µg-at NO_2-N/l) and ammonia (Range:1.53 to 4.18 µg-at NH_3-N/l) concentrations at the surface were minimum at 1500 h. Soluble reactive phosphate, nitrite and ammonia recorded maximum values at 2400 h whereas the value of nitrate was high at 2100 h. Ammonia level at the surface was more or less constant from 1200 to 1800 hrs.

4.14.2.2.2 Station-D2(Figs.15-3 and 15-4):

Dissolved oxygen content(Range:3.70 to 5.45 ml/l) at the surface layer was maximum at 1500 h after which it decreased till 0300 h. Fluctuations in the surface and bottom salinities displayed more or less the same trend with narrow variations. Soluble reactive phosphate(Range:0.75 to 1.03 µg-at PO_4-P/l), nitrate(Range:0.50 to 1.84 µg-at NO_3-N/l), nitrite(Range:0.060 to 2.000 µg-at NO_2-N/l) and ammonia(Range:1.83 to 4.58 µg-at NH_3-N/l) concentrations at the surface were at minimum level at 1500 h. Soluble reactive phosphate showed its peak at 2100 h. Nitrate, nitrite and ammonia values recorded a steady increase and reached the maximum concentration at 2400 h.

4.14.2.2.3 Station-D3(Figs.15-5 and 15-6):

A peak in dissolved oxygen concentration at the surface was observed at 1200 h(5.09 ml/l) after which it decreased with fluctuations till 0300 h(3.70 ml/l). Salinity values ranged between 34.87 and 36.9‰. Soluble reactive phosphate(Range:

0.36 to 1.00 µg-at PO_4-P/l) reached its minimum level at 1200 h. Nitrate(Range:0.84 to 1.68 µg-at NO_3-N/l), nitrite(Range:0.100 to 0.250 µg-at NO_2-N/l) and ammonia(Range:1.50 to 5.09 µg-at NH_3-N/l) contents recorded minimum values at 1500 h. Nitrate and nitrite contents at the surface layer were maximum at 2100 h, whereas soluble reactive phosphate and ammonia recorded maximum values at 2400 h.

4.14.2.2.4 Station-D4(Figs.15-7 and 15-8):

Oxygen concentration at the surface layer was maximum at 1200 h (5.26 ml/l) followed by a sharp decline till 1800 h(4.12 ml/l) after which a mild decrease was recorded in its concentration upto 0300 h(3.82 ml/l). During the period of observation, salinity values at the surface and bottom layers ranged between 33.79 and 36.80%o. Soluble reactive phosphate (Range:0.47 to 1.00 µg-at PO_4-P/l), nitrate(Range:0.54 to 1.56 µg-at NO_3-N/l), nitrite(Range:0.040 to 0.200 µg-at NO_2-N/l) and ammonia(Range:0.92 to 4.58 µg-at NH_3-N/l) concentrations at the surface were at the minimum level at 1500 h. Soluble reactive phosphate content attained its maximum at 2100 h whereas the concentration of nitrate and intrite recorded maximum values at 2400 h. Ammonia concentration in the surface layer was at its peak at 0900 h after which a sharp decline in its value was recorded. The concentration of ammonia was more or less the same from 1500 h to 2100 h.

4.14.3 Post-monsoon period:

4.14.3.1 New moon phase:

4.14.3.1.1 Station-D1(Figs.16-1 and 16-2):

The dissolved oxygen content at the surface layer increased sharply from 0900 h(4.60 ml/l) to 1500 h(5.80 ml/l) after which a gradual decline was observed till 0600 h(4.49 ml/l). Salanity at the bottom layer(Range:13.3‰ to 13.8‰) was always higher than that at the surface layer(Range:12.9‰ to 13.3‰) and minimum level was noticed at 2100 h. Soluble reactive phosphate(Range:0.80 to 1.81 µg-at PO_4-P/l) and ammonia(Range: 4.09 to 7.09 µg-at NH_3-N/l) contents at the surface stratum decreased from 0900 h to 1500 h and that of the nitrate(Range: 1.01 to 2.99 µg-at NO_3-N/l) and nitrite (Range:0.090 to 0.220 µg-at NO_2-N/l) recorded minimum level at 1200 h. The soluble phosphate concentration recorded maximum value at 2400 h, that of nitrate and nitrite at 0300 h and ammonia at 2100 h.

14.3.1.2 Station-D2(Figs.16-3 and 16-4):

Dissolved oxygen concentration at the surface was at its peak at 1500 h(5.82 ml/l) followed by a steady decrease till 0600 h(5.20 ml/l). Wide fluctuation was recorded in the salinity values at the surface and bottom layers. Both the values exhibited more or less the same trend in their pattern of distribution. A peak in salinity values was observed at 1800 h(Surface-17.08‰ and Bottom-18.25‰) followed by a

STATION - D1

Fig. 16-1 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the post-monsoon period (New moon phase)

Fig. 16-2 Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the post-monsoon period (New moon phase)

STATION - D2

Fig. 16-3 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the post-monsoon period (New moon phase)

Fig. 16-4 Results of observations on diurnal variation of soluble reactive phosphate, nitrite, nitrate and ammonia during the post-monsoon period (New moon phase)

STATION - D3

Fig. 16-5 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the post-monsoon period (New moon phase)

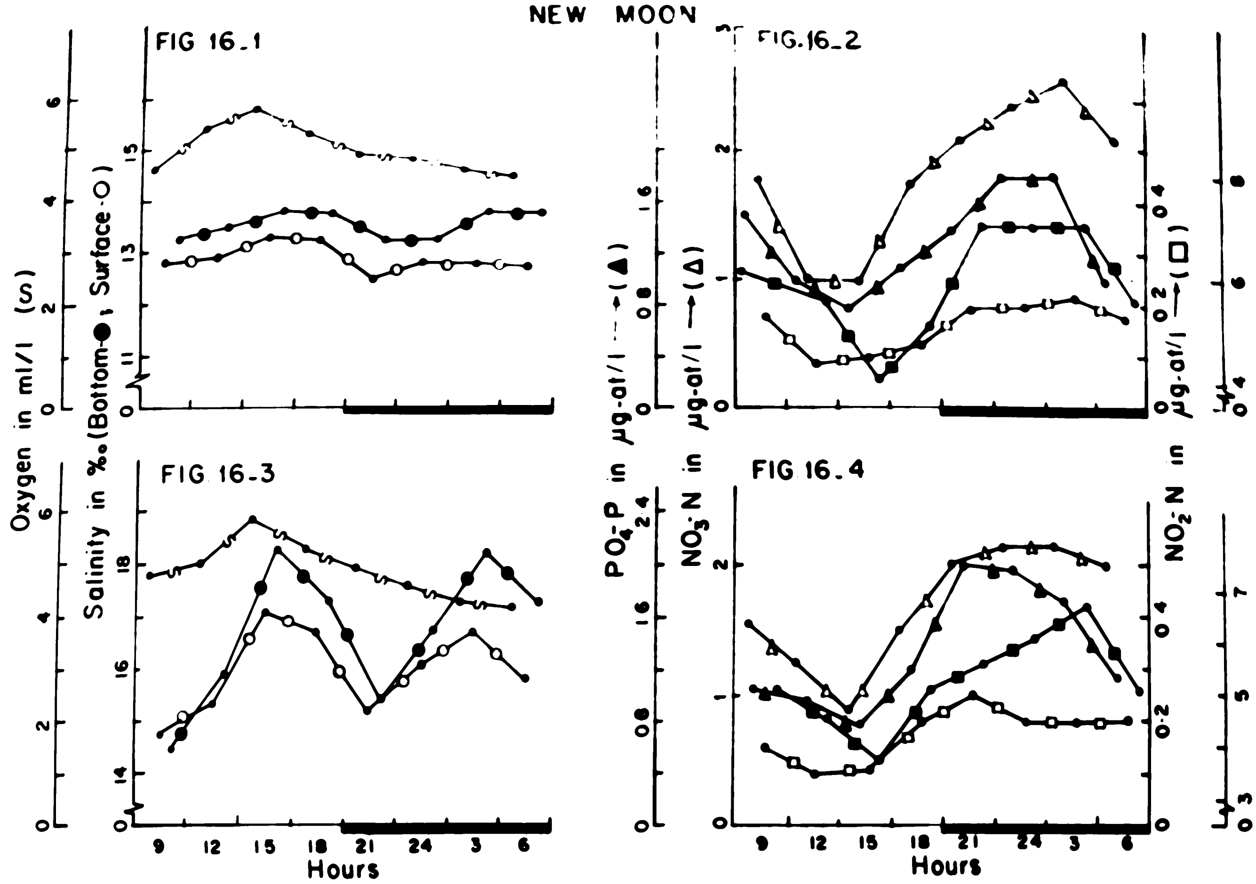
Fig. 16-6 Results of observations on diurnal variation of soluble reactive phosphate, nitrite, nitrate and ammonia during the post-monsoon period (New moon phase)

STATION - D4

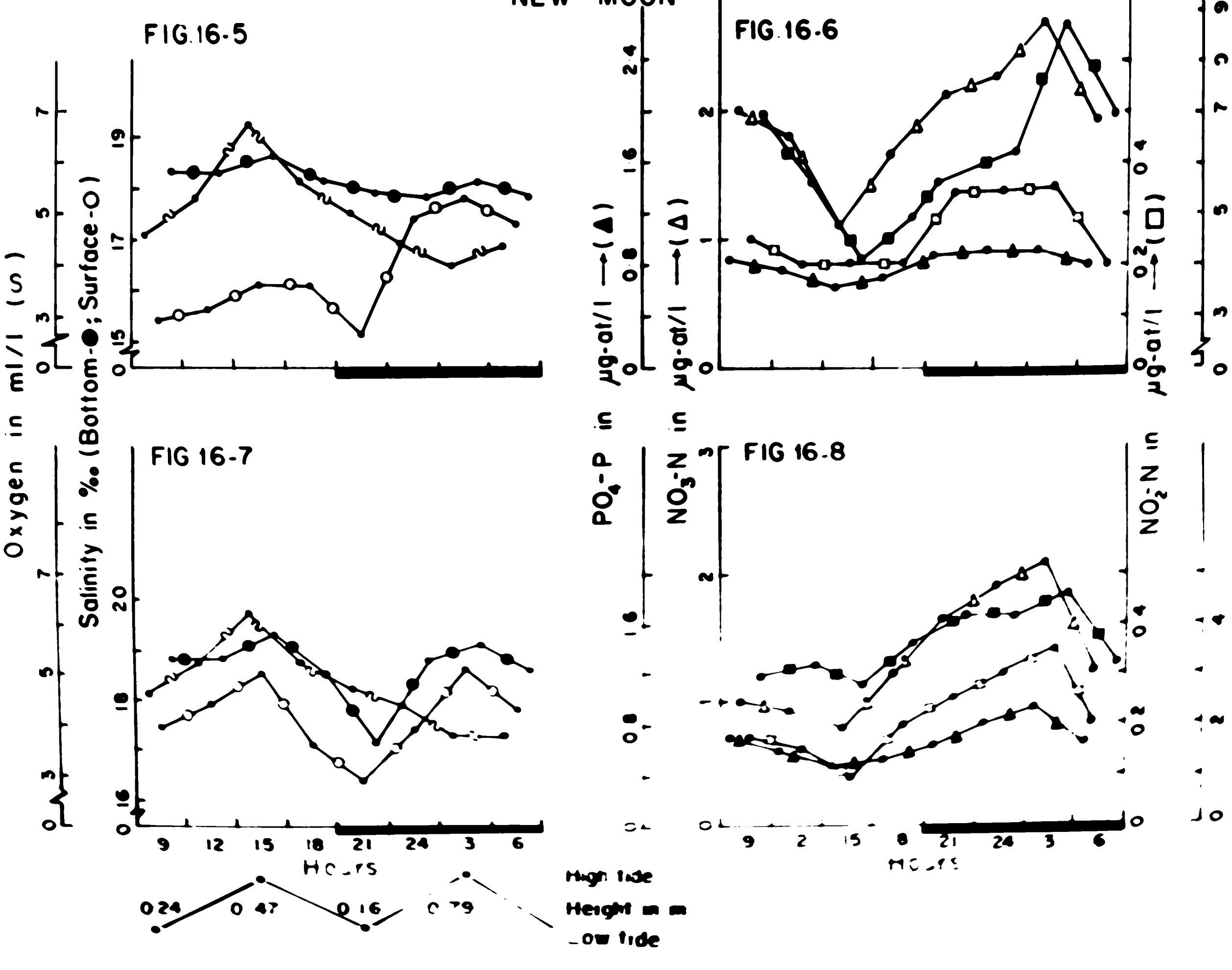
Fig. 16-7 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the post-monsoon period (New moon phase)

Fig. 16-8 Results of observations on diurnal variation of soluble reactive phosphate, nitrite, nitrate and ammonia during the post-monsoon period (New moon phase)

NEW MOON



NEW MOON



gradual decline till 2100 h(surface-15.2‰ and bottom-15.38‰). Subsequently, an increase in salinity values was noticed at 0300 h(surface-16.68‰ and bottom-18.19‰). Soluble reactive phosphate(Range:0.79 to 2.00 µg-at PO_4-P/l), nitrate(Range:0.90 to 2.1 µg-at NO_3-N/l) and ammonia(Range:3.77 to 6.72 µg-at NH_3-N/l) contents at the surface stratum showed minimum values at 1500 h. Nitrite(Range:0.100 to 0.250 µg-at NO_2-N/l) concentration was at its minimum at 1200 h. Maximum values of soluble reactive phosphate and nitrite were observed at 2100 h, that of nitrate at 2400 h and ammonia at 0300 h.

<u>Station-D3</u>(Figs.16-5 and 16-6):

A sharp increase was observed in the dissolved oxygen content at the surface from 0900 h(4.55 ml/l) to 1500 h(6.68 ml/l) followed by a steep decrease till 0300h(3.98 ml/l). Salinity content at the bottom layer ranged from 17.8‰ to 18.6‰. Surface salinity value showed a decline at 2100 h (15.5‰) followed by a sharp increase to 17.82‰ at 0300 h. Soluble reactive phosphate(Range:0.62 to 0.91 µg-at PO_4-P/l), nitrate(Range:1.11 to 2.71 µg-at NO_3-N/l) and ammonia(Range: 4.09 to 8.71 µg-at NH_3-N/l) contents at the surface showed minimum values at 1500 h whereas low values of nitrite concentration(Range:0.020 to 0.350 µg-at NO_2-N/l) was recorded from 1200 h to 1800 h. Soluble reactive phosphate exhibited maximum value at 2400 h but maximum concentration of nitrate, nitrite and ammonia were observed at 0300 h.

4.14.3.1.4 Station-D4(Figs.16-7 and 16-8):

Dissolved oxygen content at the surface sharply increased from 0900 h(4.55 ml/l) to 1500 h(6.20 ml/l) followed by a sharp decrease in its concentration till 0300 h(3.81 ml/l). Salinity values at the surface layer ranged from 16.40 to 18.62‰ and that of the bottom layer from 17.08‰ to 19.30‰. Soluble reactive phosphate(Range:0.48 to 0.94 µg-at PO_4-P/l), nitrate (Range:0.78 to 2.10 µg-at NO_3-N/l), nitrite(Range:0.100 to 0.350 µg-at NO_2-N/l) and ammonia(Range:2.81 to 4.62 µg-at NH_3-N/l) concentrations at the surface layer showed minimum values at 1500 h, after which a gradual increase was noticed in their concentration till 0300 h.

4.14.3.2 Full moon phase:

4.14.3.2.1 Station-D1(Figs.17-1 and 17-2):

Maximum concentration of dissolved oxygen was observed at the surface at 1500 h(5.48 ml/l) followed by a steady and gradual decrease upto 0600 h (3.49 ml/l). Salinity values at the bottom layer sharply decreased from 1200 h(9.08‰) to 1500 h(6.79‰) and again maximum(9.35‰) was observed at 2100 h. Surface salinity increased from 1800 h(6.70‰) to 2100 h(9.08‰) and subsequently the values declined till 0300 h(7.32‰). Low concentration of soluble reactive phosphate(Range:0.72 to 1.50 µg-at PO_4-P/l) was observed at 1500 h and its value was relatively high at 0300 h. Nitrate(Range:0.72 to 1.92 µg-at No_3-N/l), nitrite(Range:0.100 to 0.300 µg-at NO_2-N/l) and ammonia(Range:3.81 to 6.71 µg-at NH_4-N/l)showed minimum contents

STATION - D1

Fig. 17-1 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the post-monsoon period(Full moon phase)

Fig. 17-2 Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the post-monsoon period (Full moon phase)

STATION - D2

Fig. 17-3 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the post-monsoon period(Full moon phase)

Fig. 17-4 Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the post-monsoon period(Full moon phase)

STATION - D3

Fig. 17-5 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the post-monsoon period(Full moon phase)

Fig. 17-6 Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the post-monsoon period(Full moon phase)

STATION - D4

Fig. 17-7 Results of observations on diurnal variation of dissolved oxygen, surface and bottom salinity during the post-monsoon period(Full moon phase)

Fig. 17-8 Results of observations on diurnal variation of soluble reactive phosphate, nitrate, nitrite and ammonia during the post-monsoon period(Full moon phase).

FULL MOON

FIG 17-1

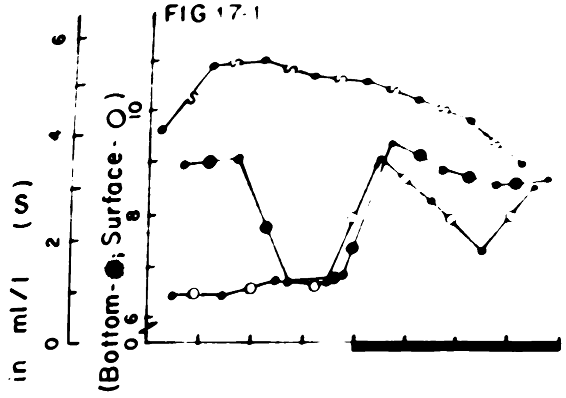


FIG 17-2

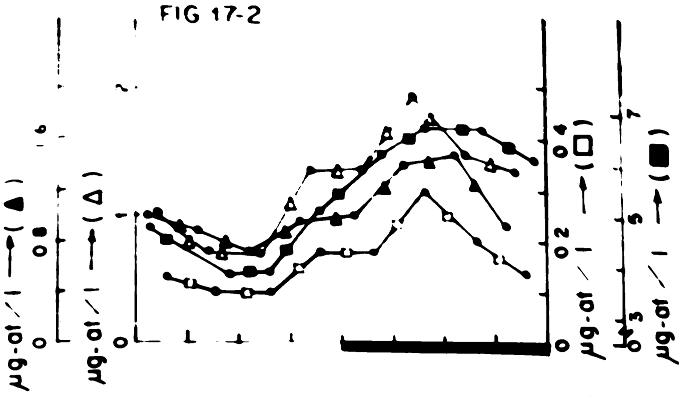


FIG 17-3

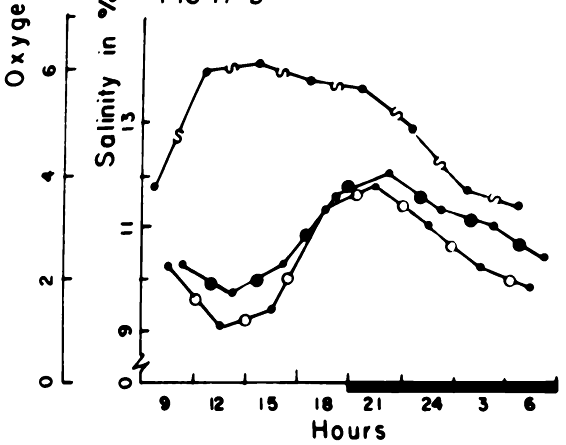
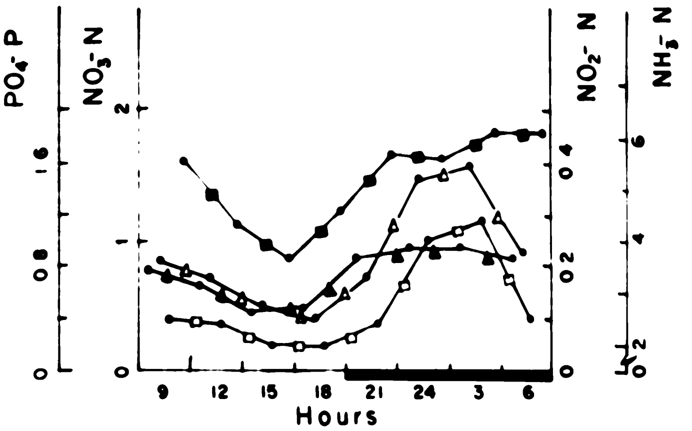


FIG 17-4



FULL MOON

FIG 17-5

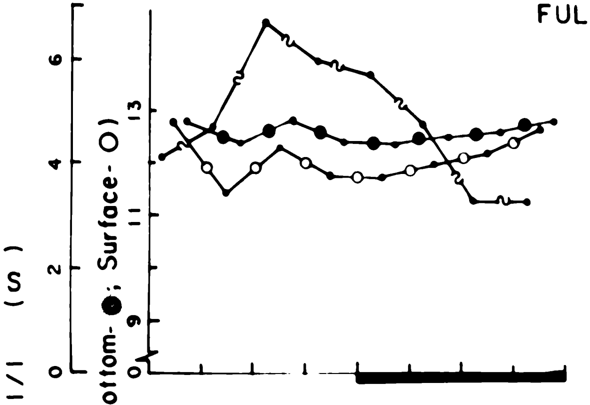


FIG 17-6

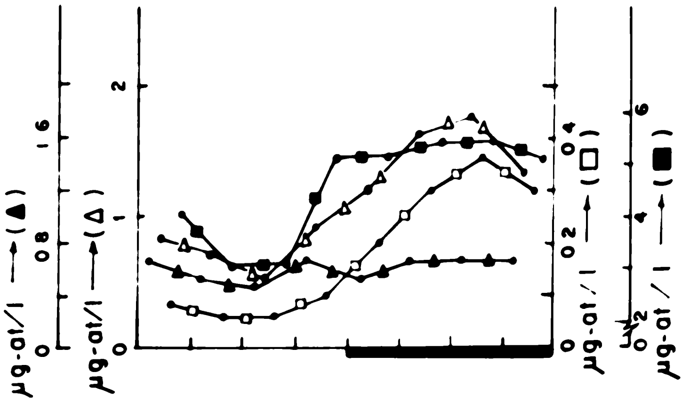


FIG 17-7

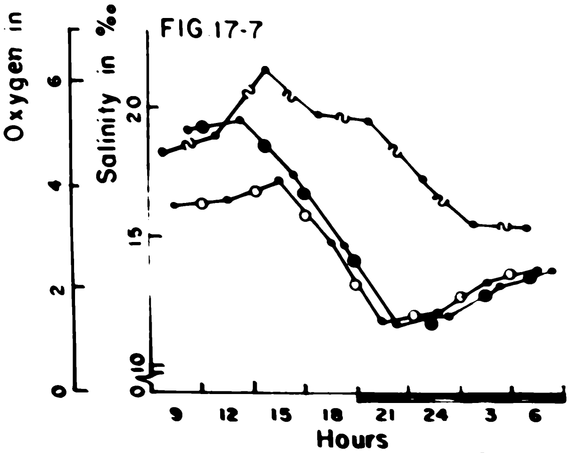
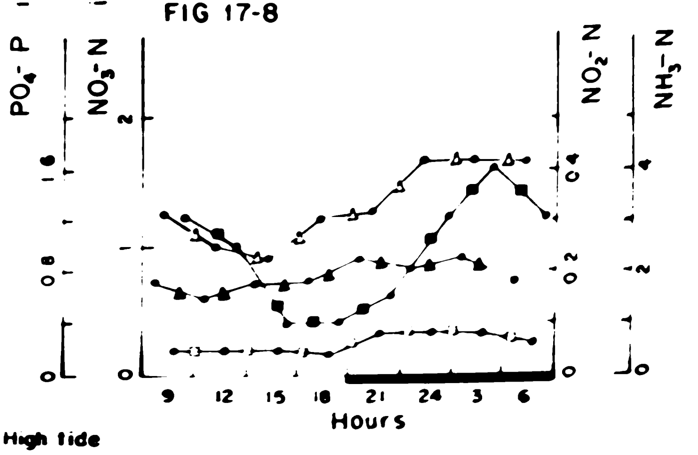
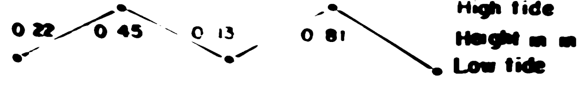


FIG 17-8





at the surface layer at 1200 h and maximum at 2400 h.

14.3.2.2 Station-D2(Figs.17-3 and 17-4):

A sharp increase was noticed in the dissolved oxygen content at the surface from 0900 h(3.80 ml/l) to 1500 h(6.12 ml/l) and subsequently a gradual and sharp decrease was recorded in its concentration upto 0600 h(3.35 ml/l). Salinity values at the surface and bottom layers followed more or less the same trend. Their concentrations were minimum at 1200 h(Surface-9.08‰ and bottom -9.70‰) and maximum level was recorded at 2100 h (Surface-11.78‰ and Bottom-11.98‰). The concentration of soluble reactive phosphate(Range:0.46 to 0.94 µg-at PO_4-P/l), nitrite(Range:0.050 to 0.290 µg-at NO_2-N/l) and ammonia(Range: 3.65 to 6.10 µg-at NH_3-N/l) concentrations at the surface layer showed minimum values at 1500 h. Nitrate content(Range:0.40 to 1.58 µg-at NO_3-N/l) in the surface layer showed low concentration at 1800h. Soluble reactive phosphate content was at its maximum concentration at 2400 h, whereas nitrate, nitrite and ammonia exhibited maximum values at 0300 h.

14.3.2.3. Station-D3(Figs.17-5 and 17-6):

Dissolved oxygen content at the surface sharply increased from 0900 h(4.01 ml/l) to 1500 h(6.72 ml/l) and a steady decrease in its values was recorded upto 0300 h(3.27 ml/l). Salinity values at the surface and bottom layers showed more or less the same pattern of distribution. A slight decrease was noticed in the surface salinity from 0900 h(12.74‰)

to 1200 h(11.39‰). Soluble reactive phosphate(Range:0.47 to 0.67 µg-at PO_4-P/l) exhibited minimum level of concentrations at 1500 h whereas nitrite(Range:0.060 to 0.360 µg-at NO_2-N/l) and ammonia(Range:3.08 to 5.40 µg-at NH_3-N/l)concentrations at the surface recorded minimum values at 1200 h. Soluble reactive phosphate did not show any significant variation thereafter whereas nitrate and nitrite contents steadily increased to reach the maximum values at 0300 h. Ammonia showed sharp increase from 1500 h(3.08 µg-at NH_3-N/l) to 1800 h(5.09 µg-at NH_3-N/l).

Station-D4(Figs.17-7 and 17-8):

Dissolved oxygen content at the surface layer sharply increased from 0900 h(4.60 ml/l) to 1500 h(6.22 ml/l)after which a steady but sharp decline was observed till 0600 h(3.18 ml/l). Salinity values at the surface and bottom layers exhibited more or less the same pattern of distribution. A steady decrease in the salinity values was observed from 1500 h(Surface-17.18‰ and bottom-17.37‰) to 2100 h(Surface and bottom layers-11.68‰). Soluble reactive phosphate(Range:0.60 to 0.90 µg-at PO_4-P/l) concentration at the surface layer was relatively low at 1200 h. Nitrate(Range:0.92 to 1.67 µg-at NO_3-N/l) and ammonia(Range: 1.02 to 4.07 µg-at NH_3-N/l) concentrations showed minimum values at 1500 h and nitrite(Range:0.040 to 0.080 µg-at NO_2-N/l) at 1800 h. Soluble reactive phosphate content was high during night. A steady increase was recorded in the nitrate content and its maximum concentration was recorded at 2400 h. A sharp increase was observed in the nitrite content from 1800 h(0.040 µg-at NO_2-N/l) to 2100 h(0.080 µg-at NO_2-N/l). Ammonia content recorded maximum value at 0300 h.

4.15 *Coastal flora*(Plates 3-1 and 3-2):

At Zone-FA1, *Cyperus sp.*, *Lippia nodiflora* and *Salicornia brachiata* were recorded. At Zone-FB1, *Cassia auriculata*, *Clerodendron sp.*, *Spinifex spinifera*, *Aerva tomentosa*, *Phoenix humilis*, *Cissus quadrangularis*, *Solanum xanthocarpum*, *Acacia arabica* and *Prosopis spicigera* were observed.

At Zone-FA2, *Cyperus sp.*, *Blumea amplectens*, *Heliotropium curassavicum*, *Salicornia brachiata*, *Avicenia officianalis*, *Ericostemma littorale* and *Sesuvium portulacostium* were present. At Zone-FB2, *Spinifex spinifera*, *Aerva tomentosa*, *Phoenix humilis*, *Cissus quadrangularis*, *Cassia auriculata*, *Prosopis spicigera*, *Solanum xanthocarpum*, *Acacia arabica*, *Clerodendron* sp.,*Leptodenia reticulata*, *Tephrosia purpurea* and *Colotropis gigantea* were recorded.

At Zone-FA3, *Cyperus sp.*, *Lippia nodiflora*, *Heliotropium curassavicum*, *Salicornia brachiata* and *Blumea amplectens* were observed.

At Zone-FA4, *Cyperus* sp., *Heliotropium curassavicum*, *Salicornia brachiata*, *Blumea amplectens* and *Avicenia officianalis* were recorded. At Zone-FB4, *Cassia auriculata*, *Clerodendron* sp., *Spinifex spinifera* and *Cissus quadrangularis* were observed.

At Zone-AA5, only *Salicoria brachiata* was found to exist. At Zone-FB5, *Spinifex spinifera*, *Aerva tomentosa*, *Phoenix humilis*, *Agave sp.*, *Solanum xanthocarpum* and *Cassia* sp. were observed.

Plate 3-1 *Salicornia* sp. at the Zone-FA5.

Plate 3-2 *Calotropis gigantea* at the Zone-FB4

Plate 3-1

Plate 3-2

Chapter-5

DISCUSSION

DISCUSSION

IN the tropical waters, the major stress on the ecology of the coastal lagoon is on the large scale temperature variation and the extremes of salinity (Mee,1978). High atmospheric temperature prevails in the Mandapam peninsula due to the acute summer coupled with minimum rainfall. The total annual rainfall from 1977 to 1983 ranged between 356.5 and 1510.5 mm. The positive correlation obtained during the present study between air temperature and water temperature explains the high values of the latter recorded in the summar period, and this is in agreement with the observations made by Geddes(1976), Cohen(1977) Edwards(1978) and Jones et al.(1978). During the monsoon period, humidity is high due to the rains and the flow of wind containing moisture from the Palk Bay, which results in the lowering of atmospheric temperature. During the north-east monsoon period the barmouth is opened and the water from the Palk Bay enters the lagoon. On the other side, the monsoon rain results in the fresh water inflow. The variation in salinity in such lagoons is mainly dependent on the interaction of sea water and fresh water circulation (Pauly,1975; Edwards,1978; Jones et al.,1978 and Comin et al., 1983). When the lagoon is isolated from the water exchange, the evaporation and seepage account for the rise in salinity which lead to the hypersaline condition of the lagoon. The fluctuation of salinity recorded in the lagoon after the closure of the bar mouth was mainly due to the occasional incursion of water from the sea during the lunar cycle. It was observed elsewhere that fresh water inflow during the monsoon period brings large quantities of nutrients from the surrounding areas Garside et al.1975; Mitchell,1965; Simpson et al.,1975; Malone,1977; Edwards,1978; Gilmartin and Revelante, 1978; Crawford et.al.,1979 and Comin et al.,1983). At Pillaimadam lagoon, concentration of all the nutrients was observed to be maximum during the period of freshwater influx which indicates that the main source of nutrients to this lagoon is through the fresh water inflow. However, the comparatively low concentration of nutrients observed during the first year can be attributed to the low rate of rainfall(monsoonal total rainfall = 922.5 mm) which in turn resulted in less land run off to the lagoon. Similar observations have been made elsewhere by Dugdale and Goering(1967), Harrison and Hobbie(1974), Windom et al.(1975), Haines(1976),Stanley and Hobbie(1977),Smith(1978), Kuenzler et al.(1979) and Nixon(1981). Moreover, the soil of this region being more of sandy by nature, contributes less to the run off. However, in the following year, the accumulation of nutrients was observed to be comparatively higher than that in the previous year, mainly due to relatively high rate of rainfall (monsoonal total rainfall = 1346.7 mm) and the concomitant high rate of nutrient loading. A more reasonable explanation for this significant difference could be that the nutrients accumulated in the "Pariya tharuvai"(Pl.1-2) from the surrounding agriculturally active areas and the subsequent effective runoff of nutrients from this reservoir to the lagoon through enhanced flow of rainwater in the second year. However, the high concentration of phosphate recorded in the months of February and March,1984 rapidly decreased within a fortnight.

Krumgalz *et al.*(1980) recorded a range of 7.65 and 8.05 for the pH of water prior to the commencement of the monsoon in the Bardawil Lagoon in Northern Sinai. In the Pillaimadom lagoon a more or less similar condition was recorded. The positive correlation observed between pH and ammonia indicates that the distribution of the former is dependent on the concentration of ammonia in water(Berner *et al.*,1970 and Gaines and Pilson,1972). The pH range was narrow in the Theedai zone(Pl.1-4) when compared to that in the upper arms of the lagoon. pH values are also correlated with photosynthetic rates(Takahashi and Ichimura,1968; Hansen *et al.*,1978 and Crawford *et al.*,1979). Generally, during the period of high alkalinity, a comparatively high rate primary production has also been recorded during the course of the present study.

The inorganic nutrients and organic matter brought in by the freshwater inflow might be responsible for the increase in the chemical composition of the sediment in the lagoon. The exchange of organic and inorganic substance across the sediment-water interface is an important process affecting the chemical composition of coastal waters(Rowe *et al.*,1975 and Klump and Martens,1981), estuaries(Pomeroy *et al.*,1965; Hale,1975 and

Nixon *et al.*, 1976) and lakes (Golterman, 1967; Lee, 1970; Keeney, 1973; Bannerman *et al.*, 1975; Filles and Swanson, 1975 and Holdren and Armstrong, 1980). In the lagoon ecosystem, the influence of temperature and pH on the phosphate concentration was not found to be significant. Large scale reduction in salinity followed by heavy rainfall might have enhanced the phosphate adsorption. A similar phenomenon was recorded by Stirling and Wormald (1977) at Tolo and Long harbours, Hong Kong. The significant correlation between organic carbon, total phosphorus and Kjeldahl nitrogen content in the sediment of the area of study suggests that the sediment within the lagoon and the coastal belt of Palk Bay contains all elements in almost constant proportions, thereby indicating a common source for these elements. If two or more independent sources were responsible for the influx of these elements into the lagoon and the Palk Bay, such a correlation could not be expected because of high rate of discharge of one element will usually be accompanied by the low rate of inflow of the other element at any one time as opined by Aston and Hewitt (1977) and Rashid and Reinson (1979).

The average value of organic carbon and the total phosphorus content of sediment from this area, except at station-V, was lower than the typical values recorded from coastal sediment by Seshappa (1953) and Mackay *et al.* (1972). Kjeldahl nitrogen content usually recorded low values. From the present study it was observed that materials such as coarse sand contain low concentration of organic carbon, total phosphorus and Kjeldahl nitrogen and a similar observation was made elsewhere by earlier workers (Aston and Hewitt,1977; Edwards,1978; Rashid and Reinson,1979 and Rosenfeld,1979a). Results obtained during the present study also show significant correlation between organic carbon, total phosphorus and Kjeldahl nitrogen with the grain size of the sediment. Particle size exerts a control on the concentration of total phosphorus in the sediment, silt and small-sized grains by showing an adsorption effect of increasing phosphorus content with decreasing grain size. High concentration of organic nitrogen was recorded in the sediment with relatively high content of mud, and a significant correlation was found between nitrogen and organic carbon as opined earlier by Rashid and Reinson(1979). Kufel and Kufel(1977) found significant positive correlation ($r = 0.69$) between organic matter and total phosphorus content of sediment and pointed out to the biogenic origin of phosphorus in the sediment. Brooks et al.(1971) found that the sediment containing 3-5% clay mineral adsorb ammonia rapidly from the solution.

The importance of redox potential(Eh) for the biological and chemical processes in marine sediments has been discussed earlier by several authors(Bass Becking et al.,1960; Berner, 1963; Fenchel,1969 and Whitefield,1969). The Eh of the sediment is closely associated with the organic matter content and granulometric factor(Parker,1975,1982 and Pearson and Stanley,1979). The clayey sediment at station-V contained the maximum level of organic matter with low Eh values, whereas the case was reverse at Station-I where sand proportion in the sediment was relatively high.

After the north-east monsoon period, the surface currents become northerly and with the advent of south-west monsoon, relatively calm condition prevail in the Palk Bay. This results in the closure of the barmouth indicating that the system has "low stability"(Mee,1978). The freshwater flow is mainly dependent on the rainfall. Hence, after the monsoon period, the lagoon becomes more of a hypersaline lake. This condition of the Pillaimadam lagoon might have direct biological impact due to the osmotic stress produced by the increased ionic strength, the decrease in the alkalinity(resulting from the precipitation of carbonates) and the decrease in oxygen solubility which arises from the increasing salinity of the lagoon water (Pillai,1956). Copeland(1967) and Geddes(1976) also observed similar condition at western Victoria. Due to high temperature, the rate of evaporation is high, and the loss of water through seepage from the floor of the lagoon to the Palk Bay also significantly affect the water level in the lagoon.

Nutrient regeneration in the benthic area supplies a significant fraction of the nutrient requirements of primary producers in the overlying water(Nixon et al.,1976; Billen,1978 and Peterson,1979). The mechanisms for the exchange of dissolved constituents across the sediment-water interface are the molecular diffusion within the interstitial water, the physical stirring of sediment by current, benthic invertebrates (Davies,1974; Hammond et al.,1977; van Derborght et al.,1977 and Robbins et al.,1979) and the irregation of sediment by macrobenthos(Goldhaber et al.,1977; Grundmanis and Murrey,1977; Aller and Yingst,1978; Hammond and Fuller(1979) and McCaffrey et al.,1980). Reducing condition arise when the consumption rate of oxygen due to the oxidation of organic matter exceeds that of supply, and the dissolved oxygen which is utilized in the oxidation process is derived from the atmosphere and photosynthesis. The major forms of anoxic respiration are denitrification, sulfate reduction and methanogenesis. When the supply of free oxygen in an enclosed water column approaches exhaution, the reduction of nitrate to nitrite is the next source of oxygen for the continued oxidation of organic matter. The first step in this denitrification is a thermodynamically favoured one. It is used as an energy source by bacteria which are active at low oxygen level. Rates of denitrification are very closely correlated in sediment to the amount of organic matter(Broadbent and clark, 1965 and Burford and Bremner,1975). Wada and Hattori(1972) found that addition of nitrite accelerates nitrite production, which suggests that the reduction of nitrate to nitrite occurs wherever oxygen is in shortsupply. The highly positive correlation obtained ($r = > 0.68$) in this study is in agreement with the above findings.

Due to the lack of water circulation and the increase in the uptake of oxygen in the sediment due to increased temperature

(Nedwell and Floodgate,1972; Pearson and Rosenberg, 1978; Howarth and Teal, 1979 and Rosenberg, 1980), the bottom water becomes anoxic which results in the proliferation of sulpher-reducing bacteria, as sulphate is quantiatively the most important electron accepter for the oxidation of organic material(Kaplan *et al*.,1963 and Jorgensen and Fenchel,1974). This leads to the production of hydrogen sulphide. Wheatland (1954) recorded the increase of sulphide roughly getting doubled for each 10°C rise in temperature. Low level of sulphide(4 μg-at/l) may act as a source of sulphur for plant growth(Crawford *et al*.,1979) but higher concentrations become highly toxic to animals(Theede *et al*.,1969). Part of sulphide is also liberated by the hydrolytic decomposition of proteins in organic detritus(Jorgensen,1977). Sulphate reduction by bacteria takes place only in environments with negative redox-potential(Postgate,1959). Throughout the period of study, the Eh values always showed negative values thereby confirming the anoxic nature of the lagoon sediment.

Change in Eh has been attributed to the reducing activity of the sedimentary sulphur bacteria(Berner,1963 and Matheron and Baulaigue,1968). Ramm and Bella(1974) and Cohen *et al*. (1977) noted Eh drop as a result of sulphide production and the former attributed the pH drop to the production of carbondioxide and organic acids.

During the period of stagnation of water due to its isolation from the Palk Bay and cessation of freshwater inflow, anoxic condition prevailed in the lagoonal environment. In the anoxic environment, H_2S as well as total sulphide concentration was observed to be in higher concentration due to sulphate reduction. Heterotrophic bacteria can catalyse the sulphate reduction(Tuttle and Jannasch,1973 and Pfennig and Bieble,1976) and it requires an organic source of energy and sulphate as a terminal hydrogen acceptor(Ivanov,1968; Berner,1972 and Ramm and Bella,1974). The reduction can also occur as dark reaction in purple sulphur bacteria(Gemerden,1967). In the remineralising of organic carbon during sulphate reduction, 2 mols of organic carbons are oxidised to carbon dioxide for every mole of sulphate reduced(Richards,1965 and Jorgensen,1977). About fifty to ninety percent of the mineralisation of total organic matter was observed to be through the sulphur cycle(Jorgensen and Fenchel,1974 and Jorgensen,1977). The carbondioxide produced during the reaction would reduce the pH of water. Methanogenesis is a major mechanism in the anaerobic environment(Strayer and Tiedje,1978) by which carbon and electrons leave the sediment (Rudd and Hamilton,1978) by the reduction of carbondioxide or by the fermentation of organic matter, especially carbohydrates (Denser,1973). Methane diffuses into the water column and if the critical concentration for the bubble formation is reached (Klots,1961), by ebullition, it is lost to the ecosystem at the air-water interface. Methane production is considered the rate-limiting step in carbon metabolism(Hungate,1966 and Toerien and Hattingh,1969). Devol(1983) suggested from his work that the methane oxidizing agent was sulphate. Here, the organic carbon content of the sediment declined as the system became more anoxic and thus implying sulphate reduction or methanogenesis. Sediment release phosphate from phosphate free seawater(Stirling and Wormald,1977). Jitts(1959) considered that desorption would occur under very extreme conditions of oxygen depletion and also possibly in conditions where hydrogen sulphide is present(Pomeroy et al.,1965; Li et al.,1972, Kufel,1976; Crawford et al.,1979 and Krom and Berner,1980). Buffer system maintains the phosphate concentration of water by appropriate desorption and adsorption reactions. Comin et al.(1983) suggested that the low proportion of soluble reactive phosphate was related to the abundance of detritic or decomposing organic material. Nitrogen limitation is a frequent condition in coastal lagoons(Stumm and Baccini,1978 and Comin et al.,1983), due to the incomplete oxidation of organic matter and bacterial nitrification in shallow waters(Valiela and Teal,1979).

Bagander and Niemisto(1978) found that the pH in oxidized surface sediments may vary between 7.5 and 8.3 and in reduced sediments between 6.9 and 7.5. The pH value in the anoxic sediment was recorded to range from 6.0 to 8.5(Teal and Kanwisher, 1966; Cohen et al.,1977; Hansen et al.,1978; Kaplan et al.,1979 and Krumgals et al.,1980).Brewer and Goldman(1976) have discussed that the decomposition of marine organic matter essentially leads to the liberation of nitric acid. Cohen et al. (1977) explained that the decrease of pH is probably caused by the fermentation processes of highly active heterotrephic bacterial communities. The sulphur oxidation of photosynthetic sulphur bacteria and cyanobacteria may further enhance the decrease of pH(Cohen *et al.*,1975). In the present study, the pH was comparatively less during the anoxic conditions which is in agreement with the above findings. Kaplan *et al.*(1979) found that ammonia was produced under anoxic conditions. Nitrate concentration was low when ammonia concentration was high(Crawford *et al.*,1979 and Callender and Hammond,1982). At Pillaimadam lagoon,highly reduced condition lead to the reduction of nitrate to ammonia and hence the ammonia concentration was comparatively higher when compared to that of the nitrate.

Primary productivity rate was comparatively high during monsoon period, and this is reflected in the population density of benthic invertebrates. During periods of stagnation, the regeneration of ammonia and phosphate at the benthic zone can support nearly half of the requirements for gross primary production(Billen,1978; Nixon,1981 and Callender and Hammond, 1982). Phosphorus is one of the most important nutrients for the phytoplankton growth(Ohle,1934; Hutchinson,1952;Cooper, 1958 and Riley and Chester,1971). Phosphate concentration below 0.1 µg-at/l becomes a limiting factor in phytoplankton growth (Crawford *et al.*,1979 and Lean and Pick,1981). But the minimum phosphate requirements for phytoplankton growth vary much and the sustained low levels of phosphate may limit the growth of phytoplankton(Blum,1966; Thomas and Dodson,1968; Corner and

Davies, 1971 and Tilman and Kilham, 1976). The growth of marine phytoplankters is often limited by the availability of dissolved inorganic nitrogen (Thomas, 1970a,b; and Ryther and Dunsten, 1971). It was observed that during summer, the rate of primary production was affected due to the low concentration of nutrients in water.

Net primary production have been used to estimate the export of energy or organic carbon from the anoxic ecosystem (Teal, 1962; and Day et al., 1973). In the oxidising environment in which all metabolism is aerobic, energy flow will be proportional to and is largely mediated by organic carbon cycling, starting from plant biomass in primary production. But in an ecosystem where metabolism is mainly anaerobic, carbon cycling will not be proportional to energy flow and a carbon budget will give an inadequate interpretation of energy flow. The energy available per unit of organic carbon respired is much less under anoxic (8 KJ for 1gC) than under oxic conditions(42 KJ for 1gC). The occurrence of sulphur phototrophic bacteria and their distribution in relation to hydrogen sulphide concentration and light intensities during the periods of stagnation has been well documented(Kusnetsov, 1959; Kondratiera, 1965; Truper and Genovese, 1968 and Takahashi and Ichimura, 1970). Overback(1974) pointed out the role of phototrophic sulphur bacteria in primary production, which in some meromictic lakes may reach 25% of the total annual production. During phases of low rate of productivity the contribution of phototrophic sulphur bacteria to the daily production may be as high as 91%(Cohen et al.,1977). Mitchell (1975) observed that the phytoplankton production did not contribute to the rapid decline in the phosphate concentration from the water and predicted that effect to the possible calcium carbonate precipitation, thereby resulting in concurrent losses in phosphate(Hepher,1958; Golterman,1967 and Orsuki and Wetzel,1972). It is well known that assimilation number is affected by various factors such as temperature, nutrients and species composition(Eppley,1972). Soluble reactive phosphate is almost depleted in the Central Basin waters with levels around 5 μg-PO_4-P/l a level considered to be "limiting level" by limnologists(Gachter et al.,1974). Limitation of phytoplankton productivity by the minor nutrients such as iron, manganese, magnesium, ethylene diamine tetraacetic acid, cobalt and molybdenum in the lagoon can not be ruled out (O'Brein et al.,1975).

All the above findings indicate that the mechanism controlling nutrient limitation and primary production in shallow lakes are not constant, and can vary from year to year and also within the year. From the results of the present study it would appear that primarily high temperature, low water level and hypersalinity and secondarily anoxic condition and low nutrient levels may be the major factors affecting the primary production rate in general and net primary production in particular in the Pillaimadam lagoon.

Observation on the distribution pattern of benthic macrofauna indicates that they were present in the lagoon during the monsoon season and when the salinity of the ambient water was 45%o. Edwards(1978) recorded *Prionospio* spp. and amphipods in the Caimanero lagoon. He also noted that in the lagoon the zones which dry out for extended periods had lowest biomass of benthic infauna and observed only polychaetes in such places. He also opined that the large aggregations of the dead shells of the *Cerithedia* sp. might have been carried by the water movement. In the Pillaimadam lagoon, a more or less similar benthic infaunal composition was observed. The logical explanation for the occurence of the enormous quantities of dead shells of *Cerithedia fluviatilis* might be due to the flooding from the Palk Bay during cyclonic monsoon.

Edwards(1978) observed that the macrofauna got depleted in a Mexican coastal lagoon during high salinity regime when reduction in water level was recorded. Jones *et al.*(1978) reported on the benthic macrofauna in a perennial hypersaline lagoon along Saudi Arabia and stated that faunal diversity was less at a salinity of 300%o. However, Edwards(1978) while discussing the faunal characteristics of such perennial lagoons stated that the results obtained from such lagoons may not hold good for other types of open lagoons or for lagoons which remain closed for most part of the year. Hammer *et al.* (1975) reported that the benthic fauna was absent in hypersaline lakes. Holm(1978) observed that the occurrence of species is not constant during different years in tropical marine lagoons. Timms(1983) recorded amphipods and chironomids at low salinities(< 13‰).

At Pillaimadam lagoon, benthic macrofauna was scarce when the salinity reached a value of 45‰ by which time the lagoon was cut off from the sea and subsequently the water level receded and anoxic condition prevailed in the lagoon. In the first year, the benthic macrofauna was represented by bivalve spats and *Perinereis* sp., but in the following year the faunal diversity was relatively high. Williams(1981) and Timms (1983) opined that the low saline condition may also be a factor for high faunal diversity. The results obtained in the macrofaunal diversity in the second year agree with their suggestions.

The dissimilarity in the distribution pattern of benthic macrofauna observed in the two years indicate that during the first year they can be included under "halophilic forms"(living in salinities 10-60‰) and in the second year in a wide range of salinity from freshwater to < 60‰. Such differences in the pattern of distribution in the different years due to the changes in the climatic conditions is a common feature for hypersaline ecosystems(William,1981*b*; Comin *et al*.,1983). An inverse relationship between salinity and benthic biomass and diversity was reported earlier(Rawson and Moore,1944; Cole,1968 Pauly,1975; Geddes,1976; Geddes *et al*.,1981; Williams, 1981).

Bayly (1970) attributed the absence of nereids to the drought condition and high salinity in Australian saline lakes. William (1972) observed that the benthic macrofaunal species diversity was relatively low in salt lakes. However, deDekker and Geddes (1980) traced the occurence of eight benthic species at salinities in excess of 100‰ and stated that the number of species that can survive does decrease as salinity increases.

Recent studies have shown the importance of sulphate reduction in the metabolism of benthic communities, and that the balance between oxygen and sulphide is an important factor in the distribution of benthic organisms (Fenchel, 1969; Jorgensen and Fenchel, 1974; Jorgensen, 1977 and Nedwell and Abram, 1978). The number of species, abundance, biomass and composition of benthic macrofauna was found to change abruptly at 2 mg O_2/l oxygen concentration (Rosenberg, 1980). Pearson and Stanley (1979) observed that the decrease in the Eh values was associated with the rapid decline in benthic macrofaunal population. It appears, therefore, that in the Pillaimadam lagoon diversity of benthic macrofauna is dependent on the salinity variation, and the abundance of species is limited by the hypersalinity, anoxic condition and high temperature.

In order to evaluate the fertility of the sediment in the vertical profile, bimonthly collection and analysis of core samples were undertaken during the period of study. The concentration of organic carbon in the core samples showed a decreasing trend with depth. Cammen (1975) explained the difference in the concentration of the same in the upper layers as due to the input of organic carbon from the surface. Kufel and Kufel(1977) recorded significant concentration of organic matter and total phosphorus in the upper layer of the sediment and their decrease in the deeper layers. Rosenfeld(1979b) noted a slight change in the organic carbon content with depth, but organic nitrogen was observed to decrease significantly. He also investigated the ratio between organic carbon and organic nitrogen and indicated the preferential utilization of organic nitrogen relative to organic carbon during early diagenesis. Clarke(1967) observed the decrease in the concentration of organic nitrogen with depth. Pillai(1956) recorded relatively rich nutrient concentration in the upper layers of the sediment in the Pillaimadam lagoon and correlated this phenomena with the periodic deposit of organic matter brought into the lagoon during inundation. Comparatively high concentration of organic carbon, total phosphorus and Kjeldahl nitrogen recorded in the upper layers of the sediment in the lagoon is in confirmity with the findings of earlier workers.

It has been reported earlier that in shallow waters, zooplankton populations are epibenthic or demersal in nature during the day time(Emery, 1968; Alldredge and King,1977; Sameoto, 1978; Youngbluth,1980 and Jones et al.,1978). Jones et al.(1978) recorded mysids, cumaceans and ostracods at a Saudi Arabian hypersaline lagoon and based on the low concentration of of zooplankton in unit volume opined that secondary production rate in the area investigated was low. Copepods dominated the zooplankton samples examined by them. Ceccherelli and Ferrari (1982) found that 95% of the zooplankton samples collected from the Valli of Comacchio consisted of copepods, tintinnids, rotifers, polychaete larvae and bivalve larvae. Cirrepede nauplii, larvae of gastropods, decapods, ascidians and eggs of invertebrates and vertebrates were recorded in minimal numbers. Pauly(1975) recorded copepods, mysids, amphipods, isopods and decapods from a coastal saline lagoon in west Africa. In the Pillaimadam lagoon, after the major rainfall, the growth of population of copepods, chiefly Acartia spp. was relatively rapid till March,1984 and their consentration in the samples from the lagoon was several times higher than that observed in November and December,1983. This relationship between rainfall and subsequent preponderence of the species of Acartia spp. has been reported from other tropical and subtropical bays (Woodmansee,1958; Reeve,1964; Grahame,1976; Youngbluth,1976 and 1980). The reduction in salinity and the heavy rainfall appears to trigger the occurrence and abundance of cladocerans, cirrepede nauplii and decapod larvae in the lagoon. In the present study, the pattern of distribution of salinity in the lagoon was almost similar to that in the Palk Bay till December and this may be the reason for the occurrence of marine forms such as coelenterates, cladocerans, mysids, heteropods, pteropods, ophioplenteus larvae and appendicularians in the samples collected from the lagoon during this period.

Earlier observations on the zooplankton distribution in the nearby Palk Bay and Gulf of Mannar also is in agreement with the present findings(Prasad, 1954, 1965 and Kartha,1960). The presence of insect larvae in the zooplankton collections in March is noteworthy.

Observation on the diel variation of hydrological parameters indicate that dissolved oxygen and nutrients showed distinct variation during day and night time. Diurnal fluctuation in the salinity values in the lagoon was dependent upon the freshwater and seawater in flow. Pauly(1975), Edwards(1978), Hansen *et al.*(1978) and Krumgalz *et al.*(1980) recorded maximum concentration of dissolved oxygen in the afternoon and minimum in the morning in similar lagoonal environment. Hansen *et al*.(1978) attributed diurnal variation of dissolved oxygen to the rate of photosynthesis in the day time and the heterotrophic processes in the dark hours. In the Pillaimadam lagoon dissolved oxygen concentration was minimum when anoxic conditions prevailed.

Lorensen(1963) observed periodicity in the carbon assimilation by phytoplankters and he recorded high rate of primary production at 1200 h at Long Island, New York. As the synthesis and destruction of pigment, and also cellullar protein essentially involve the utilisation and transformation of nitrogen and phosphorus, the changes in the concentration of inorganic nitrogen and phosphorus in the water column would reflect on the process of synthesis. New combe(1940) reported diurnal phosphate pulse with high values recorded in the morning and low values in the afternoon. He postulated that the phosphate is released in large quantities by the phytoplankters during the night and reabsorbed during the day time. Ketchum(1939b) found that only the cells deficient in phosphorus would take up phosphate in the dark hours. Eppley *et al.*(1972) recorded diurnal variation in the phosphate uptake to be minimum between 1800 and 2400 hrs and maximum during the day time. Goering *et al.*(1964), Kates and Jones(1967), Eppley and Coatsworth(1968) Eppley *et al.*,(1970), Packard *et al.*(1971), Malone *et al.* (1975) and Mac Issac(1978) observed that the maximal uptake of ammonium and nitrate by photosynthetic organisms was centered around noon and the minimal uptake was found to be around midnight. Diurnal variation in nitrate uptake rate has been found in both nitrate-poor and nitrate rich waters(Malone *et al.*,1975). Nitrate assimilation in green plants involves the reduction of nitrate to nitrite followed by photosynthetic reduction of nitrite to ammonia (Joy and Hageman,1966). Midday uptake rates for nitrate, ammonia and Urea-N were all higher in natural light than in darkness(McCarthy,1972). Except in the magnitude of variation, three was not much difference on the diurnal variation of the dissolved oxygen and nutrients observed in the Pillaimadam lagoon during the period of study.

The coastal vegetation around Pillaimadam lagoon exhibited a pattern of distribution corresponding to that described by

Boughey(1957) for enclosed lagoons. Pauly(1975) recorded *Sesuvium* in a west African coastal lagoon. Edwards(1978) noted seasonal flooding of *Salicornia* sp.and other coastal vegetation along the shore of a Mexican coastal lagoon. A floral survey conducted along the peripheral region of the Pillaimadom Lagoon during the present study indicate that the dominant vegetation was composed of *Salicornia brachiata* followed by *Cyperus* sp.

In order to facilitate comparison of the fluctuation in the hydrobiological and sedimentological characterities of the Pillaimadam Lagoon with the adjacent Palk Bay Area, regular observations on these parameters were conducted at a near shore station in the Palk Bay(Pl.1-4; Figs.9-1 to 9-4; 10-3 and 10-4 and 12-5 to 12-7). The salinity variation observed at the station in the Palk Bay in the present study closely resembled the pattern described by Jayaraman(1954) from the same area. He attributed the variation in salinity to the two monsoon driven current systems and the climate of that zone. In the present study, the low values of salinity observed in the second year, indicate that the rainfall exerts adverse influence on the salinity of the coastal waters. The sharp increase recorded in the concentration of phosphate in the Palk Bay immediately following similar peak in value of the same in the lagoon suggests that the freshwater inflow might have contributed to this increase. The positive Eh values obtained during the premonsoon period indicate the oxic nature of the sediment during this period. Due to the lengthy north-east monsoon, the Palk Bay was rough even after the January, which resulted in turbid conditions. This may, in addition to the loading of nutrients by the freshwater inflow, be the reason for negative redox potential(Eh) recorded in the postmonsoon period. The nutrient content of sediment was relatively low and this was reflected in the low abundance and diversity of benthic macrofauna at the station situated in the Palk Bay.

SECTION-II

NUTRIENT ENRICHMENT EXPERIMENTS

Chapter-1

INTRODUCTION

INTRODUCTION

THE photosynthetic production of new organic matter by the plankton community is a fundamental process of aquatic ecosystem which supports upper trophic levels and ultimately the yield harnested by man. Measurement of the rate of production of new organic matter is therefore of practical concern as well as basic scientific interest as a fundamental property of the richness of aquatic ecosystems.

Generally, coastal lagoons and estuaries have high rate of primary production as there are always nutrient input through the freshwater sources from the surrounding land masses. However, some coastal lagoons, located in the desert coasts or sandy land masses will be less productive mainly due to high temperature, low rainfall and insignificant input of nutrients from the surrounding sources. As evidenced by the results of studies on the ecology and productivity, Pillaimadam Lagoon falls in the latter category.

The most widely used method of studying nutrient limitation in aquatic environments has been the nutrient enrichment experiment, in which nutrients are supplied to a test algal species growing in filtered water or to the natural phytoplankton and responses are measured as increases in production or biomass or as changes in cellular characteristics. Recent studies of this nature may be grouped into four categories.

^{14}C bioassays (Goldman,1972), enrichment of continuous or batch cultures(Barlow _et al._,1973), enrichment experiments in large _in situ_ polyethylene enclosures(Schelske and Stoermer,1971) and experimental enrichment of whole lake ecosystems(Schindler,1971). But, no one yet attempted on a sustained study to elucidate the role played by artifitial fertilisation in aquatic productivity.

This enrichment investigation was undertaken in Pillaimadam Lagoon with the intention to increase primary production level but not to change the trophic relationships. Thus it was considered important not to add excessive quantities of nutrients. When the results of laboratory experiments on the effects of nutrient enrichment on the primary production are extrapolated to field conditions, the predictions of the experiments are seldom fulfilled, because the behaviour of a species in a net work of interacting variables in nature is quite different from its behaviour under controlled conditions. Hence, it was found necessary to execute _in vitro_ as well _in situ_ experiments.

Chapter-2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Strickland *et al.*(1969), using polyethylene tanks, studied the growth and composition of phytoplankton crops at low concentrations. Eppley *et al.*(1971), in the shipboard cultures of the phytoplankters, studied their growth and composition by supplying nitrate, ammonium or urea as the nitrogen source. Glooschenko and Curl(1971) enriched the coastal waters of North Pacific by adding nitrogen,phosphorus and iron at approximately twice the highest concentrations to be expected in that area and the response was measured as the assimilation numbers calculated from chlorophyll *a* data. The addition of phosphorus and nitrogen to a small unproductive Canadian Shield lake over a period of seventeen weeks caused several fold increase in the phytoplankton standing crop and a change in the dominant species from Chrysophyceae to Chlorophytae(Schindler,1971). Dickman and Efford(1972) investigated some of the effects of artificial fertilisation on the enclosed plankton populations in Marion lake, British Columbia. He used three different nutrients to determine whether the pattern was dependent on the type of fertilisers. O'Brein and deNoyelles(1972) enriched eight small ponds using N:P:K fertilisers and studied their effects on the zooplankton species due to elevated pH. Parsons *et al.*(1972) used commercial fertilisers to enrich a large volume of water body in the Great Central Lake and concluded that the addition of nutrients at a low but sustained level increase the primary productivity without substantially changing the nature of the food chain at the primary level of production. Powers *et al.* (1972) carried out nutrient enrichment experiments in the lakes of Minniesota and Oregon using phosphorus, nitrogen and carbon in 320-litre plastic bags to observe the algal response in the field. Glooschenko and Alvis(1973) found changes in the species composition of phytoplankton due to enrichment. The addition of nitrogen and phosphorus, alone or in combination, caused increase in numbers of algae, along with differences in species composition. Schindler *et al.*(1973)fertilised a small Canadian lake which had extremely low concentrations of dissolved inorganic carbon. The addition of phosphate and nitrate for four years increased natural inputs of phosphorus and nitrogen about five times. Phytoplankton standing crop increased nearly two times and the Cryptophyceae and Crysophyceae present in natural lakes of the area were replaced by Chlorophyta and Cyanophyta. Thompson and Hamilton(1973) measured the utilisation of sucrose by heterotrophic micro-organisms in a small Canadian lake artifically enriched with 5.54gC/sq.m/y as sucrose. Vince and Valiela(1973) used different concentrations of sodium phosphate and ammonium chloride in the Vineyard Sound and observed the results of enrichments on chlorophyll *a*, pigment ratio and species composition of phytoplankton.

O'Brien and de Noyelles(1974) investigated the effects of different levels of nutrients input, in the form of three high quality agricultural fertilizers such as ammonium nitrate, triple superphosphate and muriate of potash, on the inorganic nitrogen and reactive phosphorus concentrations, chlorophyll a, primary production and zooplankton densities in controlled fertilization study in eight experimental ponds in the United States for two years. Schelske et al.(1974) conducted nutrient enrichment experiment with different levels of phosphorus and nitrogen at Lake Michigan. Nutrients were maintained at these levels by additions at 2 or 3-day intervals. Results indicated that the responses were due to the effects of phosphorus and not of nitrogen.

Bienfang(1975) experimented on the steady state of nitrate-ammonium assimilation by phytoplankters at Waimanalo, Hawaii. Gerhart and Likens(1975) used polyethylene enclosures of 1700-litres capacity for the enrichment experiments to determine the nutrient limitation in the New Hampshire lake. In all the experiments, nitrogen and phosphorus never failed to stimulate phytoplankton growth when supplied together, although neither was effective when added alone. Weglenska et al.(1975) studied the effect of mineral fertilizers such as potassium salt and ammonium nitrate in four Polish lakes of various trophic types and found an increase in the number and fecundity of zooplankton, increase in the biomass of benthic fauna and the changes in the species composition of benthos.

Brewer and Goldman(1976) observed the alkalinity changes generated by the phytoplankton growth in the culture medium.

Verlencar(1976) investigated the growth rates of three phytoplankters as a function of urea by enriching Goa water with varying concentrations(0 to 50 µg-at N/l) of urea. McCarthy *et al.* (1977) worked on the preference of phytoplankton on the nitrogenous nutrient medium and observed that high values of phytoplankton content showed preference primarily for ammonium and secondarily for urea-N over nitrate and nitrite. Parsons *et al.*(1977), using low level nutrient enrichment of four enclosed water colums indicated an increased production with nutrients but a decrease in the transfer of efficiency between primary producers and ctenophore production in Canada.

LeBrasseur *et al.*(1978) fertilised the Great Central lake using commercial grade ammonium nitrate and ammonium phosphate fertilisers to study the annual primary production, mean chlorophyll *a*, mean zooplankton biomass, mean number of zooplankton species and the increase in the stock size of adult sockeye salmon. Eppley *et al.*(1979) studied the role of ammonium in the growth of phytoplankton in southern California coastal waters. Lean and Pick(1981) enriched three Canadian lakes to study the photosynthetic response of phytoplankton and found that the low levels of soluble reactive phosphate of 0.6 µgP/l and the rapid phosphate turnover times of 6.2 and 8.1 minutes were evidence that phosphate was in short supply. Parsons *et al.*(1981) found that the heterotrophic production by bacteria in the glucose-enriched water column depressed photosynthetic production by algae and this effect was believed to have been caused by heterotrophic growth, which compete with the autotrophic organisms for a limited supply of nitrate. Walker and O'Donnell (1981) enriched the sea water in Cleveland Bay using potassium nitrate, sodium dihydrogen phosphate and Iron Ethylene diamine tetraacetic acid individually as well as in combinations and showed that only addition of nitrogen stimulated phytoplankton growth, although addition of nitrogen plus phospherus gave maximum growth of phytoplankters.

Udayavarma *et al.* (1963) conducted enrichment experiments using superphosphate in fish ponds stiuated at the eastern side of the Pillaimadam Lagoon and studied the resultant hydrological factors and primary production.

In the present study, in order to enhance the organic production of the Pillaimadam Lagoon, commercial N:P:K fertiliser was used. To reduce the autotrophic production d-glucose was used in combination with N:P:K fertiliser. Urea, superphosphate, potash and organic manure were also experimented with different concentrations and combinations. The experiments were conducted in three sets, of which two sets were on the polythene field enclosures and one set in the laboratory tanks.

Chapter-3

MATERIAL AND METHODS

MATERIAL AND METHODS

3.1 Experimental enclosures:

Three polyethylene controlled Experimental Enclosures(CEE) were constructed near the regular sampling Station-III(henceforth to be mentioned in the text as Enclosures-B1, B2 and B3) and another three sets near Station-D3 of diurnal sampling stations(henceforth to be mentioned in the text as Enclosures-C1, C2 and C3)(Pl.4-1). Among the three CEEs, one CEE was used as control. Each CEE was 2.5 m square and 1.50 m high, with the base set at 0.5 m deep inside the sediment of the lagoon. Eight palmyra poles were fixed along the periphery of the 2.5 m square area at 1.25 m distance. Black polyethylene sheets, manufactured by the Union Carbide of India, were wound around the palmyra poles to prevent damage to the polyethylene enclosure. The 4 m broad sheet was folded to half and ironed and plastered at 10 m length. This polyethylene black sheet was inserted around the palmyra poles. Sixteen numbers of 2 Kg cement stones were kept in between the polyethylene sheet folds at the rate of two stones between the palmyra poles and the sheet enclosures were tucked in the sediment to a depth of 0.5 m. Above the water level bamboo sticks were used to keep the polyethylene sheets upright.

Between each experiment, the polyethylene sheets were removed and mended using plaster tapes. Damaged polyethylene

Plate 4-1 Controlled Experimental Enclosures at Site-C.

Plate 4-2 *in vitro* Experimental tanks.

Plate 4-1

Plate 4-2

sheets were replaced by new ones. Reconstruction of the CEE was done prior to the beginning of each experiment.

3.2 *In vitro* tanks:

Five fibre glass tanks (Tanks-A1, A2, A3, A4 and A5) of 1 m^3 capacity were used. These tanks were kept at the field laboratory and were filled with lagoon water (Pl.4-2).

3.3 Fertilisers:

Commercial grade fertilisers such as 17:17:17-N:P:K-Complex, Urea, Superphosphate, Potash and Organic mixture made by 'KOTHARI' Fertiliser Company, Madras were used for the experiment. In addition, chemical fertilisers like sodium phosphate and potassium nitrate were also used in the experiments. To control the autotrophic production, d-glucose was used in combination with the fertilisers in some experiments.

3.4 Experiment-1:

Using 17:17:17-N:P:K-Complex and d-glucose this experiment was conducted. Instead of mixing the fertiliser at a stretch, a simple method to add the fertiliser in a slow, but continuous manner was devised. To achieve this, new pots with a pin hole at the bottom were selected. The fertilizers were mixed in distilled water and hung over the CEEs and tanks in such a manner that the liquid fertiliser mixed with the water column only gradually. It was ensured that the fertiliser got mixed with the water within 24 h without leaving any remnant.

Fertilisers were added in three lots ie., on the day of experiment, third and sixth day of the experiment. Table-10 presents the concentrations of the nutrients added.

Among the Enclosures-B1, B2 and B3 one enclosure was fertilised with N:P:K fertiliser and d-glucose and N:P:K fertiliser alone was used in another enclosure. The third enclosure was used as control. At Enclosures-C1, C2 and C3, the same procedure was flllowed as for Enclosures-B1, B2 and B3 respectively. The fertiliser was added at the nutrient concentration of 8.571 µg-at NH_3-N/l, 20.571 µg-at Urea-N/l and 11.613 µg-at PO_4-P/l for each lot. Glucose was added at the rate of 1.67 mg/l for each instalment. The concentration of nitrients used in the *in vitro* tanks were also the same as for the *in situ* enclosures. The additional fibre glass tanks received 27.571 µg-at NO_3-N/l and 13.822 µg-at P/l at each instalment. Pots were hung above the control tanks through which distilled water was allowed to drip.

3.5 Experiment-2:

This experiment was basically the same as that of the Experiment-1 except that the fertiliser was added in one lot. Hence, the initial concentration of the nutrients was thrice that of the Experiment-1. The fertiliser was dissolved in distilled water and mixed in the enclosures directly. The control enclosures and tank received only distilled water. The fertiliser was added in order to increase the nutrients concentrations in the following manner: 25.71 µg-at NH_3-N/l, 61.71 µg-at Urea-N/l 34.84 µg-at PO_4-P/l, 5 mg/l d-glucose, 82.71 µg-at NO_3-N/l and 41.47 µg-at PO_4-P/l (Table-11).

3.6 Experiment-3:

Enclosures-C1 and C2 were used to test the *in situ* effect of fertilization by organic mixture. One enclosure was used as the control and the other as the experimental enclosure. The organic mixture was added in order to increase the nutrient concentrations to 80 µg-at N/l and 18.064 µg-at P/l. The fertilizer was mixed well in distilled water and added directly in a single lot. Control enclosure received distilled water alone. In the *in vitro* experiment, one tank(Tank-A1) was used as the control tank and the remaining four tanks(Tanks-A2,A3, A4 and A5) were used for experiments. The type of fertilizers and the concentration used are shown in Table-12.

3.7 Experiment-4:

In this experiment, only *in vitro* study was made using three tanks(Tanks-A1, A2 and A3) of which one was maintained as control. In the remaining two tanks, the first tank received organic mixture in order to increase the nutrients concentration to 80 µg-at N/l and 18.064 µg-at P/l, potassium to the level of 14.87 µg-at K/l with 5 mg/l d-glucose. Organic mixture and Potash were added to the second tank with the same concentration as in the first tank(Table-13).

3.8 Sampling:

Water samples were collected from all the *in situ* and *in vitro* enclosures prior to the addition of fertilisers. Sampling was done at a depth of 5 cm. Usually the enclosures and tanks were sampled between 0600 h to 0730 h. After the addition of fertilisers, sampling was done on the third, sixth, ninth, twelfth and fifteenth days.

3.9 Chemical analyses:

The samples were analysed for estimating the dissolved oxygen content, salinity, pH, soluble reactive phosphate, nitrate, nitrite and ammonia. The method of sampling, preservation and analytical procedures were all the same as for the analyses of regular hydrological samples, except that the water samples for soluble reactive phosphate, nitrate, nitrite and ammonia were first filtered through combusted Whatman-GF/C glass-fibre filters before analyses.

3.10 Estimation of primary production:

The gross and net primary production was investigated using 'Light and Dark Bottle' method. The analytical procedure was the same for the regular analyses of the samples collected for the ecological studies. The phytoplankters responsible for 'blooms' in the experimental tanks were identified into broad taxonomic categories and the results presented.

3.11 Statistical Analysis:

Analysis of variance(ANOVA) was conducted to test the significance between treatments in the primary production.

The mean comparisons were made by the least significant difference(LSD) test. "Control corrected gross and net primary productions" were used for statistical analysis (Dickman and Efford,1972). The summaries of the treatment mean comparisons are presented in Table-14.

Chapter-4

RESULTS

RESULTS

The fertilisation experiments in the Controlled Experimental Enclosures(CEE) were carried out from February to May, 1984. Altogether four sets of experiments were conducted, of which the first three sets were in *in situ* as well as in vitro in CEE and fibreglass tanks respectively(Plate 4-1 and 4-2). The first two sets of experiments were conducted more or less in the same pattern except for the method of addition of fertilizers, and were carried out using N:P:K-Complex, d-glucose, sodium phosphate and potassium nitrate. The third set of experiment was carried out using organic manure, potash, superphosphate and urea. In the last batch of *in vitro* experiments, the chemicals used were organic mixture, potash and d-glucose.

4.1 Experiment-1:

Table-10: Details of enrichment experiment-1 conducted during February, 1984(Duration-15 days)

Tank	Fertiliser used	Nutrients concentration in µg-at/l/lot			
		NH_3-N	Urea-N	PO_4-P	d-glucose in mg/l
In situ:					
Encl-B1	Control	-	-	-	-
Encl-B2	N:P:K+ d-glucose	8.57	20.57	11.61	1.67
Encl-B3	N:P:K	8.57	20.57	11.61	-
Encl-C1	Control	-	-	-	-
Encl-C2	N:P:K+ d-glucose	8.57	20.57	11.61	1.67
Encl-C3	N:P:K	8.57	20.57	11.61	-
In vitro:					
Tank-A1	Control	-	-	-	-
Tank-A2	N:P:K+ D-Glucose	8.57	20.57	11.61	1.67
Tank-A3	N:P:K	8.57	20.57	11.61	-
Tank-A4	KNO_3+Na_2HPO_4	20.57NO_3-N	-	13.82	-

4.1.1 Enclosure-B1:

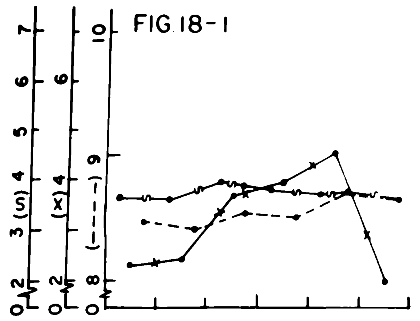
The dissolved oxygen content of water fluctuated between 3.63 and 3.96 ml/l, with a slight rise from the third day(3.58 ml/l) to the sixth day(3.96 ml/l). Salinity values varied from 2.01 to 4.52%o during the period of the experiment. A gradual rise was observed from the day of experiment(2.29%o) to the twelfth day(4.52%o) followed by an abrupt decrease on the last day(2.01%o). The pH of water gradually increased from the day of experiment(8.46) to the twelfth day(8.70) with slight variation recorded on the third day(8.40)(Fig.18-1). Soluble reactive phosphate ranged from 0.33 to 1.07 µg-at PO_4-P/l during the period of experiment. The concentrations of Nitrate and nitrite steadily decreased from 0.69 µg-at NO_3-N/l and 0.20 µg-at NO_2-N/l to 0.10 µg-at NO_3-N/l and 0.05 µg-at NO_2-N/l respectively(Fig.18-2). Ammonia values showed gradual increase from 4.96 µg-at NH_3-N/l from the day of experiment to 8.75 µg-at NH_3-N/l on the twelfth day. Gross primary production values recorded an increase from 117.1 mgC/m^3/day on the day of experiment to 231.7 mgC/m^3/day on the last day. Net primary production was observed on the sixth day(85.8 mgC/m^3/day), twelfth day(90.1 mgC/m^3/day) and the last day(42.9 mgC/m^3/day) during the course of the experiment(Fig.18-3).

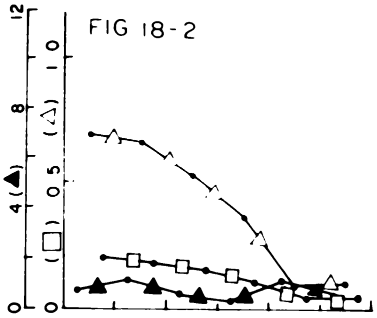
4.1.2 Enclosure-B2:

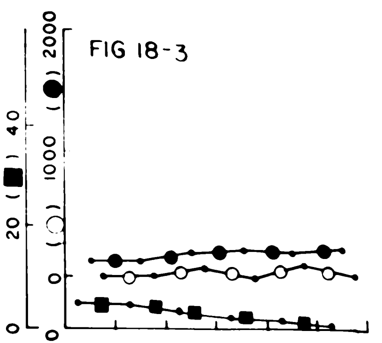
A slight decrease was noted in the concentration of oxygen from the day of expdriment(3.68 ml/l) to the third day(3.48 ml/l). Its values sharply increased till the ninth day(4.95 ml/l), after which a steady decrease was noticed. Salinity values fluctuated

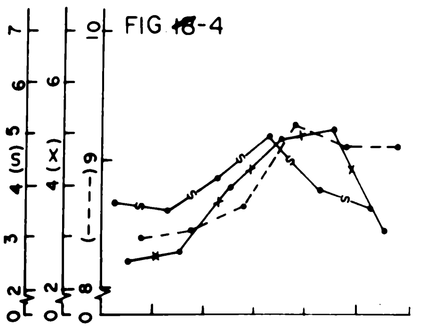
NUTRIENT ENRICHMENT EXPERIMENT-1

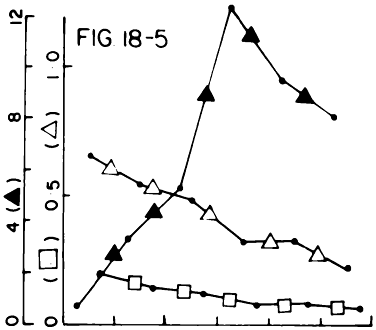
Fig. 18-1 to 18-3	Results of observations on the variation in the dissolved oxygen, salinity, pH soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental enclosure-B1(Control)
Fig. 18-4 to 18-6	Results of observations on the variation in the dissolved oxygen, salinity, pH soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental enclosure-B2(N:P:K + d-glucose)
Fig. 18-7 to 18-9	Results of observations on the variation in the dissolved oxygen, salinity, pH soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experiments enclosure-B3(N:P:K)
Fig. 18-10 to 18-12	Results of observations on the variation in the dissolved oxygen, salinity, pH soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experiments enclosure-B1(Control)
Fig. 18-13 to 18-15	Results of observations on the variation in the dissolved oxygen, salinity, pH soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experiments enclosure-C2(N:P:K + d-glucose)-

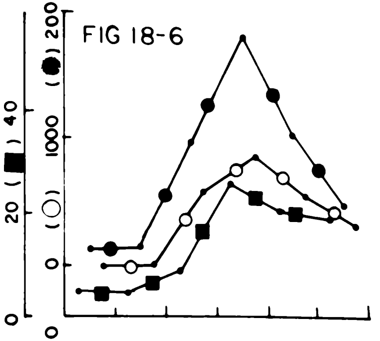


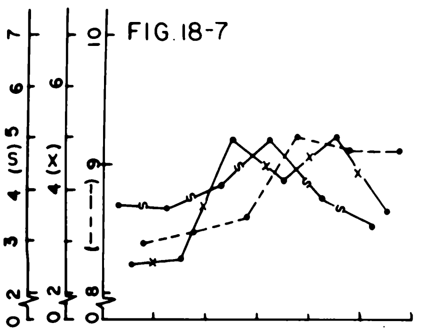


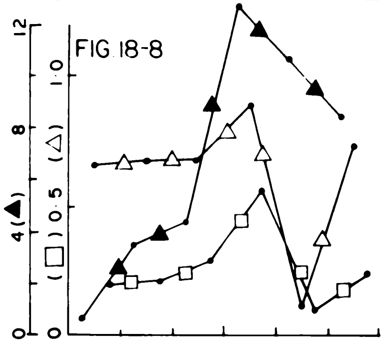


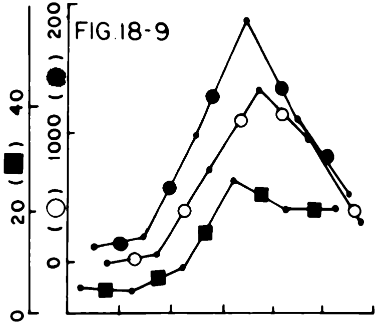


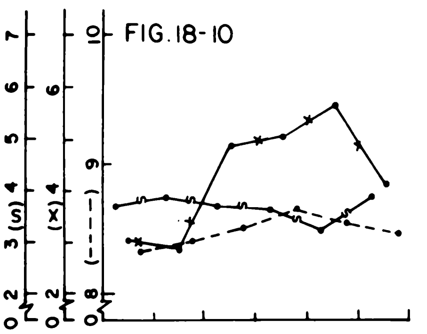


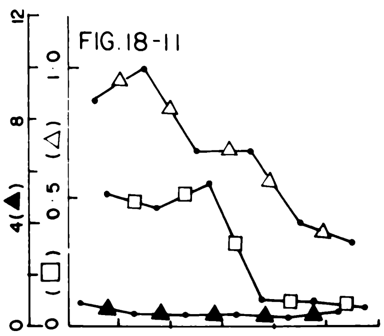


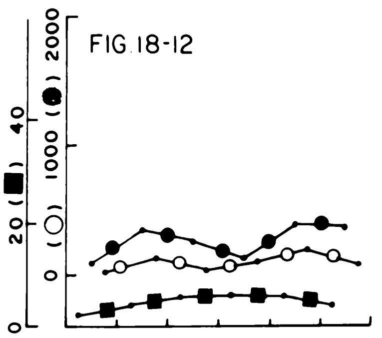


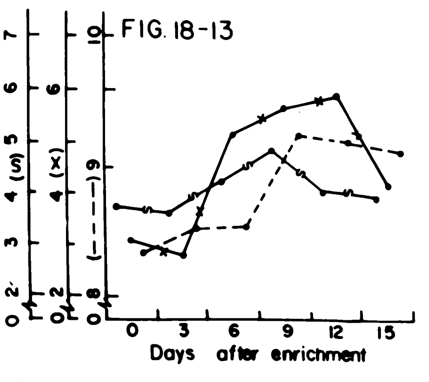


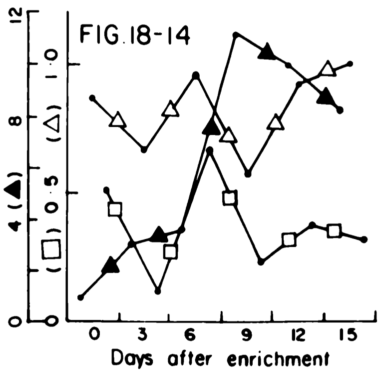


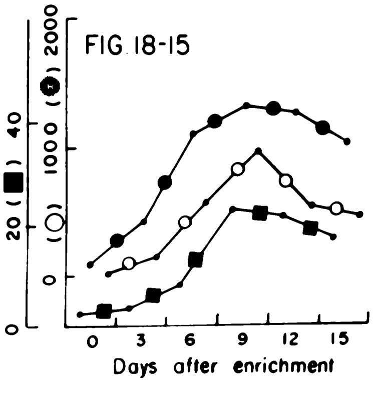












Legends to figures 18-1 to 18-15;
∽-Oxygen in ml/l
x-Salinity in ‰
--- pH

▲-PO_4^--P in µg-at/l
△-NO_3^--N in µg-at/l
□-NO_2^--N in µg-at/l

■-NH_3^--N in µg-at/l
●-Gross production in mgC/m³/day
○-Net production in mgC/m³/day

between 2.54 and 5.04‰. A gradual rise in salinity was noticed from the day of experiment(2.54‰) to the twelfth day(5.04‰) followed by a sudden decrease on the last day(3.07‰). The pH of the water increased from the day of experiment(8.38) to the ninth day(9.25) followed by a decrease on the twelfth day(9.10)(Fig. 18-4). Soluble reactive phosphate increased steadily till the ninth day(12.36 µg-at PO_4P/l) followed by a sharp decrease till the last day(8.09 µg-at PO_4-P/l). Nitrate and nitrite concentrations steadily decreased from 0.64 µg-at NO_3-N/l and 0.20 µg-at NO_2-N/l to 0.22 µg-at NO_3-N and 0.06 µg-at NO_2-N/l respectively (Fig.18-5). Ammonia concentration sharply increased from the third day(4.51 µg-at NH_3-N/l) to the ninth day(26.48 µg-at NH_3-N/l) followed by a sharp decrease till the last day(19.53 µg-at NH_3-N/l). The gross primary production values showed steep increase from the third day(133.1 mgC/m^3/day) to the ninth day(1814.7 mgC/m^3/day) after which a sharp decrease was noticed. Net primary production values showed the same trend of fluctuation as gross primary production values with its peak recorded on the ninth day(855.9 mgC/m^3/day)(Fig.18-6).

Enclosure-B3:

A mild decrease was observed in the dissolved oxygen content from the day of experiment(3.68 ml/l) to the third day(3.64 ml/l), followed by steady increase till the ninth day(4.97 ml/l)after which a sharp decrease was observed till the last day of experiment (3.32 ml/l). Salinity values gradually increased from the day of experiment(2.54‰) to the sixth day(4.93‰) after which a decline was noted in the ninth day followed by an increase in the twelfth day(5.00‰). The last day of experiment recorded low salinity value(3.59‰). The pH of the water increased from the day of experiment(8.38) to the ninth day(9.22) followed by a decrease on the twelfth day(9.10)(Fig.18-4). Soluble reactive phosphate increased steadily till the ninth day(12.78 μg-at PO_4-P/l) after which a sharp fall was noticed till the last day of experiment (8.37 μg-at PO_4-P/l). Nitrate was at its peak on the ninth day(0.88 μg-at NO_3-N/l) followed by a steep decrease on the twelfth day(0.12 μg-at NO_3-N/l) and a sharp rise in its value was noticed on the last day of experiment(0.73 μg-at NO_3-N/l). Nitrite concentration recorded its peak value on the ninth day (0.56 μg-at NO_2-N/l)(Fig.18-8). Ammonia concentration sharply increased from the third day(4.40 μg-at NH_3-N/l) to the ninth day(25.86 μg-at NH_3-N/l) after which a steady decrease was observed till the last day(20.30 μg-at NH_3-N/l). The gross primary production values showed a steep increase from the third day(107.4 mgC/m^3/day) to the ninth day(1874.8 mgC/m^3/day) followed by a sharp decrease till the last day(536.09 mgC/m^3/day). Net primary production values showed the same trend of fluctuation as that of the gross primary production values, with its peak recorded on the ninth day(1347.5 mgC/m^3/day) of the experiment (Fig.18-9).

4.1.4. Enclosure-C1:

Dissolved oxygen concentration ranged between 3.25 and 3.87 ml/l during the period of experiment. Salinity values showed a slight decrease on the third day(2.9‰) followed by a steady increase till the twelfth day(5.8‰) and afterwards a decline was noticed on the last day(4.1‰). The pH of the water gradually increased from the day of experiment(8.33) to the ninth day(8.65) followed by a gradual decrease till the last day(8.48) (Fig.18-10). Soluble reactive phosphate steadily decreased from the day of experiment(0.86 µg-at PO_4-P/l) to the twelfth day(0.28 µg-at PO_4-P/l) followed by a sharp rise on the last day(0.61 µg-at PO_4-P/l). Nitrate concentration gradually decreased from the third day(1.00 µg-at NO_3-N/l) to the last day(0.33 µg-at NO_3-N/l). A peak in nitrite concentration was observed on the sixth day (0.55 µg-at NO_2-N/l) followed by sharp decrease till the last day (0.07 µg-at NO_2-N/l)(Fig.18-11). Ammonia content gradually increased from the day of experiment(2.11 µg-at NH_3-N/l) to the ninth day(6.07 µg-at NH_3-N/l) followed by a steady decrease till the last day(4.14 µg-at NH_3-N/l). Gross primary production values varied between 107.2 and 387.3 mgC/m^3/day with its peak on the last day of experiment(387.3 mgC/m^3/day). Net primary production ranged from 12.9 to 193.0 mgC/m^3/day, with maximum value recorded on the twelfth day(193.0 mgC/m^3/day)(Fig.18-12).

4.1.5 Enclosure-C2:

Dissolved oxygen content gradually increased from the third day(3.60 ml/l) to the ninth day(4.82 ml/l) followed by a steady decrease till the last day(3.90 ml/l). Salinity values showed a decrease on the third day(2.8‰) followed by a steady increase till the twelfth day(5.8‰), after which a decline was noticed on the last day(4.1%) . The pH of water sharply increased from the day of experiment(8.33) to the ninth day(9.25) and subsequently a gradual decline in its value was noticed (Fig.18-13). Soluble reactive phosphate sharply increased from the day of experiment (0.86 µg-at PO_4-P/l) to the ninth day(11.05 µg-at PO_4-P/l), followed by a gradual decrease till the last day(8.31 µg-at PO_4-P/l). Nitrate fluctuated from 0.58 to 1.00 µg-at NO_3-N/l and nitrite from 0.12 to 0.67 µg-at NO_2-N/l during the period of experiment(Fig.18-14). Ammonia concentration gradually increased from the day of experiment(2.11 µg-at NH_3-N/l) to the ninth day (23.12 µg-at NH_3-N/l) followed by a smooth decline till the last day(16.80 µg-at NH_3-N/l). A steep increase was recorded in the gross primary production values from the third day(414.6 mgC/m^3/day) to the ninth day(1408.96 mgC/m^3/day), after which a steady decline was recorded till the last day(1043.20 mgC/m^3/day). Net primary production was at its peak on the ninth day(954.5 mgC/m^3/day) followed by steady decline till the last day(450/mgC/m^3/day)(Fig.18-15).

4.1.6 Enclosure-C3:

Dissolved oxygen concentration gradually increased from the day of experiment(3.70 ml/l) to the ninth day(5.03 ml/l) followed by a steady decrease till the last day(3.99 ml/l). Salinity values decreased mildly from the day of experiment (3.1‰) to the third day(2.9‰) followed by a steady increase till the twelfth day(6.2‰) after which a decline was noticed in the last day(4.0‰). The pH of water increased sharply from the day of experiment(8.33) to the ninth day(9.30) followed by steady decline till the last day(9.10)(Fig.19-1). Soluble reactive phosphate sharply increased from the day of experiment (0.86 µg-at PO_4-P/l) to the ninth day(11.45 µg-at PO_4-P/l), followed by a smooth decline till the last day(8.67 µg-at PO_4-P/l). Nitrate concentration showed a sharp decrease from the day of experiment(0.87 µg-at NO_3-N/l) to the sixth day(0.28 µg-at NO_3-N/l) followed by a steep increase on the ninth day(0.67 µg-at NO_3-N/l). Nitrite concentration ranged from 0.08 to 0.51 µg-at NO_2-N/l during the period of experiment(Fig.19-2). Ammonia content gradually increased from the day of experiment (2.11 µg-at NH_3-N/l) to the sixth day(7.86 µg-at NH_3-N/l) followed by a sharp rise on the ninth day(23.76 µg-at NH_3-N/l) after which a steady decrease was noticed till the last day (16.46 µg-at NH_3-N/l). The gross primary production values increased sharply from the third day of experiment(437.5 mgC/m^3/day) to the ninth day(1496.5 mgC/m^3/day) followed by a steady decline till the last day(1024.5 mgC/m^3/day. Net primary production closely followed the same trend as that of the gross primary production recording its peak value on the ninth day (1120.6 mgC/m^3/day)(Fig.19-3).

4.1.7 Tank-A1:

Dissolved oxygen content ranged between 3.39 ml/l and 4.15 ml/l. A slight increase was noticed from the day of experiment(3.92 ml/l) to the ninth day(4.15 ml/l). Salinity values gradually increased from the day of experiment(2.4‰)

NUTRIENT ENRICHMENT EXPERIMENT-1

Fig. 19-1 to 19-3	Results of observations on the variation in the dissolved oxygen, salinity, pH soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental enclosure-C3(N:P:K)
Fig. 19-4 to 19-6	Results of observations on the variation in the dissolved oxygen, salinity, pH soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A1(Control)
Fig. 19-7 to 19-9	Results of observations on the variation in the dissolved oxygen, salinity, pH soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A2(N:P:K + d-glucose)
Fig. 19-10 to 19-12	Results of observations on the variation in the dissolved oxygen, salinity, pH soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A3(N:P:K)
Fig. 19-13 to 19-15	Results of observations on the variation in the dissolved oxygen, salinity, pH soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A4(KNO_3 + Na_2HPO_4)

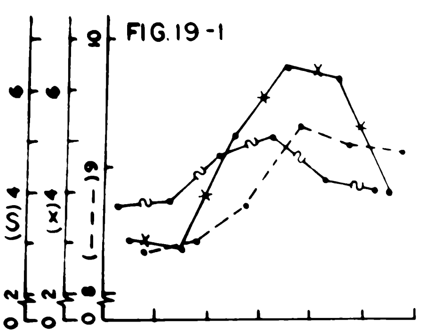


FIG. 19-1

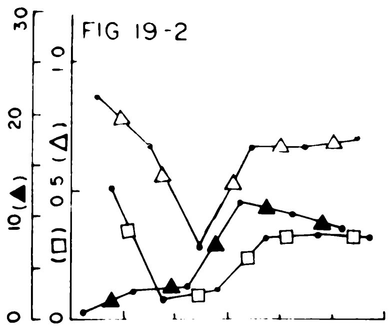


FIG 19-2

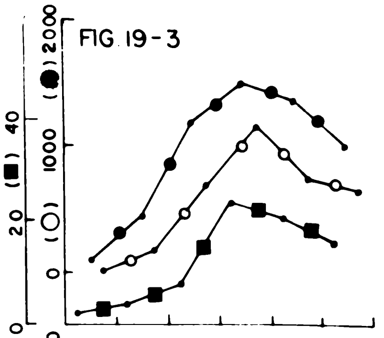


FIG. 19-3

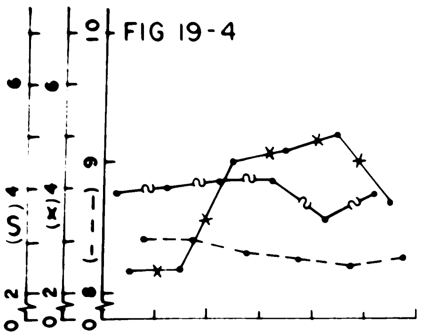


FIG 19-4

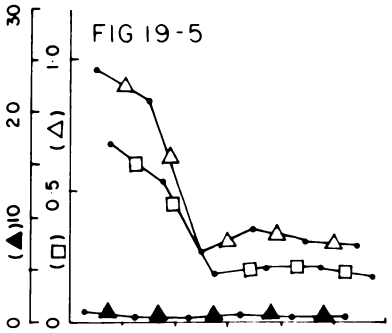
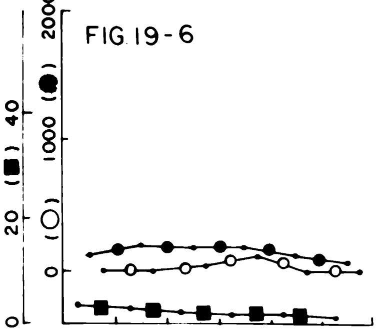


FIG 19-5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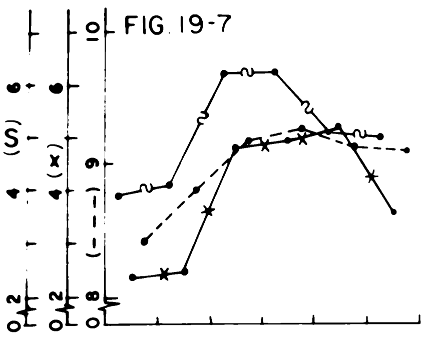


FIG. 19-7

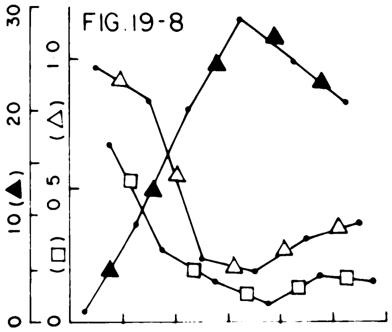


FIG. 19-8

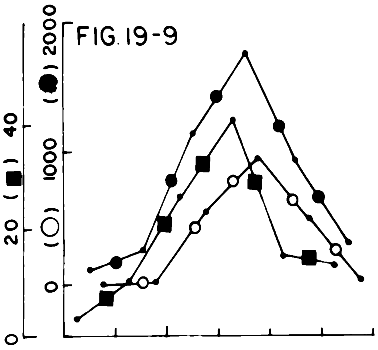


FIG. 19-9

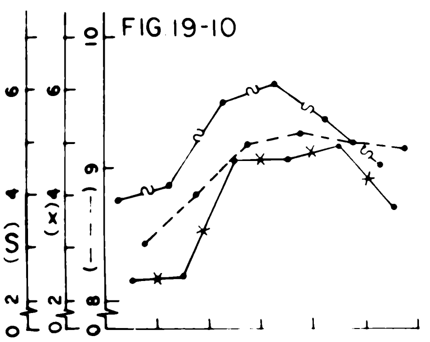


FIG 19-10

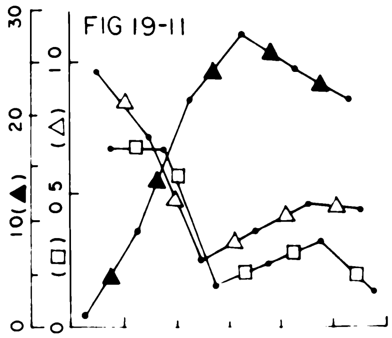


FIG 19-11

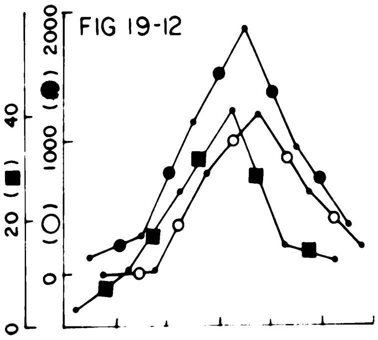


FIG 19-12

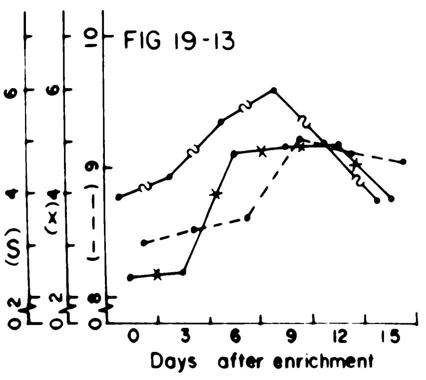


FIG 19-13

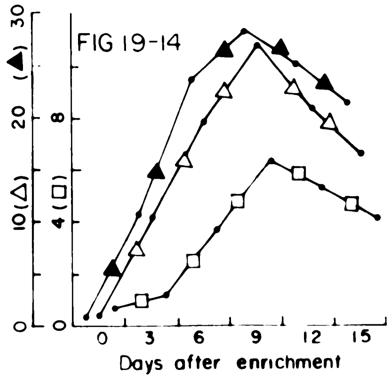


FIG 19-14

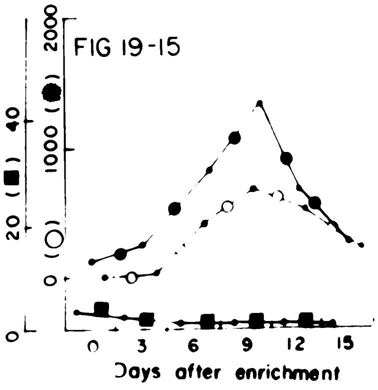


FIG 19-15

Legends to figures 19-1 to 19-15 ;

∽ - Oxygen in ml/l
X- Salinity in ‰
---- pH

▲-PO_4-P in µg-at/l
△-NO_3-N in µg-at/l
□-NO_2-N in µg-at/l

■-NH_3-N in µg-at/l
●-Gross production in mgC/m³/day
○-Net production in mgC/m³/day

to the twelfth day(5.0‰) followed by a sharp decrease on the last day(3.7‰). The pH of water showed mild decrease from the day of experiment(8.42) to the twelfth day(8.20) followed by a slight increase(8.25)(Fig.19-4). Soluble reactive phosphate fluctuated between 0.33 and 0.88 µg-at PO_4-P/l during the period of experiment. Nitrate content sharply decreased from tho day of experiment(0.96 µg-at NO_3-N/l) to the sixth day(0.27 µg-at NO_3-N/l). Nitrite concentration fluctuated from 0.168 to 0.667 µg-at NO_2-N/l during the period of experiment(Fig.19-5). The ammonia content gradually decreased from the day of experiment (3.63 µg-at NH_3-N/l) to the last day(1.05 µg-at NH_3-N/l). Gross primary production values varied from 60.0 to 198.6 mgC/m^3/day during the period of experiment. Net primary production was recorded on the sixth day(45.9 mgC/m^3/day) and the ninth day (111.5 mgC/m^3/day)(Fig.19-6).

4.1.8 Tank-A2:

Dissolved oxygen content sharply increased from the third day(4.12 ml/l) to the ninth day(6.16 ml/l) followed by a gradual decline till the last day of experiment(5.06 ml/l). Salinity values gradually increased from the day of experiment(2.4‰) to the twelfth day(5.2‰) followed by sharp decline on the last day (3.6‰). The pH of water increased sharply from the day of experiment(8.42) to the ninth day(9.25) after which a gradual decline was recorded till the last day(9.10)(Fig.19-7). The soluble reactive phosphate steeply increased from the day of experiment(0.88 µg-at PO_4-P/l) to the ninth day(28.81 µg at

PO_4-P/l) followed by a steady decline till the last day(20.81 µg-at PO_4-P/l). Nitrate concentration sharply declined from the day of experiment(0.96 µg-at NO_3-N/l) to the ninth day(0.20 µg-at NO_3-N/l) followed by a mild increase till the last day (0.38 µg-at NO_3-N/l). Nitrite ranged from 0.08 to 0.67 µg-at NO_2-N/l during the period of experiment(Fig.19-8). Ammonia content steeply rose from the day of experiment(3.63 µg-at NH_3-N/l) to the ninth day(41.48 µg-at NH_3-N/l) after which a sharp decline was noticed till the last day(13.78 µg-at NH_3-N/l). Gross primary production values increased sharply from the third day(232.1 mgC/m^3/day) to the ninth day(1767.0 mgC/m^3/day) followed by a steep decline till the last day(320.3 mgC/m^3/day). Net primary production values closely followed the trend of fluctuation of gross production values with its peak recorded on the ninth day(968.8 mgC/m^3/day)(Fig.19-9).

4.1.9 Tank-A3:

Dissolved oxygen content steeply increased from the third day(4.18 ml/l) to the ninth day(6.12 ml/l) followed by a gradual decrease till the last day(4.54 ml/l). Salinity values gradually increased from the day of experiment(2.4‰) to the twelfth day (5.0‰) followed by a sharp decline on the last day(3.8‰). The pH of water increased steeply from the day of experiment(8.42) to the ninth day(9.25) after which a gradual decrease was noticed till the last day(9.15)(Fig.19-10). Soluble reactive phosphate steeply increased from the day of experiment(0.88 µg-at PO_4-P/l) to the ninth day(27.56 µg-at PO_4-P/l) which was succeeded by a steady decline till the last day(21.57 µg-at PO_4-P/l). Nitrate concentration sharply declined from the day of experiment(0.96 µg-at NO_3-N/l) to the sixth day(0.25 µg-at NO_3-N/l) followed by a gradual increase till the twelfth day(0.45 µg-at NO_3-N/l). Nitrite concentration ranged from 0.133 to 0.667 µg-at NO_2-N/l during the period of experiment(Fig.19-11). Ammonia content sharply rose from the day of experiment(3.63 µg-at NH_3-N/l) to the ninth day (40.94 µg-at NH_3-N/l) followed by a steep decline till the last day(12.46 µg-at NH_3-N/l). The gross primary production values increased sharply from the third day(284.5 mgC/m^3/day) to the ninth day(1863.4 mgC/m^3/day) followed by a sharp decline till the last day(357.3 mgC/m^3/day). Net primary production values closely followed the trend of variation in gross primary production values and the peak value was recorded on the ninth day(1191.7 mgC/m^3/day)(Fig.19-12).

4.1.10 Tank-A4:

Dissolved oxygen content steeply increased from the day of experiment(3.92 ml/l) to the ninth day(5.94 ml/l) followed by a gradual decline till the last day(3.86 ml/l). Salinity values gradually increased from the day of experiment(2.38‰) to the twelfth day(4.96‰), after which a decline was observed on the last day(3.91‰). The pH of water increased sharply from the day of experiment(8.42) to the ninth day(9.22) followed by a gradual decline till the last day(9.05)(Fig.19-14). The soluble reactive phosphate steeply increased from the day of experiment (0.88 µg-at PO_4-P/l) to the ninth day(28.05 µg-at

PO_4-P/l) followed by a gradual decrease till the last day(21.33 µg-at PO_4-P/l). Nitrate concentration sharply increased from the day of experiment (0.96 µg-at NO_3-N/l) to the ninth day (26.81 µg-at NO_3-N/l) after which a sharp decline was observed till the last day(16.53 µg-at NO_3-N/l). Nitrite concentration closely followed the trend of fluctuation in nitrate content and its values ranged from 0.67 to 6.36 µg-at NO_2-N/l(Fig.19-14). Ammonia concentration steadily decreased from the day of experiment(3.63 µg-at NH_3-N/l) to the last day(0.88 µg-at NH_3-N/l). Gross primary production values increased sharply from the third day(231.1mgC/m^3/day) to the ninth day(1324.7 mgC/m^3/day) followed by a steep decrease till the last day(250.1 mgC/m^3/day). Net primary production values closely followed the pattern of fluctuation of gross primary production values and the peak value was recorded on the ninth day(730.8 mgC/m^3/day) (Fig.19-15).

4.2 Experiment-2:

Table-11: Details of enrichment experiment-2 conducted during March,1984(Duration-15 days)

Tank	Fertiliser used	Nutrients concentration in µg-at/l			
		NH_3-N	Urea-N	PO_4-P	d-glucose in mg/l
In situ:					
Encl-B1	Control	-	-	-	-
Encl-B2	N:P:K+d-glucose	25.71	61.71	34.84	5.0
Encl-B3	N:P:K	25.71	61.71	34.84	-
Encl-C1	Control	-	-	-	-
Encl-C2	N:P:K+d-glucose	25.71	61.71	34.84	5.0
Encl-C3	N:P:K	25.71	61.71	34.84	-
In vitro:					
Tank-A1	Control	-	-	-	-
Tank-A2	N:P:K+d-glucose	25.71	61.71	34.84	5.0
Tank-A3	N:P:K	25.71	61.71	34.84	-
Tank-A4	KNO_3+Na_2HPO_4	82.71NO_3-N	-	41.47	-

4.2.1 Enclosure-B1:

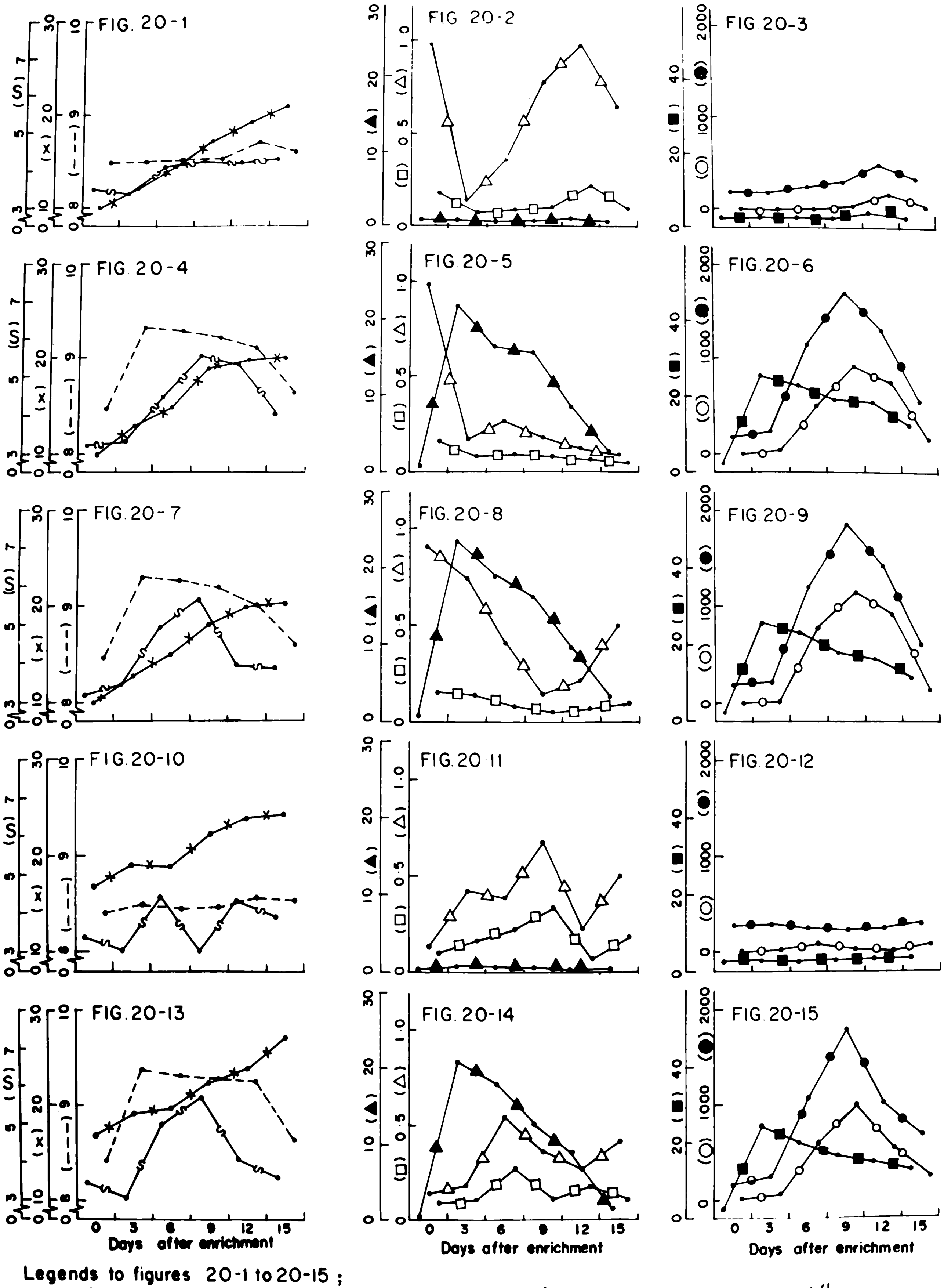
Dissolved oxygen content varied from 3.44 to 4.28 ml/l with a moderate increase from the third day(3.44 ml/l) to the sixth day(4.26 ml/l). Salinity values steadily increased from the day of experiment(10.1‰) to the last day(20.9‰). The pH of water varied between 8.48 and 8.70 during the period of experiment and an increase in its values was recorded from the ninth day(8.51) to the twelfth day(8.70)(Fig.20-1). Soluble reactive phosphate ranged from 0.33 to 0.87 μg-at PO_4-P/l with erratic fluctuation. Nitrate concentration varied between 0.14 and 0.98 μg-at NO_3-N/l during the period of experiment, with a sharp decrease from the day of experiment(0.98 μg-at NO_3-N/l) to the third day(0.14 μg-at NO_3-N/l) after which it increased gradually till the twelfth day(0.98 μg-at NO_3-N/l). Nitrite content ranged from 0.065 to 0.229 μg-at NO_2-N/l during the period of experiment(Fig.20-2). Ammonia concentration evinced a slight increase from the third day(2.05 μg-at NH_3-N/l) to the twelfth day(4.90 μg-at NH_3-N/l) followed by a decline on the last day(3.09 μg-at NH_3-N/l). Gross primary production values recorded a gradual increase from the day of experiment(175.8 mgC/m^3/day) to the twelfth day(496.0 mgC/m^3/day), after which a decline was noticed on the last day(351.6 mgC/m^3/day). Net primary production was recorded on the ninth(40.1 mgC/m^3/day), twelfth day(188.7 mgC/m^3/day) and the last day(34.3 mgC/m^3/day) during the period of experiments(Fig.20-3).

4.2.2 Enclosure-B2:

Dissolved oxygen concentration gradually increasdd from

NUTRIENT ENRICHMENT EXPERIMENT-2

Fig. 20-1 to 20-3	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental enclosure-B1(Control)
Fig. 20-4 to 20-6	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental enclosure-B2(N:P:K + d-glucose)
Fig. 20-7 to 20-9	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experiments enclosure-B3(N:P:K)
Fig. 20-10 to 20-12	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experiments enclosure-C1(Control)
Fig. 20-13 to 20-15	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experiments enclosure-C2(N:P:K + d-glucose).



Legends to figures 20-1 to 20-15 ;
∽-Oxygen in ml/l
x-Salinity in ‰
---- pH

▲-PO_4^--P in µg-at/l
△-NO_3^--N in µg-at/l
□-NO_2-N in µg-at/l

■-NH_3^--N in µg-at/l
●-Gross production in mgC/m³/day
○-Net production in mgC/m³/day

the third day(3.32 ml/l) to the ninth day(5.57 ml/l), after which a steady decline was recorded till the last day(4.05 ml/l). Salinity values gradually increased from the day of experiment (10.1‰) to the last day(20.0‰). The pH of water was at its peak on the third day(9.32) followed by a steady decrease till the last day(8.64)(Fig.20-4). The soluble reactive phosphate concentration recorded a maximum on the third day(21.88 µg-at PO_4-P/l) after which a sharp decline was observed till the last day of the experiment(2.67 µg-at PO_4-P/l). Nitrate content sharply decreased from the day of experiment(0.98 µg-at NO_3-N/l) to the third day(0.18 µg-at NO_3-N/l) after which it fluctuated between 0.09 and 0.27 µg-at NO_3-N/l. Nitrite concentration ranged from 0.050 to 0.170 µg-at NO_2-N/l(Fig.20-5). Ammonia concentration was at its peak on the third day(25.60 µg-at NH_3-N/l) of the experiment followed by a gradual decrease till the last day(13.26 µg-at NH_3-N/l). A steep increase was recorded in the gross primary production values from the third day(257.3 mgC/m^3/day) to the ninth day(1701.8 mgC/m^3/day) after which a sharp decline was noticed till the last day(559.0 mgC/m^3/day). Net primary production values closely followed the pattern of gross primary production rate and recorded a peak on the ninth day(912.7 mgC/m^3/day)(Fig.20-6).

2.3 Enclosure-B3:

Dissolved oxygen content gradually increased from the day of experiment(3.15 ml/l) to the ninth day(5.64 ml/l), followed by a steep decline till the last day(3.87 ml/l). Salinity values steadily increased from the day of experiment(10.1‰) to the last day(20.3‰). The pH of water was at its peak on the third day(9.30) after which a gradual decline in its value was recorded till the last day(8.60)(Fig.20-7). The soluble reactive phosphate recorded maximum on the third day(23.62 µg-at PO_4-P/l) followed by sharp decline till the last day(2.73 µg-at PO_4-P/l). Nitrate content gradually decreased from the day of experiment(0.90 µg-at NO_3-N/l) to the ninth day(0.14 µg-at NO_3-N/l) followed by a steady increase till the last day (0.50 µg-at NO_3-N/l). Nitrite concentration closely followed the pattern of fluctuation of nitrate and ranged from 0.050 to 0.150 µg-at NO_2-N/l(Fig.20-8). Ammonia concentration recorded a peak on the third day(25.39 µg-at NH_3-N/l), followed by a gradual decrease till the last day(11.53 µg-at NH_3-N/l). A sharp increase was recorded in the gross primary production values from the third day(210.2 mgC/m^3/day) to the ninth day(1835.2 mgC/m^3/day), followed by a steep decline till the last day(608.8 mgC/m^3/day). Net primary production values closely followed the trend of fluctuation of gross primary production values, with its peak recorded on the ninth day(1140.7 mgC/m^3/day)(Fig.20-9).

<u>Enclosure-C1</u>:

Dissolved oxygen content fluctuated from 3.03 to 4.38 ml/l during the period of experiment. Salinity values steadily increased from the day of experiment(16.8‰) to the last day (24.3‰). The pH of water gradually increased from the day of experiment(8.40) to the last day(8.55), with a slight decrease on the sixth day(8.43)(Fig.20-10). Soluble reactive phosphate ranged from 0.13 to 0.53 μg-at PO_4-P/l during the period of experiment. Nitrate content fluctuated between 0.13 and 0.67 μg-at NO_3-N/l and nitrite between 0.060 and 0.334 μg-at NO_2-N/l (Fig.20-11). Ammonia concentration gradually increased from the day of experiment(2.24 μg-at NH_3-N/l) to the twelfth day(3.18 μg-at NH_3-N/l), with a slight decline on the sixth day(2.63 μg-at NH_3-N/l). Gross primary production values ranged from 128.8 to 187.3 mgC/m^3/day, and the peak in net primary production was recorded on the last day of the experiment(80.6 mgC/m^3/day(Fig. 20-12).

4.2.5 Enclosure-C2:

Dissolved oxygen content recorded a gradual increase from the third day(3.07 ml/l) to the ninth day(5.71 ml/l) after which a steady decrease was recorded till the last day(3.60 ml/l). Salinity values steadily increased from the day of experiment (16.8‰) to the last day(27.2‰). The pH of water recorded a maximum on the third day(9.35), followed by a steady decline till the last day(8.64)(Fig.20-13). The soluble reactive phosphate concentration was at its peak on the third day(20.68 μg-at PO_4-P/l) after which a sharp decline was observed till the last day(1.67 μg-at PO_4-P/l). Nitrate content ranged from 0.13 to 0.54 μg-at NO_3-N/l and nitrite from 0.090 to 0.270 μg-at NO_2-N/l during the period of experiment(Fig.20-14). Ammonia content recorded a peak value on the third day(24.58 μg-at NH_3-N/l) followed by a gradual decline till the last day(13.05 μg-at

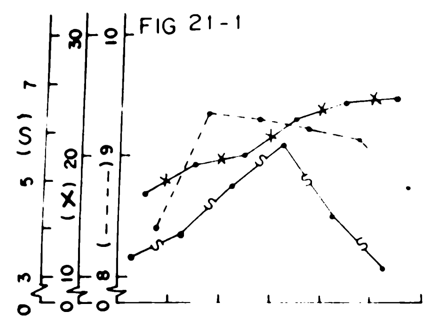
NH$_3$-N/l). Gross primary production values sharply increased from the third day(243.0 mgC/m^3/day) to ninth day(1776.3 mgC/m^3/day) followed by a sharp decrease till the last day(684.9 mgC/m^3/day). Net primary production values closely followed the trend of fluctuation of gross primary production rate and recorded maximum value on the ninth day(1007.8 mgC/m^3/day)(Fig.20-15).

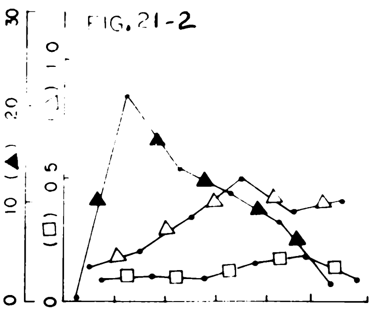
Enclosure-C3:

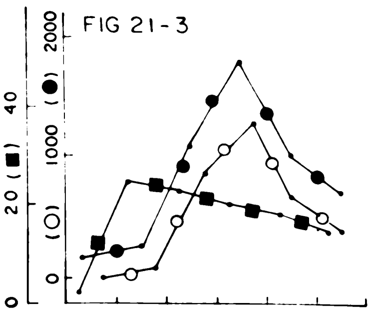
Dissolved oxygen content gradually increased from the day of experiment(3.39 ml/l) to the ninth day(5.68 ml/l), followed by a sharp decrease till the last day(3.14 ml/l). Salinity values steadily increased from the day of experiment(16.8‰) to the last day(24.6‰). The pH of water was at its peak on the third day(9.35) followed by a steady decline till the last day (8.72)(Fig.21-1). The soluble reactive phosphate was at its peak on the third day(21.00 µg-at PO$_4$-P/l) and subsequently a sharp decline was noted in its concentration till the last day (1.53 µg-at PO$_4$-P/l). Nitrate concentration fluctuated from 0.13 to 0.50 µg-at NO$_3$-N/l and nitrite from 0.085 to 0.150 µg-at NO$_2$-N/l during the period of experiment(Fig.21-2). Ammonia concentration recorded a peak value on the third day(25.18 µg-at NH$_3$-N/l), followed by a gradual decrease till the last day (15.29 µg-at NH$_3$-N/l). Gross primary production rate recorded an increase from the third day(254.7 mgC/m^3/day) to the ninth day(1804.4 mgC/m^3/day) after which a sharp decline was noticed till the last day(727.6 mgC/m^3/day). Net primary production values closely followed the trend of fluctuation of gross

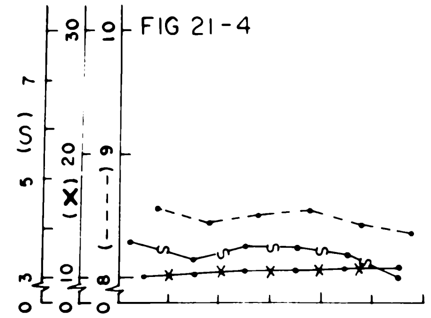
NUTRIENT ENRICHMENT EXPERIMENT-2

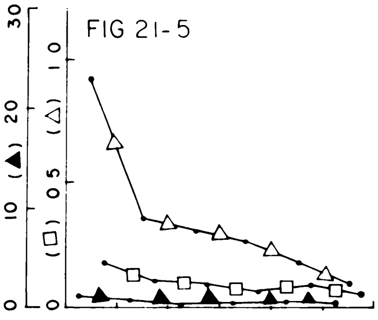
Fig. 21-1 to 21-3	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental enclosure-C3(N:P:K)
Fig. 21-4 to 21-6	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A1(Control)
Fig. 21-7 to 21-9	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A2(N:P:K + d-glucose)
Fig. 21-10 to 21-12	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A3(N:P:K)
Fig. 21-13 to 21-15	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A4(KNO_3 + Na_2HPO_4)

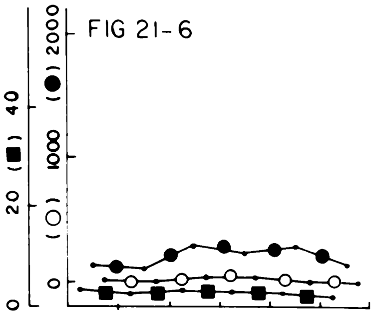


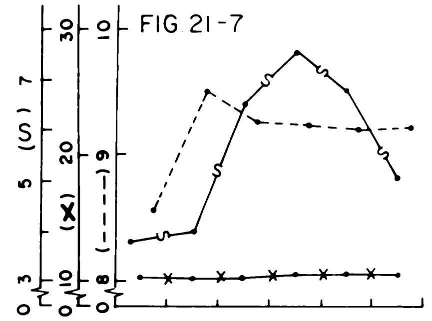


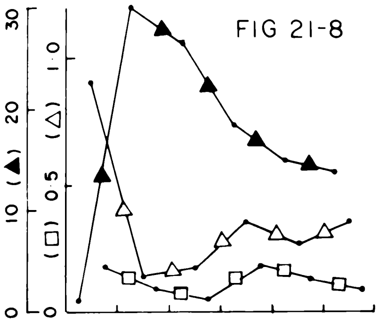


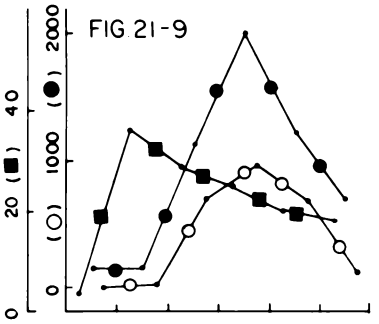


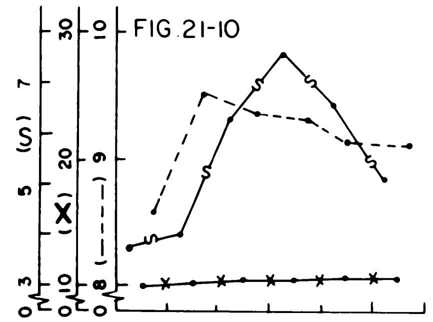


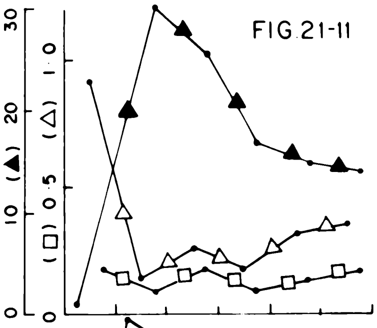


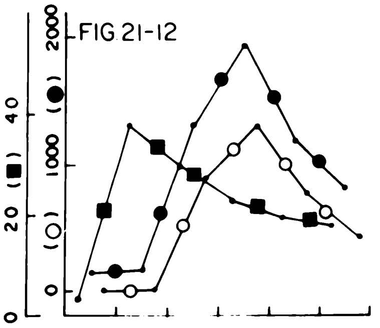


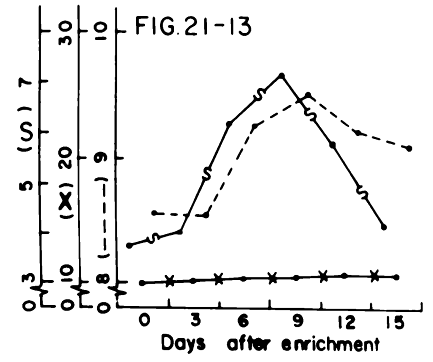


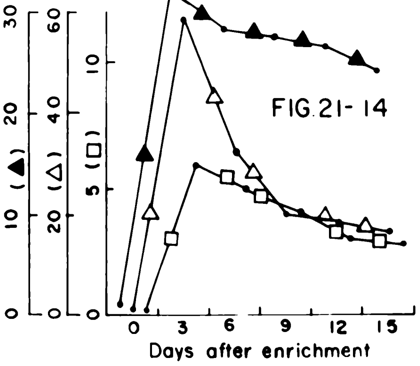


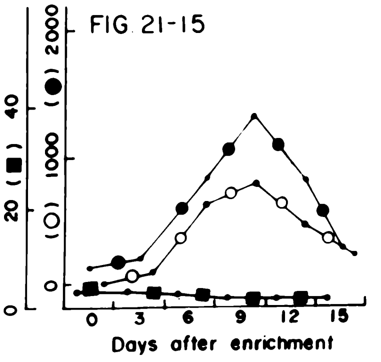












Legends to figures 21-1 to 21-15 ;
ᔕ - Oxygen in ml/l
x – Salinity in ‰
- - - - pH

▲-PO_4^- P in μg-at/l
△-N O_3^- N in μg-at/l
□-N O_2^- N in μg-at/l

■-NH_3^-N in μg-at/l
●-Gross production in mgC/m³/day
○-Net production in mgC /m³/day

production rate, with its peak recorded on the ninth day(1284.3 mgC/m^3/day)(Fig.21-3).

4.2.7 Tank-A1:

Dissolved oxygen concentration ranged between 3.00 and 3.76 ml/l during the period of experiment. Salinity values showed mild increase from the day of experiment(10.0‰) to the last day(10.6‰) The pH of water fluctuated from 8.35 to 8.55 during the period of study(Fig.21-4). Soluble reactive phosphate steadily decreased from the day of experiment(0.93 µg-at PO$_4$-P/l) to the last day(0.26 µg-at PO$_4$-P/l). Nitrate content declined from the day of experiment (0.91 µg-at NO$_3$-N/l) to the last day(0.09 µg-at NO$_3$-N/l). Nitrite concentration varied from 0.050 to 0.180 µg-at NO$_2$-N/l, and ammonia content fluctuated from 2.08 to 3.56 µg-at NH$_3$-N/l during the period of study(Fig.21-5). Gross primary production values varied between 102.9 and 295.9 mgC/m^3/day with the peak value recorded on the sixth day. Net primary production was fecorded on the sixth (30.0 mgC/m^3/day) and ninth(38.6 mgC/m^2/day) days(Fig.21-6).

4.2.8 Tank-A2:

Dissolved oxygen content recorded a sharp increase from the third day(3.98 ml/l) to the ninth day(7.53 ml/l) followed by a gradual decline till the last day(5,03 ml/l). Salinity values slightly increased from the day of experiment(10.0‰) to the last day(10.6‰). The pH of water was at its peak on the third day(9.50) followed by a steady decrease till the twelfth day (9.10)(Fig.21-7). The soluble reactive phosphate concentration was at its peak on the third day(30.38 µg-at PO_4-P/l) followed by sharp decrease till the last day(14.03 µg-at PO_4-P/l). Nitrate content decreased sharply from the day of experiment (0.91 µg-at NO_3-N/l) to the third day(0.14 µg-at NO_3-N/l) after which it ranged between 0.18 and 0.36 µg-at NO_3-N/l. Nitrite concentration ranged between 0.050 and 0.195 µg-at NO_2-N/l(Fig. 21-8). Ammonia content was at its peak on the third day(36.27 µg-at NH_3-N/l) after which a steady decline was noticed till the last day(17.86 µg-at NH_3-N/l). Gross primary production values rapidly increased from the third day(141.8 mgC/m^3/day) to the ninth day(2026.4 mgC/m^3/day) after which a steep decline was noticed till the last day(729.4 mgC/m^3/day). Net primary production recorded the peak value on the ninth day(960.7 mgC/m^3/day)(Fig.21-9).

4.2.9 Tank-A1:

Dissolved oxygen concentration increased from the third day(3.98 ml/l) to the ninth day(7.56 ml/l) followed by a sharp decline till the last day(5.10 ml/l). Salinity values recorded slight increase from the day of experiment(10.0‰) to the last day(10.6‰). The pH of the water was at its peak on the third day(9.52) followed by a gradual decline till the last day(9.12) (Fig.21-10). The soluble reactive phosphate recorded maximum value on the third day(30.08 µg-at PO_4-P/l), followed by a sharp decline till the last day(14.31 µg-at PO_4-P/l). Nitrate concentration decreased rapidly from the day of experiment(0.91 µg-at NO_3-N/l) to the third day(0.14 µg-at NO_3-N), after which it fluctuated between 0.18 to 0.36 µg-at NO_3-N/l till the last day. Nitrite content ranged between 0.090 and 0.180 µg-at NO_2-N/l during the period of experiment(Fig.21-11). Ammonia concentration recorded maximum value on the third day(37.64 µg-at NH_3-N/l), after which a steady decline was recorded till the last day(17.86 µg-at NH_3-N/l). Gross primary production rate increased sharply from the third day (166.3 mgC/m^3/day) to the ninth day(1936.7 mgC/m^3/day) followed by a sharp decrease till the last day(801.3 mgC/m^3/day). Net primary production values closely followed the pattern of fluctuation of gross primary production rate and recorded a peak on the ninth day (1306.3 mgC/m^3/day)(Fig.21-12).

4.2.10 Tank-A4:

Dissolved oxygen concentration sharply increased from the third day(4.07 ml/l) to the ninth day(7.15 ml/l) followed by a sharp decline till the last day(4.14 ml/l). A mild increase in salinity values was noticed from the day of experiment(10.0‰) to the last day(10.6‰). The pH of water sharply increased from the third day(8.65) to the ninth day(9.50) after which a steep decline in its value was recorded(9.10)(Fig.21-13). Soluble reactive phosphate content recorded maximum value on the third day(32.08 µg-at PO_4-P/l) followed by a gradual decrease till the last day(24.38 µg-at PO_4-P/l). Nitrate content recorded a peak on the third day(58.41 µg-at NO_3-N/l) followed by a sharp decrease till the last day(17.05 µg-at NO_3-N/l). The peak concentration of nitrite was observed on the third day(6.085 µg-at NO_2-N/l) after which a gradual decline in its value was noticed till the last day(2.900 μg-at NO_2-N/l)(Fig.21-14). Ammonia content gradually decreased from the third day(3.65 μg-at NH_3-N/l) to the last day(2.07 μg-at NH_3-N/l). Gross primary production values increased sharply from the third day(195.9 mgC/m^3/day) to the ninth day(1305.6 mgC/m^3/day) followed by a steep decline till the last day(273.2 mgC/m^3/day). Net primary production rate closely followed the same trend of fluctuation as that of the gross primary production values, and the peak value was recorded on the ninth day(880.3 mgC/m^3/day)(Fig.21-15).

4.3 Experiment-3:

Table-12: Details of experiment-3 conducted during April, 1984 (Duration-15 days).

Tank	Fertiliser used	Concentrations added in μg-at/l		
		N	P	K
In situ:				
Encl-C1	Control	-	-	-
Encl-C2	Organic mixture	80.00	18.06	-
In vitro:				
Tank-A1	Control	-	-	-
Tank-A2	Organic mixture	80.00	18.06	-
Tank-A3	Potash	-	-	14.87
Tank-A4	Superphosphate	-	25.8	-
Tank-A5	Urea	82.14	-	-

4.3.1 Enclosure-C1:

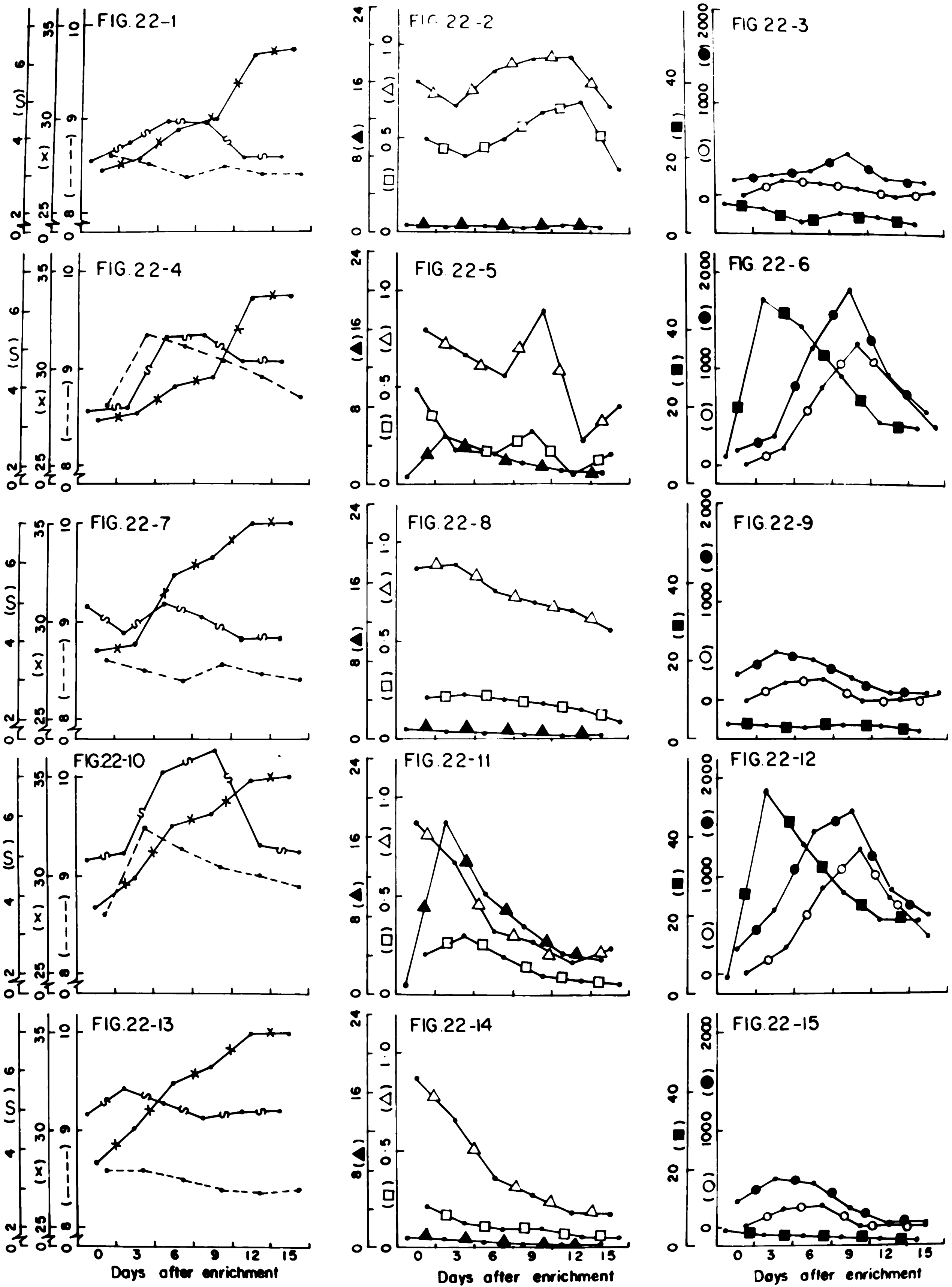
Dissolved oxygen content gradually increased from the day of experiment(3.42 ml/l) to the ninth day(4.41 ml/l), followed by a sharp decline on the twelfth day(3.47 ml/l). Salinity values gradually increased from the day of experiment(27.3‰) to the last day(33.8‰). The pH of water varied between 8.38 and 8.62(Fig. 22-1). The soluble reactive phosphate ranged from 0.33 to 0.81 µg-at PO_4-P/l during the period of experiment. Nitrate concentration fluctuated from 0.67 to 0.94 µg-at NO_3-N/l and nitrite from 0.335 to 0.685 µg-at NO_2-N/l during the period of study(Fig.22-2). Ammonia content ranged between 3.04 and 7.68 µg-at NH_3-N/l during the period of experiment. Gross primary production values gradually increased from the day of experiment (162.9 mgC/m^3/day) to the ninth day(467.4 mgC/m^3/day), after which it declined sharply till the last day(162.9 mgC/m^3/day). Net primary production rate was at its peak on the third day (150.1 mgC/m^3/day)(Fig.22-3).

4.3.2 Enclosure-C2:

Dissolved oxygen content increased sharply from the third day(3.50 ml/l) to the ninth day(5.35 ml/l) followed by a steady decline till the last day(4.70 ml/l). Salinity values gradually increased from the day of experiment(27.3‰) to the last day (33.8‰). The pH of water recorded high value on the third day (9.35) followed by a gradual decline till the last day(8.70) (Fig.22-4). Soluble reactive phosphate was at its peak on the third day(4.97 µg-at PO_4-P/l) after which a gradual decline was noticed till the last day(1.25 µg-at PO_4-P/l). Nitrate content varied from 0.23 to 0.90 µg-at NO_3-N/l and nitrite from 0.500 to 0.490 µg-at NO_2-N/l during the period of experiment(Fig.22-5). Ammonia concentration registered its peak on the third day(47.94 µg-at NH_3-N/l) after which a sharp decline was noticed till the

NUTRIENT ENRICHMENT EXPERIMENT-1

Fig. 22-1 to 22-3	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental enclosure-C1(Control)
Fig. 22-4 to 22-6	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Enclosure-C2(Organic mixture)
Fig. 22-7 to 22-9	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A1(Control)
Fig. 22-10 to 22-12	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A2(Organic mixture)
Fig. 22-13 to 22-15	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A3(Potash)



Legends to figures 22-1 to22-15;

ᔕ - Oxygen in ml/l

x - Salinity in ‰

---- pH

▲-PO_4-P in µg-at/l

△-NO_3^- N in µg-at/l

□-NO_2^- N in µg-at/l

■-NH_3-N in µg-at/l

●-Gross production in mgC/m^3/day

○-Net production in mgC/m^3/day

last day(15.09 μg-at NH_3-N/l). Gross primary production values showed sharp increase from the third day(304.5 mgC/m^3/day) to the ninth day(1825.0 mgC/m^3/day) followed by a steep decline till the last day(550.4 mgC/m^3/day). Net primary production recorded a peak value on the ninth day(1247.9 mgC/m^3/dayl(Fig. 22-6).

4.3.3 Tank A-1:

Dissolved oxygen content ranged from 4.05 to 4.97 ml/l during the period of experiment. Salinity gradually increased from the day of experiment(28.4‰) to the last day(35.0‰). The pH of water fluctuated from 8.40 to 8.60(Fig.22-7). Soluble reactive phosphate gradually decreased from the day of experiment (0.93 μg-at PO_4-P/l) to the twelfth day(0.18 μg-at PO_4-P/l). Nitrate and nitrite concentrations decreased gradually from the third day(0.89 μg-at NO_3-N/l and 0.225 μg-at NO_2-N/l) to the last day(0.55 μg-at NO_3-N/l and 0.090 μg-at NO_2-N/l)(Fig.22-8). Ammonia concentration varied from 2.04 to 4.09 μg-at NH_3-N/l during the period of experiment. Gross primary production rate was at its peak on the third day(476.0 mgC/m^3/day) after which a steady decline was observed till twelfth day(60.9 mgC/m^3/day), followed by a mild rise on the last day(79.1 mgC/m^3/day). Net primary production was observed on the third day(17.15 mgC/m^3/day), sixth day(210.1 mgC/m^3/day) and the last day(55.7 mgC/m^3/day)(Fig.22-9).

4.3.4. Tank-A2:

Dissolved oxygen content increased sharply from the third day(5.09 ml/l) to the ninth day(7.69 ml/l) followed by a sharp decrease till the last day(5.12 ml/l). Salinity values gradually increased from the day of the experiment(28.4%o) to the last day (35.0%o). The pH of water showed maximum value on the third day (9.48), followed by a gradual decrease till the last day(8.90) (Fig.22-10). Soluble reactive phosphate was at its peak on the third day(17.24 µg-at PO_4-P/l) followed by a sharp decline till the last day(3.51 µg-at PO_4-P/l). Nitrate content gradually decreased from the day of experiment(0.87 µg-at NO_3-N/l) to the twelfth day(0.16 µg-at NO_3-N/l). Nitrite concentration was at its peak on the third day(0.295 µg-at NO_2-N/l) followed by a steady decline till the last day(0.050 µg-at NO_2-N/l)(Fig.22-11). Ammonia concentration recorded maximum value on the third day (51.43 µg-at NH_3-N/l), after which a sharp decline in its values was observed till the last day(18.70 µg-at NH_3-N/l). Gross primary production rate sharply increased from the third day(653.2 mgC/m^3/day) to the ninth day(1663.7 mgC/m^3/day) followed by a rapid decline till the last day(591.0 mgC/m^3/day). Net primary production values closely followed the pattern of fluctuation of gross primary production rate and recorded a peak value on the ninth day(1262.9 mgC/m^3/day)(Fig.22-12).

4.3.5 Tank-A1:

Dissolved oxygen content fluctuated between 4.81 and 5.54 ml/l during the period of experiment. Salinity values gradually increased from the day of experiment(28.4%o) to the last day (35.0%o). The pH of water gradually decreased from the day of experiment(8.60) to the twelfth day(8.35) followed by a slight rise in its value on the last day(8.40)(Fig.22-13). Soluble reactive phosphate gradually declined from the day of experiment (0.93 µg-at PO_4-P/l) to the last day(0.10 µg-at PO_4-P/l). Nitrate and nitrite concentration decreased gradually from the day of experiment(0.87 µg-at NO_3-N/l and 0.21 µg-at NO_2-N/l) to the last day(0.17 µg-at NO_3-N/l and 0.050 µg-at NO_2-N/l)(Fig.22-14). Ammonia content gradually decreased from the day of experiment (4.02 µg-at NH_3-N/l) to the last day(1.09 µg-at NH_3-N/l). Gross primary production rate was at its peak on the third day(501.7 mgC/m^3/day) after which a sharp decline was noticed till the twelfth day(4.3 mgC/m^3/day). Net primary production was observed on the third day(182.1 mgC/m^3/day), sixth day(225.8 mgC/m^3/day) and the last day(12.9 mgC/m^3/day)(Fig.22-15).

4.3.6 Tank-A4:

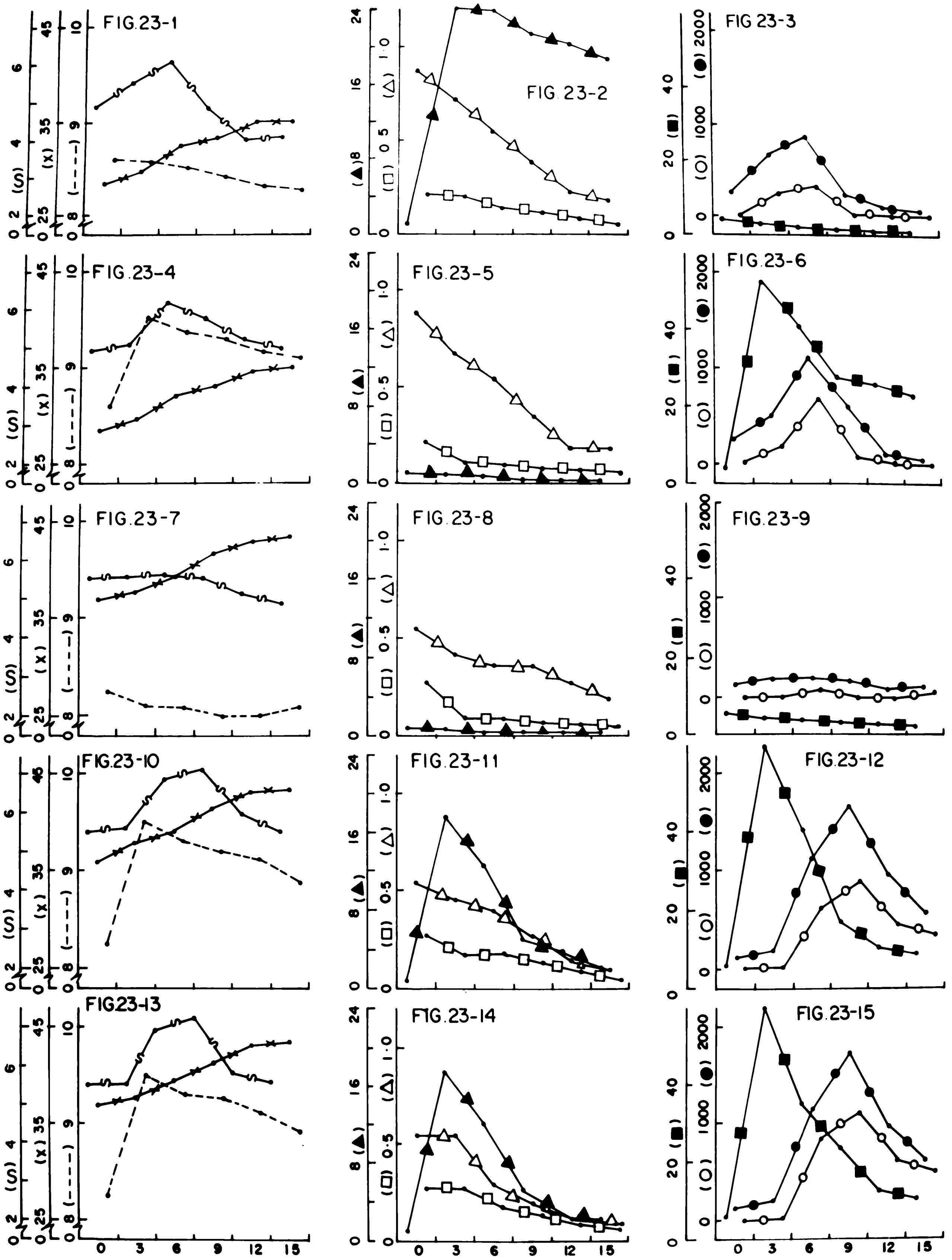
Dissolved oxygen concentration ranged from 3.98 to 6.03 ml/l during the period of experiment with its peak value recorded on the sixth day(6.03 ml/l). Salinity values gradually increased from the day of experiment(28.4‰) to the last day(35.0‰). The pH of water gradually decreased from the day of experiment(8.60) to the twelfth day(8.30) followed by a mild increase on the last day(8.35)(Fig.23-1). Soluble reactive phosphate recorded maximum value on the third day(24.09 µg-at PO_4-P/l) after which a gradual decline was recorded till the last day(18.82 µg-at PO_4-P/l). Nitrate, nitrite and Ammonia concentrations gradually decreased from the day of experiment(0.87 µg-at NO_3-N/l, 0.210

NUTRIENT ENRICHMENT EXPERIMENT-3

Fig. 23-1 to 23-3	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A4(Superphosphate)
Fig. 23-4 to 23-6	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experiment Tank-A5(Urea)

NUTRIENT ENRICHMENT EXPERIMENT-4

Fig.23-7 to 23-9	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A1(Control)
Fig. 23-10 to 23-12	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A2(Organic mixture + Potash + d-glucose)
Fig. 23-13 to 23-15	Results of observations on the variation in the dissolved oxygen, salinity, pH, soluble reactive phosphate, nitrate, nitrite, ammonia and gross and net primary production rates in the experimental Tank-A3(Organic mixture + Potash)



Legends to figures 23-1 to 23-15,

∽- Oxygen in ml/l
x - Salinity in ‰
---- pH

▲-PO_4^- P in µg-at/l
△-NO_3^- N in µg-at/l
□-NO_2^- N in µg-at/l

■-NH_3 N in µg-at/l
●-Gross production in mgC/m^3/day
○- Net production in mgC/m^3/day

µg-at NO_2-N/l and 4.02 µg-at NH_3-N/l) to the last day(0.18 µg-at NO_3-N/l) 0.050 µg-at NO_2-N/l and 1.08 µg-at NH_3-N/l)(Fig.23-2). Gross primary production rate showed a moderate increase from the third day(665.2 mgC/m^3/day) to the sixth day(864.0 mgC/m^3/day) which was followed by a sharp decrease till the last day(55.8 mgC/m^3/day). Net primary production values fluctuated between 12.5 and 310.8 mgC/m^3/day with its peak value recorded on the sixth day(310.8 mgC/m^3/day)(Fig.23-3).

4.3.7 Tank-A5:

Dissolved oxygen content gradually increased from the day of experiment(4.89 ml/l) to the sixth day(6.16 ml/l) after which a gradual decline was recorded till the last day(4.99 ml/l). Salinity values showed gradual increase from the day of experiment(28.4‰) to the last day(34.9‰). The pH of water recorded peak value on the third day(9.50) followed by a steady decline till the last day(9.10)(Fig.23-4). Soluble reactive phosphate, nitrate and nitrite concentrations gradually decreased from the day of experiment(0.93 µg-at PO_4-P/l, 0.87 µg-at NO_3-N/l and 0.210 µg-at NO_2-N/l) to the last day(0.10 µg-at PO_4-P/l, 0.18 µg-at NO_3-N/l and 0.050 µg-at NO_2-N/l)(Fig.23-5). Ammonia content recorded maximum value on the third day(52.43 µg-at NH_3-N/l) followed by a sharp decline till the last day(23.66 µg-at NH_3-N/l). Gross primary production valued showed an increase from the third day(491.9 mgC/m^3/day) to the sixth day(1125.0 mgC/m^3/day) followed by a sharp decline till the last day(42.9 mgC/m^3/day). Net primary production closely followed the trend of fluctuation of gross primary production rate and ranged from 6.6

to 681.0 mgC/m³/day, and the maximum value was recorded on the sixth day (Fig.23-6).

4.4 Experiment-4:

Table-13: Details of Experiment-4 conducted during May,1984
(Duration-15 days)

Tank	Fertilizer used	Concentrations added in µg-at/l			
		N	P	K	d-glucose (in mg/l)
In vitro					
Tank-A1	Control	-	-	-	- -
Tank-A2	Organic mixture + Potash + d-glucose	80.00	18.06	14.87	5.0
Tank-A3	Organic mixture X Potash	80.00	18.06	14.87	-

4.1 Tank-A1:

Dissolved oxygen content ranged from 4.87 to 5.61 ml/l during the period of experiment. Salinity values showed gradual increase from the day of experiment(36.9‰) to the last day (43.3‰). The pH of water ranged between 8.00 and 8.25 during the period of experiment(Fig.23-7). Soluble reactive phosphate, nitrate, nitrite and ammonia concentrations gradually decreased from the day of experiment(0.86 µg-at PO_4-P/l, 0.54 µg-at NO_3-N/l, 0.270 µg-at NO_2-N/l and 6.13 µg-at NH_3-N/l) to the last day (0.10 µg-at PO_4-P/l, 0.19 µg-at NO_3-N/l, 0.050 µg-at NO_2-N/l and 2.52 µg-at NH_3-N/l)(Fig.23-8). Gross primary production rate fluctuated between 85.8 and 193.0 mgC/m³/day during the period of experiment, and its peak value was recorded on the ninth day. Net primary production was observed on the day of experiment(8.6 mgC/m^3/day), the sixth day(80.5 mgC/m^3/day) and the last day(60.0 mgC/m^3/day) of experiment(Fig.23-9).

4.4.2 Tank-A2:

Dissolved oxygen content recorded an incfease from the third day(5.61 ml/l) to the ninth day(7.11 ml/l) after which a sharp decline was noticed till the last day(5.48 ml/l). Salinity values gradually increased from the day of experiment(35.9‰) to the last day(43.4‰). The pH of water recorded maximum value on the third day(9.50) after which a sharp decline was noticed till the last day(8.87)(Fig.23-10). Peak concentration of soluble reactive phosphate was recorded on the third day (17.68 µg-at PO_4-P/l) followed by a sharp decrease till the last day(2.24 µg-at PO_4-P/l). Nitrate and nitrite contents gradually decreased from the day of experiment(0.54 µg-at NO_3-N/l and 0.270 µg-at NO_1-N/l) to the last day(0.10 µg-at NO_3-N/l and 0.050 µg-at NO_2-N/l)(Fig.23-11). Ammonia concentration decreased from its peak value on the third day(61.82 µg-at NH_3-N/l) to 8.76 µg-at NH_3-N/l on the last day. Gross primary production values increased sharply from the third day(205.1 mgC/m^3/day) to the ninth day(1680.0 mgC/m^3/day), after which a sharp decrease was noticed till the last day(581.6 mgC/m^3/day). Net primary production rate closely followed the trend of fluctuation of gross primary production values and maximum value was recorded on the ninth day(893.3 mgC/m^3/day)(Fig.23-12).

4.4.3 Tank-A1:

Dissolved oxygen concentration recorded an increase from the third day(5.52 ml/l) to the ninth day(7.20 ml/l), followed by a sharp decrease till the last day(5.54 ml/l). Salinity values showed a steep increase from the day of experiment (36.9‰) to the last day(43.4‰). The pH was at its peak on the third day(9.47) followed by a steady decrease till the last day(8.92)(Fig.23-13). Soluble reactive phosphate concentration was maximum on the third day(17.50 µg-at PO_4-P/l), after which a sharp decline was noticed till the last day(2.10 µg-at PO_4-P/l). Nitrate and nitrite contents gradually decreased from the third day(0.54 µg-at NO_3-N/l and 0.270 µg-at NO_2-N/l) to the last day (0.09 µg-at NO_3-N/l and 0.065 µg-at NO_2-N/l)(Fig.23-14). Ammonia concentration recorded a peak value on the third day (60.13 µg-at NH_3-N/l) followed by a sharp decline till the last day(10.47 µg-at NH_3-N/l). A sharp increase was observed in the gross primary production values from the third day(201.3 mgC/m^3/day) to the ninth day(1735.6mgC/m^3/day) followed by a sharp decline till the last day(610.1 mgC/m^3/day). Net primary production values closely followed the pattern of fluctuation of gross primary production values and a peak was recorded on the ninth day(1108.1 mgC/m^3/day)(Fig.23-15).

4.5 Phytoplankters:

In all the control tanks, *Oscillatoria salinarum* and *Nitzschia closterium* were observed in addition to high content of organic debris.

The N:P:K enriched water was greenish in colour when bloom appeared. Dominant species in the bloom was *Oscillatoria salinarum* followed by other species of blue green algae. Nannoplankters were represented by *Chlorella* sp., *Corteria* sp., and *Chlorococcum* sp. *Chlorococcales* such as *Scenedesmus* sp., and desmids such as *Euastrum* sp., *Desmidium* sp. and *Cosmarium* sp. were also present other than *Oscillatoria* sp. Chemically fertilised water showed brownish colour when bloom appeared. Pinnate diatoms such as *Nitzschia closterium*, *Cymbella marina*, *Synedra* sp., *Navicula* sp., *Amphora* sp. and *Amphiprora* sp. were abundant in addition to *Oscillatoria salinarum*.

In the experiments where organic mixture was used as fertiliser, the blooming of *Nitzschia closterum* was observed. In the experiments where urea was used as fertiliser blooming of nannoplankters represented by *Chlorella* sp. and other members of Chlorococcales(Chlorophyceae) were investigated. In the enrichment experiments with super phosphate, the bloom of *Nitzschia closterium*, *Navicula* sp. and *Amphora* sp. were observed. In the tanks where potash was used for enrichment, few diatoms such as *Cymbella* sp. and *Navicula* sp. were recorded.

4.6 *Statistical analysis*(Table-14):

The statistical analysis showed that there was no difference in the rate of gross primary production between experiment-1 and experiment-2 in the *in situ* method and *in vitro* method. Chemically fertilised tanks showed significantly

Table - 14; Result of the least significant difference test of the "Control corrected" Gross and net primary productions of the enrichment experiments at 5% level.

Gross primary production

	Encl. & Tanks	Experiment - I							Experiment - II							Experiment - III					Expt - IV		Encl & Tanks	
		B2	B3	C2	C3	A2	A3	A4	B2	B3	C2	C3	A2	A3	A4	C2	A2	A3	A4	A5	A2	A3		
Expt-1	B2		N.S	N.S	N.S	N.S	N.S	S	N.S	N.S	N.S	N.S	N.S	N.S	S	N.S	N.S	S	S	S	N.S	N.S	B2	Expt-1
	B3	S		N.S	N.S	N.S	N.S	S	N.S	N.S	N.S	N.S	N.S	N.S	S	N.S	N.S	S	S	S	N.S	N.S	B3	
	C2	N.S	S		N.S	N.S	N.S	S	N.S	N.S	N.S	N.S	N.S	N.S	S	N.S	N.S	S	S	S	N.S	N.S	C2	
	C3	S	N.S	S		N.S	N.S	S	N.S	N.S	N.S	N.S	N.S	N.S	S	N.S	N.S	S	S	S	N.S	N.S	C3	
	A2	N.S	S	N.S	S		N.S	S	N.S	N.S	N.S	N.S	N.S	N.S	S	N.S	N.S	S	S	S	N.S	N.S	A2	
	A3	S	N.S	S	N.S	S		S	N.S	N.S	N.S	N.S	N.S	N.S	S	N.S	N.S	S	S	S	N.S	N.S	A3	
	A4	N.S	S	N.S	S	N.S	S		S	S	S	S	S	S	N.S	S	S	S	S	S	S	S	A4	
Expt-2	B2	N.S	S	N.S	S	N.S	S	N.S		N.S	N.S	N.S	N.S	N.S	S	N.S	N.S	S	S	S	N.S	N.S	B2	Expt-2
	B3	S	N.S	S	N.S	S	N.S	S	S		N.S	N.S	N.S	N.S	S	N.S	N.S	S	S	S	N.S	N.S	B3	
	C2	N.S	S	N.S	S	N.S	S	N.S	N.S	S		N.S	N.S	N.S	S	N.S	N.S	S	S	S	N.S	N.S	C2	
	C3	S	N.S	S	N.S	S	N.S	S	S	N.S	S		N.S	N.S	S	N.S	N.S	S	S	S	N.S	N.S	C3	
	A2	N.S	S	N.S	S	N.S	S	N.S	N.S	S	N.S	S		N.S	S	N.S	N.S	S	S	S	N.S	N.S	A2	
	A3	S	N.S	S	N.S	S	N.S	S	S	N.S	S	N.S	S		S	N.S	N.S	S	S	S	N.S	N.S	A3	
	A4	N.S	S	N.S	S	N.S	S	N.S	N.S	S	N.S	S	N.S	S		S	S	S	S	S	S	S	A4	
Expt-3	C2	S	N.S	S	N.S	S	N.S	S	S	N.S	S	N.S	S	N.S	S		N.S	S	S	S	N.S	N.S	C2	Expt-3
	A2	S	N.S	S	N.S	S	N.S	S	S	N.S	S	N.S	S	N.S	S	N.S		S	S	S	N.S	N.S	A2	
	A3	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		S	S	N.	S	A3	
	A4	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		S	S	S	A4	
	A5	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		S	S	A5	
Expt-4	A2	N.S	S	N.S	S	N.S	S	N.S		N.S	S	N.S	N.S	S	N.S	S	S	S	S	S		N.S	A2	Expt-4
	A3	S	N.S	S	N.S	S	N.S	S	S	NS	S	N.S	S	N.S	S	N.S	N.S	S	S	S	S		A3	
	Encl & tanks	B2	B3	C2	C3	A2	A3	A4	B2	B3	C2	C3	A2	A3	A4	C2	A2	A3	A4	A5	A2	A3	Encl & tanks	
		Experiment - I							Experiment - II							Experiment - III					Expt-IV			

Net primary production

Where,

Encls = Enclosure

Expt = Experiment

S = Significant different at 5% level

NS = Not significantly different at 5% level low rate of gross primary production in both the experiments. There was no significant difference between the N:P:K-Complex and organic mixture in their influence on the gross primary production rate. Individual enrichment with potash, superphosphate and urea showed significantly low rate of gross production when compared with those enriched by N:P:K-Complex and organic mixture. Enrichment with potash, when compared with that of superphosphate and urea, showed significantly low gross production rate. Urea enrichment resulted in significantly high rate of gross production than the superphosphate enrichments.

Statistically there was no significant difference in the net primary production rate between Experiment-1 and Experiment-2 both in the *in situ* and *in vitro* methods. Chemically fertilized tanks showed significantly low rate of net primary productions in the experiments. d-glucose has significantly decreased the net primary production rate in all the experiments when compared with the non-glucose treated enclosures. Significantly low net primary production rate was observed in the individual enrichment experiments with potash, superphosphate and urea as compared with those by N:P:K-Complex and organic mixture. Urea enrichment showed significantly high rate of net primary production when compared to the enrichment by superphosphate and potash.

Chapter-5

DISCUSSION

DISCUSSION

Brandt(1899) opined that concentration of phosphorus and nitrogen in the water controls the fixation of energy by the primary producers. Subsequently, several workers have observed that the nutrient enrichment results in the increase of production at the primary trophic level. The nutrient enrichment studies were mainly aimed at understanding the important changes in the major environmental parameters. However, some of the enrichment experiments conducted earlier indicate that there was little or no change in the nutrient concentrations of the enrivonment due to enrichment(Einsele,1941; Holden,1961; Hepher, 1966; Smith,1969). In the present study a direct relationship was observed between the level of nutrient input and the resultant nutrient concentration. This result is in close agreement with the observations of O'Brein and deNoyelles(1974) employing phosphorus and inorganic nitrogen treatments. Relatively low rate of increase in the soluble reactive phosphate and the ammonia concentrations in the in situ enclosures during Experiment-1, following addition of nutrients twice, may be due to the high rate of uptake of these elements by phytoplankters, adsorption to the particulate organic matter, absorption by the sediment and due to the seepage through the sediment. Pratt(1948), Mandel(1964) and Schindler et al.(1971) also observed the same trend in their experiments. The results obtained in the experiments conducted in the in vitro tanks indicate the possible effect of the sediment on the nutrients. After the addition of nutrients for the third time, large amount of the same remained in solution which may be due to the saturation of the sediment as discussed by Pratt(1948). Comparatively lesser rate of increase in the nutrient concentrations at the Enclosures-C2 and C3 when compared to that at the Enclosures -B2 and B3 show the influence of the sediment on the enrichment experiments. However, the rate of primary production was not significantly different at the two sites indicating the supply of nutrients above the optimum level. It is noteworthy that the sediment type at Enclosure-B is more sandy, whereas that at Enclosure-C is highly silty and clayey. Based on the correlation observed between the grain-size and nutrient content of the sediment, it may be stated that the rate of adsorption of nutrients by the sediment at Enclosure-C was relatively high. In the control enclosures, the concentration of soluble reactive phosphate, nitrate, nitrite and ammonia usually decreased from the beginning of the experiment and the primary production rate also varied accordingly. Whenever low rate of primary production was recorded in the in situ and in vitro control tanks, a simultaneously low level of any one or all of the nutrients was also observed. This effect was more pronounced in the in vitro control tanks.

Utilization of nitrate requires an energy expenditure for both induction of the enzyme system and reducing potential

(Eppley *et al.*,1969). In eucaryotic algae, either an ATP-Urea amidolyase enzyme system or an urease system is considered essential for the assimilation of urea-N(Leftley and Syrett, 1973). In the *in vitro* experiment where chemical fertilisers were used, the ammonia concentration constantly decreased from the first day of experiment eventhough the nitrate concentration remained relatively high. This is in close agreement with the findings of earlier workers who observed the preferential utilisation of ammonia among the nitrogen compounds by the phytoplankters in the laboratory unialgal cultures, enriched coastal waters and in natural environment and the suppression of nitrate assimilation by ammonia even at a concentration of 0.5-1.0 µg-at N/l(Syrett,1962; Guillard,1963; Morris and Syrett,1963*a*; Grant *et al.*,1967, Eppley *et al.*,1969; MacIssac and Dugdale,1969; Strickland *et al.* 1969; Goering *et al.*, 1970; Eppley and Rogers,1970; MacCarthy 1972*a*; McCarthy and Eppley,1972; MacIssac and Dugdale,1972; Harvey and Caperon, 1976; Conway,1977; MacCarthy *et al.*,1977; Serra *et al.*,1978; Eppley *et al.*,1979 and MacIssac *et al.*,1979).

McCarthy *et al.*(1977) observed that urea was utilised after ammonia in the order of preference and when the sum of available ammonia and urea was insufficient to meet the nitrogen demand by phytoplankters then nitrate was utilised. Though urea-N was present in the N:P:K fertiliser used, only the concentration of ammonia was estimated in the present study. The high content of ammonia observed after the addition of fertilisers than the concentration of ammonia-N added suggests that the urea-N have been converted into ammonia-N. However, only limited studies were made earlier which would indicate that increased urea concentration could inhibit ammonia uptake (Healey 1977; Kaufman _et al._, 1983). Wada and Hattori (1972) observed that addition of nitrate accelerates nitrite production whereas addition of ammonia suppresses it. The record of low nitrite levels in the present study where ammonia concentration was high is in close agreement with their findings.

Berner _et al._ (1970) observed a strong correlation between pH and ammonia in the anoxic pore waters of marine sediment. In the enrichment experiments conducted during the present study, the variation of pH values of the enriched water appear to follow primarily the ammonia concentration in the water and secondarily to the rate of primary production as observed earlier by Schindler _et al._ (1971), Schelske _et al._ (1974) and Emerson (1975). The latter condition was more pronounced in the experiments where chemical fertilisers were used. Goldman _et al._ (1972) have pointed out that uptake of nitrate during photosynthesis generate strong base, whereas assimilation of ammonia leads to production of acid.

The results obtained in the Experiment-2 where the fertilisers were added in one treatment were similar to those recorded by Hayes _et al._ (1952), Phillips (1964) and Dickman and Efford (1972). They observed in similar experiments that the concentration of dissolved phosphorus and nitrate decreased rapidly following fertilization, and by the end of a fortnight the added nutrients were comparatively in low concentration. The high concentration of phosphate resulting from single application of superphosphate usually lasted for less than a week in the experiments conducted by Orr(1947) and Pratt(1948). The significant difference between the Experiment-1 and Experiment-2 suggest that there is no effect in the "split-treatment". However, when compared with the other investigations addition of nutrients at the concentration used in Experiment-2 in one treatment appears to be slightly high. Further, the concentration of nutrients evinced a decreasing trend during the course of the experiment and the presence of nutrients was felt only upto a fortnight. It seems, therefore, that the addition of fertilisers once in a fortnight at concentration rate used in one lot in the Experiment-I would enhance the productivity of the lagoon.

In the experiments conducted, chemically enriched water showed significantly low levels of gross production. The possibility of contaminants in the commercial fertilisers acting as a source of minor nutrients cannot be ruled out. Tampi(1969) stated that the water in the Pillaimadam lagoon lacks in minor nutrients. The stimulatory effect by the minor nutrients on primary productivity has been discussed earlier (Goldman,1960, 1964 and 1965; Kalff, 1971; O'Brein _et al._,1975). An initial "lag phase" was investigated in the proliferation of phytoplankters after the enrichment in all the experiments, but that effect was less pronounced in the latter two experiments. This "lag phase" phenomenon of population growth among unicellular organisms is well documented (Phelps,1935; Riley,1943; Swingle,1947; Bustow and Schwit,1968; Healey,1973; Ihlenfaldt and Gibson,1975; Lean and Nalewajko,1976). Riley (1943) attributed the "lag" as a period of rapid growth and rapid death. Swingle(1947) opined that the "lag" in some cases is due to the competition between the autotrophic organisms and the bacterial flora associated with the organic deposits at the bottom, for inorganic nutrients. But, this explanation could not be applied to the "lag phase" observed in the present experiment since an abundant supply of nutrients remained throughout the "lag phase". It is well known that nutrient-deficient algae are low in RNA and protein but rich in carbohydrate or lipid, and hence there is less need for increased carbon fixation. Healey(1979), using the enrichment of 10 μg-at P/l of phosphorus and 50 μg-at N/l of nitrogen, showed that the metabolism is first directed towards nutrient uptake and assimilation and subsequently to the conversion of accumulated carbon to constituents needed to support increased growth.

In the experiments conducted during the present study individual addition of potash, superphosphate and urea has not triggered the rate of primary production significantly. Several authors have observed that the combined addition of NO_3 or NH_3+ PO_4 to the medium resulted in maximum increase of primary productivity(Dickman and Efford,1972; Parson *et al.*,1972;

Powers *et al.*,1972; Gerhart and Likens,1975; Persson,1975; Fee,1979, Walker and O'Donnell,1981). In the present experiments, treatment with urea resulted in high rate of primary production when compared to that with superphosphate. This indicate the acute shortage of nitrogen among the nutrients in the ecosystem. The role of nitrogen as a limiting factor in the growth of marine phytoplankton is well documented (Thomas,1966 and 1970b; Ryther and Dunsten,1971; Vince and Valiela,1973). It is also well known that urea can be one of the major sources of nitrogen for marine phytoplankters(Newell *et al.*,1967; McCarthy,1970; Eppley *et al.*,1971; McCarthy,1972b; McCarthy and Eppley 1972; Carpenter *et al.*,1972; Eppley *et al.*, 1973; Harvey and Caperon,1976; Kaufman *et al.*,1983) Vince and Valiela(1973) and Mitchell and Burns(1981) observed that the enrichment by ammonium increased primary production rate but the addition of phosphate did not enhance the same. In the experiments conducted by them the addition of both ammonium and phosphate resulted in high rate of production indicating that phosphate was of secondary importance in stimulating the rate of production when nitrogen was present in adequate quantity. Results of the present study is in agreement with their findings.

It was observed that the addition of d-glucose decreased the rate of net primary production significantly. It was recorded earlier that in the presence of an organic carbon source, inorganic nitrogen is used as a nitrogen source for the synthesis of amino acids and is incorporated into the heterotrophic biomass. (Nicholas,1963; Painter,1970). Numerous algal and bacterial species can utilise glucose heterotrophically. However, appreciable quantities of glucose probably do not accumulate in the system because glucose is readily utilised by both marine bacteria and algae(Saunders,1957; Lewin and Lewin,1960). Seki *et al.*(1968) found that addition of little amount of glucose resulted in a sharp increase in the bacterial biomass but relatively large amount inhibited their growth. Parsons *et al.*(1981) observed that the addition of glucose resulted in a shift from mainly photosynthetic process to heterotrophic process. In the case where addition of glucose was limited, there was 47% depression in photosynthesis and they assumed that the respired carbon gave rise, in part, to new heterotrophic particulate organic carbon. However, this effect was believed to have been caused by heterotrophic growth out-competing the autotrophic organisms for a limited supply of nitrate. Vaccaro *et al.*(1968) found that the densities of phytoplankton exhibited a positive correlation with the glucose concentration in natural environments. They suggested that the decreasing glucose concentration might reflect a smaller excess of photosynthetic production over growth, and resulting decrease in the amount of organic material excreted. Sibert and Brown(1975) opined that if a significant fraction of particulate matter is available to a detritus-based food chain in an estuary, then heterotrophic production may not have any effect on primary production. In conclusion, it may be stated than since the availability of phosphate and inorganic nitrogen was adequate in the experimental systems, the rate of gross production was not affected by the heterotrophic production inspite of the addition of d-glucose, which is known to trigger the production of the latter.

SECTION-III

A CRITICAL ASSESSMENT ON THE SUITABILITY OF THE LAGOON FOR MARICULTURE PRACTICES

A CRITICAL ASSESSMENT ON THE SUITABILITY OF THE LAGOON FOR MARICULTURE PRACTICES

The nutrient enrichment experiments conducted in the Pillaimadam Lagoon indicate that the lagoon is deficient in nitrogen and phosphorus respectively. Loading of nutrients into the lagoon by the freshwater inflow is not significant as agricultural activity in the Mandapam Peninsula is relatively limited. The nutrient concentration of the water recorded during the present study reveals that this lagoon falls under the category of "ultra-oligotrophic type"(O'Brien and deNoyeller,1974). Moreover, when the fresh water and sea water inflow cease the lagoon becomes more of anoxic in nature. But it was observed that the concentration of hydrogen sulphide in the water was not detrimental to the organisms inhabiting this area. When the sediment is agitated, the concentration of hydrogen sulphide in the water becomes high, but it does not attain detrimental level. The fouling by organisms such as barnacles on the poles which support the culture pens in the area may pose a problem to the successful culture activitias (Mohan,1983g). However, this could be overcome by covering the poles with thin black polythene sheets which prevented the settling of spat due to the smooth surface.

In the course of investigations carried out it was observed that the major deterrents in conducting mariculture practice in the lagoon can be categorised under two major heads:

1. Low rate of primary production due mainly to the "ultra - oligotrophic nature of the lagoon water;
2. Periodical recurrence of low water level in the lagoon when it gets isolated from the sea. This results in poor plankton production, hypersaline condition, and vulnerability of the cultured organisms to predation.

In order to overcome these maladies, some remedial measures are suggested here;

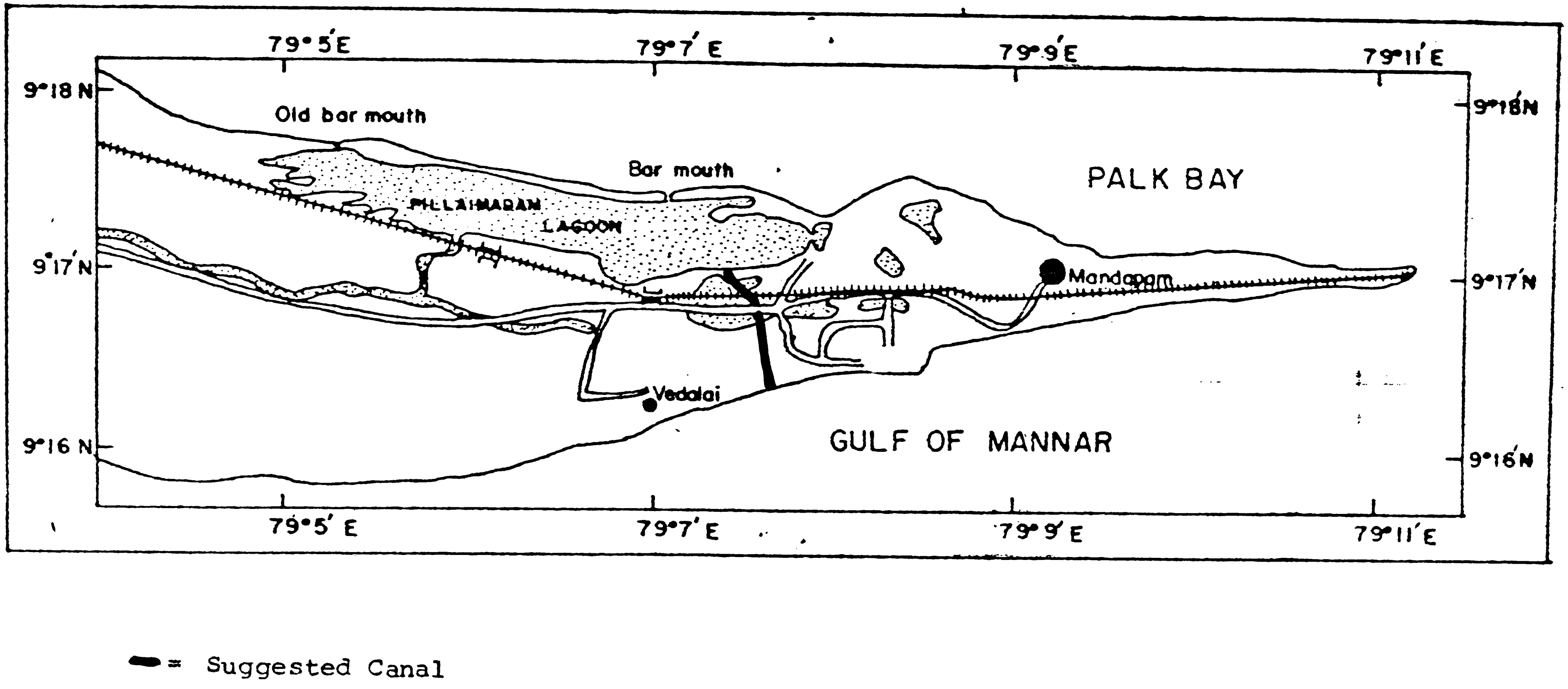
The lagoon can be fertilised by 17:17:17-N:P:K fertiliser to enhance the productivity at the primary level. Based on the <u>in vitro</u> and <u>in situ</u> nutrient enrichment experiments it is estimated that about 500 Kg. of N:P:K fertiliser is required to fertilise the existing area of the lagoon, between the point of fresh water flow and bar mouth when the level of water is about 0.75 m. Such treatment with fertiliser should be repeated every fortnight. By this way, the rate of primary production could be enhanced by about seven to ten times in an area of about 40 hectares which will have direct impact on the tertiary trophic level. If the concentration of nutrients added are comparatively lower than that recommended, change in trophic structure due to nutrients enrichment cannot be expected. In the present study, it was observed that 5 g of 17:17:17 N:P:K-Complex fertiliser can successfully initiate the rate of primary production in 3 m^3 of water. Hence, the amount of fertiliser to be added for enrichment should be carefully estimated based on the volume of water present in the area under consideration for mariculture practices. The use of d-glucose to control the autotrophic production may be considered at a subsequent stage.

In short-term culture the quantity of water in the site should be taken into consideration *ie.*, the culture should be practised only when the level of water is 30 cm and above. The salinity factor appears secondary, as the height of the water regulates the salinity in the lagoon. In the present investigations it was observed that the suitable level of water for aquaculture practise(30 cm and above) usually exists between the second half of October to first half of April. In addition to the *Chanos* sp. being cultured at present, other euryhaline fishes such as *Aphanius dispar* (Ruppel) which can tolerate high salinities upto 70‰(Jones *et al.*,1978) may also be experimented in the lagoon, after investigating the biological impact of this species on the ecosystem.

Perennial culture does not seem to be possible with the existing nature of the ecosystem. Even if the barmouth could be artificially opened and widened, flooding of water into the lagoon was observed only for a short duration during the high tide periods of new moon or full moon days. Subsequently, sand dunes begin to appear in the artificially opened bar mouth mainly due to the wave action, resulting in its closure. Moreover, with the onset of south-west monsoon, the wind velocity pushes the level of Palk Bay lower than the floor of the lagoon. Hence seepage with high rate of evaporation due to hot summer accelarates the lowering of the water level of the lagoon. During the north-east monsoon, as the prevailing meteorological conditions are reversed, the lagoon is filled with water. This natural change in wind direction could be used beneficially to practice intensive culture in the lagoon.

It is observed during the present study that the water currents of the Palk Bay and Gulf of Mannar are monsoonal in nature. During the north-east monsoon, the surface currents are directed southwards with the resultant flow of water from the Palk Bay to the Gulf of Mannar. During the south-west monsoon, the condition is reversed. Due to the prolonged south-west winds, the speed of surface currents in this area may rise upto 2 knots per hour(Admiralty Chart,1981). Keeping this in view, it is suggested that a perennial water connection of about 2 Km long could be maintained through an excavated channel connecting the Gulf of Mannar to the Pillaimadam Lagoon(Pl.S-1). Though the initial investment may appear to be high, the relief it would bring about would be permanent and at least 200 heatares of area could be successfully made use of for intensive mariculture, as the level of water inside the lagoon will be maintained at the suitable level alternatively by the incursion from the Palk Bay and the supply from the Gulf of Mannar through the proposed canal.

PLATE 5-1: MAP SHOWING THE PROPOSED CANAL



SUMMARY

SUMMARY

PILLAIMADAM LAGOON, located between 09°17'N and 09°17' 48"N and 79°5'E and 79°8'E, and situated along the Palk Bay Coast of Mandapam Peninsula was selected for the present investigation. The lagoon is a shallow waterbody(deepest area = 1.5 m) which extends over 300 ha.

I. The period of study extended from July,1982 to June,1984. Five stations were located inside the lagoon and one station in the adjacent inshore area of Palk Bay, in order to carry out periodic investigations on the fluctuation in the ecological and productivity parameters.

II. Meteorological data pertaining to monthly mean, minimum and maximum temperature, wind velocity, rainfall and relative humidity at this region were collected and analysed. Maximum temperature of this region was experienced from March(32°C)to September(35°C). South-west monsoon and north-east monsoon winds were observed to exert profound influence on the climatology of this region. The former is felt in summer months with an average speed of 15 to 22 kms/h while the latter blew from October to February and brought in monsoonal rains. Poor rainfall was usually felt in this region with a record of 922.5 mm during the monsoon period of 1982 and 1346.7 mm in 1983. Relative humidity was high during the monsoon periods, recording values from 77 to 87%.

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III. Freshwater supply into the lagoon was mainly due to the inflow of water during the monsoonal rains, and sea water incursion was recorded only during the north-east monsoon period. During the rest of the period, the bar mouth remained closed, thereby implying the low stability of this ecosystem. Fluctuation in the level of water in the lagoon is chiefly dependent on the pattern of coastal circulation. Relatively high water level in the lagoon recorded during the north-east monsoon period (Ca 100 cm) was due to the rise in the level of Palk Bay. During summer months, evaporation and seepage to the sea decrease the level of water in the lagoon (10 cm), eventhough occasional innundations occur during lunar phases.

IV. The temperature of water was mainly dependent on the temperature of atmosphere and the level of water. During summer period, temperature of water varied from 27.0°C to 34.5°C and during north-east monsoon period from 24.0°C to 26.0°C.

V. During summer, the dissolved oxygen content ranged between 1.0 and 2.5 ml/l while during the north-east monsoon period its range fluctuated between 4.0 and 6.0 ml/l. The salinity of the lagoonal environment was found to be influenced by the freshwater inflow, seawater incursion and circulation during north-east monsoon period. Salinity value, as low as 3‰ was observed during October-December.

During summer period, (April-August) hypersaline condition prevailed in the lagoon and salinity value recorded was more than 150‰. pH and ammonia content in water showed positive correlation with each other(r = > 0.67). Soluble reactive phosphate, nitrate, nitrite and ammonia concentrations apparently showed an increase during the period of monsoonal rains, suggesting that the loading of these elements in the ecosystem is from the freshwater source. Nitrate concentration usually showed positive correlation with the nitrate concentration(r = > 0.64). The hydrogen sulphide content of water was low(< 3.5 µg-at H_2S-s/l) when active water circulation was observed in the lagoon.

VI. The temperature of sediment showed positive correlation with the temperature of water(r = > 0.73). During north-east monsoon period the pH of sediment was comparatively more alkaline(> 7.50) and Eh, though always evinced negative potential, was at comparatively high levels(> -100mV) during the period of study. Organic carbon, total phosphorus and Kjeldahl nitrogen contents of the sediment increased during the north-east monsoon period, thereby implying that the major source of these elements are from freshwater. The positive correlations obtained between these parameters further emphasis a common origin for them. The total sulphide content of sediment showed low level(< 20.0 ug/g wet wt) during north-east monsoon period.

VII. Gross primary production and net primary production rates showed relatively increased values during north-east monsoon period, but the overall rate of primary production in the lagoon was relatively less(< 450 mgC/m^3/day) when compared to other coastal ecosystems.

VIII. After the north-east monsoon period, the lagoon remains cut off from the sea due to the sand bar and fresh water inflow also diminish after the cessation of rain. This resulted in the anoxic condition and the same got intensified with the advancement of the summer period. Dissolved oxygen content evinced a decreasing trend(< 2 ml/l). The water attained hypersaline condition(>150‰). The pH of water indicated less alkaline condition(<8.0). Soluble reactive phosphate, nitrate, nitrite and ammonia concentrations were relatively low being<0.30 μg-at PO_4-P/l,<0.80 μg-at NO_3-N/l, <0.05 μg-at NO_2-N/l and <5.00 μg-at NH_3-N/l respectively. Hydrogen sulphide content of water increased as the anoxic condition got intensified(>10.0 μg-at H_2S-S/l).

IX. During the period of anoxic condition, the pH of the sediment was almost near the neutral range (ca 7.0). The Eh of sediment was very low(<-250mV). Organic carbon, total phosphorus and Kjeldahl nitrogen contents during the period of anoxic condition were comparatively low. The total sulphide content recorded high values(>65 μg/g wet wt). Sulfate reduction, denitrification, methanogenesis and mineralisation were discussed based on the results of observations conducted during the period of anoxic condition in the ecosystem.

X. The gross primary production(< 200 mgC/m^3/day) and net primary production rates were relatively low during anoxic condition and the latter frequently recorded nil values.

XI. The zooplankton samples predominently consisted of copepods and the other taxa. They occurred in the samples in the following order of abundance: amphipods, copepod eggs, decapod larvae, fish eggs, lamellibranchs, gastropods, coelenterates, cladocerans, ostracods, cumaceans, isopods, mysids, *Lucifer* sp., chaetognaths, polychaetes, heteropods, pteropods, appendicularians, fish larvae, copepod nauplii, ophiopleuteus larvae and insect larvae. Species specificity of the zooplankters was a characteristic feature observed during marine and brackish water regimes in the lagoon.

XII. Benthic macrofauna were collected and studied. Bivalve spats, *Perinereis* sp., *Chironomus* sp., *Pulliella armata* and amphipods were recorded in the benthic macrofaunal community, and their abundance were estimated per square meter.

XIII. The grain size analysis of the sediment showed that the sediment is sandy in nature except at eastern region of the lagoon where it is clayey.

XIV. Studies on the vertical profile of the chemical nature of the sediment revealed that organic carbon, total phosphorus and Kjeldahl nitrogen contents of the sediment decreased in their concentrations vertically downwards. In course of time, increase of their contents in the upper layer of sediment was discernible, but in the lower layers the temporal change in their concentration was of less magnitude. The sand proportion of the sediment increased vertically downwards.

XV. Studies on the diurnal variation of hydro-biological parameters revealed that the concentrations of soluble reactive phosphate, nitrate, nitrite and ammonia were apparently low during the day time and they evinced an increasing trend during the night hours. The dissolved oxygen content of water was relatively high during the sunlit hours of the day. Salinity values at surface and bottom layers usually followed the pattern of water circulation inside the lagoon.

XVI. Coastal flora were collected from the periphery of the lagoon from different zones, and twenty one species were identified. Salicornia sp. was found to be abundant with wide range of distribution around the lagoon.

XVII. The salinity pattern in Palk Bay was dependent mainly on the monsoonal currents periodically prevailing in this area. Nutrient loading was observed at the zone of interaction between Palk Bay and the lagoon due mainly to the influx of water from the latter. The macrobenthic fauna were represented by *Glycera alba*, *Perinereis* sp., bivalve spats, amphipods, spats of *Oliva* sp., *Prionospio* sp., *Ancistrosyllis constricta* and *Nephthys* sp. *Perineries* sp. was found to be widely distributed in the sandy area, where as *Prionospio* sp., were dominant in the area where the nature of the sediment was silty.

XVIII. The nutrient enrichment experiments showed that gross and net primary production rates could be enhanced to more than seven-fold manner by employing commercial N:P:K-Complex fertilisers or organic manure.

XIX. d-glucose treatment was found to result in significant lowering of net primary production suggesting concomitant increase in the heterotrophic production.

XX. Experiments conducted using chemical fertilisers resulted in relatively less rate of gross and net primary production, when compared to those in which enrichments were carried out employing commercial fertilisers. It is probable that this is indicative of the non-availability of the minor nutrients for the phytoplankters.

XXI. Individual enrichment experiments conducted using commercial fertilisers such as Potash(K), superphosphate(PO_4) and urea-N resulted in significantly less rate of primary production when compared with N:P:K-Complex and organic manure.

However, Urea enrichment resulted in significantly high rate of primary production than that of the superphosphate suggesting the primary deficiency of nitrogen in the lagoon system.

XXII. The phytoplankters in the enriched water were represented by *Oscillatoria salinarum*, *Nitzschia closterium*, *Cymbella marina*, *Synedra* sp., *Navicula* sp., *Amphora* sp., *Amphiprora* sp., *Scenedesmus* sp., *Euastrum* sp., *Desmidium* sp., *Cosmarium* sp., *Chlorella* sp., *Corteria* sp. and *Chlorococcum* sp., in varying numbers. Frequently, *Oscillatoria salinarum* occurred in blooms in the experimental tanks.

XXIII. A critical assessment of the lagoon for its suitability for mariculture employing short-term culture practice has been made, and suggestions are presented in the thesis for viable and perennial culture activity.

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