STATISTICAL EVALUATION OF PLANKTON DIVERSITY IN MANGROVE ECOSYSTEMS IN COCHIN AREA

Dissertation submitted by Kum. SHAJINA I. in partial fulfilment for the Degree of Master of Science (Mariculture) of the Cochin University of Science and Technology

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CERTIFICATE

This is to certify that this dissertation is a bonafide record of work carried out by Kum. SHAJINA, I., under my supervision and that no part thereof has been presented before for any other degree.

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** ** **

PREFACE

Mangroves are unique ecosystems which provide food,, fodder and a host of other products to the coastal populations in tropical and sub-tropical areas. They help in preventing natural calamities such as large scale soil erosion and floods. Mangroves characterise an ecosystem where both terrestrial and aquatic fauna interact and strike a perfect balance. Due to the presence of high organic matter these areas act as important nursery grounds for a number of finfishes and shellfishes. The export of nutrients and rich detrital load from mangroves to adjoining areas such as estuaries makes these locations also important in the context of fishery. Mangroves are also important from the view of acquaculture. These areas with suitable modifications can be converted into culture ponds with high rate of production.

The ecological studies on mangroves have concentrated around various flora which form the major terrestrial component of this ecosystem Studies on floral phenology, litter production, decomposition and root systems are areas that have received wide attention. Mangrove swamps have a key role to play in the nutrient cycle and ecology of the coastal waters. However, studies related to export of organic and inorganic nutrients have not received much attention. Much less is known about the primary and secondary production of mangrove areas. The temporal and spatial variations in hydrography, phytoplankton and zooplankton of estu and coastal waters has formed part of many significant studies of those

ecosystems. But the sources of nutrients and food in the form of organic matter to these ecosystems is mangroves. The knowledge of the physico chemical factors and productivity of mangroves is still in its infancy Also there is only a little information on the interaction between chemical and biological processes in mangrove areas.

In mangrove swamps primary productivity is attributed to several sources, one among them being phytoplankton. The planktonic community has a close resemblence with those of adjacent water systems. Although the role and nature of plankton in mangroves has been the focus of attention in the past, a clear picture of various processes has not emerge.

How healthy an ecosystem can well be explained by the richness of the species and the evenness of the distribution of the species to which it provides habitat niche. It is reasonable to assume that the hydrology of the system has to play a prominent role in allowing different organisms to seek niche in the environment. One of the prime obecectives of the present study is to focus on this pivotol problem of the richness of the mangrove system in respect of various groups of phytoplankton and zoo-plankton and how it varies in relation to hydrographic characteristics. This is accomplished by constructing what are called Diversity Indices and by studying their behaviours in relation to hydrographic parameters.

A common and consistent phenomenon observed in ecological communities is the variation in species abundance. Diversity indices are statistical tools for analysing ecological patterns.

With this in view, the present study is aimed at understanding the phyto and zooplankton community of two mangrove areas of the Cochin estuarine system. The hydrography of the ecosystem has also been studied to understand its relationship with plankton. An attempt is made to construct indices for a better understanding of the complex ecosystems. It is hoped that the present observations will add to the meagre existing knowledge of the hydrology and planktonic components of mangrove ecosystems.

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INTRODUCTION

Mangrove forests are complex intertidal, soft substrate habitats that occur circumtropically and comprise a substantial portion of protected coasts and estuaries. As a unique protective margin between land and sea, mangrove swamps attract faunal components from adjoining terrestrial and aquatic ecosystems in addition to harbouring many indigenous animal species (Macintosh, 1982).

The mangrove forests provide native populations with a seemingly endless variety of derivid products: timber, thatching, charcoal, medications, animal fodder etc. (de la Cruz, 1979). The mangrove environment also yields an abundant supply of food: fish and prawns from its water ways, shellfish such as oysters and crabs from the shore zone and bird's egg, honey and edible fruits from forest areas (Macintosh, 1982). Aquaculture activities in mangrove swamps dateback about 500 years with coastal milkfish culture in Indonesia. Apart from milkfish farming the only other widespread culture practice in mangrove swamps is the trapping and holding system of marine prawn cultivation. This is based on the tidal inflow of juvenile prawns into mangrove ponds constructed in the intertidal zone. A similar form of prawn rearing in conjunction with paddy cultivation is carried out in the coastal 'bheries' of West Bengal and in Cochin backwaters (Menon 1954; George et al., 1968; Jhingran, 1975; Kurian and

Sebastian, 1976) Krishnamurthy and Prince Jayasheelan (1986) and Parulakar (1985) discuss the prospects of aqaculture in mangrove ecosystem of India. Brand (1982) analysed the possibilities of mariculture in the mangrove lagoon of Baja California, Mexico. Mangroves also act as an important source of seed for commercially important prawns and fishes (Achuthankutty and Sreekumaran Nair, 1980; Staples, 1980; Bopaiah and Neelakandan, 1986; Vance et al., 1990; Achuthankutty, 1990).

A review of literature indicates that studies on the hydrology of mangrove areas are limited. Gopalakrishnan et al. (1988) studied the phytoplankton and zooplankton in the prawn fields of Cochin area in relation to hydrography and nutrients. Seasonal variations in the total biomass and organic matter of the plankton in the marine zone of the Vellar estuary was examined by Seshadri (1957). Joshi and Jemale (1975) made observations on the ecology of mangrove of Terekhol and Vashistri rivers. The environmental characteristics of an estuarine mangrove in Goa was observed by Untawale and Parulaker (1976). They found that nutrients especially inorganic phosphate exhibit an inverse relationship with sediment load. Rajgopalan et al. (1983) studied the productivity in three different mangrove areas; Cochin backwater, Killai backwater and Andaman Nicobar islands and observed that the production varied in these areas, but generally indicated a good production rate. Boto and Wellington (1983) monitored the phosphorus and nitrogen nutrient status of an Australian mangrove

forest. They concluded that mature leaves of mangrove plants are useful indicators of mangrove forest nutritional status. Vyshkvartsev et al. (1983) studied the factors determining productivity of Nhaphu bay in the South China Sea. They established that there is a periodic inflow of nutrients into the bay mainly from terrigenous run-off and mangrove thickets and an outflow of water enriched with particulate matter. Alongi (1990) examined the effect of tidal upwelling of mangrove detritus on sediment nutrient chemistry, nutrient regeneration and oxygen fluxes in a coastal area of central Great Barrier Reef. The change of some chemical characters of a dry paddy and mangrove soil sample when submerged in water were studied by Marcus et al. (1988). The changes during the first two weeks of submergence were most significant. Martinet Bourgeois and Pascaline (1982) studie the chemical characteristics of the mangrove of Guadeloupe. Among the various mangrove areas studied by them, the area which is influenced by the canal showed the best chemical conditions for primary production. The mangrove litter production and their nutrient content in a tidal creek of Lothian island of Sundarbans was examined by Ghosh et al. (1990). Nutrient content inn the leaves were generally higher than that of other components of the litter. Healey et al. (1988) observed the abundance and diostribution of bacterioplankton in the Gambia river of West Africa. The fungal activity in 'Mangalvan' one of the stations selected in the present studdy is given by Prabhakaran et al. (1987). The fungi ioslated showed phosphate solubilizing activity

indicating possible role of these active fungi in the nutrient regeneration of the ecosystem by solubilizing insoluble phosphorous compounds and making them available to other organisms. Kannan and Krishnamurthy (1985) examined the impact of nutrients on phytoplankton at Porto Novo. Rajgopalan et al. (1986) surveyed the mangrove areas in the Cochin est urine system and found wide seasonal fluctuations in the environmental factors. The physico-chemical features of the Cochin backwater were studied by Balakrishnan, (1957), Ramamritham and Jayaraman (1963) Cherian (1967), Josanto (1971) Wellershaus (1971) and Sankaranarayanan et al. (1986).

Phytoplankton in mangroves are diverse and play an important role in the productivity and food webs of these complex ecosystems. It is impossible to define a typical phytoplankton of the mangrove because, in most cases the mangrove is subjected to sudden and massive environmental changes. Thus only a few species which are adapted to unstable conditions can develop. According to the seasons, oceanic or continental influences vary and the composition and production of phytoplankton reflect the resulting situation.

Desai (1988) studied the alkaline phosphatase activity of phytoplankton from mangrove ecosystems of Goa and found that average relative alkaline phosphatase activity in the bottom layer exceeded that of the surface layer. The phytoplankton biomass and primary production from

3 types of mangrove,one each from Atlantic Ocean Indian Ocean and Caribbean

Sea, is described by Ricard (1984). Bustillos et al. (1979) compared the abundance and species diversity of phytoplankton in three different mangrove areas of Mexico. The productivity and chlorophyll levels of mangrove is affected by the riverine input (Day et al. (1982). The phytoplankton populations of a mangrove in the French West Indies is characterised by a larger taxonomic diversity, but the differences in composition of the population were beyond the control of salinity, tides, water stratification and continental inflow (Richard and Delesalle, 1979). Although the phytoplankton studies of mangrove areas are few, a number of studies are available on the phytoplankton of Cochin backwaters (Quasim et al., 1969; Quasim et al., 1975; Gopinathan, 1972; Preetha Paul, 1990).

The prawn culture fields adjoining the Cochin backwater system has been studied for their phytoplankton content (George, 1974; Gopinathan et al., 1982; Reddy, 1986; Legendre et al., 1987; Gopalakrishnan et al., 1988; Devapriyan, 1990; Mathews, 1987, 1992; Gomathy,1990).

In almost all studies of mangrove ecosystems the role of zooplankton has been neglected or mentioned only briefly (Grindley, 1984). This is because most of the studies in mangrove ecosystems are related to either productivity or their associated benthic fauna. A wide variety of holoplanktonic and meroplanktonic organisms appear in the zooplankton of mangroves. Ambler et al. (1991) observed swarm formation of copepods

and their population structure near mangrove cays. Shanmugham et al. (1986) also observed that copepods form the major constituent contributing 70-90% of the total zooplankton population from Pichavaram mangroves. The dynamics of zooplankton in an isolated mangrove swamp revealed that the dominant organisms changed to holoplankton with passage of time (Sawamoto, 1990). Pages et al. (1986) observed the plankton biomass and primary production to be the highest upriver, while the species diversity and biomass of zooplankton are low. The fish fauna of a mangrove swamp from New Caledonia with details of species collected, population structure and a study of zooplankton is dealt by Moncoiffe (1989). Thollot (1989) surveyed the characterstics of the mangrove icthyofauna of New Caledonia and observed that the catches indicated abundance of juveniles and small species. Mangroves and seagrass beds offer attractive habitat for fishes especially postlarvae and developing juveniles as they offer some advantage for early survival of young juveniles (Parrish, 1989). Pinto (1987) studied the environmental factors influencing the occurrence of juvenile fish in the mangroves of Philippines. Out of the 8 species investigated 3 species showed positive correlation to phosphate in the water, 2 to organic carbon in the sediments, nitrate, silicate and pH and 1 to salinity and carotenoids in the water. Hendrickx (1984) collected zooplankton samples from a mangrove channel and emphaised the importance of non living particles in detrital organic matter. There do not appear to be distinct zooplankton communities dependent on mangrove ecosystems and their distribution patterns appear to be determined by hydrological parameters such as residence time and salinity, irrespective of the location of mangrove areas (Grindley, 1984). Sanchez et al. (1979) compared the

the dynamics and composition of zooplankton in relation to hydrological parameters in 3 mangrove areas of Mexico. Santhanam et al. (1975) collected zooplankton from various aquatic biotopes of Porto Novo. The annual mean values of zooplankton showed that the nertic biotope had maximum number of organisms followed by mangrove biotope. The highly variable complexity of mangrove environment seems to alter the zooplanktonic composition from time to time (Palaniappan and Bhaskaran, 1985).

How healthy an ecosystem can well be explained by the richness of the species and the evenness of the distribution of the species to which it provides hibitat niche. It is reasonable to assume that the hydrography of the system has to play a prominent role in allowing different organisms to seek niche in the environment. One of the prime objectives of the present study is to focus on this pivotol problem of the richness of the mangrove system in respect of various groups of phytoplankton and zooplankton and how it varies in relation to hydrographic characteristics. This is accomplished by constructing what are called diversity indices and by studying their behaviour in relation to hydrographic parameters.

A common and consistant phenomena observed in ecological communities is the variation in species abundance. Diversity indices are statistical tools for analysing ecological patterns. The variation in species abundance has led ecologists to pose central question pertaining to the nature of communities. In a given community, how many species are

there and what are their relative abundance and how many are rare or common?

Different models of species abundance have been developed for fitting species abundance data (Whittakar, 1972) and led to the general model requiring only a few, easily estimated and ecologically inter-pretable parameters.

Diversity is composed of two components one, the total number of species and two, how the abundance of data are distributed among the species. The number of species in the community is often termed as 'speciess richness' by ecologists. The second component is 'species eveness' or equitability. Evenness refers to how the species abundance distributed among the species.

A number of indices have been proposed for richness and evenness and termed as richness indices and evenness indices respectively. Indices that attempt to combine both richness and evenness into a single value are refered to as diversity indices.

Phytoplankton ecology of selected stations of Bay of Bengal was studied on different aspects such as quanitative, distributional pattern, species diversity, general succession and the nature of similarity indices.

A comparative account of different station, comprising mangrove, backwater and estuary was given by Santhanam et al. (1975).

Phytoplankton distribution studies in Cochin Backwaters have been made using Fisher's species Diversity Index (Jayalakshmi et al 1986).

Copepod component of zooplankton of Cochin Backwater was studied in detail using Fisher's Diversity Index and Margalefs' Diversity Index in relation to hydrographic parameters (Pillai et al. 1973).

From the above revew of literature, it is evident that studies on mangroves in relation to dynamics in hydrology and plankton content are few. With a view to understand these parameters the present study was undertaken on the plankton groups available in the mangrove ecosystems of Cochin area to examine:

1. The variations in hydrography of mangrove ecosystems,

2,. Quantitative and qualitative abundance of phytoplankton and zooplankton,

and

3. Diversity indices of plankton groups in relation to these parameters.

MATERIALS AND METHODS

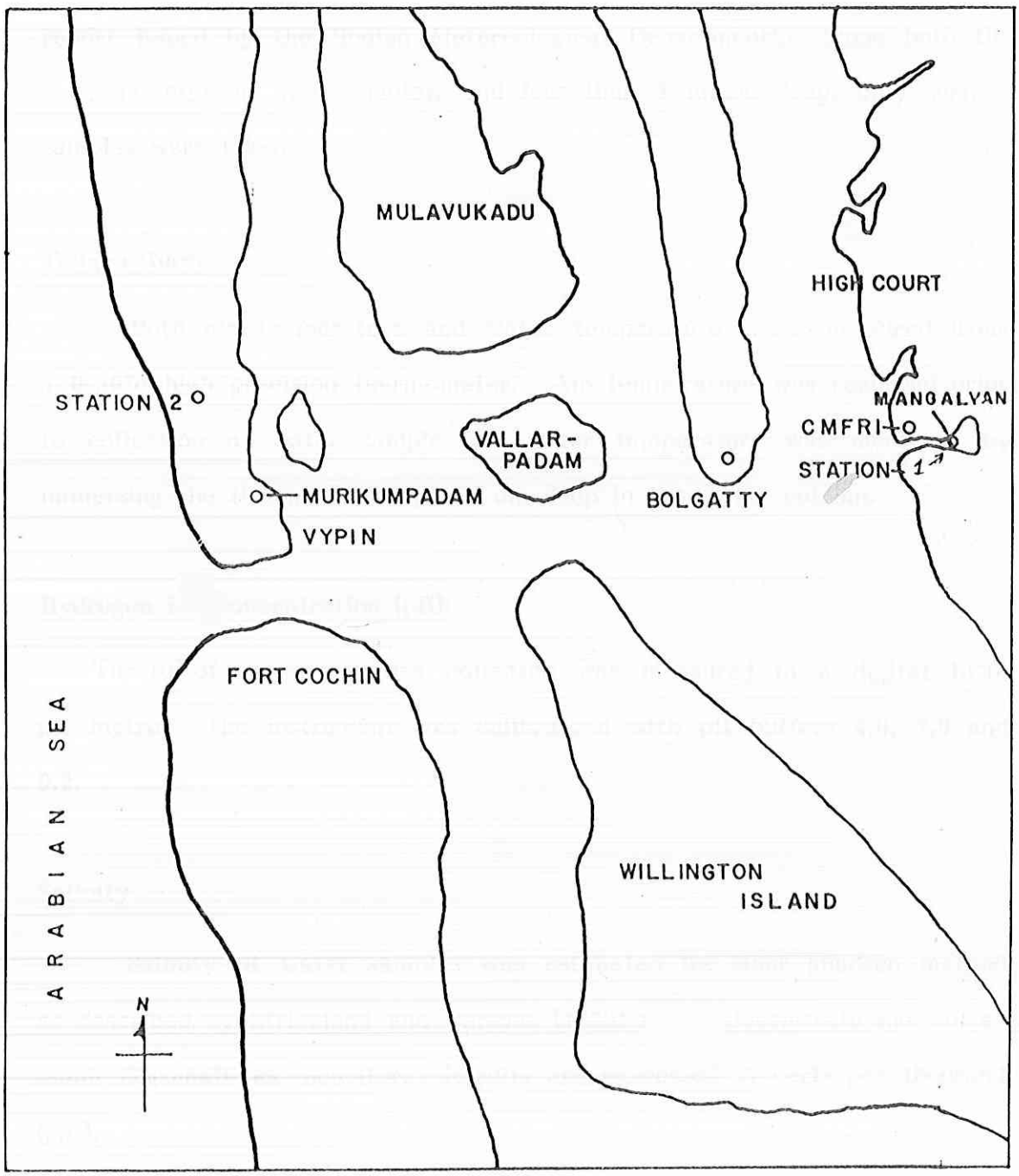
STUDY AREA

A preliminary survey was conducted in the last week of May 1992 to fix suitable stations for the study. Based on the extent of area, tidal influx and dominance of species of Mangrove flora, two stations were selected. The first station is located in 'Mangalavan', a bird sanctuary, adjacent to the Central Marine Fisheries Research Institute buildings. A typical mangrove ecosystem with a net work of channels at Puthuvyppu in Vypeen island was identified as the second station. The main species of Mangrove plants in first station are Acanthus ilicifolius, Rhizopora mueronata and Avecinnia officianalis. At Puthuvyppu various species belonging to Acanthus, Exoecaria, Clerodendrum, Aegiceras, Avecinnia and Rhizopora are found.

STUDY PERIOD AND SAMPLING FREQUENCY

A total of twenty one water and plankton samples each from both the stations were collected during the south west monsoon in June and continued up to September 1992. Time of sampling was maintained uniformly between 07 00 to 11 00 hours in the morning. The parameters examined were water and air temperature, salinity, pH, dissolved oxygen and inorganic nutrients such as nitrate, phosphate and silicate. Water samples were collected from surface in narrow mouthed 250 ml polythene

Fig.1 THE COCHIN BACK WATERS AT ERNAKULAM SHOWING THE SAMPLINGS SITES (not drawn to scale)



bottles. Weekly and monthly rainfall data were obtained from daily weather report issued by the 'Indian Metereological Department'. Since both the sampling stations were shallow and less than 1 metre deep, only surface samples were taken.

Temperature:

Both air temperature and water temperature were measured using a 0-50°c high precision thermometer. Air temperature was recorded prior to collection of water sample and water temperature was measured by immersing the thermometer upto 5 cm deep in the water column.

Hydrogen ion concentration (pH):

The pH of water samples collected was measured in a digital ECIL pH metre. The instrument was calibrated with pH buffers 4.0, 7.0 and 9.2.

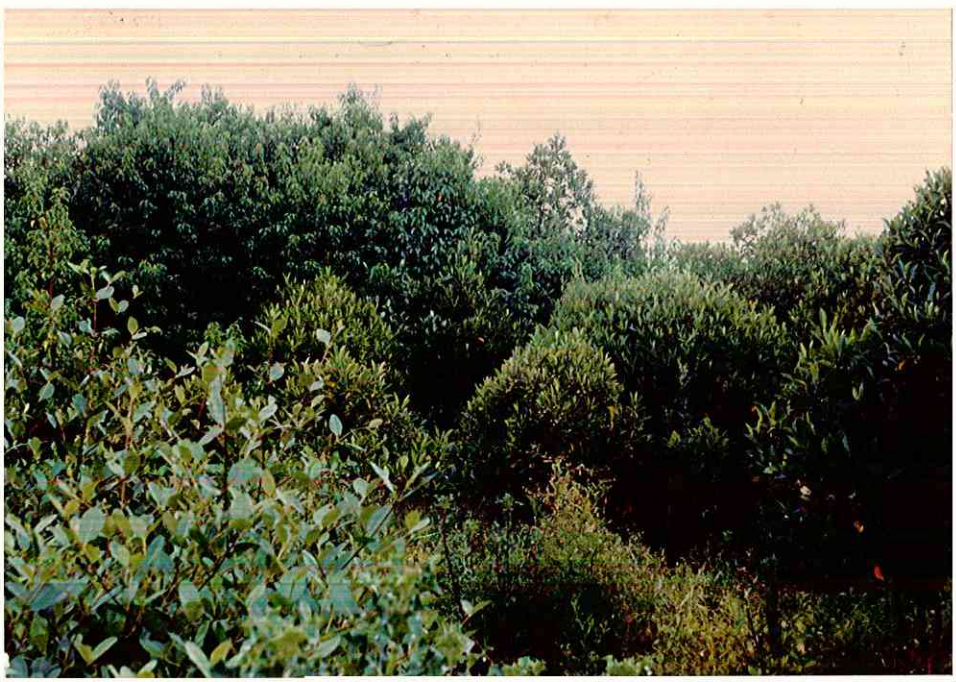
Salinity

Salinity of water samples was estimated by Mohr knudsen method as described by Strickland and Parsons (1968) using Silvernitrate and Potassium Chromate as indicator. Results are expressed in parts per thousand (ppt).

Dissolved oxygen:

The dissolved oxygen content of the water sample was estimated

A VIEW OF 'MANGALVAN' - STATION - I



MANAGROVES AT PUTHUVYPU - STATION -2

by modified Winkler technique as given by Strickland and Parsons (1968). The estimations were done in the laboratory after fixing the sample with Winkler. A and Winkler. B solutions at the collection site itself. Dissolved oxygen content is expressed in Ml/lit.

NUTRIENTS

For estimating the nutrients, the method outlined by Strickland and Parsons (1968) and Parsons et al (1984) was followed and Spectrophotometric measurements are taken on a Spectrophotometer.

a) **Reactive Phosphorus:**

The method given by Strickland and Parsons (1968) was used for determination of phosphate. To a 100 ml sample 10 + 0.5 mixed reagnt (molybdic and ascorbicacid and trivalent antimony) was added and mixed. The resulting complex hetropoly acid was reduced with in 2 to 3 hours. The extinction of the solution was measured at 885 nm. For standard phosphorus, different concentrations of pot assium dihydrogen phosphate was made and the graph plotted.

b) **Nitrate-Nitrogen:**

Nitrate nitrogen was estimated by the method of Morris and Riley as described by Strickland and Parsons (1968) with slight modification. To a sample of 50 ml, 2 ml, of buffer reagent (phenol solution + Sodium hydroxide solution) was added and with rapid mixing 1 ml of reducing agent (copper sulphate + Hydrazine Sulphate) was also added. The flask

was kept in dark for 20 hours and later this sample was mixed with 2 ml of acetone. After two minutes interval, 1 ml each of Sulphonilamide solution and NNED was added and mixed thoroughly. Aftr 10 minute the absorption was measurd at a wave length of 543 nm in the Spectrophotometer. Standard nitrate stock solution was prepared at different concentrations and values were plotted. Standard graph was plotted in a graph sheet. Concentration of nitrate is expreessed in μg at 1 lit.

c) **Silicate - Silicon:**

Silicate was estimated by Mulin and Rilay method as given by Parsons et al (1984). The determination of dissolved Silicon compounds in natural water is based on the formation of a yellow silico molybdic acid when a more or less similar sample is treated with a molybdic reagent Since both of the yellow silico molybdic acid isomers are rather weak in colour, they are reduced to instensely coloured blue complexes. A mixture of metol and Sulphate was used as reducing agent. The extinction was measured at 810 nm.

In addition to hydrological parameters percentage of cloud cover estimated by eye, depth of water column measured by a metre scale and flow velocity were also collected. The speed of flow of 2 x 2 cm^2 thermocol piece was timed over a distance of 5 metres.

BIOLOGICAL PARAMETERS

Collection of phytoplankton:

For the study of phytoplankton, settling method was used. Water samples were collected from four different locations in the station and pooled into one litre plastic bottle.

Preservation and Concentration of phytoplankton samples:

A 10% neutral formalin was used to fix the phytoplankton at the time of collection itself and was shaken well for uniform mixing. The sample was kept for one day for sedimentation. The next day, half of the supernatent was decanted carefully and on the third day the rest of the supernatent was removed for further analysis.

Phytoplankton cell count:

Preserved samples were shaken well and poured into a beaker of 100 ml capacity and covered with a watch glass and allowed to remain over night. The supernatent was then poured into another beaker, without disturbing the sedimented particles, to suspension and made up to 20 ml in a measuring cylinder. From this, one ml was pipetted out into a Sedwick rafter counting chamber. From the average values, the total cell count of each taxonomic group per litre is computed and from this, total phytoplankton concentration per metre cube was estimated. The method followed for identification of phytoplankton was that of Subrahmanyan (1946).

Collection of Zooplankton:

Zooplankton samples are collected from both the stations by filtering about one cubicmetre (1000 litres) of water through a handnet made of bolting silk with a collecting bucket (Suresh, 1991). The mesh size of the net was 0.33 mm. The filtering was carried out using a plastic bucket of 10 litre capacity by pouring quickly drawn 100 buckets water through the net. The zooplankters collected in the collecting bucket were preserved in 5% formalin. Results are expressed as total number of organisms of each broad taxonomic group per cubic metre.

Analysis and estimation of Zooplankotn

Samples were analysed for qualitative and quantitative study of zooplankton groups. As the plankton samples from the mangrove marshes contained detritus, leaves, twigs, fruits etc. the displacement volume did not give satisfactory results. Quantitative estimation was therefore made in terms of number of zooplankton present. Zooplankton separated from the debris were counted. Zooplankters were identified and grouped into major categories. Number of Zooplankton is expressed as total number per metre cube.

For counting and identifying zooplankton, the counting chamber designed by C.M.F.R.I. was used. Before counting, the larger particles like decaying leaves, fruits, twigs etc were removed.

Statistical Analysis

The results obtained through the investigation were statistically treated to obtain diversity indices, richness indices and evenness of phytoplankton and zooplankton separately and to relate them to the ecological parameters. Correlation analysis was carried out to ascertain the association of various hydrographic parameters with the counts of zooplankton and phytoplankton. Students' 't' test was applied to test the hypothesis whether the mean counts of the two stations are the same. Meteorolo gical parameters were correlated with various plankton groups. The correlation analysis as described by Snedecor and Cochran (1967) applied. The diversity indices, richness indices and evenness indices were calculated as described by Ludwig and Reynolds (1988) and details are as follows:

Diversity is composed of two distinct components one, richness and two, evenness. Richness refers to the total number of species present and evenness to the equitable distribution of species to the total population.

The present study envisages to obtain the distributional pattern, abundance and total plankton groups and as a result diversity of each group of phytoplankton and zooplankton.

a) Richness indices

Margalef Index, $R1 = \frac{S-1}{\ln(n)}$ (1964)

Where S, the total number of species and n the total number of individuals observed. Alternatively, another index of richness proposed by Menhinic (1964) is

$$\text{Menhinic Index, } R2 = \frac{S}{\sqrt{n}}$$

Here, R2 as an index of richness is more valuable where a functional relationship between S and n of the form $S = k\sqrt{n}$ exists, where k is a constant.

Peet (1974) termed diversity indices as heterogeneity indices as diversity indices incorporate with richness and evenness.

b) Diversity Indices

Simpson's index : Simpson (1949) an index of diversity as,

$$\lambda = \sum_{i=1}^{S} p_i^2$$

Where pi the proportion of abundance of the i^{th} species and

$$p_i = \frac{n_i}{N} \quad i = 1, 2, 3, \ldots\ldots S.$$

Where n_i is the number of individuals of i^{th} species, N, total individuals of all, S species and

$$\lambda = \sum_{i=1}^{S} \frac{n_i(n_i-1)}{n(n-1)}$$ as an unbiased estimator of

λ varies from 0 to 1 and gives the probability that two individuals drawn at random from a population belong to the same species. If the

probability is high that both individuals belong to the same species, then the diversity of the sample is low.

Shannon's Index H' is widely used in diversity index. It measures the average "uncertainty" in predicting to what species an individual chosen will belong. Uncertainity increases as the number of species increases

$$\text{Shannon's Index } H' = -\sum_{i=1}^{S^*} p_i \ln (p_i)$$

Where H' is the average uncertainity per species S*, total species p_i are proportional abundance.

c) Evenness Indices

$$E_1 = \frac{H^1}{\ln(S)}$$

$$E_2 = \frac{e^{H'}}{S}$$

$$E_3 = \frac{e^{H'} - 1}{S - 1}$$

$$E_4 = \frac{1/T}{e^{H'}}$$

$$E_5 = \frac{1/T - 1}{e^{H'} - 1}$$

E_2, E_3 and E_1 are sensitive to species richness and E_4 & E_5 relatively unaffected by species richness.

RESULTS

1. Ecological parameters

The regular data collection was made from both the stations from June to September, 1992 and a sample of 21 observations each was made.

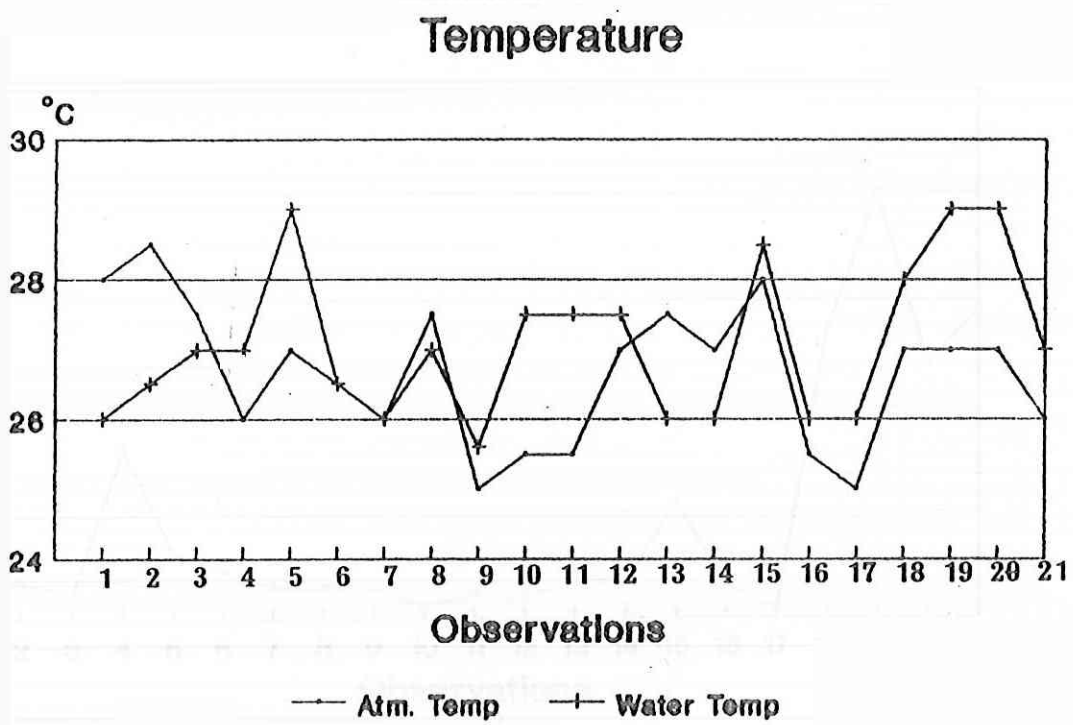
1. Temperature:

The readings made from the sample of twenty one observations beginning from June to September showed that variation was more or less similar in both the stations. The values of water temperature ranged between a minimum of 25.6°C and a maximum of 29°C during second and fourth week of July in Station 1 (Figure 2). Third week and fourth week of July recorded maximum and minimum temperature in station 2 (Figure 6). First fortnight, values in August were more or less stable in station 1. A similar trend was observed in station 2, values ranging between 25°C and 31°C (Tables 3 & 4).

2. pH:

pH values recorded maximum concentration during the last week of June in station I and a sudden decline during first week of July. The values varied from 8.3 to 7.2. Observed values in August showed concentration more or less stabilised (Figure 2). The values in station 2 were slightly higher on almost all observations and maximum of 8.9 was recorded in first week of September. The pH concentration in station 2 was observed stabilised after first week of September (Fig 6). A minimum

Fig. 2. Variations in temperature and pH at Station I.



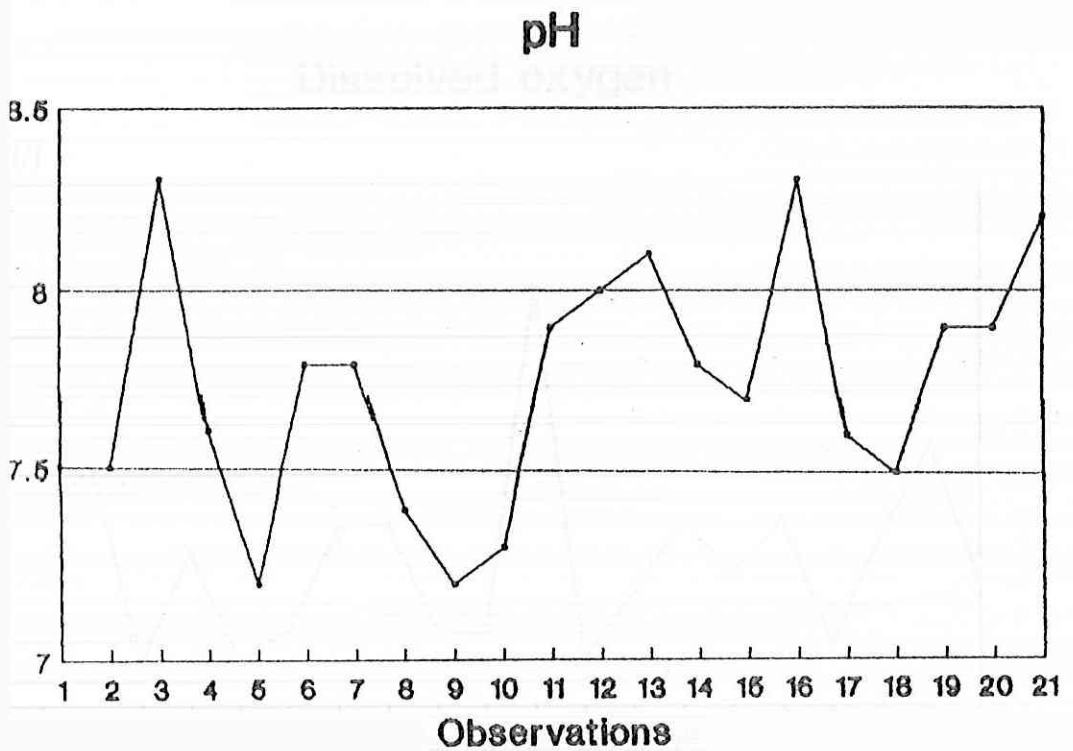
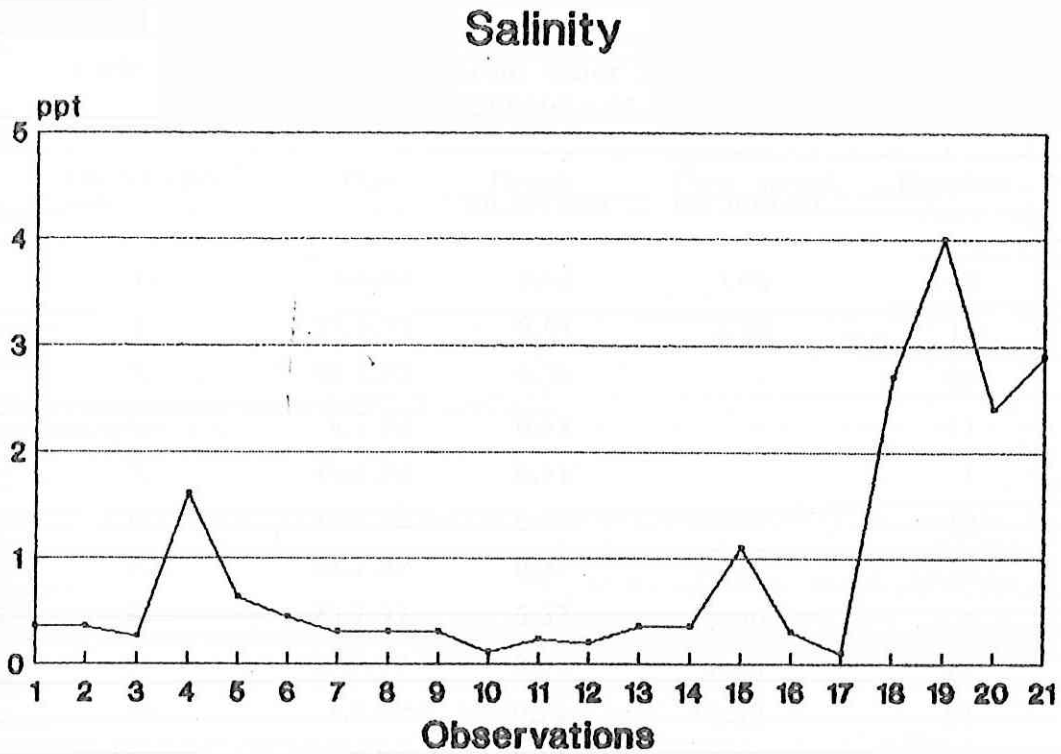


Fig. 3. Changes in salinity and dissolved oxygen at Station I



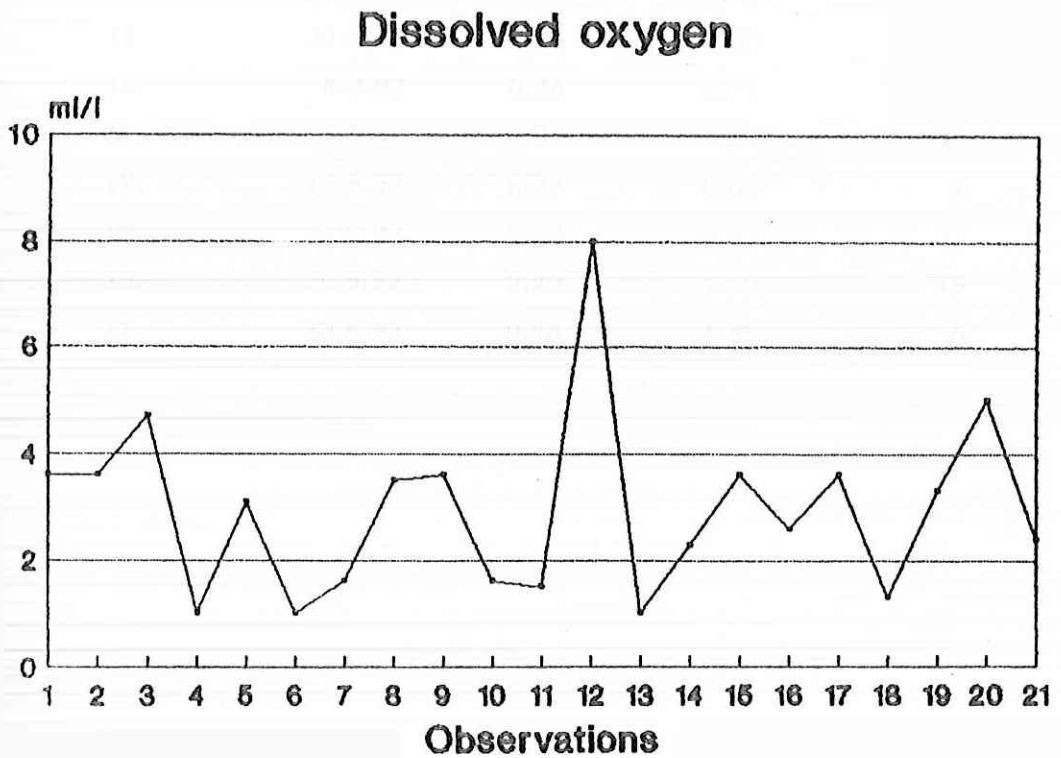


Table 1. **Values observed from water samples for various meteorological Parameters at station. 1**

Observation No.	Date	Depth (in metre)	Flow speed (in metre)	Rainfall	Tide height
1.	7.6.92	0.42	5.00	42	0.33
2.	25.6.92	0.41	2.50	10	0.70
3.	30.6.92	0.50	-	80	0.39
4.	4.7.92	0.41	-	11	0.17
5.	14.7.92	0.41	-	1	00.80
6.	18.7.92	0.28	7.00	12	0.25
7.	21.7.92	0.37	4.50	1	0.41
8.	25.7.92	0.37	2.50	9	0.72
9.	27.7.92	0.95	7.50	17	0.83
10	1.8.92	0.74	10.02	83	0.50
11.	5.8.92	0.40	3.00	8	0.50
12.	14.8.92	0.42	3.00	1	0.23
13.	20.8.92	0.32	0.75	14	0:49
14.	22.8.92	0.42	0.75	8	0.65
15.	27.8.92	0.28	1.00	2	0.86
16.	4.9.92	0.36	0.75	5	0.56
17.	7.9.92	0.37	3.00	29	0.76
18.	17.9.92	0.24	0.00	0	0.49
19.	22.9.92	0.43	0.75	12	0.75
20.	24.9.92	0.49	4.00	19	0.81
21.	30.9.92	0.48	7.50	0	0.49

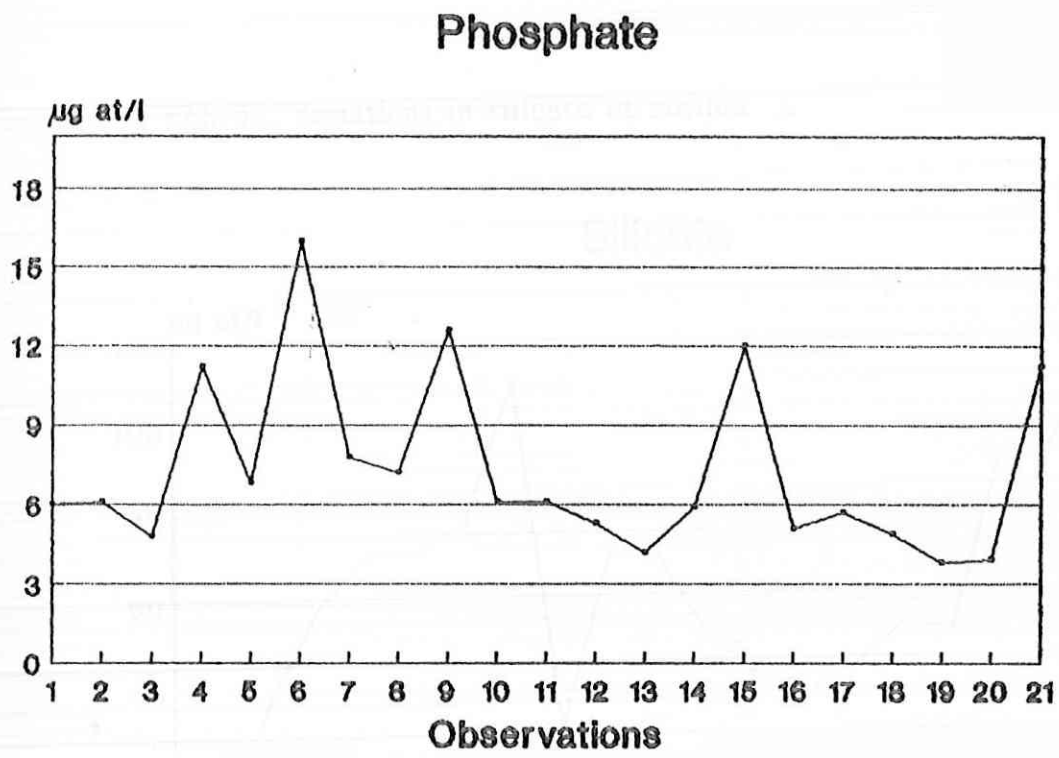
value of 7.5 was observed in the first week of June in station 2 (Tables 3 & 4).

3. Salinity: Comparatively very low values were recorded in station 1 where the minimum value of 0.11 was obtained in the first week of August. A maximum of 4 ppt was recorded by the end of September (Table 3). Low salinity amounted the quality of water near to freshwater. A sharp increase in salinity was noticed in the beginning of July which got stabilished in the following weeks (Figure 3). In station 2 highest salinity was recorded during second week of June which declined gradually till August first week. Again, salinity increased by second week of August in station 2 and steadily increased afterwards (Figure 7). The values ranged between 11.36 ppt in station 2 (Table 4).

4. Dissolved Oxygen:

Dissolved oxygen content in station 1 was higher than that in station 2 on almost all observations. Dissolved oxygen content abruptly declined in the first week of July and by the middle of August attained maximum. Dissolved oxygen content again started decreasing till middle of September in station 1 (Figure 3 & Table 3). The maximum and minimum values ranged from 8.0 ml/lit to 0.79 ml/lit. Subsequently values gradually increased. The oxygen content increased by first week of July in station 2 and steadily continued till third week when it started again decreasing. The variation in the oxygen content during the study period was not very high in station 2 (Table 4).

Fig. 4. Fluctuations in phosphate and nitrate at Station I.



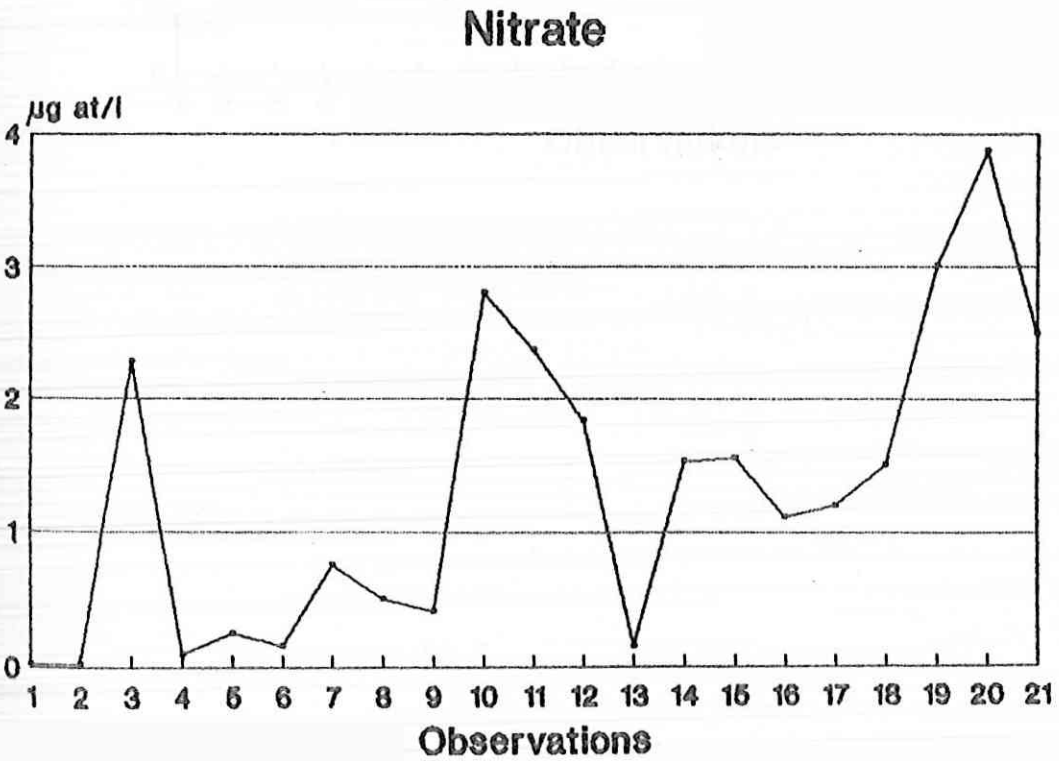


Fig. 5. Variations in silicate at station I.

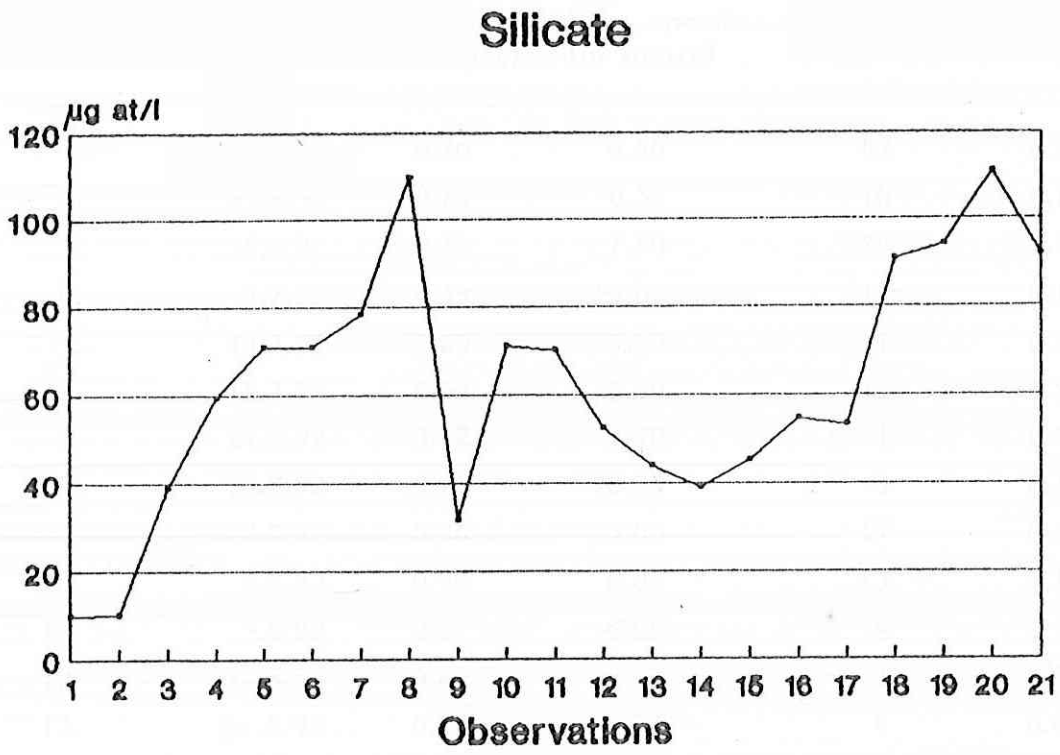


Table 2. **Values observed from water samples for various meteorological Parameters at station. 2**

Observation No.	Date	Depth (in metre)	Flow speed (in metre)	Rainfall	Tide height
1.	7.6.92	0.70	0.50	42	0.33
2.	25.6.92	0.74	0.50	10	0.70
3.	30.6.92	0.74	7.50	84	0.37
4.	4.7.92	0.59	10.00	11	0.17
5.	14.7.92	0.69	5.00	1	0.80
6.	18.7.92	0.54	6.50	12	0.80
7.	21.7.92	0.72	7.50	1	0.41
8.	25.7.92	0.71	10.00	9	0.72
9.	27.7.92	0.56	5.00	17	0.83
10.	1.8.92	0.90	0.00	83	0.17
11.	5.8.92	0.67	0.00	8	0.50
12.	14.8.92	0.60	4.00	1	0.23
13.	20.8.92	0.74	0.75	4	0.49
14.	22.8.92	0.73	1.00	8	0.65
15.	27.8.92	0.93	1.00	2	0.86
16.	4.9.92	0.54	2.00	4	0.56
17.	7.9.92	0.76	4.00	24	0.76
18.	17.9.92	0.59	0.00	0	0.49
19.	22.9.92	0.70	6.00	12	0.75
20.	24.9.92	0.95	0.00	19	0.81
21.	30.9.92	0.39	8.00	0	0.49

5. Phosphate: The phosphate readings were fluctuating between 3.8 and 16.0 µg at/l in station 1 (Table 3). The maximum value of 16.0 was recorded in the third week of July and the minimum of 3.8 in the third week of September (Figure 4). The values were more or less stable during June. The readings in August and September were not so stable. In station 2 readings were comparatively higher in all the months. The values obtained in June were more or less stable (Figure 7). A maximum of 19.4 µg at/l was recorded during fourth week of August and a minimum of 5.38 µg at/l in the third week of September in Station 2 (Table 4).

6. Nitrate: The values ranged from 0.02 to 3.8 µg at/l in station 1 (Table 3). The readings were low from June to July except in the last week of June. August onwards values steadily increased and a maximum of 3.87 µg at/l was attained in the fourth week of September. Till second week of August, values were stable (Figure 4). The readings in station 2 (Figure 8) were comparatively higher in almost all observations and a different pattern was depicted. The values were higher during June and July and a maximum of 3.68 µg at/l was recorded in the first week of June in station 2. The minimum reading of 0.20 µg at/l was recorded during the last week of August. The readings in September steadily increased and attained 3.3 µg at/l (Table 4).

7. Silicate: The readings in station 1 fluctuated between 10.0 µg at/l and 109.6 µg at/l (Table 3). The values recorded in June were lower but steadily increased and attained the maximum in the third week of July (Figure 5). Again, values slowly decreased till third week of August.

Fig. 6. Variations in temperature and pH at Station II.

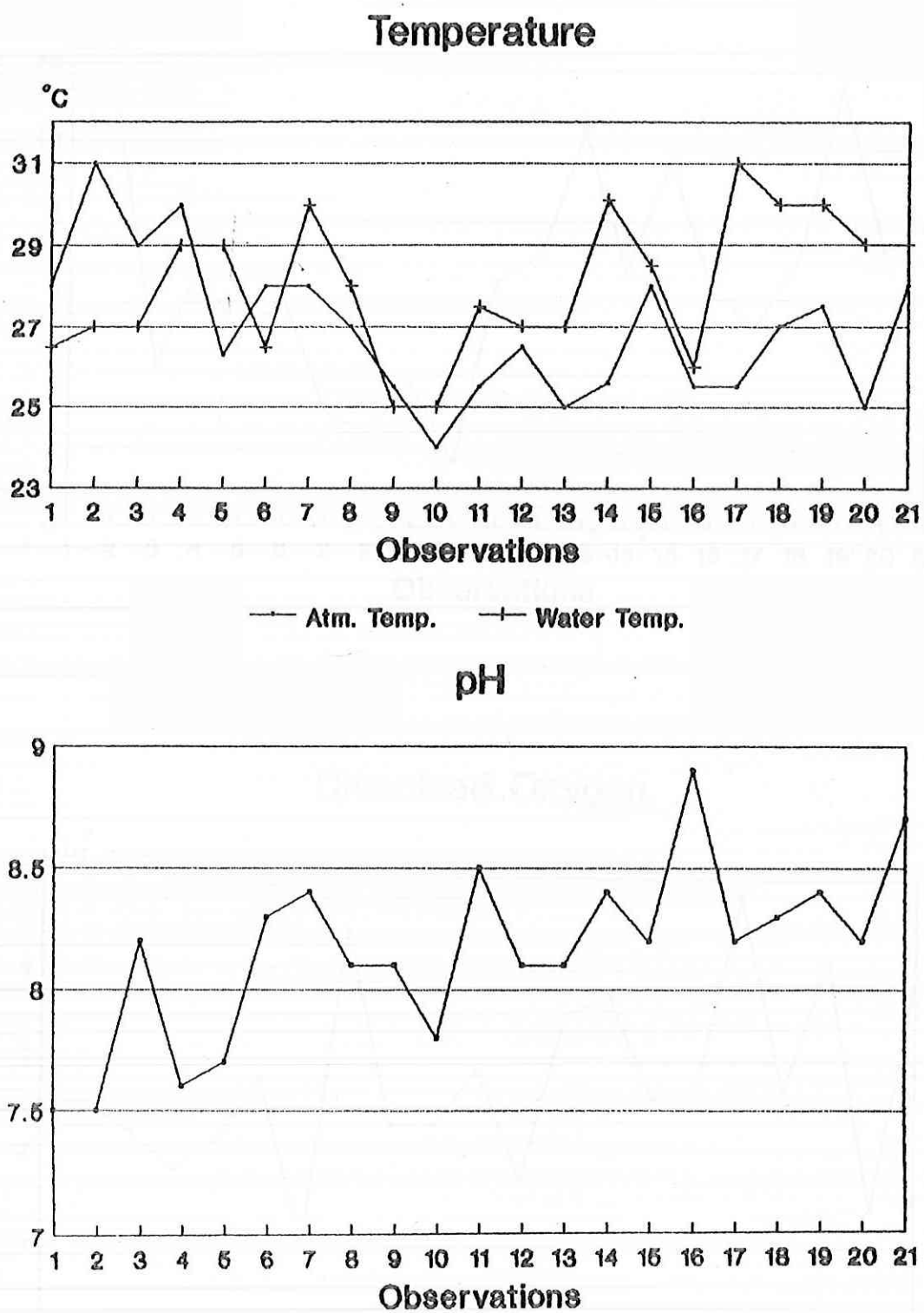
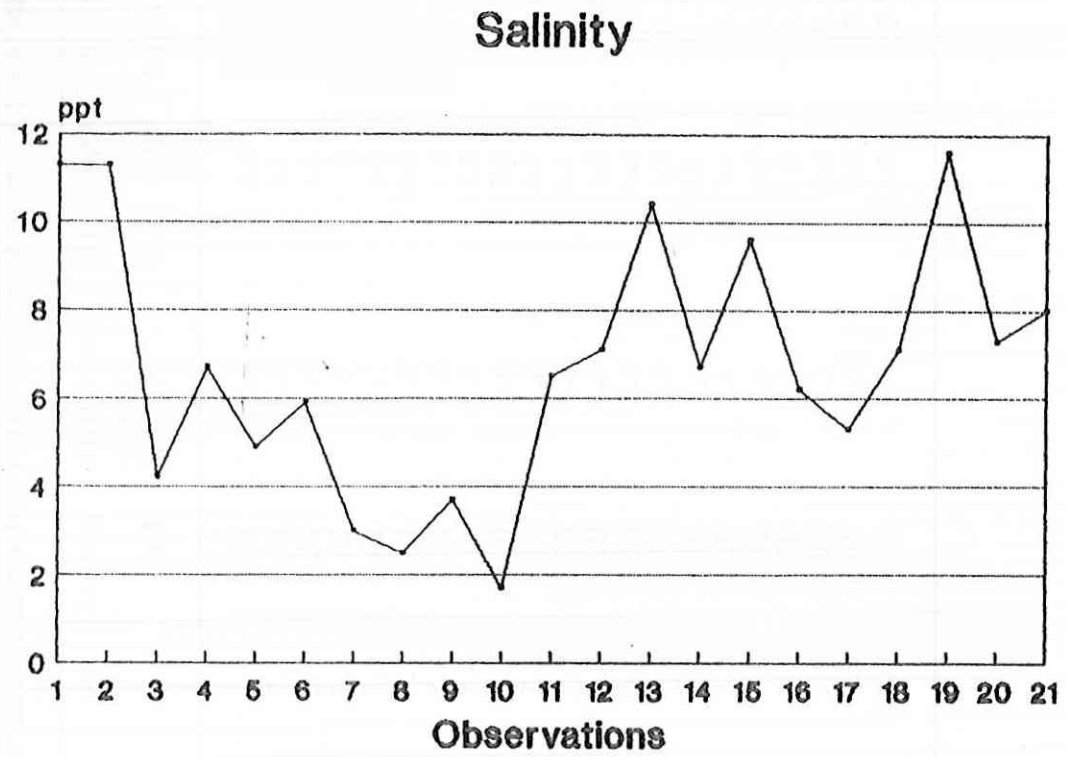


Fig. 7. Changes in Salinity and Dissolved oxygen at Station II.



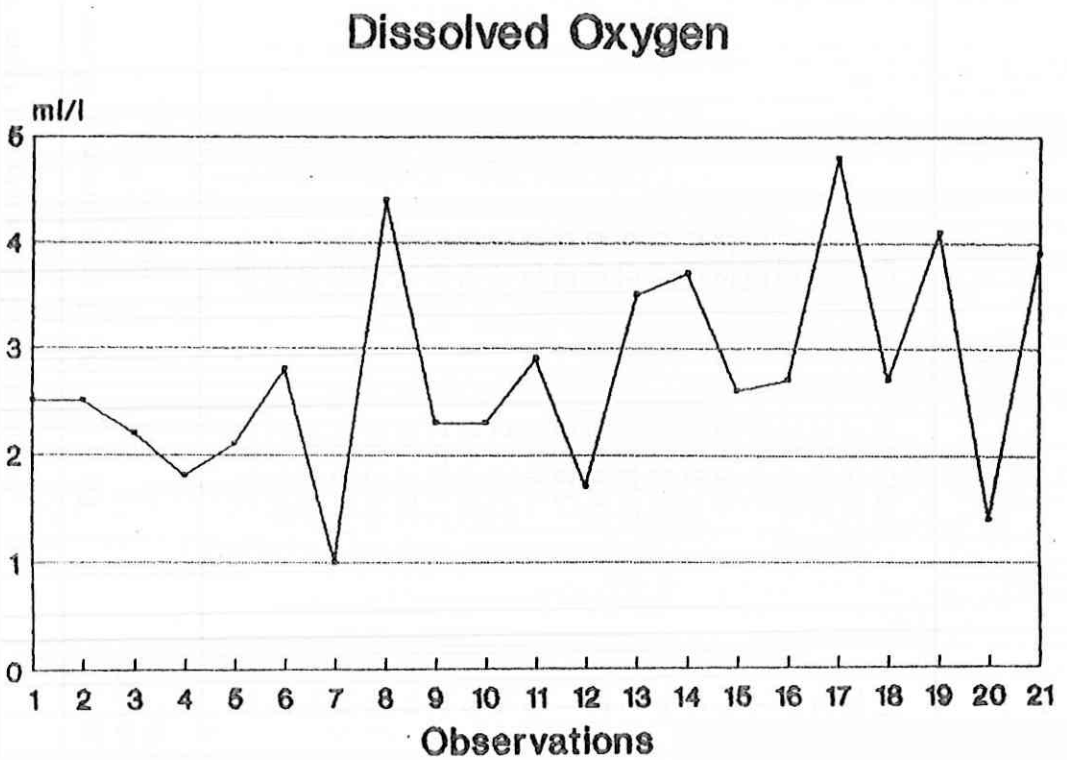


Table 3. Values observed from water sa mples for various hydrographical parameters at station. 1

Observation No.	Date	At. Temperature (°C)	Water temperature (°C)	pH	Salinity (‰)	Dissolved oxygen (ml/l)	Phosphate (ug at/l)	Nitrate (ug at/l)	Silicate (ug at/l)
1.	7.6.92	28.0	26.0	7.5	3.35	3.6	6.0	0.02	10.0
2.	25.6.92	28.5	26.5	7.5	0.35	3.6	6.1	0.02	10.2
3.	30.6.92	27.5	27.0	8.3	0.26	4.7	4.8	2.28	38.8
4.	4.7.92	26.0	27.0	7.6	1.60	1.0	11.2	0.10	59.5
5.	14.7.92	27.0	29.0	7.2	0.63	3.1	6.8	0.25	70.9
6.	18.7.92	26.5	26.5	7.8	0.44	1.0	16.0	0.16	70.9
7.	21.7.92	26.0	26.0	7.8	0.30	1.6	7.8	0.76	78.3
8.	25.7.92	27.5	27.0	7.4	0.30	3.5	7.2	0.51	109.6
9.	27.7.92	25.0	25.6	7.2	0.30	3.6	12.6	0.41	31.5
10.	1.8.92	25.5	27.5	7.3	0.11	1.6	6.1	2.80	71.2
11.	5.8.92	25.5	27.5	7.9	0.23	1.5	6.1	2.37	70.2
12.	14.8.92	27.0	27.5	8.0	0.20	8.0	5.3	1.83	52.4
13.	20.8.92	27.5	26.0	8.1	0.35	1.0	4.2	0.15	43.9
14.	22.8.92	27.0	26.0	7.8	0.35	2.3	5.9	1.53	39.0
15.	27.8.92	28.0	28.5	7.7	1.10	3.6	12.0	1.56	45.1
16.	4.9.92	25.5	26.0	8.3	0.30	2.6	5.1	1.11	54.5
17.	7.9.92	25.0	26.0	7.6	0.10	3.6	5.7	1.20	53.2
18.	17.9.92	27.0	28.0	7.5	2.70	1.3	4.9	1.50	90.8
19.	22.9.92	27.0	29.0	7.9	4.00	3.3	3.8	3.01	93.9
20.	24.9.92	27.0	29.0	7.9	2.40	5.0	3.9	3.87	110.9
21.	30.9.92	26.0	27.0	8.2	2.90	2.4	11.2	2.50	91.8

Comparatively higher values were recorded in September in station 1. The values recorded in station 2 did not show high fluctuations, values remaining comparatively low. The minimum of 30.3 /ug at/l was recorded in the fourth week of July and the maximum of 98.7 /ug at/l during the fourth week of September (Figure 9). The readings steadily increased from June first week and attained a value of 98.8 /ug at/l during the third week of July and a sudden decline was recorded in the fourth week of July. The values increased steadily from August onwards in station 2 (Table 4).

2. Meteorological parameters:

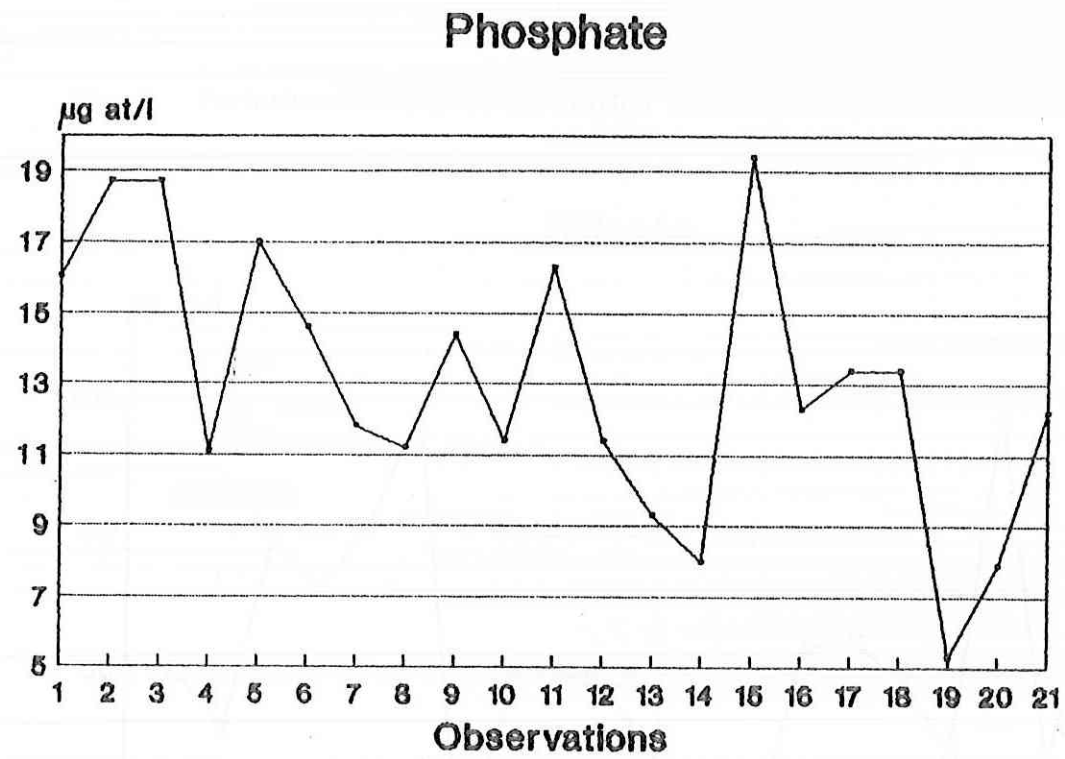
1. Depth of water:

The water depth ranged between 0.28 m and 0.95 m in station 1 and maximum water depth was recorded in the last week of July. The minimum value occurred in the last week of August. In station 2, depth on all observed days was higher. Maximum depth of 0.95 m was recorded in September fourth week (Table 1 & 2).

2. Rain fall:

Rain fall data obtained from Meteorological Department showed that a total of 2409 mm rainfall occurred during June to September. Maximum of 84 mm of rain occurred during the last week of June. Monsoon got reduced in July but the first week of August it got intensified further.

Fig. 8. Fluctuations in Phosphate and Nitrate at Station II.



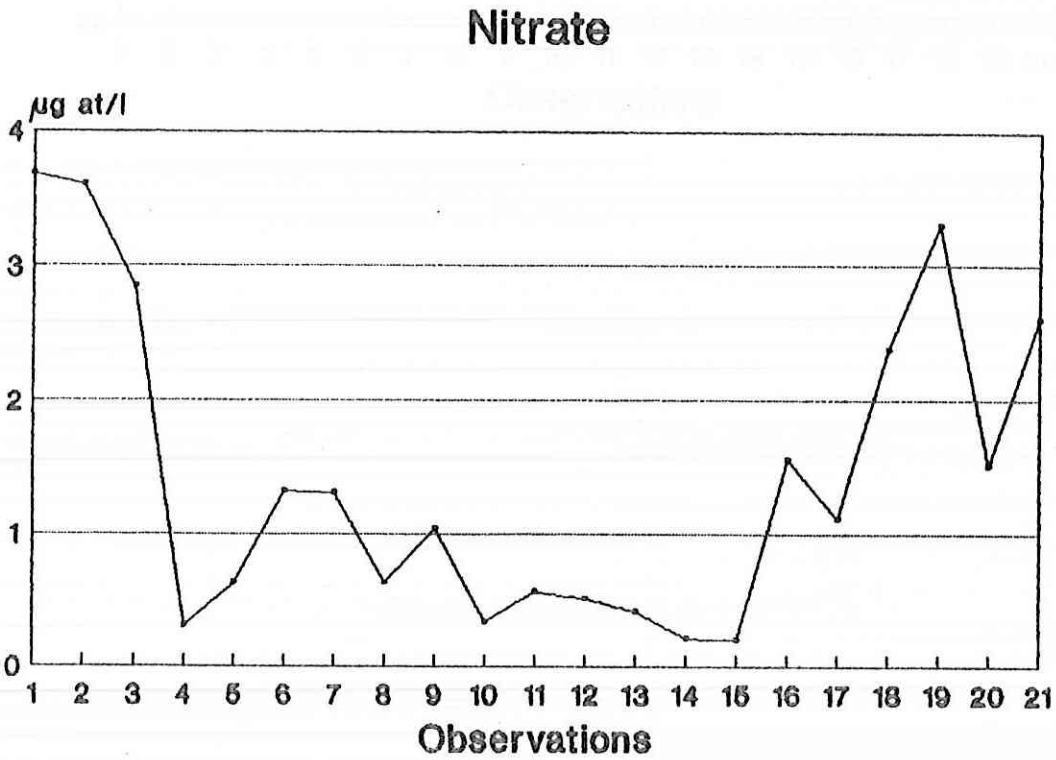


Fig. 9. Variations in silicate at station II.

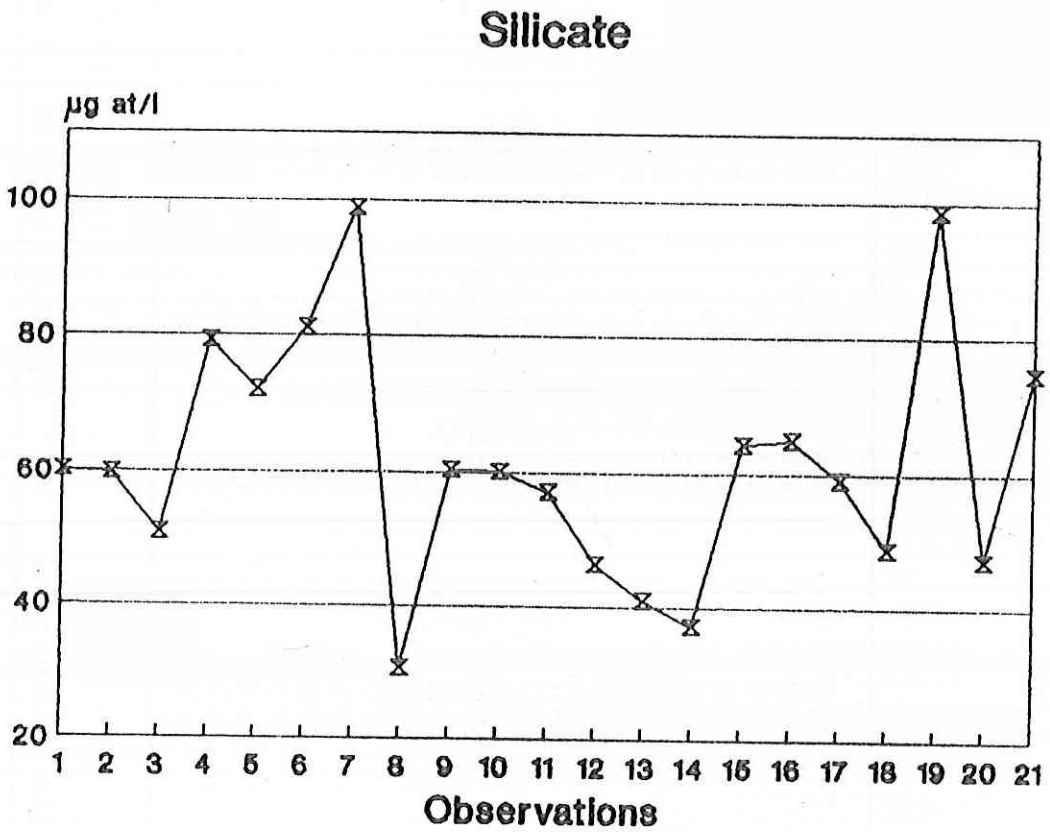


Table 4. **Values observed from water samples for various hydrological parameters at station. 2**

Observation No.	Date	At. Temperature (°C)	Water temperature (°C)	pH	Salinity (‰)	Dissolved oxygen (ml/l)	Phosphate (µg at/l)	Nitrate (ug at/l)	Silicate (ug at/l)
1.	7.6.92	28.0	26.5	7.5	11.3	2.5	16.0	3.68	60.0
2.	25.6.92	31.0	27.0	7.5	11.3	2.5	18.7	3.60	59.7
3.	30.6.92	29.0	27.0	8.2	4.2	2.2	18.7	2.85	50.7
4.	4.7.92	30.0	29.0	7.6	6.7	1.8	11.1	0.30	79.3
5.	14.7.92	26.3	29.0	7.7	4.9	2.1	17.0	0.62	72.1
6.	18.7.92	28.0	26.5	8.3	5.9	2.8	14.6	1.32	81.1
7.	21.7.92	28.0	30.0	8.4	3.0	1.0	11.8	1.32	98.8
8.	25.7.92	27.0	28.0	8.1	2.5	4.4	11.2	0.63	30.3
9.	27.7.92	25.0	25.0	8.1	3.7	2.3	14.4	1.04	60.3
10.	1.8.92	24.0	25.0	7.8	1.7	2.3	11.4	0.38	60.1
11.	5.8.92	25.5	27.5	8.5	6.5	1.9	16.3	0.56	57.0
12.	14.8.92	26.5	27.0	8.1	7.1	1.7	11.4	0.51	46.2
13.	20.8.92	25.0	27.0	8.1	10.4	3.5	9.3	0.41	40.8
14.	22.8.92	25.6	30.1	8.4	6.7	3.7	8.0	0.21	37.1
15.	27.8.92	28.0	28.5	8.2	9.6	2.6	19.4	0.20	69.3
16.	4.9.92	25.5	26.0	8.9	6.2	2.7	12.3	1.56	65.0
17.	7.9.92	25.5	31.0	8.2	5.3	4.8	13.4	1.11	59.0
18.	17.9.92	27.0	30.0	8.3	7.1	2.7	13.4	2.38	48.6
19.	22.9.92	27.5	30.0	8.4	11.6	4.1	5.3	3.30	98.7
20.	24.9.92	25.0	29.0	8.2	7.3	1.4	7.9	1.51	47.0
21.	30.9.92	28.0	29.0	8.7	8.0	3.9	12.2	2.68	74.7

3. Tide height:

The values obtained showed that tide height was normal and below 1m.

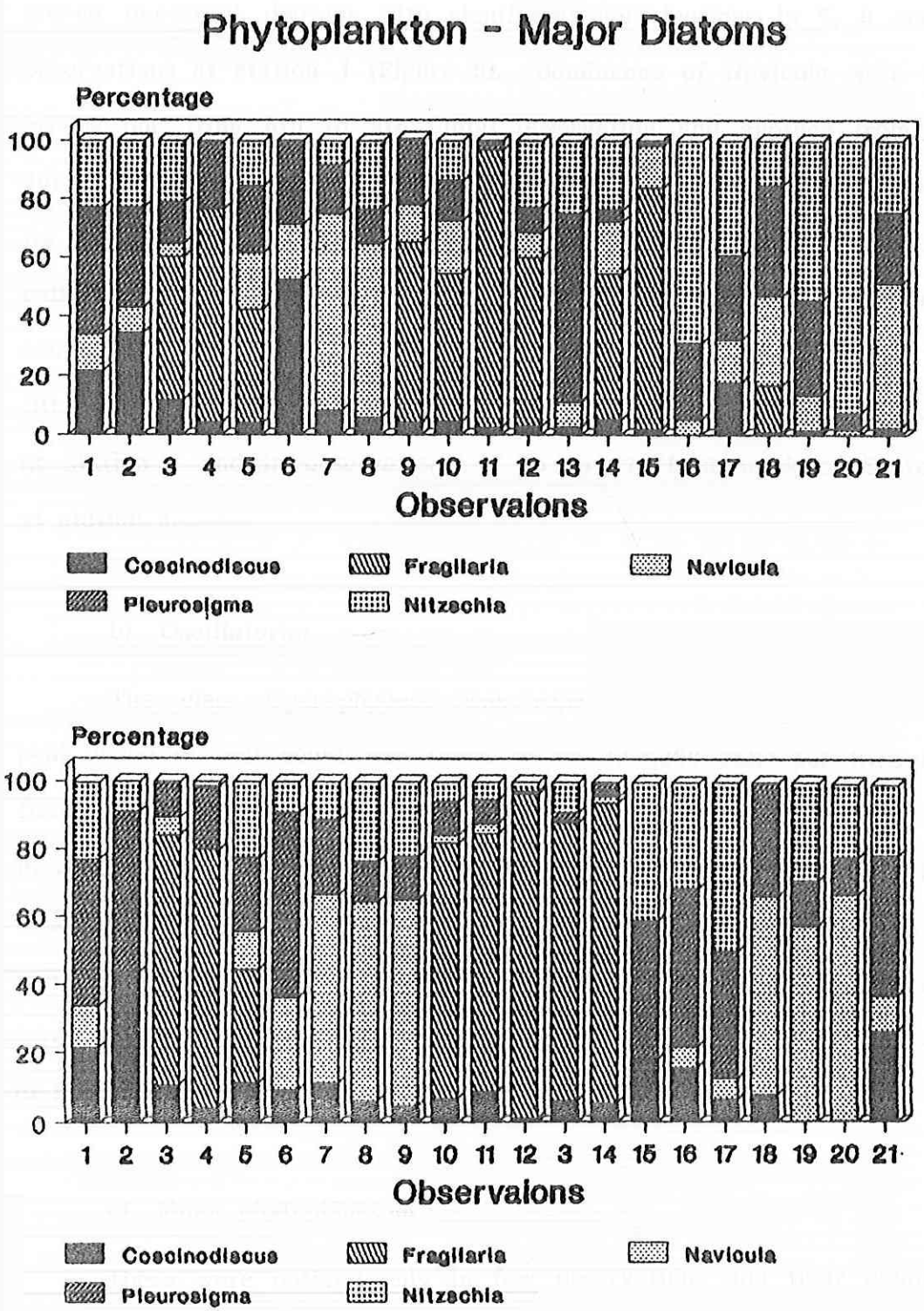
3. Biological Parameters

1. Phytoplankton:

a) Major Diatoms:

The cell count per litre for all the phytoplankton groups are given in Tables 5 and 6 and the percentage composition of the major diatoms are illustrated in Figure 9. Diatoms were the most important phytoplankton observed at both the stations. They are constituted by 5 genera : Coscinodiscus, Fragilaria, Navicula, Pleurosigma and Nitzschia. The cells/litre for Coscinodiscus ranged from 20 to 20,210 at station 1 (Table 5). and from 2000 to 80 at station 2 (Table 6). Among the major diatoms the occurrence of Coscinodiscus was low during most of the observations with an exception in the observation 6 (middle week of July) when it found 52%. A similar pattern was also observed in station 2 with maximum contribution in observation 2 (last week of June) (Figure 9). The cell count of Fragilaria ranged from 60 to 6210 at station 1 and from 412 to 82,700 at station 2. The maximum count of Fragilaria at both the stations were observed in the last week of August. Fragilaria at station 1 was maximum in observation 11 (94%) and observation 15 (81%) Fragilaria was the dominant diatom in observation 3 and 4 (first week of July) and continuously from observations 10 to 14 (August) (33 to 95%). The cell count of Navicula ranged from 20 to 36,400 at station 1 and from

Fig. 10. Percentage occurrence of the major diatoms at Station I (above) and Station II (below)



40 to 14,400 at station 2 (Tables 5 & 6). the peak values were observed in the last week of September. Navicula formed only a minor component among important diatoms with significant contributions in 7, 8 and 21st observations at station 1 (Figure 9). dominance of Navicula were in two groups one from 6th to 9th (July) observation and another from 18 to 20th observation (September). the peak count of 32,000 cells per litre for Pleurosigma was observed in September last at station 1 and 50,000 cells per litre in the middle week of September at both the station with counts of 18,200 and 72,500 cells/litre at stations 1 and 2 respectively. Nitzschia formed the dominant diatom in observations 16 and 20 (September) at station 1 and in observations 15 to to 17 (first week of September) at station 2.

b) Oscillatoria:

The class Cyanophyceae was represented by Oscillatoria. The peak value of cell count was found to be 3,66,300 cells per litre in the first week of September in station 1 and 25,500 in the last week of August in Station 2. The variations in Oscillatoria at the two stations followed a similar pattern. The percentage were low upto observations 14 and maximum percentages were recorded in observations 16 (first week of September) at station 1 and observation 15 and 20 (first and last week of September) at station 2.

c) Minor phytoplankton:

These were noticed only in few observations and their count was found to be comparatively low. The groups were dinoflagellates (Peridinium

Fig. 11. Fluctuations in the occurrence of Cyanophyceae (Oscillatoria) at Station I (above) and Station II (below)

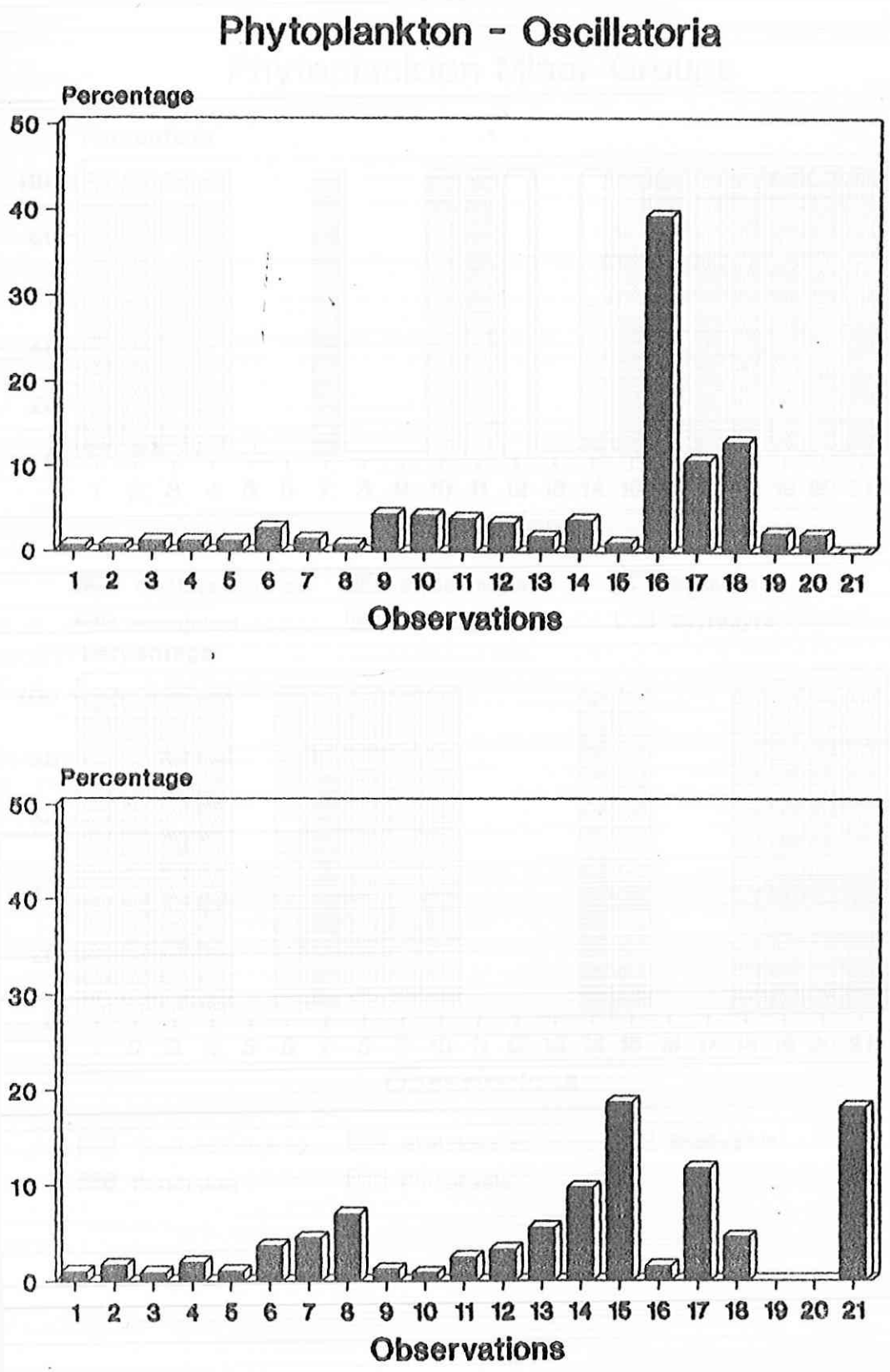


Fig. 12. The composition of minor phytoplankton groups at Station I (above) and Station II (below)

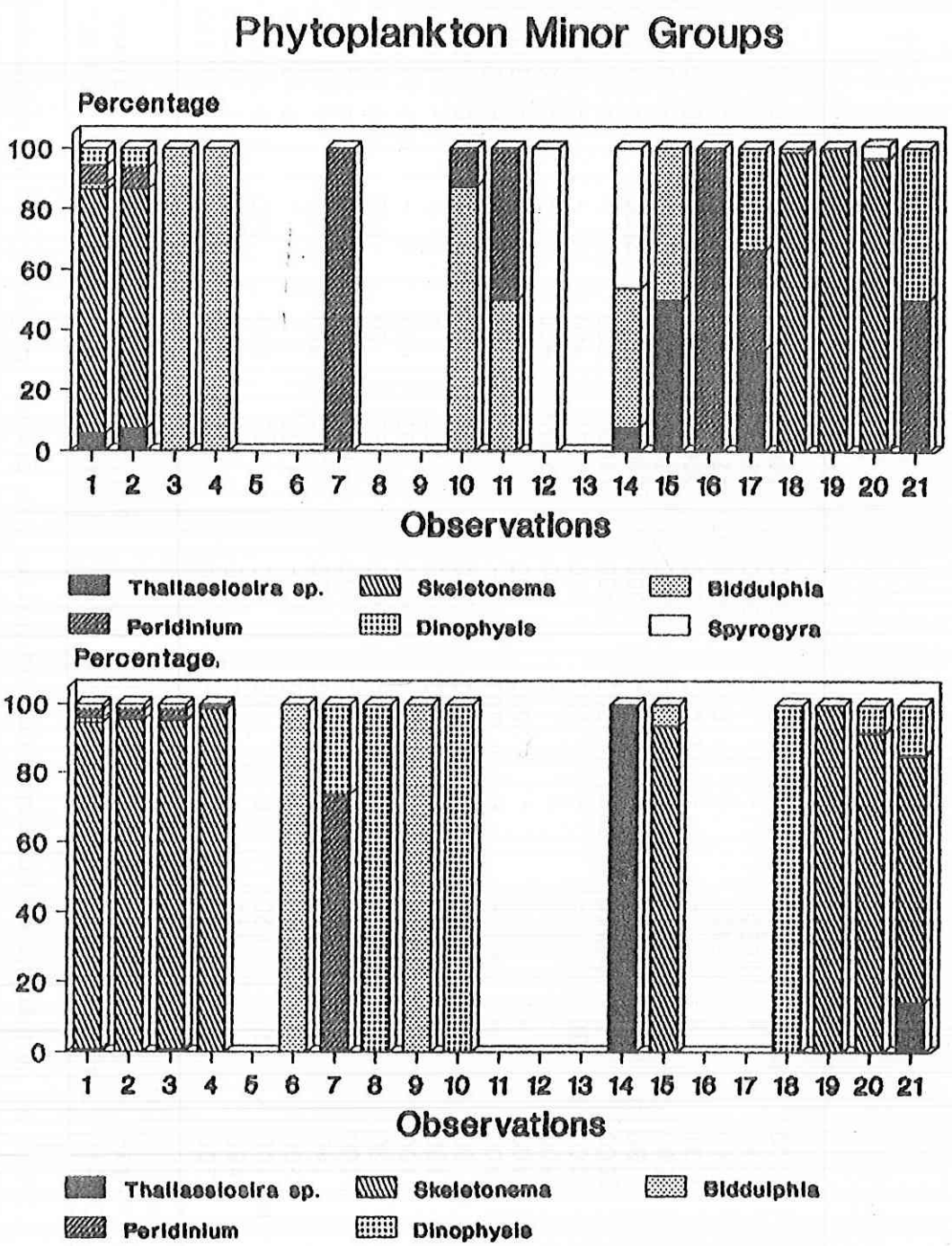


Table 5. Variations of phytoplankton (Number/m^3) at station 2. From June to September 1992

Observations	Date	Coscinodiscus	Thalassiosira	Skeletonema	Biddulphia	Fragilaria	Navicula	Pleurosigma	Nitzschia	Peridinium	Dinophysis	Oscillatoria	Spyrogyra	Total count/l
1.	7.6.92	208	82	11720	160	-	120	220	120	302	201	11102	-	24535
2.	25.6.92	480	-	11540	-	-	120	480	320	310	211	19340	-	32801
3.	30.6.92	100100	91	11620	40	412	40	120	180	360	210	9421	-	22594
4.	4.7.92	200	-	13600	100	3400	-	1100	-	-	80	21100	-	34580
5.	14.7.92	140	-	-	-	1400	700	840	560	-	-	11200	-	16765
6.	18.7.92	1100	-	-	100	-	400	600	-	-	-	40850	-	43050
7.	21.7.92	80	-	-	-	-	640	160	80	448	160	49600	-	51168
8.	23.7.92	100	-	-	-	-	1000	200	400	-	625	77000	-	79325
9.	27.7.92	120	-	-	240	1680	360	600	-	-	-	13800	-	79825
10.	1.8.92	80	-	-	-	880	320	240	240	-	400	8800	-	16800
11.	5.8.92	400	-	-	-	15200	-	500	-	-	-	26600	-	10960
12.	14.8.92	100	-	-	-	2000	300	300	800	-	-	35500	-	42700
13.	20.8.92	100	-	-	-	-	300	2300	900	-	-	61100	-	39000
14.	22.8.92	100	180	-	-	1000	360	80	480	-	-	106440	-	64700
15.	27.9.92	2000	-	18500	1200	82700	14400	1000	800	-	-	205500	-	110640
16.	4.9.92	80	-	-	-	-	5000	25000	67000	2000	-	17000	-	177300
17.	7.9.92	2000	-	-	-	-	1600	3200	4400	-	-	130000	-	116000
18.	17.9.92	1021	-	-	-	21000	4000	50000	20000	-	3000	500000	-	139200
19.	22.9.92	1060	-	113900	-	1005	16000	42500	72500	-	-	-	-	1279500
20.	24.9.92	1062	-	70250	-	-	12000	38500	64521	302	6021	-	-	199687
21.	30.9.92	1000	8000	25000	-	-	20000	10000	10000	201	5000	200000	-	264000

Table 5. **Variations of phytoplankton (Number/m^3) at station 1. from June to September 1992**

Observations	Date	Coscinodiscus	Thalassiosira	Skeletonema	Biddulphia	Fragilaria	Navicula	Pleurosigma	Nitzschia	Peridinium	Dinophysis	Oscillatoria	Spyrogyra	Total count/l
1.	7.6.92	190	100	1460	40	-	-	1320	240	160	102	7000	-	10588
2.	25.6.92.	1000	200	1100	-	-	-	1100	200	100	-	7500	-	11090
3.	30.6.92	66	-	-	33	466	33	66	-	-	-	11830	-	12820
4.	4.7.92	100	-	-	33	1900	-	466	33	-	-	11830	-	14365
5.	14.7.92	20	-	-	-	60	20	40	40	-	-	11800	-	11980
6.	18.7.92	20	-	-	-	-	60	120	20	-	-	26200	-	26420
7.	21.7.92	20	-	-	-	-	100	40	20	100	-	14400	-	14680
8.	23.7.92	-	-	-	-	-	160	120	4100	-	-	7840	-	122200
9.	27.7.92	100	-	-	-	-	-	500	300	-	-	41500	-	42400
10.	1.8.92	340	-	-	140	4000	136	510	310	20	-	40000	-	45456
11.	5.8.92	520	-	-	80	4600	180	420	300	80	-	36620	-	42800
12.	14.8.92	40	-	-	-	1120	-	40	-	-	-	32200	-	36400
13.	20.8.92	80	-	-	-	6210	-	40	-	-	-	17000	-	18360
14.	22.8.92	360	20	-	120	-	120	300	-	-	-	35110	-	42380
15.	27.9.92	40	20	-	-	-	-	90	90	20	-	10400	120	15980
16.	4.9.92	3700	-	-	-	-	1480	11100	7400	1021	-	366300	-	404321
17.	7.9.92	1021	1000	-	-	-	1000	6050	8100	082	1000	101000	-	120153
18.	17.9.92	920	-	8050	-	-	7000	4000	-	-	120	121000	-	154040
19.	22.9.92	-	-	60200	-	-	36400	8400	18200	-	-	21000	-	169400
20.	24.9.92	80	40	40201	-	-	25210	4100	8340	-	120	20000	18000	19891
21.	30.9.92	20210	-	-	-	-	8000	32000	16000	10000	-	-	-	114210

and Dinophysis) Chlorophyceae (Spyrogyra) and diatoms (Thallasiossira, Skeletonema and Biddulphia). Thallasiossira and Skeletonema were represented in the months of June and September only. While the other groups showed sporadic occurrance. In terms of percentage contributions the major genera at station 1 were Skeletonema, Biddulphia and Peridinium. At station 2, the major genera were skeletonima Biddulphia and Dinophysis. The green alga Spyrogyra was noticed only in station 1, in few observations.

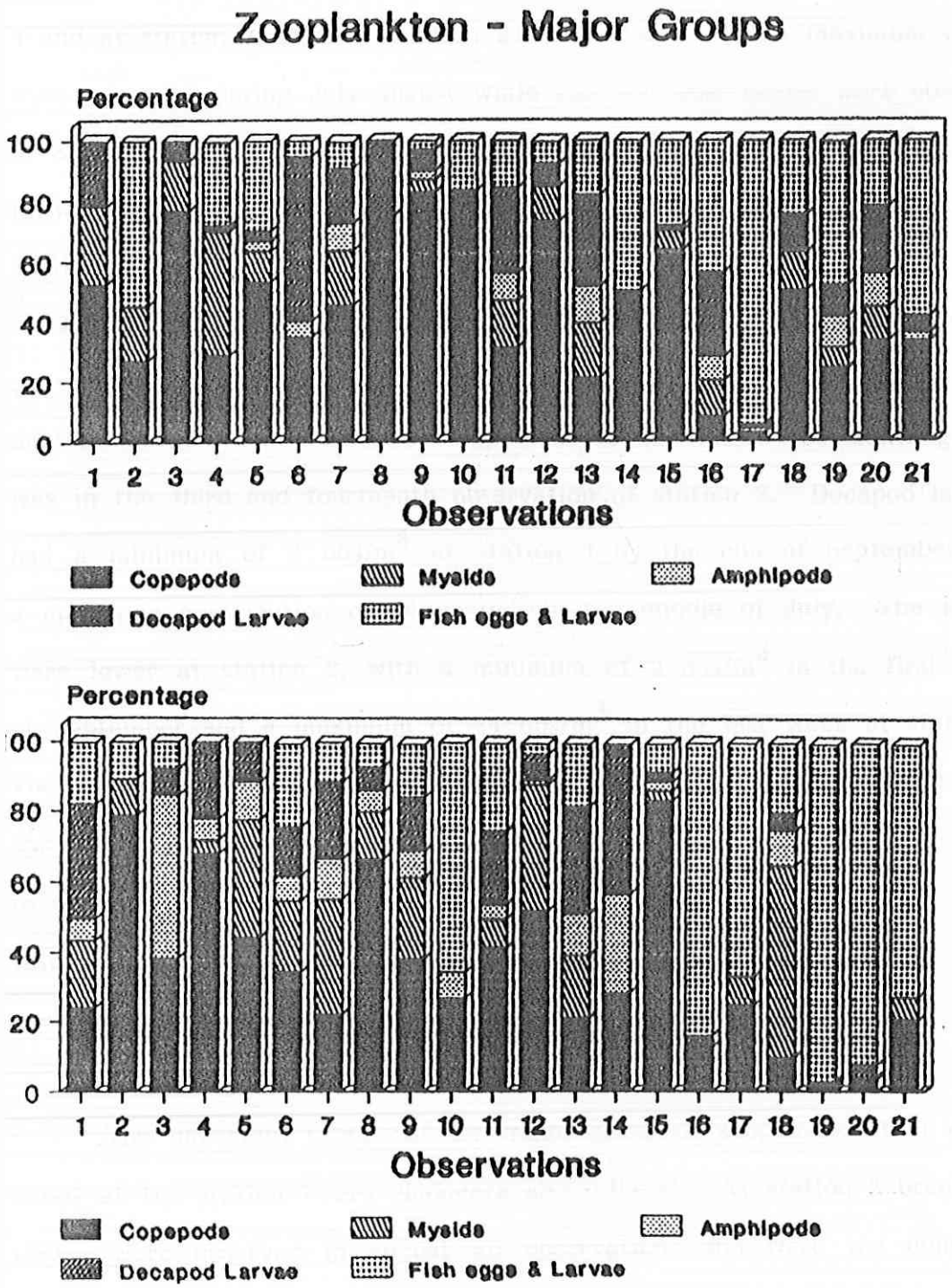
2. Zooplankton

Based on abundace and the total number of zooplankton 2 groups were recognised. The major groups existed are copepods mysids, amphipods, decapod larvae and fish eggs and larvae. Cladocera, tanaids, brachyuran larvae were treated as minor group. Zooplankters which were rare and in very small quantity such as polychaete, lucifers, water insects etc. were included in the category 'others'. The numbers of zooplankton/m^3 at station 1 and 2 are given in the Tables 7 & 8 and the percetage composition of the major and minor groups are showed in figures 12 and 13.

a) Major zooplankton groups:

Copepods were the most abudant zooplakton in terms of both number and percentage frequency of occurrence. It showed a minimum of 4 nos/m^3 in the first week of September to a maximum of 160 nos/m^3 in the last week of July at station 1 similarly in station 2, a low value of 4 nos/m^3 and high of 446 nos/m^3 in the last week of August was recorded. Except on two occasions copepods formed more than 20% of the major zooplankton forms at station 1. An identical trend was also

Fig. 13. Percentage groups of major groups of Zooplankton at Station I (above) and Station II (below).



observed at station 2 with copepods more than 60% of total major groups in some observations. Mysids had a range of 2 to 76 nos/m^3 at station 1 and at station 2, it was between 2 and 48 nos/m^3. The maximum values were recorded during July-August while the minimum values were observed in September. The percentage contribution of mysids to over all major forms was low at both stations. Amphipods showed a peak of 14 nos/m^3 in the last week of August and a minimum of 2 nos/m^3 in the last week of July at station 1. At station 2, the minimum and maximum values and month of its occurrence were identical to those of station 1. The only substantial contribution of amphipods to the major zooplanktn groups was in the third and fourteenth observation of station 2. Decapod larvae, had a minimum of 4 nos/m^3 at station 1 by the end of September and a maximum contribution of 84 nos/m^3 in the middle of July. The values were lower at station 2, with a minimum of 2 nos/m^3 in the first week of September and a maximum of 24 nos/m^3 in the last week at station 2. The percentage occurrence of decapod larvae at both stations were poor and its occurrence were erratic. Fish eggs and larvae varied from 2 nos/m^3 to 630 nos/m^3. The peak values observed in September while the minimum values were recorded in April. They formed a major component of the abundant zooplankton at both stations.

The important groups of the minor group of zooplankton that dominated at the station 1were cladocera and 'others'. At station 2 brachyura larvae were observed in almost all observations and were the dominant group.

Fig. 14. Variations in the different minor zooplankton groups at Station I (above) and Station II (below)

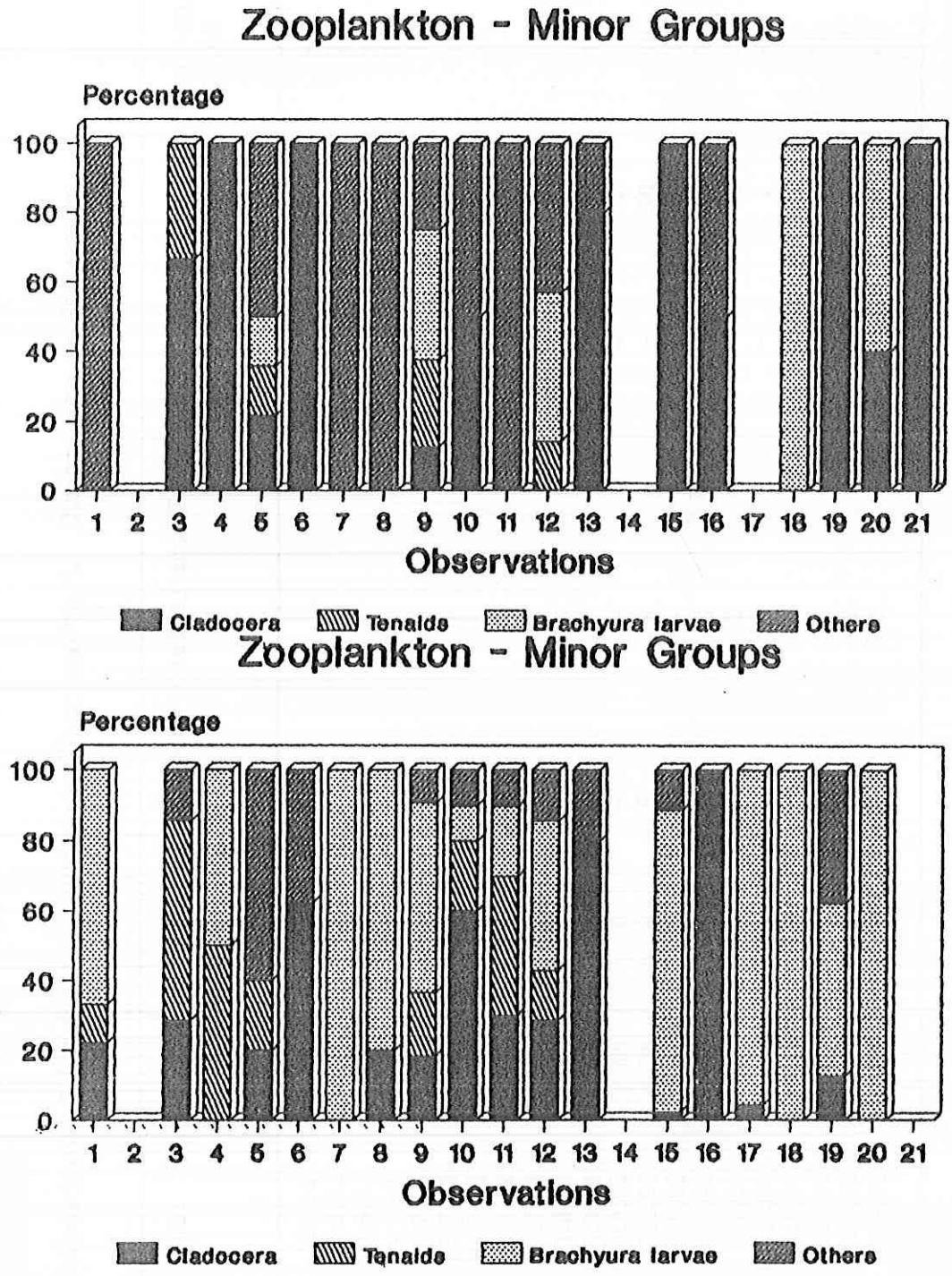


Table 7. **Variations of Zooplankton (Numbers/m^3) at station 1. During June to September**

Observations	Date	Copepods	Mysids	Amphipods	Cladoecrans	Tanaids	Brachyuran Larvae	Decapod Larvae	Fish eggs Larvae	Others	Total number m^3
1.	7.6.92	58	28	-	-	-	-	24	-	4	114
2.	25.6.92	12	8	-	-	-	-	-	24	-	44
3.	30.6.92	92	20	-	4	2	-	-	-	-	126
4.	4.7.92	54	76	2	4	-	4	2	52	-	190
5.	14.7.92	32	6	2	6	4	-	2	18	14	88
6.	18.7.92	54	6	8	2	-	-	84	8	-	156
7.	21.7.92	10	-	2	-	-	-	4	2	2	24
8.	25.7.92	6	4	-	-	-	6	2	-	12	20
9.	27.7.92	116	6	4	2	4	-	10	4	4	156
10.	1.8.92	10	-	-	6	-	-	-	2	6	24
11.	5.8.92	20	10	6	-	-	6	18	10	2	66
12.	14.8.92	38	6	-	-	2	-	4	4	6	66
13.	20.8.92	14	12	8	8	-	-	20	12	2	76
14.	22.8.92	16	-	-	-	-	-	-	16	-	32
15	27.8.92	80	8	-	8	-	-	2	36	-	134
16.	4.9.92	4	6	4	2	-	-	14	22	2	44
17.	7.9.92	4	-	2	-	-	-	2	140	-	148
18.	17.9.92	16	4	-	-	-	2	4	8	-	34
19.	22.9.92	14	4	6	2	-	-	6	28	-	60
20.	24.9.92	6	2	2	2	-	4	4	4	-	24
21.	30.9.92	24	-	2	12	-	-	4	42	-	84

Table 8. **Variations of Zooplankton (Numbers/m^3) at station 2. During June to September.**

Observations	Date	Copepods	Mysids	Amphipods	Caldoecrans	Tanaids	Brachyuran Larvae	Decapod Larvae	Fish eggs Larvae	Others	Total number m^3
1.	7.6.92	15	12	4	2	1	6	20	11	-	71
2.	25.6.92	30	4	-	-	-	-	-	4	-	38
3.	30.6.92	10	-	12	4	8	-	2	2	2	40
4.	4.7.92	68	4	6	4	4	-	22	-	-	108
5.	14.7.92	24	18	6	2	2	-	6	-	6	64
6.	18.7.92	40	24	8	-	20	-	16	28	12	148
7.	21.7.92	4	6	2	-	-	2	4	2	-	20
8.	21.7.95	20	4	2	2	-	8	2	2	-	40
9.	27.7.92	10	6	2	2	2	6	4	4	1	37
10.	1.8.92	14	-	4	12	4	2	-	34	2	72
11.	5.8.92	20	4	2	6	8	4	10	12	2	66
12.	14.8.92	70	48	2	4	2	6	10	4	2	148
13.	20.8.92	14	12	8	8	-	-	20	12	2	76
14.	22.8.92	4	-	4	-	-	-	6	-	-	14
15.	27.8.92	446	16	14	2	-	79	14	44	10	625
16.	4.4.92	8	-	-	2	-	-	2	52	-	64
17.	7.9.92	6	2	-	2	-	46	-	16	-	72
18.	17.9.92	4	22	4	-	-	4	2	8	-	44
19.	22.9.92	6	4	2	2	-	8	8	618	6	652
20.	24.9.92	26	4	-	-	-	4	24	630	-	688
21.	30.9.92	24	8	-	-	-	-	-	84	-	116

Among the decapod larvae and fish larvae many species and groups of both cultivable and non-cultivable, forms of finfishes and shell fishes were noticed. The fish larvae and fingerlings which are collected along with the zooplankton include, Elops sp., Ambassis sp., Megalops sp., Terapon sp. etc. and both penaeid and non-penaeid prawns including Penaeus indicus, Penaeus monodon, Metapenaeus dobsoni, Acetus indicus and Macrobrachium species.

4. Statistical Analysis

Equality of the mean values of the hydrographic parameters observed in the two stations was tested statistically by applying students 't' test. The results indicated that the mean atmospheric temperature did not differ significantly in the two stations ($t = 0,6299$, $p > 0.53$). But the mean water temperature is found to differ significantly between the two stations ($t = 2.067$, $P < 0.05$) mean salinity value in the two stations differed significantly ($t = 8.54$, $p = 0.0000$). Dissolved oxygen on the other hand did not show significat difference in the mean values in the two stations ($t = 0.4484$, $p > 0.65$). Among the nutrients, phosphate differed significantly.

Table 10 & 11 give the means ad standard deviations of counts of major groups of phytoplankters and zooplakters in the stations observed. It could be observed that the major groups of phytoplankton exhibit wide variations in their occurrence in both the stations. 't' test was applied to ascertain the equality of mean counts of major groups of phytoplankton in the two stations after subjecting the data to logarithmic transformation.

Table. 9 a). Correlation of matereologial parameters on major phytoplankton groups (Station 1 & 2)

Name of group	Water flow	Rainfall
Coscinodiscus	0.167	-0.145
Skeletonema	0.012	-0.025
Biddulphia	-0.057	-0.011
Fragilaria	-0.172	-0.126
Navicula	-0.027	-0.148
Pleurosigma	-0.065	-0.181
Nitzschia	-0.063	-0.115
Peridinium	0.178	-0.119
Oscillatoria	-0.154	-0.228

Table. 9.b) Correlation of matereological parameters on major zooplankton groups (Station 1 & 2)

Name of group	Water flow	Rainfall
Copepods	-0.061	-0.062
Mysids	-0.175	-0.082
Amphipods	0.081	0.053
Decapod larvae	0.119	-0.046
Fish eggs & larvae	-0.049	-0.034

Table. 10 . Summary statistics of observations on phytoplankton

	Station 1		Station 2	
Name of group	Mean	SD	Mean	SD
Coscinodiscus	1372.7	4393.4	549.1	622.5
Skeletonema	5286.2	15364.7	13149.0	28138.2
Biddulphia	21.2	41.7	87.6	263.0
Fragilaria	1083.6	1943.1	622.7	18332.3
Navicula	3804.7	9414.9	3698.1	6190.1
Pleurosigma	3372.5	7253.7	8474.3	15853.8
Nitzschia	3039.7	5471.3	11585.8	24095.4
Peridinium	591.9	2175.9	186.8	442.5
Oscillatoria	44787.1	79543.9	73540.6	114965.5

Table. 11. Summary statistics of observations on Zooplankton

	Station 1		Station 2	
Name of group	Mean	SD	Mean	SD
Copepods	32.4	31.9	41.4	94.6
Mysids	9.5	16.8	9.4	11.4
Amphipods	2.3	2.7	3.9	3.9
Decapod larvae	10.2	18.3	8.2	8.0
Fish eggs & larvae	20.6	31.1	74.6	183.9

The test indicated that only the group Navicula showed significant difference in the mean counts of the two stations. Similarly, 't' test applied on the mean counts of major groups of zooplankton in the two stations showed that none of the groups differed significantly in the two stations.

Tables 12 & 13 give the correlation coefficients betwee hydrographic parameters and major groups of phytoplankton and zooplakton respectively. It could be seen from the Table 13 that among the major groups of zooplankton, fish eggs ad larvae is havig significant correlation with salinity. Similarly, copepods and amphipods show high correlation with phosphate. From table it could be seen that among minor groups of phytoplankton, skeletonema does show significant correlation with salinity, nitrate and silicate. Only Fragilaria is found to have correlation with phosphate. A very high correlation is observed to exist between Navicula and nitrate and similarly between Navicula and silicate. Similarly, high correlation is found to exist between Pleurosigma and salinity and between Pleurosigma and nitrate. Among the remaining groups, Nitzchia is found to have significant correlation with salinity. Tables 9 give the correlation coefficient between major groups of phytoplankton and zooplankton with flow of water and rainfall. It could be seen that none of the coefficients is significant.

Indices of richness, evenness and diversity are given in Tables 14. A perusal of the indices on richness of phytoplankton groups in station 1 shows that comparatively higher values are obtained in the beginning of the study period in the month of June. Thereafter the indices show

Table. 12 . Correlations of ecological parameters on phytoplankton groups (stations 1 & 2)

	Salinity	DO2	Phosphate	Nitrate	Silicate
Coscinodiscus	-0.004	-0.044	0.035	0.156	0.191
Skeletonema	0.440*	0.106	-0.210	0.458**	0.350*
Biddulphia	0.250	-0.090	0.345	-0.108	0.013
Fragilaria	0.273	-0.036	0.348*	-0.140	-0.016
Navicula	0.263	0.175	-0.218	0.471**	0.463**
Pleurosigma	0.350*	-0.008	-0.077	0.344*	0.153
Nitzschia	0.368*	0.028	-0.144	0.299	0.193
Peridinium	-0.029	-0.068	0.040	0.178	0.195
Oscillatoria	0.144	0.044	0.070	0.034	0.167

* P <0.05 Significant ** P <0.01 Highly Significant

Table. 13 . Correlations of ecological parameters on zooplankton groups (stations 1 & 2)

	Copepods	Mysids	Amphipods	Decapod larvae	Fish eggs & larvae
At. temp.	0.179	0.041	0.091	-0.012	-0.127
Wt. temp.	0.027	-0.065	-0.030	-0.141	0.264
pH	-0.015	-0.052	0.125	-0.028	0.222
Salinity	0.167	0.055	0.224	0.004	0.341*
DO2	-0.001	-0.193	-0.280	-0.289	-0.009
Phosphate	0.339*	0.097	0.400**	0.141	-0.177
Nitrate	-0.238	-0.239	-0.148	-0.235	0.201
Silicate	-0.102	-0.206	0.050	-0.039	0.109

* P <0.05 Significant . ** P <0.01 Highly Significant

Table. 14 . Richness Diversity and Evenness Indices of Phytoplankton - Station 1

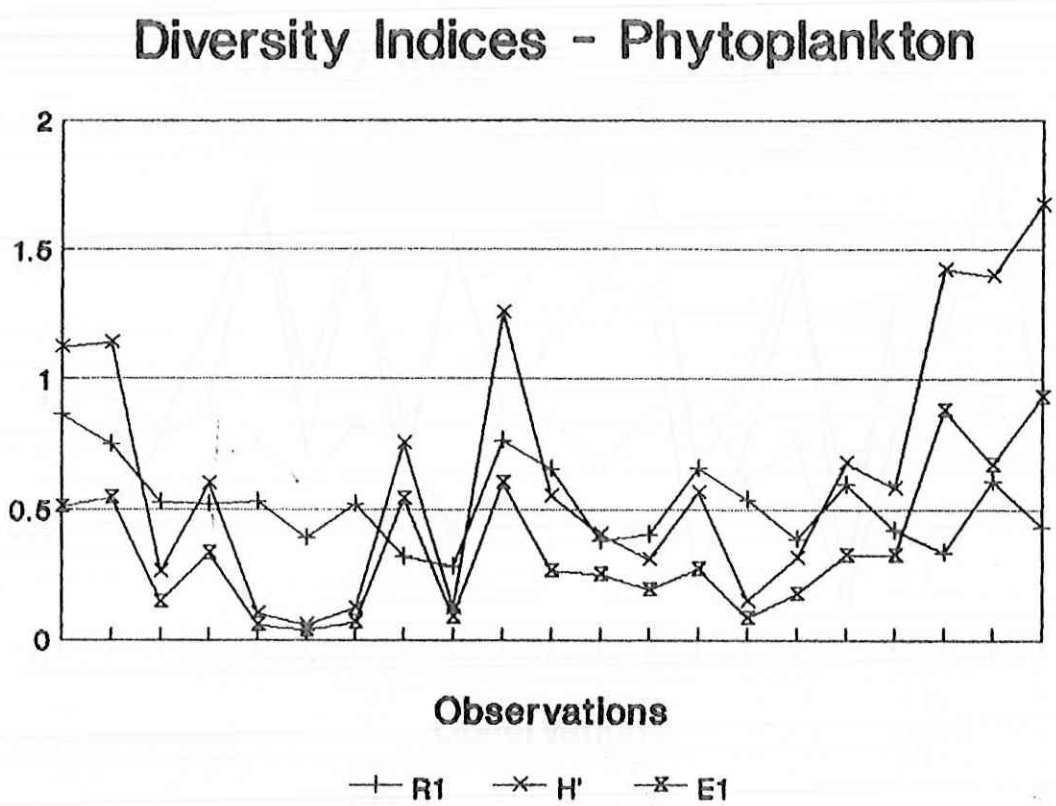
RICHNESS		DIVERSITY		EVENNESS				
R1	R2	K'	H'	E1	E2	E3	E4	E5
0.863	0.088	0.475	1.121	0.510	0.341	0.258	0.686	0.534
0.751	0.076	0.476	1.137	0.547	0.389	0.303	0.674	0.520
0.530	0.054	0.898	0.261	0.146	0.216	0.060	0.858	0.381
0.522	0.050	0.697	0.601	0.335	0.304	0.165	0.786	0.527
0.532	0.055	0.970	0.101	0.056	0.184	0.021	0.932	0.289
0.393	0.031	0.983	0.057	0.036	0.211	0.015	0.960	0.284
0.521	0.049	0.962	0.121	0.067	0.188	0.025	0.921	0.305
0.319	0.032	0.524	0.753	0.543	0.531	0.375	0.898	0.807
0.282	0.019	0.958	0.123	0.088	0.283	0.043	0.923	0.334
0.765	0.082	0.364	1.253	0.603	0.438	0.357	0.785	0.700
0.656	0.039	0.744	0.553	0.266	0.217	0.105	0.772	0.466
0.380	0.026	0.779	0.404	0.251	0.300	0.123	0.856	0.567
0.407	0.037	0.861	0.311	0.194	0.273	0.091	0.850	0.441
0.657	0.039	0.709	0.566	0.272	0.002	0.109	0.801	0.540
0.539	0.058	0.952	0.149	0.083	0.193	0.032	0.905	0.313
0.388	0.009	0.878	0.318	0.176	0.229	0.075	0.828	0.368
0.598	0.023	0.714	0.678	0.326	0.246	0.138	0.711	0.413
0.422	0.016	0.742	0.584	0.326	0.299	0.159	0.752	0.438
0.337	0.013	0.279	1.420	0.882	0.827	0.784	0.868	0.826
0.609	0.026	0.285	1.397	0.672	0.506	0.435	0.868	0.824
0.436	0.019	0.211	1.670	0.932	0.885	0.862	0.893	0.868

comparatively lower values. Again, in the first week of August, the values are once again higher but decrease thereafter with a tendency to increase towards the end of September. The trend is almost identical in station 2 also. Evenness index shows how equitably of various groups are present in the population. The table 14 shows the five indices worked out on evenness. At the first station, the evenness index (E1) on major groups of phytoplankton shows comparatively high values in the beginning of the study period and shows a decreasing trend till the last week of July. The index which shows a higher value in the first week of August got stabilised at a lower level but by the last week it started showing an increasing tred touching maximum value. However, at station 2, the index did not show much variation but showed an increasing trend towards the end of September (Figure 15).

The indices of diversity which combines the effects of richness and evenness are given in Tables 14 & 15. Diversity index H' also shows a trend similar to richness index in respect of major groups of phytoplankton remaining high in June, first week of August and then towards the end of September when it shows the trend of increasing further. In between periods the index 'H', remains at low levels. The trend is almost identical at station 2 also except that the index started an increasing trend by last week of August.

Figure 16 show the fluctuations of indices of richness, evenness and diversity in respect of major groups of zooplanktons in the two stations during the study period. It can be seen that at station 1, the index of

Fig. 15. Richness, diversity and evenness indices of phytoplankton Station I (above) and Station II (below)



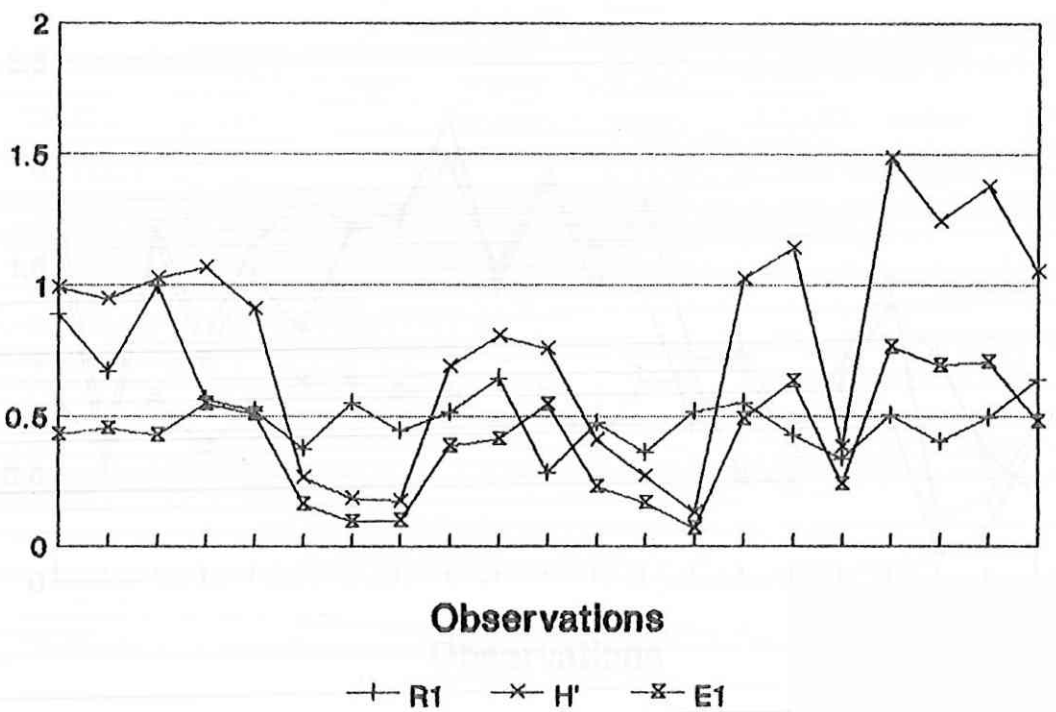
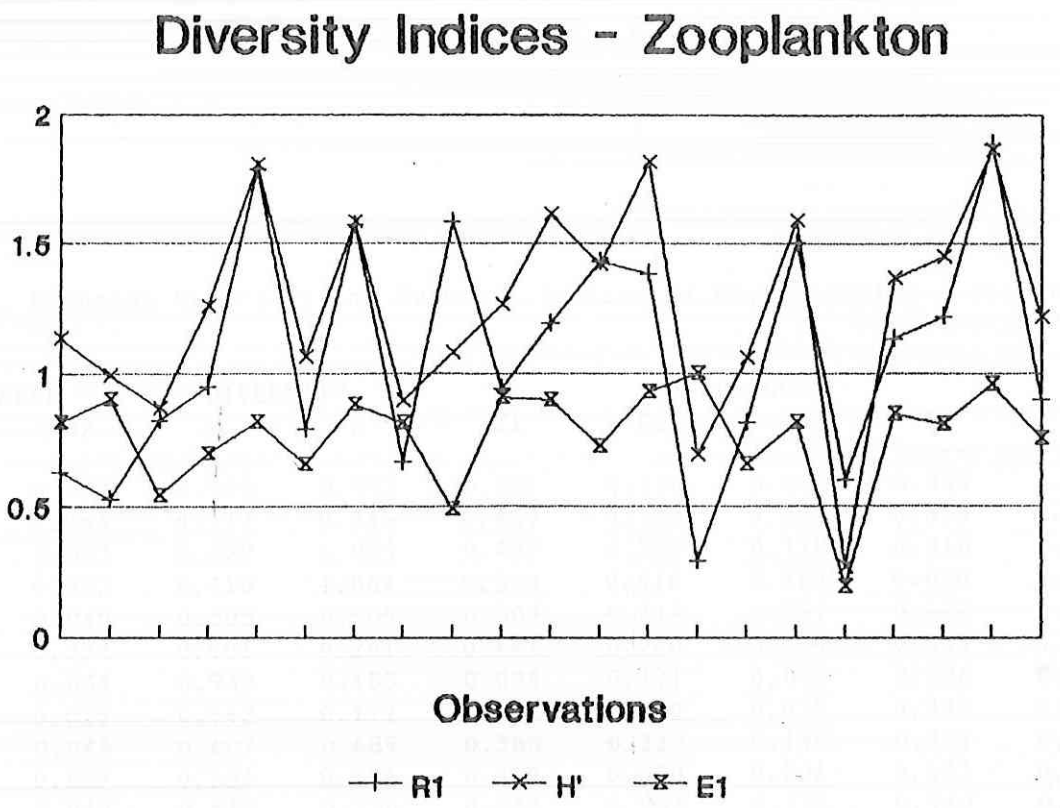


Fig. 16. Richness, diversity and evenness indices of zooplankton Station I (above) and Station II (below)



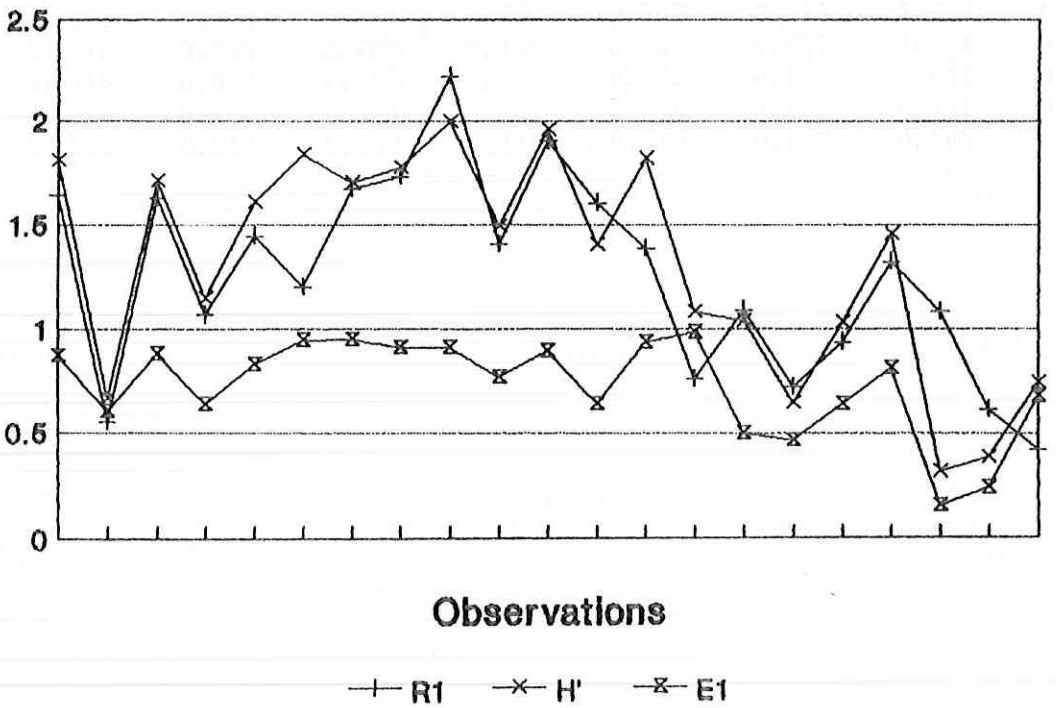


Table. 15 . Richness Diversity and Evenness Indices of Phytoplankton - Station 2

RICHNESS		DIVERSITY		EVENNESS				
R1	R2	λ	H'	E1	E2	E3	E4	E5
0.891	0.064	0.444	0.992	0.431	0.370	0.188	0.835	0.738
0.673	0.044	0.472	0.945	0.454	0.322	0.225	0.823	0.711
0.997	0.073	0.439	1.024	0.427	0.253	0.178	0.818	0.716
0.567	0.035	0.410	1.067	0.548	0.415	0.318	0.838	0.753
0.521	0.049	0.585	0.909	0.508	0.414	0.297	0.688	0.478
0.375	0.024	0.901	0.261	0.162	0.260	0.074	0.855	0.368
0.553	0.031	0.940	0.183	0.094	0.171	0.033	0.886	0.319
0.443	0.021	0.942	0.172	0.096	0.198	0.038	0.893	0.324
0.514	0.046	0.687	0.689	0.385	0.332	0.198	0.731	0.460
0.645	0.067	0.654	0.806	0.414	0.320	0.206	0.683	0.426
0.281	0.019	0.515	0.758	0.547	0.534	0.378	0.910	0.830
0.473	0.030	0.832	0.408	0.228	0.251	0.101	0.800	0.412
0.361	0.020	0.893	0.267	0.166	0.261	0.077	0.857	0.390
0.517	0.021	0.960	0.128	0.066	0.162	0.023	0.916	0.304
0.551	0.014	0.947	1.024	0.492	0.348	0.255	0.770	0.641
0.429	0.018	0.403	1.140	0.636	0.521	0.425	0.794	0.697
0.337	0.013	0.849	0.381	0.237	0.293	0.116	0.804	0.382
0.504	0.018	0.264	1.488	0.765	0.633	0.572	0.854	0.812
0.403	0.012	0.333	1.243	0.694	0.577	0.493	0.867	0.814
0.493	0.016	0.290	1.376	0.707	0.566	0.493	0.871	0.828
0.639	0.017	0.541	1.052	0.479	0.318	0.233	0.645	0.455

Table. 16 . Richness Diversity and Evenness Indices of Zooplankton - Station 1

RICHNESS		DIVERSITY		EVENNESS				
R1	R2	λ	H'	E1	E2	E3	E4	E5
0.633	0.375	0.359	1.134	0.818	0.777	0.703	0.896	0.846
0.529	0.452	0.391	0.995	0.906	0.902	0.852	0.945	0.913
0.827	0.445	0.560	0.872	0.542	0.478	0.348	0.746	0.564
0.953	0.435	0.313	1.256	0.701	0.585	0.502	0.911	0.875
1.787	0.959	0.205	1.804	0.821	0.675	0.634	0.804	0.765
0.792	0.400	0.411	1.061	0.659	0.578	0.472	0.841	0.757
1.573	1.225	0.217	1.583	0.884	0.812	0.774	0.944	0.930
0.668	0.671	0.432	0.898	0.817	0.818	0.727	0.944	0.905
1.584	0.721	0.560	1.079	0.491	0.327	0.243	0.607	0.405
0.944	0.816	0.275	1.265	0.913	0.886	0.846	1.025	1.035
1.193	0.739	0.209	1.612	0.900	0.835	0.802	0.953	0.941
1.432	0.862	0.355	1.418	0.728	0.590	0.521	0.683	0.582
1.385	0.803	0.165	1.816	0.933	0.878	0.857	0.987	0.984
0.289	0.354	0.484	0.693	1.000	1.000	1.000	1.033	1.067
0.817	0.432	0.432	1.060	0.659	0.577	0.472	0.802	0.697
1.504	0.953	0.245	1.590	0.817	0.700	0.650	0.832	0.789
0.600	0.329	0.895	0.266	0.192	0.326	0.102	0.856	0.383
1.134	0.857	0.287	1.365	0.848	0.783	0.729	0.890	0.852
1.221	0.775	0.286	1.450	0.809	0.710	0.652	0.821	0.766
1.888	1.429	0.130	1.864	0.958	0.921	0.908	1.189	1.224
0.903	0.546	0.347	1.216	0.756	0.675	0.594	0.854	0.792

richness (R1) was highly fluctuating touching a maximum 1.787 in mid July and a minimum of 0.789 in the fourth week of August. However, at station 2, this index showed an increasing trend from the beginning of the study period till first week of August when it attained a maximum value of 1.90 and thereafter showed a decreasing trend touching a minimum value of 0.421 in the end of September. Evenness index (E1) on the other hand remained steady with minor fluctuation, till the first week of September in station 1 when there was a sudden drop but regained in the second week. In station 2 also this index remained steady with minor variation, but, showed a sudden drop in the fourth week of September with a tendency to rise to the steady value afterwards. Diversity index H' showed a trend similar to the richness idex R1 in both the stations. This can be expected as since the evenness index is more or less stable, the diversity ,is expected to follow the trend of richness. Thus, in station 1 the index H' fluctuates widely as the richness index but in station 2, it shows a decreasing trend till the first week of September and thereafter increases till the third week of September.

In order to ascertain whether the number of groups in the stations bear any associationship with any of the nutrients, correlation coefficients were worked out. It is found that the number of groups is correlated with nitrate ($r = 0.406$, $P < 0.01$). As a consequence, it was further tested whether the diversity index also bears any relationship with nitrate. It is observed that diversity index H' is correlated with nitrate ($r = 0.50$, $P < 0.01$).

Table. 17 . Richness Diversity and Evenness Indices of Zooplankton - Station 2

RICHNESS		DIVERSITY		EVENNESS				
R1	R2	⅄	H	E1	E2	E3	E4	E5
1.642	0.949	0.176	1.806	0.869	0.761	0.727	0.932	0.919
0.550	0.487	0.636	0.661	0.601	0.645	0.468	0.812	0.612
1.627	1.107	0.190	1.709	0.878	0.789	0.754	0.954	0.944
1.068	0.577	0.440	1.142	0.637	0.522	0.427	0.725	0.597
1.443	0.875	0.236	1.607	0.826	0.713	0.665	0.849	0.811
1.201	0.575	0.169	1.836	0.944	0.896	0.879	0.944	0.933
1.669	1.342	0.158	1.700	0.946	0.908	0.890	1.162	1.198
1.731	1.237	0.169	1.771	0.910	0.840	0.813	1.005	1.006
2.216	1.480	0.135	1.995	0.908	0.817	0.794	1.006	1.007
1.403	0.825	0.286	1.492	0.767	0.635	0.574	0.786	0.723
1.900	1.091	0.157	1.955	0.890	0.785	0.758	0.901	0.885
1.601	0.740	0.333	1.401	0.638	0.451	0.382	0.741	0.756
1.385	0.803	0.165	1.816	0.933	0.878	0.857	0.987	0.984
0.758	0.802	0.297	1.079	0.982	0.981	0.971	1.146	1.221
1.088	0.320	0.533	1.036	0.498	0.352	0.260	0.666	0.483
0.721	0.500	0.673	0.645	0.465	0.477	0.302	0.780	0.537
0.935	0.589	0.459	1.027	0.638	0.558	0.448	0.781	0.659
1.321	0.905	0.294	1.451	0.810	0.711	0.000	0.000	0.000
1.080	0.313	0.893	0.314	0.151	0.171	0.053	0.818	0.324
0.612	0.191	0.841	0.381	0.237	0.293	0.116	0.812	0.407
0.421	0.279	0.568	0.744	0.677	0.702	0.552	0.836	0.688

In order to ascertain whether the distribution of zooplankton is in any way influenced by the distribution of major groups of phytoplankton. linear correlation coefficients were estimated between major groups of phytoplankton and zooplankton. In some cases it is observed that some of the groups of phytoplankton are perfectly independent of zooplankton. Thus for correlation coefficient between Coscinodiscus and Copepods is almost nil ($r = 0.020$, $P < 0.90$). Significant correlation exists, however, between Fish eggs & larvae and some of phytoplankton groups viz., Navicula Pleurosigma and Nitzschia. None of the other zooplankton groups exhibit any correlation with any of the phytoplankton group.

D I S C U S S I O N

The hydrological parameters studied showed wide fluctuations probably because the study was undertaken during the south west monsoon period. Fresh water conditions prevailed at station, during the initial stages of study. Tropical rainfall, especially in the mangrove forested areas, occuring between June to September is collected into the rivers. After some delay due to the time taken for water to travel from inland regions to the coast enters into the sea through mangrove, estuaries, lagoons or deltas. This inflow of fresh water often causes a seasonal drop in the salinity of adjacent coastal waters (Untawale and Parulekar, 1976) 'Mangalavan' being located in the main land thereof seems to have a greater influence of land run off than that of station 2 at Puthuvype in Vypeen Island. Although not highly significant a negative relation exists between salinity and tide height. This indicates that an increase in surface salinity occurs during neap tide especially at station 1. This increase may be a consequence of strong vertical mixing during the neap tide period and a reduced run off at the time. Similarly a negative relationship exists between salinity and flow speed at both stations during the initial stages. This indicates that there is a continuous fresh water flushing irrespective of the tide. Parulaker (1985) found that

salinity variations are more pronounced and often more sudden in a mangrove ecosystem than in an estuary. Uncles et al. (1990) have reported the influence of tide on current and salinity in a mangrove estuary of Malayasia. The mangrove flora at station 2 is diverse with more number of species when compared to that of station 1. Salinity plays an important role in zonation and distribution of mangrove trees. In higher salinities reported at Station 2 may therefore contribute to the high species diversity (Dagana, 1985).

Dissolved oxygen and pH are similar to the observation reported from other mangroves (Ovalle et al., 1990). The pH values are close to neutral with slightly alkaline conditions during certain observations. Dissolved oxygen values tend to be low in mangrove ecosystems probably due to the presence of high oxidisable matter organising from mangrove litter. Oxygen is mainly consumed on the bottom muddy surface due to biological and chemical actions. This depletion is counteracted by mixing with surface waters in which the oxygen is not so rapidly consumed (Mazda et al 1990). The reduced dissolved oxygen at both the stations indicate that there is an increased sediment bacterial activity on the organic matter and a consequent utilization of oxygen from overlying waters. Raman (1986) found significant quantities

of bacteria, fungi and actinomycetes in the mangrove soils. Jose (1989) and Preetha (1991) estimated high litter production at Puthuvypu.

The values of inorganic nutrients observed are similar to those reported by (Kannan and Krishnankutty, 1985, Ovalle et al. 1990). Station 2 is a high mangrove being located about 1 km away from the estuary, whereas 'Mangalavan' is close to the estuary with the connecting canal being about 100 metre long. The mean phosphate values observed at station 2 is almost twice as that of station 1. This suggests that ground water is probably an important source of phosphorous in mangrove areas. The values of nitrate are similar at both the stations indicating that ground water, estuarine water and mangrove pore water are all equally important (Ovalle et al. 1990). At station 1, higher nitrate values were observed during lowtide in the first few observations, which may suggest nutrification of ammonia orginating in mangrove water could be occurring at this mangrove (Wolaver et al. 1984, Ovalle et al. 1990). Ovalle et al. 1990 opined that major silica values in low mangroves may be related to pure water inflow. A comparison of the nutrients at both the stations indicates that phosphate in higher at station 2. This may suggest that there

is an active outflow of phosphate to the estuary from the mangrove at Puthuvypu than at Mangalvan. Wattayakorn et al. (1990) showed that a plot of salinity with concentrations of nutrients would show whether the nutrients have a concentrative nature or a reactive nature. Silicate at station 1 was found to have linear relationship and hence conservative while at station 2 th relationship was a weak one. There was no distinguishible pattern for phosphate at both the sites while nitrate also show conservative nature at both the stations. Wattayakorn et al. (1990) did not find a relatioship for both nitrate and nitrite at a mangrove swamp in Thailand. While the other observations were similar to the observations made in this study.

The abundance and composition of both phytoplankton and zooplankton from other mangroge areas are broadly similar to the observations made here. (Santhanam et al. 1975, Grindley, Ricard, 1984, Palaniappan and Bhaskaran, 1985, Sawamoto, 1990).

A computer literature search spaning the past decade for studies on the relation between hydrography and phyto and zooplankton and their species diversity of mangroves indicated that there are only a few references available. Observations on these aspects are widely reported from reservoirs, rivers, estuaries, coastal waters and world oceans. The discussion therefore on the

present observations rely heavily on the findings from other ecosystems. The major hydrographical factors that influenced phytoplankton were salinity, phosphate, nitrate and silicate. Most important among the nutrients was nitrate which influenced 3 genera, while silicate showed relationship with 2 and phosphate effected the abundance of fragilaria. Lee and Choa (1990) identified water temperature, dissolved oxygen, nitrate nitrogen and phosphate phosphorous as the environmental factors that influence phytoplankton. The quantity of phytoplankton observed in the mangroves is generally lower than those reported for associated estuaries and bays. The dilute waters of the mangroves (as indicated by low salinities results is higher water stability and hence as pointed out by Uribe (1988), the phytoplankton growth cycle would be longer with low biomass The importance of nitrate in productivity and plankton biomass was shown by Briggs (1992), who reports that' when surface waters were depleted in nitrate, the chlorophyll standing stocks, primary productivity and zooplankton biomass are extremely low. By comparison, when there was measurable nitrate, chlorophyl standing stocks and primary production in the surface layer was 1.5 to 2 times higher. Nitrogenous nutrients have also been limiting in phytoplankton cultures (Devassy and Goes, 1991, Davidson et al, 1991, Gilbert

and Garside 1992). Another factor which has an impact on the formation of planktonic community are the river drainage and differences in climatic conditions (Patalas and Salki., 1992). Availability of adequate light is the other prominent factors which affects the phytoplankton. Wrigley et al. (1991) observed that despite high nutrient concentrations, reduction in light or other associated factors results in low phytoplankton biomass. Severe light limitation also restricted phytoplankton development in a highly eutrophic lake (Reynolds and Bellinger, 1992). Matsuda et al. (1990) concluded that phytoplankton growth is influenced by river drianage and solar radiation. The low biomass of phytoplankton observed may therefore be attributed to the reduced light due to the cloudy conditions that prevailed and also due to the shading effect of the mangrove trees. Based on observations of many marine ecosystem. Durate et al. (1992) concluded that phytoplankton hetrogeneity is limited in hydrographically complex systems. They attributed the phytoplankton reduction partially to delay in phytoplankton growth response following perturbations. In deeper waters thermal stratification and nutriclines characterize areas of chlorophyll maximum figueiras and Pazos, 1991). The abundance of particular groups is also related to the N:P ratio for example, Takamura et al. (1992) observed a shift from one phytoplankton species to another accompanied by transition from nitrogen

dependence to phosphorus dependence. The predominance of Oscillatoria Nitzchia, Pleurosigma, Navicula, Fragilaria, Biddulphia and Skeletonema at Station 2 may therefore be due to higher phosphate. The echanced phosphate is credited to increased urban and agricultural activity at Puthuvypu. Phytoplankton in mangrove therefore seems to be related primarily to salinity, incident light and the abundance of nutrients especially nitrate and phosphate.

Zooplankton was related to only 2 ecological parameters. Fish eggs and larvae showed a significant relationship with salinity while copepods and amphipods were related to phosphate. Although Biggs (1992) found relationship between nitrate and zooplankton biomass, significant relationship was lacking between these two parameters in the present study. Mackar (1992) observed that zooplankton biomass and species composition differed sharply between various regions along with changes in temperature, salinity, nutrients and phytoplankton distribution. Salinity controls the distribution of marine forms of zooplankton (Sarkar et al. 1985). The various groups being predominantly estuarine forms did not show any relationship with salinity except for the fish eggs and larvae group. Garcia - soto et al. (1991) based on satelite imagery found that zooplankton abundances were confined to low salinity inshore areas while sardine larvae did not show any clear relationship with

hydrographic parameters. The groups of larvae of finfishes and shellfishes obtained were mainly fresh water and estuarine ones. (Owan and Shaw, 1991) found similar temporal and spatial trends in fish larval abundance and zooplankton biomass, but there was no correlation between larval abundance and zooplankton biomass. They suggested that the seasonal presence of reverine water may be important to larval fish. The abundance of mature and egg bearing copepods in the samples may be an indication that mangrove areas are the breeding sites for important zooplankton groups. The observations of Ambler et al. (1991) and Sameoto and Herman (1992) also supports this view. The number of individuals/M3 and consequently dry weight biomass were much lower than those reported by Srinivasan and Santhanam (1991) for Pulluvazhi back water. They attributed this abundance to macrozooplankton particularly copepods larvae and molluscan velligers. The micro zooplankton which observed in mangrove were tanaids and brachyuran larvae with sporadic appearance in the sample. The ecological parameters of mangroves does not seem to have a profound influence on the distribution and abundance of zooplankton. The controlling albeit only in selected cases are salinity and phosphate.

The highly variable complex of mangrove environments seems to alter the zooplanktonic composition from time to time. The zooplankton density was less when compared to adjacent waters like

estuaries and back waters. Qasim (1977) opined that the representation of zooplankton organisms in the mangrove swamps are few in numbers and groups and their role in the food chain was meagrely known. The low numbers of zooplankton in the mangrove environment may be due to the shallowness of the area (average 1m depth) and the high turbid nature of water. Turbidity of the water plays an important role in the distribution of zooplankton in the estuaries (Dutt et al. 1984, Baidya, 1984).

Of late the diversity indices are becoming quite popular among ecologists as tools for comparing different ecosystems. Eventhough these indices do have limitations in allowing precise probablistic conclusions, they serve as useful tools in making empirical studies. Comparison of different ecosystems entail the comparison of species available and also how equitably these species are distributed in the community. Corresponding two indices are 1) the richness index and 2) evenness index. The diversity index is one which combines the properties of both richness and evenness. Richness indices used in the study are R1 and R2 (defined elsewhere). The use of R1 and R2 as richness indices are to be used only when the number of species is linearly related to the sample size. Evenness indices E1, E2, E3, E4 and E5 (defined elsewhere) are worked out in the present study. It

can be shown that E1, E2 and E3 are highly sensitive to species number with the result even the occurrence of a rare species in very small number may change the values rapidly while E4 and E5 being ratios remain more or less stable and in that sense they are more reliable (Ludwig and Reynold 1988). Diversity indices through popularly used by ecologists do have some limitations. Since thee index of diversity combines the species number the equitability, the same value of diversity may result from different patterns of distribution. For example, high richness value combined with low evenness may result in the same diversity value as from a distribution of low richness and high evenness.

Fundamentally the species diversity is a function of the number of species occuring in an environment. It is reasonable to assume that this number of species or groups is correlated with hydrographic parameters. Correlation coefficient between the number of groups of phytoplankton and other parameters viz, nitrate, phosphate and silicate etc. were estimated. Among the nutrients, only nitrate is found to have significant correlation with number of groups. Since diversity draws information from the number of groups, it is expected that diversity index (say H') also may be related with nitrate and the study established this assumption showing correlation coefficient of 0.500, ($p < 0.01$).

SUMMARY

The objective of the present work is to understand more about the distributional pattern, abundance and diversity of plankton groups from two mangrove ecosystems in Cochin area. Knowledge about the environmental factors of the study area is an essential pre-requsite in the investigation of abundance and diversity of any biological community. An attempt was therefore made in the present study to evaluate statistically the relationship of the various plankton groups with environmental parameters.

The conclusions drawn from the present investigation were based on 21 observations made during a period of 4 months. The observations were made on the temperature, salinity, pH, dissolved oxygen nitrate, phosphate and silicate and their statistical relationship with biological parameters like phytoplankton and zooplankton. Diversity indices for zooplankton and phytoplankton were also derived.

The equality of the mean values of the hydrological parameters observed in the two stations was tested statistically by students 't' test. The atmospherie temperature did not differ significantly between stations. The water temperature values were found to differ and it ranged from 25.6°c - 29°c at station 1 and 25°c to 35°c at station 2. The pH values in the two ecosystems ranged from 7.2 - 8.5 indicating a more alkaline

nature of the environment. Salinity showed significant variation and it ranged from 0.11 ppt to 4.0 ppt at station 1 and 1.7 ppt to 11.30 ppt at station 2. Dissolved oxygen on the other hand did not show much difference between stations. Among the nutrients phosphate differed significantly in its mean value in the two stations. The variations ranged from 3.8 /ug at/l - 16 /ug at/l at station 1 and 5.38 /ug at/l - 19.4/ug at/l at station 2.

The dominant group of phytoplankton present in both the mangrove stations formed Coscinodiscus and Pleurosigma. The blue green algae Oscillatoria was also found in abundance. The dominant zooplanktons observed were copepods and fish eggs and larvae. Larvae and Juveniles of cultivable species of both finfishes and shell fishes were also found in the zooplankton samples.

The statistical analysis carried out in the present investigation include 't' test, correlation coefficients and diversity indices. 't' test was applied to ascertain the equality of the mean count of major groups of plankton in the two stations after subjecting the data to logarithimic transformation. The test indicates that only the group Navicula showed significant difference in the mean counts of the two stations and the same test for zooplankton in both the stations showed that none of the group differed significantly between stations.

Study of correlation among major groups of zooplankton and phytoplankton indicated significant correlation between fish eggs and larvae and some groups of phytoplankton viz. Navicula, Pleurosigma and Nitzschia.

Correlation coefficient between the number of groups of phytoplakton and other parameters viz. nitrate, phosphate and silicate etc. were estimated. Among the nutrients, only nitrate is found to have significant correlation with number of groups. Since the diversity draws information from the number of groups, it is expected that the diversity index (say H') also may be related with nitrate and the study established this assumption showing correlation coefficient of 0.500, ($P < 0.01$).

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