4. PLANKTON

4. Plankton

4.1. Introduction

Plankton are the 'wanderers' of the aquatic ecosystem. They are considered as an index of fertility (Prasad, 1969) and landings of fish are directly proportional to the quantity of plankton (Chidambaram and Menon, 1945). Plankton include two groups, namely phytoplankton and zooplankton.

Phytoplankton, the drifting microscopic plants of the aquatic system, form the basis for the production of zooplankton, fish, shellfish, mammals, etc. They form the 'pastures of the seas'. They comprise 95% of the 'primary (organic) production', on which, the 'secondary production' (production of zooplankton) and 'tertiary production' (production of fish, shellfish, mammals, etc.,) depend upon. Hence studies are carried out on their composition, distribution, seasonal variation and productivity from estuaries and adjacent seas.

4.2. Review of Literature

Extensive studies were carried out on plankton at the global level (Digby, 1953; Riley, 1957; Bureell, 1972; Reinger, 1973; Smayda, 1973; Sinclair, 1977; Marshall, 1978; Barlow, 1982; Tremblay *et al*., 1997; Grey *et al.* , 1997; Blaber *et al.,* 1997; Froneman and McQuaid, 1997; Tamigneaux *et al.* , 1999 and Howland *et al.* , 1999).

Study on plankton in India was initiated by Sewell (1913). Gopinathan (1975) extensively studied the estuarine diatoms along the east and west coasts of India.

Nair *et al.* (1984) reported the phytoplankton ecology of the estuaries throughout the west coast. The phytoplankton of certain estuaries along the west coast of India were observed by George (1958); Gopinathan *et al.* (1970); Qasim *et al.* (1972); Bhargava *et al.* (1973); Devassy and Bhattathiri (1974); Joseph and Pillai (1975); Pillai *et al.* (1975); Silas and Pillai (1975); Mathew and Nair (1980); Qasim and Sengupta (1981); Ragothaman and Reddy (1982) and Nair *et al.* (1983); Bijoy Nandan and Abdul Azis (1996) and Goes *et al.* (1999).

The studies on phytoplankton of east coast were carried out by Prasad (1954); Rangarajan (1958); Seshadri (1957); Shetty *et al.* (1962); Santhakumari (1971); Vijayalakshmi and Venugopalan (1973); Devendran *et al.* (1974); Krishnamurthy *et al.* (1974); Ramadhas *et al.* (1975); Santhanam *et al.* (1975); Sundararaj and Krishnamurthy (1975); Santhanam (1976); Chandramohan and Bhatnagar (1976); Ramadhas (1977); Sundararaj (1978); Thangaraj *et al.* (1979); Ilangovan (1981); Chandran (1982); Sivakumar (1982); Ilangovan and Krishnamoorthy (1983); Thangaraj (1984); Mani (1984); Prabha Devi (1986); Jegadeesan (1986); Balusamy (1988); De *et al.* (1994); Gopinathan *et al.* (1994); Gouda and Panigrahy (1996) and Ratna Bharati *et al.* (2001).

Zooplankton constitute an assemblage of small animals with limited motility of pelagic habitat and form the 'secondary production'. Extensive studies on the qualitative and quantitative account of zooplankton ecology were available from the east coast of India. (Ramasarma *et al.,* 1964; Chandramohan, 1963; Krishnamurthy, 1967; Subbaraju, 1968; Krishnamurthy and Sundararaj, 1972; Subbaraju and Krishnamurthy, 1972; Santhanam *et al.,* 1975; Krishnamurthy and Santhanam, 1975; Srikrishnadhas *et al.,* 1975; Thangaraj *et al.,* 1979; Chandran, 1982; Sivakumar, 1982; Thangaraj, 1984; Jegadeesan, 1986; Prabha Devi, 1986; Kalidasan *et al.,* 1987; Balusamy, 1988; Govindasamy and Kannan, 1991; Pattanaik and Sarma, 1997; Mishra and Panigrahy, 1999; Chandra Mohan *et al.,* 1999 and Perumal *et al.,* 1999).

The studies on the ecology of zooplankton were more extensive in the west coast than that of the east coast (George, 1958; Mary John, 1958; Nair and Tranter, 1971; Qasim *et al.,* 1972; Goswami and Singbal, 1974; Dwivedi *et al.,* 1974; Madhupratap and Haridas, 1975; Haridas, 1975; Silas and Pillai, 1975; Rao *et al.,* 1975; Goswami and Selvakumar, 1977; Madhupratap, 1978; Abdul Azis, 1978; Divakaran *et al.,* 1982; Arunachalam *et al.,* 1982; Goswami, 1983; Nair and Abdul Azis, 1987; Bijoy Nandan, 1991; Shibu, 1991; Padmavati and Goswami, 1996; Karande *et al.*, 1997; Mustafa *et al.*, 1999 and Santhakumari *et al.,* 1999).

In the present study, various aspects of plankton community of Manakkudy estuary, such as species composition, species diversity, species richness, species evenness, population density and seasonal variation were investigated.

4.3. Materials and Methods

Monthly samples of plankton were collected for a period of two years from February 1990 to January 1992.

For qualitative analysis of phytoplankton, No.30 plankton net (bolting silk; mesh aperture size 48 µm) was used and for the qualitative analysis of zooplankton No.10 plankton net (bolting silk; mesh aperture 158µm) was used.

For the quantitative study of phytoplankton one litre of surface water was sampled in a polythene bottle with a few drops of 5% neutral formalin as preservative. Preserved plankton were allowed to settle for 24 hours. Settled phytoplankton were studied quantitatively. For the quantitative study of zooplankton 100 litres of surface water was filtered through a specific net. The samples were fixed with a few drops of 5% neutral formalin. The plankton were counted with the help of a Utermohl's inverted plankton microscope.

The species diversity of plankton was determined using the Shannon's formula (Pielou,1975).

$$H^1 = \Sigma - Pi \log_2 Pi$$

Where H^1 is the diversity in bits per individual.

pi = *ni* /N (ni being the number of individuals of the i'th species, N being the total number of individuals and S is the total number of species).

Species richness (SR) was calculated by using Gleason's, (1922) formula.

$$SR = S - 1/\log_2 N$$

where S is the number of species and $\log_2 N$ is the natural logarithm of the total number of individuals of all species in the sample.

Evenness or equitability 'J' was calculated using the formula of Pielou (1966).

$$J = H^1/\log_2 S$$

where H^1 is the species diversity in bits per individual and S is the total number of species.

4. 4. Results

4. 4. 1. Phytoplankton

4.4.1.1. Population Density

The monthly variation in the density of phytoplankton population at stations I, II and III during 1990 -'91 and 1991-'92 is given in Fig. 4.1.

The fluctuations in population density varied extensively between seasons, stations and years. At station I it varied from 2375 cells/ℓ in February to 20525 cells/ℓ in May during 1990-'91 and from 6150 cells/ℓ in June to 20250 cells/ℓ in March during 1991-'92.

At station II the density fluctuated between 8150 cells/ℓ in November and 32750 cells/ℓ in May during 1990-'91 and between 3000 cells/ℓ in June and 41400 cells/ℓ in April during 1991-'92.

At station III the population density ranged between 5725 cells/ℓ in November and 31700 cells/ℓ in June during 1990-'91 and between 3800 cells/ℓ in June and 31485 cells/ℓ in May during 1991-'92.

In the present study, high population density was observed at station II followed by station III and I during both the years. Seasonal average values of population density were maximum during premonsoon season and minimum during postmonsoon period in all the stations during both the years. The annual average was higher during 1991-'92 and lower during 1990-'91.

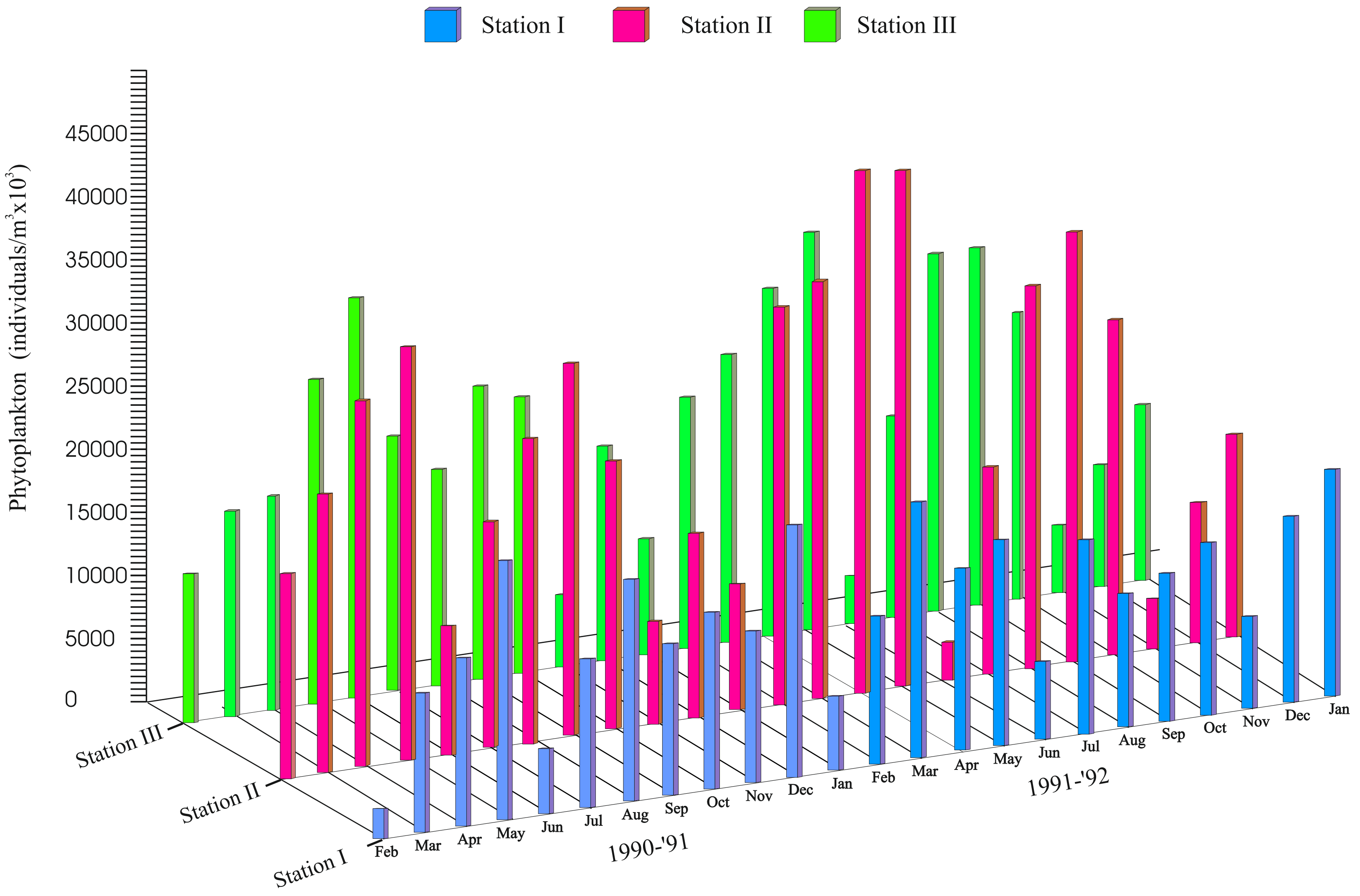

Fig. 4.1: The variations in population density of phytoplankton at station I, II and III during 1990-'91 and 1991-'92.

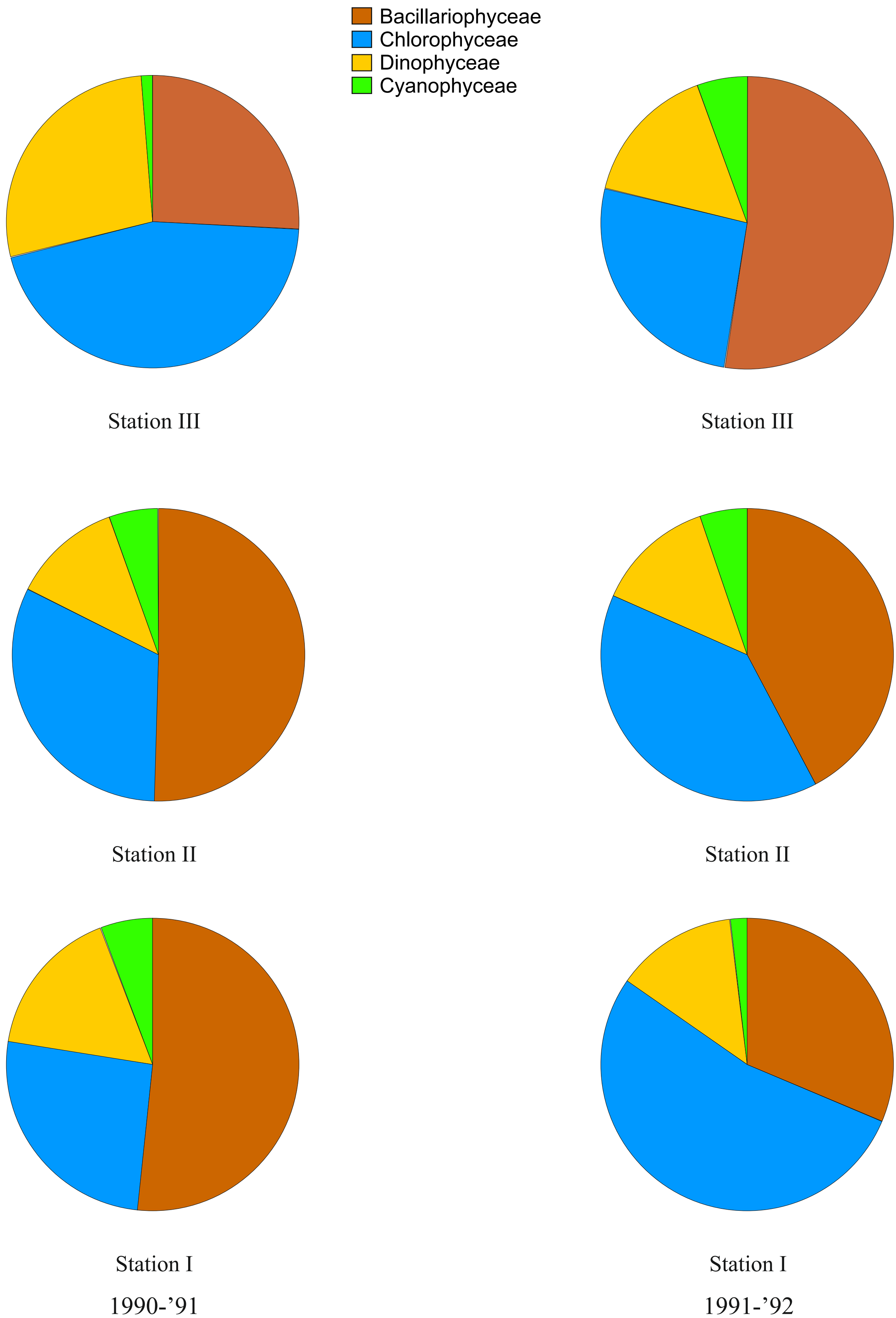

Fig 4.2. : Relative abundance of the various groups of phytoplankton at station I, II and III in Manakkudy estuary during 1990-'91 and 1991-'92

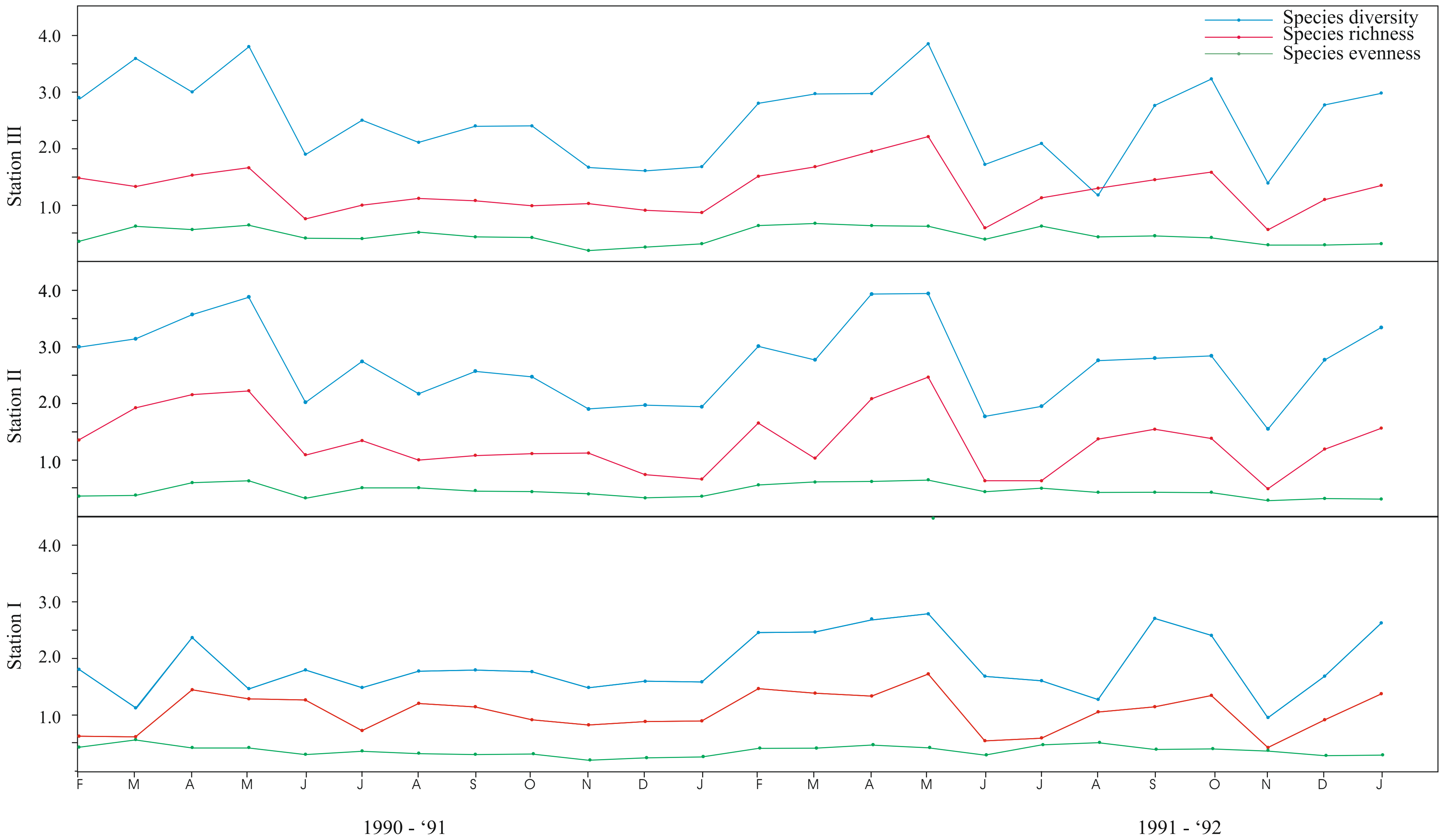

Fig. 4.3. The species diversity, species richness and species evenness of phytoplankton at station I, II and III during 1990-'91 and 1991-'92.

4. 4.1. 2. Species Composition

The phytoplankton is comprised of four major groups namely Bacillariophyceae (diatoms), Chlorophyceae, Cyanophyceae and Dinophyceae (dinoflagellates). It consisted of a total number of 78 species. Of these, 42 species were Bacillariophyceae, 15 were Chlorophyceae, 12 were Cyanophyceae and 9 species were Dinophyceae. In general, the diatoms ranked first in abundance. This was followed by Chlorophyceae, Cyanophyceae and then Dinophyceae. This trend was observed throughout the study period except during certain periods of freshwater flow, especially during monsoon months in which period Chlorophyceae dominated the population .

Among the total phytoplankton encountered, the diatoms constituted 42%, Chlorophyceae 35%, Cyanophyceae 19%, Dinophyceae 4% during 1990-'91 and during 1991-'92 diatoms constituted 43% followed by Chlorophyceae 39%, Cyanophyceae 14% and Dinophyceae 4%.

A check list of phytoplankton recorded in Manakkudy estuary is given in Table 4.1

Table 4.1 : Check list of phytoplankton recorded in Manakkudy estuary.

Bacillariophyceae

Amphora normani	*Fragillaria* sp.
Asterionella japonica	*Gyrosigma balticum*
Bacillaria paradoxa	*Melosira granulata*
Bacteriastrum comosum	*M.sulcata*
B. elongatum	*Navicula gracilis*
B.delicatulum	*Nitzschia closterium*
Bellerochea malleus	*N.longissima*
Biddulphia aurita	*N.seriata*
B.heteroceros	*N.sigmoidea*
B.sinensis	*Pleurosigma angulatum*
Cambylodiscus iyengari	*P.elongatum*
Chaetoceros affinis	*P.normanii*
C. decipiens	*Rhizosolenia alata*
Coelastrum sp.	*R.setigera*
Coscinodiscus centralis	*R.stoltherforthii*
C. gigas	*Skeletonema costatum*
C.marginatus	*Synedra formosa*
C. oculus iridis	*Thalassionema nitzschicoides*
C. radiatus	*Thalassiosira subtilis*
Cyclotella striata	*Thalassiothrix frauenfeldii*
Cymbella cistula	*Triceratium favus*

Dinophyceae

Ceratium furca
C.macroceros
C.pulchellum
C.trichoceros
Dinophysis sp.
Gymnodinium sp.
Peridinium oceanicum
P.conicum
P.depressum

Cyanophyceae

Anabaena sp.
Closterium sp.
Aphanocapsa sp.
Glocotrichia sp.
Lyngbya sp.
Merismopedia sp.
Microcystis aeruginosa
Nostoc communie
Phormidium sp.
Spirulina sp.
Trichodesmium erythraeum

Chlorophyceae

Closterium sp.
Coelastrum sp.
Dictyosphaerium sp.
Eudorina sp.
Pandorina sp.
Ophiocytium
Pediastrum boryanum
P. calathratum
Protococcus sp.
Richterella sp.
Scenedesmus quadricauda
Spirogyra pseudocylindrica
Ulothrix sp.
Volvox aureus
Zygnema sp.

4.4.1.3. Species Diversity

The species diversity (H^{1}) for phytoplankton during 1990-'91 and 1991-'92 is presented in Fig. 4.3.

The species diversity at station I varied from a minimum value of 1.15 bits/individuals in March to a maximum value of 2.39 bits/

individuals in April during 1990-'91 and from 0.98 bits/individuals in November to 2.81 bits/individuals in May during 1991-'92.

The species diversity for phytoplankton at station II ranged between 1.94 bits/individuals in November and 3.92 bits/individuals in May during 1990-'91 and between 1.59 bits/individuals in November and 3.98 bits/individuals in May during 1991-'92.

At station III the species diversity fluctuated from 1.62 bits/ individuals in December to 3.81 bits/individuals in May during 1990-'91 and from 1.19 bits/individuals in August to 3.86 bits/individuals in May during 1991-'92.

The annual average species diversity of phytoplankton was maximum in station II followed by station III and I. The species diversity indices were high during premonsoon season and low during monsoon season.

4.4.1.4. Species Richness

The species richness (SR) of phytoplankton collected from Manakkudy estuary at station I, II and III during 1990-'91 and 1991-'92 is presented in Fig. 4.3.

The species richness at station I varied from a low value of 0.64 bits/individuals in March to a high value of 1.47 bits/individuals in April during 1990-'91 and from a low value of 0.45 bits/individuals in November to a high value of 1.75 bits/individuals in May during 1991-'92.

At station II the species richness of phytoplankton ranged between 0.65 bits/individuals in January and 2.21 bits/individuals in May during 1990-'91 and between 0.48 bits/individuals in November and 2.45 bits/individuals in May during 1991-'92.

At station III the species richness fluctuated from 0.77 bits/individuals in June to 1.67 bits/individuals in May during 1990-'91 and from 0.58 bits/individuals in November to 2.22 bits/individuals in May during 1991-'92.

In Manakkudy estuary, the annual average species richness was maximum at station II and minimum in station I. High species richness was recorded during 1991-'92 and low during 1990-'91. High species richness coincided with premonsoon and low species richness coincided with monsoon.

4.4.1.5. Species Evenness

The species evenness of phytoplankton collected from Manakkudy estuary at station I, II and III during 1990-'91 and 1991-'92 is presented in Fig. 4.3.

The species evenness at station I recorded a minimum of 0.23 bits/individuals in November and a maximum of 0.59 bits/individuals in March during 1990-'91 and a minimum of 0.31 bits/individuals in December and a maximum of 0.54 bits/individuals in August during 1991-'92.

At station II species evenness varied from 0.34 bits/individuals in June and December to 0.61 bits/individuals inApril during 1990-'91 and from 0.30 bits / individuals in November to 0.66 bits / individuals in May during 1991-’92.

At station III it fluctuated between 0.21 bits/individuals in November and 0.66 bits/individuals in May during 1990-’91 and between 0.31 bits/individuals in November and December and 0.69 bits/individuals in March during 1991-’92.

The annual average species evenness of phytoplankton was maximum in station II and minimum in station I. The seasonal mean evenness was maximum during premonsoon season and minimum during monsoon season. The annual average species evenness was maximum during 1991-’92 and minimum during 1990-’91.

4.4.1.6. Comparative Study

During 1990-’91 station I recorded 70 species, station II recorded 72 species and station III recorded 58 species. During 1991-’92 station I and II recorded 68 species each and station III recorded 55 species. Comparatively, station II registered more species followed by station I and III during both the years. However, during 1991-’92 station I recorded more species than that of station III.

In station I and II diatoms were dominant and in station III, freshwater algae were dominant.

Estuarine phytoplankton formed the major composition in station II. The phytoplankton density at this station was found to be the maximum when compared to station I and III.

The phytoplankton showed two prominent peaks. The primary peaks were noticed in May during 1990-'91 and in April during 1991-'92 and the secondary peaks were noticed in September during both the years.

Station II was dominated by *Chaetoceros* sp., *Rhizosolenia* sp., *Navicula* sp., *Nitzschia* sp., *Pleurosigma* sp., *Cambylodiscus iyengari, Thalassiosira subtilis, Coelastrum* sp., *Spirulina* sp. and *Spirogyra* sp., *Amphora* sp., *Melosira* sp., *Cyclotella* sp., *Coscinodiscus* sp., *Fragillaria* sp., *Biddulphia* sp., *Skeletonema* sp. and *Trichodesmium* sp. were commonly found at station II. The species such as *Coelastrum, Zygnema, Scenedesmus, Ulothrix, Pediastrum boryanum, Microspora, Peridinium and Bacillaria paradoxa* were rarely encountered.

Station I was dominated by species like *Navicula, Nitzschia, Peridinium, Ceratium furca, Asterionella japonica, Biddulphia aurita, Bacillaria paradoxa, Coscinodiscus marginatus, Cyclotella, Melosira sulcata, Nitzschia sigmoidea, Skeletonema costatum, Peridinium oceanicum, Scenedesmus, Ulothrix* and *Closterium.*

Ceratium trichoceros, Peridinium conicum, Rhizosolenia alata, Nitzschia longissima, Amphora, Coscinodiscus oculus iridis and *Spirulina* were commonly found in station I. The rare species were *Fragillaria, Bacteriastrum comosum, Ceratium pulchellum, Ulothrix* and *Microcystis aeruginosa.*

The dominant representatives of station III were *Spirogyra* sp., *Spirulina* sp., *Pediastrum* sp., *etc.* In addition, *Microcystis* sp., *Phormidium* sp., *Merismopedia* sp., *Trichodesmium erythraeum, Volvox aureus, Anabaena* sp., *Zygnema* sp. were commonly found. *Ulothrix* sp. and *Ophiocytium* sp. were rarely encountered.

4.4.1.7. Statistical Treatment

The annual average values of phytoplankton density were maximum at station II and minimum at station I during both the years. The annual mean of phytoplankton density was higher during 1991-'92 and lower during 1990-'91 (Table 4.2). Seasonal average values of phytoplankton density were maximum during premonsoon season and minimum during postmonsoon season (Table 4.3).

The annual mean values and seasonal mean values of species diversity, species richness and species evenness of phytoplankton also followed the same pattern as that of density except for the minimum seasonal mean values which occurred during monsoon season.

Simple correlation analysis of phytoplankton density showed positive correlation with salinity, oxygen, pH, primary production and chlorophylls and negative correlation with hydrogen sulphide and nutrients.

4.4.1.7.1. Bacillariophyceae

During 1991-'92 Bacillariophyceae had not exhibited any significant variation in the mean values over the three stations. During 1990-'91 it had recorded the highest mean value in station II. Though this higher value was significantly higher than that in station III, it was not significantly higher than that in station I. The average values in station I and station III were on par with each other. The maximum recorded value was 21050 cells/ℓ in station II during 1991-'92 and the minimum was 650 cells/ℓ station I during 1990-'91.

Table 4.13 reveals that in station I in 1990-'91 increase in gross primary production, net primary production, chlorophylls 'a' and 'c' alone would further help Bacillariophyceae. In 1991-'92 apart from additions in salinity at the two levels, pH at the two levels, gross primary production, net primary production, chlorophylls 'a' and 'c', the reductions in H_2S, phosphate, nitrate and nitrite also would favour Bacillariophyceae.

In the second station (Table 4.14) in 1990-'91 increases in surface temperature, gross primary production, net primary production, chlorophylls 'a' and 'c' were favourable. In 1991-'92 increases in salinity at the two levels, pH at the two levels, gross primary production, chlorophylls 'a' and 'c' were favourable and decrease in oxygen at the two levels, silicate, phosphate, phosphorus, nitrate and nitrite would favour Bacillariophyceae.

In station III (Table 4.15) in 1990-'91 only additions in gross primary production and net primary production would favour Bacillariophyceae where as in 1991-'92 apart from additions in gross production, net primary production and the three chlorophylls, the reductions in phosphorus, nitrate and nitrite would also favour Bacillariophyceae.

4.4.1.7.2. Chlorophyceae

Chlorophyceae had recorded significantly lower mean values in station I in both the years, whereas, in the other two stations, average values were on par with each other and significantly higher than that in station I in both the years. The maximum value recorded was 18975 cells/ℓ in station III during 1991-'92 and the minimum was 125 cells/ℓ in station I during 1990-'91.

The details presented in Table 4.16 reveal that in station I in 1990-'91 increase in nitrite and chlorophyll 'b' and 'c' seemed to increase Chlorophyceae where as decreases in visibility alone seemed to do good for Chlorophyceae. In 1991-'92 decrease in surface H_2S seemed to do good for this and also decreases in depth and oxygen at the two levels would be favourable.

In station II (Table 4.17) in 1990-'91 the increase in temperature at the surface and bottom, gross primary production, net primary production and the chlorophyll 'a', 'b' and 'c' was favourable. In 1991-'92 the increase in salinity at two levels, pH at the two levels, gross production and all the three chlorophylls was very favourable for Chlorophyceae where as decrease in oxygen at the two levels, silicate, phosphorus, phosphate, nitrate and nitrite was also favourable.

In station III (Table 4.18) in 1990-'91 the increase in temperature both in surface and bottom, gross production, net primary production and chlorophyll 'a' and 'b' was favourable and also the decrease in nitrite level was also favourable to Chlorophyceae. In 1991-'92 increase in salinity at the two levels, bottom pH, gross primary production, net primary production and the chlorophylls was very favourable and the decrease in oxygen at the two levels, silicate, phosphorus, phosphate, nitrate and nitrite would do good to Chlorophyceae.

4.4.1.7.3. Cyanophyceae

During 1990-'91 the mean values of Cyanophyceae in the three stations had not exhibited any significant difference among themselves and during 1991-'92 all the mean values were significantly different from each other in which station II had recorded the maximum average, followed by station III and station I . The maximum recorded value was 18150 cells/ℓ in station III during 1990-'91 and the minimum value was 25 cells/ℓ in station I during 1991-'92.

The analysis on Cyanophyceae in Table 4.19 reveals that in station I, in 1990-'91 the increase in the oxygen at the two levels would be more favourable where as the decrease in atmospheric temperature and H_2S would have the same effect.

In station II (Table 4.20) in both years no parameter had found to show any effect on this.

In station III (Table 4.21) in 1990-'91 the increase in gross production and the three chlorophylls were favourable to Cyanophyceae. In 1991-'92 only increases in the levels of oxygen at the surface and bottom would be favourable Cyanophyceae.

4.4.1.7.4. Dinophyceae

The average values computed for Dinophyceae showed that in 1990-'91 the mean values in station I and II were on par and both of them were significantly higher than that in station III. Similarly during 1991-'92 in station II, the mean values were significantly greater than that in station I and III, but these two were on par. The maximum recorded value was 2350 cells/ℓ in station II during 1990-'91 and the minimum was 0 in all the stations in both the years.

Results presented in Table 4.22 reveal that in station I, in 1990-'91 none of the parameters except H_2S could give any information on Dinophyceae. In 1991-'92 increase in the salinity at the two levels, gross production, net primary production and chlorophyll 'a' would be favourable where as only decrease in H_2S, silicate, phosphorus, phosphate, nitrate and nitrite would favour Dinophyceae.

In station II (Table 4.23) in 1990-'91 the results were identical with station I in the same year. In 1991-'92 increases in salinity at the two levels, pH at the two levels, gross production and chlorophyll 'c' would do favour to this where as decreases in oxygen at the two levels, silicate, phosphorus, phosphate, nitrate and nitrite would be more favourable further to Dinophyceae.

In station III (Table 4.24) in 1990-'91 only depth had positive relationship with this. In 1991-'92 increases in gross production, net primary production and the three chlorophylls would be more favourable to Dinophyceae.

Table 4.2 : Mean and standard error of phytoplankton (groupwise). The mean values are written in the increasing order with the station numbers along with it in the paranthesis, S1 indicating station 1, S2 indicating station 2 and S3 indicating station 3. Bars above the means are used to indicate statistically on par values. The value in the paranthesis below each mean indicates the standard error.

S.No.	PARAMETERS	1990 – '91			1991 – '92		
1	Bacillariophyceae	4791.6667 (S3) (2380.34)	6268.75 (S1) (3658.24)	9916.75 (S2) (5267.8)	5826.0833 (S3) (4271.6)	6975 (S1) (4435.25)	10116.667 (S2) (2255.04)
2	Chlorophyceae	3118.75 (S1) (2187.47)	6260.4167 (S2) (3588.67)	8447.9167 (S3) (3766.09)	3533.3333 (S1) (1746.21)	9525 (S2) (5982.23)	9881.25 (S3) (5209.6)
3	Cyanophyceae	2027.0833 (S1) (2552.282)	2385.4167 (S2) (2107.76)	5181.25 (S3) (4766.95)	2100.0 (S1) (3319.24)	2457.0833 (S3) (2147.0)	3110.42 (S2) (3667.12)
4	Dinophyceae	177.0833 (S3) (133.764)	716.6667 (S1) (539.5)	1085.4167 (S2) (709.63)	351.0833 (S3) (268.74)	735.4167 (S1) (569.135)	1281.25 (S2) (886.46)

Table 4.3 : Mean values of the phytoplankton and zooplankton in the premonsoon, monsoon and postmonsoon seasons in all the stations during 1990-'91 and 1991-'92.

I	Premonsoon						Monsoon						Postmonsoon					
	1990-'91			1991-'92			1990-'91			1991-'92			1990-'91			1991-'92		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Phytoplankton	11812.5	25025.25	19262.5	15668.75	36712.5	25434.0	11618.75	20437.5	23050.00	10956.25	20943.75	17137.5	12962.5	13481.25	14481.25	13406.25	14443.75	12975.0
Zooplankton	6215.75	8077.25	6788.5	6635.5	11212.25	9468.5	3141.3333	3635.00	2341.25	3675.00	4525.25	445.75	1654.00	2759.00	2549.00	2845.75	2796.75	2390.25

Table 4.4: Simple correlation of phytoplankton and zooplankton with rainfall in all the stations during 1990-'91 and 1991-'92.

YEAR	1990-'91			1991-'92		
Station	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Phytoplankton	0.683*	-0.268	-0.230	+0.586*	-0.529	-0.554
Zooplankton	0.688*	0.361	-0.395	-0.444	-0.261	-0.442

Table 4.5 : Simple correlation of phytoplankton with physico - chemical parameters, nutrients, primary production and chlorophylls for all stations during 1990-'91and 1991-'92.

Phytoplankton	1990-'91 Station I	1991-'92 Station I	1990-'91 Station II	1991-'92 Station II	1990-'91 Station III	1991-'92 Station III
Depth	-0.096	-0.201	0.100	-0.305	0.025	-0.260
Light penetration	0.112	-0.274	0.207	-0.076	0.323	0.198
Atmospheric temperature	0.138	0.654	0.424	0.016	-0.066	-0.016
Surface temperature	0.111	0.489	0.638*	0.044	0.435	-0.044
Bottom temperature	0.407	0.117	0.185	0.055	0.252	0.005
Surface salinity	-0.253	0.564*	0.297	0.815**	0.328	0.560*
Bottom salinity	-0.173	0.602*	0.280	0.645*	0.365	0.559*
Surface oxygen	0.595*	-0.346*	-0.225	-0.593*	-0.164	-0.437
Bottom oxygen	-0.650*	-0.285	-0.256	-0.619*	-0.254	-0.441
Surface pH	-0.403	0.385	0.275	0.691**	0.360	0.242
Bottom pH	-0.291	0.122	0.130	0.659*	0.289	0.554
Surface H_2S	-0.562*	-0.646*	-	-	-	-

Continued…

Bottom H_2S	0.511	0.489	-	-	-	-
Silicate	-0.175	-0.514	-0.486	-0.605*	-0.429	-0.511
Phosphorus	-0.200	-0.498	0.351	-0.672*	-0.397	-0.653*
Phosphate	0.161	-0.462	-0.400	-0.739**	-0.430	-0.604*
Nitrate	-0.012	-0.575*	-0.450	-0.737**	-0.341	-0.690**
Nitrite	-0.370	-0.649*	-0.513	-0.817**	-0.676**	0.985**
N/P ratio	-0.055	-0.717**	-0.349	-0.604*	-0.409	0.985**
Gross primary production	-0.212	0.651*	0.031	0.547	0.106	0.656*
Net primary production	0.910**	0.995**	0.957**	0.378	0.942**	0.772*
Chlorophyll 'a'	0.989**	0.784**	0.791**	0.996*	0.268	-0.689*
Chlorophyll 'b'	0.726**	-0.248	0.555	0.677*	-0.106	-0.860*
Chlorophyll 'c'	0.932**	0.437	0.793**	0.986**	0.302	0.938**
c/a ratio	0.733**	-0.389	0.556*	0.524	0.381	0.248

Table 4.6: Simple correlation of phytoplankton and zooplankton with gross primary production at station I, II and III during 1990 – '91 and 1991 – '92.

	1990-'91			1991-'92		
	Station I	Station II	Station III	Station I	Station II	Station III
Phytoplankton	-.212	.031	.106	.651*	.547	.656*
Zooplankton	.521	.508	.738**	.749	.757**	.817**

Table 4.7: Simple correlation of phytoplankton and zooplankton with net primary Production at station I, II and III during 1990 – '91 and 1991 – '92.

	1990-'91			1991-'92		
	Station I	Station II	Station III	Station I	Station II	Station III
Phytoplankton	.906**	.957**	.942**	.965**	.378*	.972**
Zooplankton	.335	.543	.349	.271	.069	.733**

Table 4.8 : Simple correlation of chlorophyll 'a' with phytoplankton and zooplankton at station I, II and III during 1990 – '91 and 1991 – '92.

	1990-'91			1991-'92		
	Station I	Station II	Station III	Station I	Station II	Station III
Phytoplankton	.828**	.214	.371	.444	.127	.349
Zooplankton	.439	-.018	.020	.366	-.417	.155

Table 4.9: Simple correlation of chlorophyll 'b' with phytoplankton and zooplankton at station I, II and III during 1990 – '91 and 1991 –'92.

	1990-'91			1991-'92		
	Station I	Station II	Station III	Station I	Station II	Station III
Phytoplankton	.521	.555	.454	.476	.677*	.966**
Zooplankton	.669**	-.110	.724**	.609*	.056	.740**

Table 4.10 : Simple correlation of chlorophyll 'c' with phytoplankton and zooplankton at station I, II and III during 1990 – '91 and 1991 – '92.

	1990-'91			1991-'92		
	Station I	Station II	Station III	Station I	Station II	Station III
Phytoplankton	.065	.626*	.945**	.510	.841**	.938
Zooplankton	.301	-.040	.302	.575	.324	.780**

Table 4.11: Simple correlation of phytoplankton and zooplankton with chlorophyll c/a ratio at station I, II and III during 1990 – '91 and 1991 – '92.

	1990-'91			**1991-'92**		
	Station I	Station II	Station III	Station I	Station II	Station III
Phytoplankton	.688*	-.556	.381	.001	.524	.248
Zooplankton	.332	.410	.489	-.132	.150	.349

Table 4.12 : Simple correlation of phytoplankton with zooplankton at station I, II and III during 1990-'91 and 1991-'92.

1990-'91			**1991-'92**		
Station I	Station II	Station III	Station I	Station II	Station III
-.123	.245	.259	.326	.685*	.680*

Table 4.13 : Results of regression analysis with correlation for Bacillariophyceae (Y) in station I during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 –'91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=921.175+1528.971^{NS} x	0.333^{NS}	Y=9391.561-721.649^{NS} x	-0.173^{NS}
2.	Visibility	Y=1248.682+8896.887^{NS} x	0.393^{NS}	Y=4923.465+3965.595^{NS} x	0.203^{NS}
3.	Temperature-Atmosphere	Y=4282.356+72.496^{NS} x	0.030^{NS}	Y=-1566.15+315.463^{NS} x	0.175^{NS}
4.	Temperature-Surface	Y=1375.305+189.302^{NS} x	0.099 ^{NS}	Y=-1223.420+319.834^{NS} x	0.122 ^{NS}
5.	Temperature-Bottom	Y=-15868.838+843.337^{NS} x	0.464^{NS}	Y=16145.928-356.037^{NS} x	-0.196 ^{NS}
6.	Salinity-Surface	Y=5743.091+44.266^{NS} x	0.082^{NS}	Y=3451.804+331.076* x	0.644*
7.	Salinity-Bottom	Y=5729.035+39.930^{NS} x	0.088^{NS}	Y=2784.817+312.895** x	0.702**
8.	Oxygen-Surface	Y=5860.09+87.633^{NS} x	0.026 ^{NS}	Y=14517.479-1503.734^{NS} x	-0.408^{NS}
9.	Oxygen-Bottom	Y=4281.952+452.316 ^{NS} x	0.132 ^{NS}	Y=13481.383-1364.022^{NS} x	-0.394^{NS}
10.	pH-Surface	Y=19967.78-1816.847^{NS} x	-0.212^{NS}	Y=-36920.999+5952.672* x	0.650*
11.	pH-Bottom	Y=8650.421-313.343^{NS} x	-0.033 ^{NS}	Y=-38191.269+6080.269* x	0.642*
12.	H_2S-Surface	Y=9620.037-1002.117* x	-0.619*	Y=11171.283-600.447 ^{NS} x	-0.289^{NS}
13.	H_2S-Bottom	Y=5512.648+38.941^{NS} x	0.117 ^{NS}	Y=-1223.420+319.834 ^{NS} x	0.122 ^{NS}
14.	Silicate	Y=8529.94-23.265^{NS} x	-0.227^{NS}	Y=12870.067-55.379^{NS} x	-0.547 ^{NS}
15.	Phosphorus	Y=8682.891-1551.671^{NS} x	-0.259^{NS}	Y=12637.090-3959.504^{NS} x	-0.482^{NS}
16.	Phosphate	Y=7470.766-997.523^{NS} x	-0.106 ^{NS}	Y=12570.158-4940.537* x	-0.586*
17.	Nitrate	Y=7686.699-181.944 ^{NS} x	-0.181^{NS}	Y=11675.149-680.258* x	-0.653*
18.	Nitrite	Y=8647.677-7083.654 ^{NS} x	-0.291^{NS}	Y=12850.991-16398.114** x	-0.723**
19.	Gross production	Y=176.262+125.403** x	0.855**	Y=-3402.191+194.572** x	0.791**
20.	Net production	Y=854.547+67.397** x	0.720**	Y=-1516.341+210.095* x	0.634*
21.	Chlorophyll 'a'	Y=1103.347+2159.75* x	0.604*	Y=-4863.327+4624.346** x	0.750**
22.	Chlorophyll 'b'	Y=5231.403+1307.580 ^{NS} x	0.198^{NS}	Y=7847.779-622.302^{NS} x	-0.075 ^{NS}
23.	Chlorophyll 'c'	Y=2566.736+3026.17* x	0.619*	Y=-846.108+6517.590* x	0.616*

Table 4.14 : Results of regression analysis with correlation for Bacillariophyceae (Y) in station II during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=11879.466-1358.751^{NS} x	-0.172^{NS}	Y=19888.252-8349.404^{NS} x	-0.358^{NS}
2.	Visibility	Y=8329.532+2888.915^{NS} x	0.116^{NS}	Y=9627.77+1048.396^{NS} x	0.029^{NS}
3.	Temperature-Atmosphere	Y=-105550.997+741.095^{NS} x	0.251^{NS}	Y=-6895.852+606.507^{NS} x	0.211^{NS}
4.	Temperature-Surface	Y=-31154.460+1543.547* x	0.572*	Y=-11209.927+815.289^{NS} x	0.212^{NS}
5.	Temperature-Bottom	Y=-3383.946+472.774^{NS} x	0.184^{NS}	Y=-395.347+367.018^{NS} x	0.128^{NS}
6.	Salinity-Surface	Y=6564.238+377.04^{NS} x	0.351^{NS}	Y=3081.480+1003.832** x	0.860**
7.	Salinity-Bottom	Y=6489.623+299.967^{NS} x	0.376^{NS}	Y=3086.017+703.065** x	0.758**
8.	Oxygen-Surface	Y=14257.137-881.894^{NS} x	-0.201^{NS}	Y=50982.072-7544.382** x	-0.728**
9.	Oxygen-Bottom	Y=13900.018-853.101^{NS} x	-0.193^{NS}	Y=48341.979-7553.166* x	-0.691*
10.	pH-Surface	Y=-33063.911+5784.097^{NS} x	0.287^{NS}	Y=-96815.001+14282.948** x	0.785**
11.	pH-Bottom	Y=-15438.4+3369.082^{NS} x	0.187^{NS}	Y=-82027.663+12148.231** x	0.730**
12.	Silicate	Y=16774.347-61.873^{NS} x	-0.434^{NS}	Y=24327.017-118.284* x	-0.692*
13.	Phosphorus	Y=15266.79-3064.462^{NS} x	-0.362^{NS}	Y=25276.64-9421.009* x	-0.687*
14.	Phosphate	Y=15719.382-4440.79^{NS} x	-0.325^{NS}	Y=24906.530-10723.768** x	-0.817**
15.	Nitrate	Y=14947.522-574.016^{NS} x	-0.397^{NS}	Y=21249.599-1433.425** x	-0.858**
16.	Nitrite	Y=13688.859-9776.525^{NS} x	-0.385^{NS}	Y=20028.978-23051.887** x	-0.840**
17.	Gross production	Y=499.917+117.222** x	0.870**	Y=-1912.406+125.739** x	0.942**
18.	Net production	Y=795.692+148.713** x	0.849**	Y=9119.691+8.941^{NS} x	0.197^{NS}
19.	Chlorophyll 'a'	Y=3926.431+1791.721* x	0.670*	Y=-1456.019+2673.19** x	0.951**
20.	Chlorophyll 'b'	Y=7296.114+1109.264^{NS} x	0.258^{NS}	Y=3085.559+3257.656^{NS} x	0.543^{NS}
21.	Chlorophyll 'c'	Y=3417.159+3370.575**x	0.705**	Y=-1116.817+4807.483** x	0.949**

Table 4.15 : Results of regression analysis with correlation for Bacillariophyceae (Y) in station III during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=1985.115+1674.637^{NS} x	0.261^{NS}	Y=10405.750-3913.13^{NS} x	-0.280^{NS}
2.	Visibility	Y=4823.492-62.689^{NS} x	-0.005^{NS}	Y=6121.379-633.229^{NS} x	-0.026^{NS}
3.	Temperature-Atmosphere	Y=-9366.715+474.583^{NS} x	0.269^{NS}	Y=1214.018+161.026^{NS} x	0.094^{NS}
4.	Temperature-Surface	Y=-4034.355+323.199^{NS} x	0.296^{NS}	Y=1880.274+146.231^{NS} x	0.083^{NS}
5.	Temperature-Bottom	Y=2349.943+92.665^{NS} x	0.092^{NS}	Y=429.629+200.178^{NS} x	0.112^{NS}
6.	Salinity-Surface	Y=3731.774+155.106^{NS} x	0.265^{NS}	Y=3711.812+405.94^{NS} x	0.445^{NS}
7.	Salinity-Bottom	Y=3614.734+123.996^{NS} x	0.281^{NS}	Y=3645.691+293.326^{NS} x	0.434^{NS}
8.	Oxygen-Surface	Y=5390.644-115.059^{NS} x	-0.054^{NS}	Y=20971.960-2721.631^{NS} x	-0.460^{NS}
9.	Oxygen-Bottom	Y=6222.441-289.143^{NS} x	-0.140^{NS}	Y=20874.681-2884.254^{NS} x	-0.499^{NS}
10.	pH-Surface	Y=-30541.485+4788.231^{NS} x	0.420^{NS}	Y=-13317.047+2583.709^{NS} x	0.174^{NS}
11.	pH-Bottom	Y=-23561.684+3821.206^{NS} x	0.313^{NS}	Y=-28829.918+4648.692^{NS} x	0.421^{NS}
12.	Silicate	Y=6592.773-16.007^{NS} x	-0.253^{NS}	Y=9724.554-30.484^{NS} x	-0.423^{NS}
13.	Phosphorus	Y=7178.610-1152.046^{NS} x	-0.287^{NS}	Y=15093.100-4871.822* x	-0.604*
14.	Phosphate	Y=5346.864-372.824^{NS} x	-0.060^{NS}	Y=12046.619-4151.636^{NS} x	-0.523^{NS}
15.	Nitrate	Y=5814.051-91.495^{NS} x	-0.141^{NS}	Y=10746.365-536.270* x	-0.603*
16.	Nitrite	Y=7104.957-5047.178^{NS} x	-0.482^{NS}	Y=10822.757-9427.686** x	-0.714**
17.	Gross production	Y=1154.174+49.322* x	0.578*	Y=-2056.485+106.882** x	0.913**
18.	Net production	Y=301.396+80.423* x	0.610*	Y=-1491.379+140.047** x	0.832**
19.	Chlorophyll 'a'	Y=1931.238+840.067^{NS} x	0.537^{NS}	Y=-1126.203+2083.082** x	0.880**
20.	Chlorophyll 'b'	Y=3003.034+744.747^{NS} x	0.355^{NS}	Y=173.920+2416.15** x	0.717**
21.	Chlorophyll 'c'	Y=2370.479+1552.873^{NS} x	0.518^{NS}	Y=-70.363+3271.260** x	0.803**

Table 4.16 : Results of regression analysis with correlation for Chlorophyceae (Y) in station I during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=1138.666+450.787^NS^ x	0.220^NS^	Y=7443.952-1167.814** x	-0.712**
2.	Visibility	Y=9190.168-1735.931* x	-0.633*	Y=2805.979+1405.968^NS^ x	0.183^NS^
3.	Temperature-Atmosphere	Y=4596.354-2618.704^NS^ x	-0.193 ^NS^	Y=-3340.510+253.882^NS x^	0.358^NS^
4.	Temperature-Surface	Y=-12416.071+566.964^NS^ x	0.397^NS^	Y=-5195.958+340.545^NS^ x	0.330^NS^
5.	Temperature-Bottom	Y=-11668.259+572.031^NS^ x	0.502^NS^	Y=-4220.362+301.017^NS^x	0.420^NS^
6.	Salinity-Surface	Y=7081.258-521.325^NS^ x	-0.091^NS^	Y=2999.947+50.122^NS^ x	0.248^NS^
7.	Salinity-Bottom	Y=3212.664-7.909^NS^ x	-0.024^NS^	Y=2977.659+41.494^NS^ x	0.236^NS^
8.	Oxygen-Surface	Y=4486.795-14.076^NS^ x	-0.230^NS^	Y=8617.654+1013.654* x	-0.699*
9.	Oxygen-Bottom	Y=1444.530-359.018^NS^ x	-0.180^NS^	Y=8170.606-972.175** x	-0.713**
10.	pH-Surface	Y=-10985.256+537.295^NS^ x	0.495^NS^	Y=13718.019-1381.130^NS^ x	-0.383^NS^
11.	pH-Bottom	Y=10291.842-951.338^NS^ x	-0.186^NS^	Y=15556.647-1618.575^NS^ x	-0.434^NS^
12.	H_2S-Surface	Y=2889.546+16.957^NS^ x	0.063 ^NS^	Y=1156.014-924.294** x	-0.768**
13.	H_2S-Bottom	Y=5127.385-816.042^NS^ x	-0.439 ^NS^	Y=-5195.958+340.545^NS^ x	0.330
14.	Silicate	Y=2226.033+740.844^NS^ x	0.132^NS^	Y=4582.637-9.857^NS^ x	-0.247^NS^
15.	Phosphorus	Y=4270.144-147.741^NS^ x	-0.245^NS^	Y=3356.596+40.825^NS^ x	0.059^NS^
16.	Phosphate	Y=5020.610-1222.406^NS^ x	-0.341^NS^	Y=4878.213-1187.531^NS^ x	-0.358^NS^
17.	Nitrate	Y=4725.869-4785.466^NS^ x	-0.329^NS^	Y=2854.172+484.250^NS^ x	0.149^NS^
18.	Nitrite	Y=868.559+1839.393* x	0.629*	Y=2412.879+437.678^NS^ x	0.180^NS^
19.	Gross production	Y=1224.072+23.585^NS^ x	0.421^NS^	Y=3372.678+1.679^NS^ x	0.051^NS^
20.	Net production	Y=1334.089+29.098^NS^ x	0.400^NS^	Y=3255.103+3.773^NS^ x	0.079^NS^
21.	Chlorophyll 'a'	Y=1174.567+34.821^NS^ x	0.287^NS^	Y=3766.7-5.774^NS^ x	-0.044^NS^
22.	Chlorophyll 'b'	Y=-259.492+1412.505* x	0.660*	Y=3805.385-2.440^NS^ x	-0.219^NS^
23.	Chlorophyll 'c'	Y=1006.255+2662.808* x	-0.676*	Y=2928.186+11.582^NS^ x	0.168^NS^

Table 4.17 : Results of regression analysis with correlation for Chlorophyceae (Y) in station II during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=9446.059-910.834^{NS} x	-0.202^{NS}	Y=18501.846-7670.333^{NS} x	-0.392^{NS}
2.	Visibility	Y=4727.863+2721.407^{NS} x	-0.123^{NS}	Y=8505.318+2186.595^{NS} x	0.065^{NS}
3.	Temperature-Atmosphere	Y=-32081.825+1387.954* x	0.690 *	Y=5010.944+160.929^{NS} x	0.067^{NS}
4.	Temperature-Surface	Y=-31230.765+1409.001**x	0.765 **	Y=3500.253+230.318^{NS} x	0.072^{NS}
5.	Temperature-Bottom	Y=2411.979+136.793^{NS} x	0.078^{NS}	Y=8514.822+35.270^{NS} x	0.015^{NS}
6.	Salinity-Surface	Y=4681.406+177.583^{NS} x	0.243^{NS}	Y=4025.312+784.735** x	0.801**
7.	Salinity-Bottom	Y=4983.673+111.75^{NS} x	0.206^{NS}	Y=4723.361+480.164* x	0.617 *
8.	Oxygen-Surface	Y=9996.369-759.083^{NS} x	-0.254 ^{NS}	Y=42089.068-6011.828* x	-0.692*
9.	Oxygen-Bottom	Y=10846.851-982.281^{NS} x	-0.326 ^{NS}	Y=40226.302-6066.452* x	-0.662*
10.	pH-Surface	Y=-12459.601+2519.235^{NS}x	0.183^{NS}	Y=-66891.551+10207.019* x	0.669*
11.	pH-Bottom	Y=1923.440+576.279^{NS}x	0.047^{NS}	Y=-62123.312+9446.053* x	0.677*
12.	Silicate	Y=10996.598-42.732^{NS} x	-0.440 ^{NS}	Y=19828.715-85.766* x	-0.598*
13.	Phosphorus	Y=10431.310-2389.056^{NS} x	-0.414 ^{NS}	Y=20824.856-7022.179* x	-0.610*
14.	Phosphate	Y=10718.374-3411.702^{NS} x	-0.366^{NS}	Y=20634.452-8055.192** x	-0.732**
15.	Nitrate	Y=9878.980-412.882^{NS} x	-0.419^{NS}	Y=17342.996-1006.609** x	-0.718**
16.	Nitrite	Y=9606.835-8673.222^{NS} x	-0.501^{NS}	Y=16979.444-17335.916** x	-0.753**
17.	Gross production	Y=468.625+72.097** x	0.785**	Y=-765.821+107.57** x	0.961**
18.	Net production	Y=904.072+87.332** x	0.732**	Y=8270.37+11.252^{NS} x	0.295^{NS}
19.	Chlorophyll 'a'	Y=2440.237+1142.626* x	0.627 *	Y=-244.52+2256.675** x	0.957**
20.	Chlorophyll 'b'	Y=1897.335+1846.807* x	0.629 *	Y=2948.680+3046.944* x	0.606*
21.	Chlorophyll 'c'	Y=1902.756+2259.807* x	0.694*	Y=188.885+3995.484** x	0.941 **

Table 4.18 : Results of regression analysis with correlation for Chlorophyceae (Y) in station III during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=8763.370-188.227^{NS} x	-0.019^{NS}	Y=18217.943-5548.855^{NS} x	-0.452^{NS}
2.	Visibility	Y=4993.686+6804.132^{NS} x	0.339^{NS}	Y=10939.074-2281.842^{NS}x	-0.096^{NS}
3.	Temperature-Atmosphere	Y=5783.337+89.316^{NS} x	0.032^{NS}	Y=11935.471-71.721^{NS} x	-0.034^{NS}
4.	Temperature-Surface	Y=-24274.91+1198.273* x	0.694 *	Y=10589.241-26.238^{NS} x	-0.012^{NS}
5.	Temperature-Bottom	Y=-16572.235+949.531*x	0.595*	Y=6259.551+134.344^{NS} x	0.061^{NS}
6.	Salinity-Surface	Y=7408.907+152.05^{NS} x	0.164^{NS}	Y=5752.535+792.713** x	0.713**
7.	Salinity-Bottom	Y=6418.923+213.766^{NS} x	0.307^{NS}	Y=5568.043+580.252** x	704**
8.	Oxygen-Surface	Y=14197.914-1104.530^{NS} x	-0.327 ^{NS}	Y=36206.447-4730.494* x	-0.656**
9.	Oxygen-Bottom	Y=13978.838-1117.734^{NS} x	-0.343 ^{NS}	Y=32960.932-4423.513* x	-0.628*
10.	pH-Surface	Y=-27690.301+4897.331^{NS} x	0.271^{NS}	Y=-51222.372+8247.030^{NS} x	0.455^{NS}
11.	pH-Bottom	Y=-19443.682+3758.976^{NS} x	0.195^{NS}	Y=-61752.567+9608.829**x	0.713**
12.	Silicate	Y=14359.742-52.542^{NS} x	-0.524^{NS}	Y=17220.461-57.388* x	-0.653*
13.	Phosphorus	Y=12835.232-2117.515^{NS} x	-0.334^{NS}	Y=23988.244-7416.277** x	-0.754**
14.	Phosphate	Y=15856.754-4975.156^{NS} x	-0.503^{NS}	Y=20725.95-7237.842** x	-0.747**
15.	Nitrate	Y=14169.571-512.043^{NS} x	-0.499^{NS}	Y=17887.843-872.653** x	-0.805**
16.	Nitrite	Y=13830.338-11743.465**x	-0.709**	Y=17138.046-13692.067** x	-0.851**
17.	Gross production	Y=961.127+101.516** x	0.752**	Y=-80.811+135.079** x	0.947**
18.	Net production	Y=-1476.834+177.757** x	0.852**	Y=-329.577+195.423** x	0.952**
19.	Chlorophyll 'a'	Y=2982.476+1605*.122 x	0.644*	Y=740.890+2738.685** x	0.949**
20.	Chlorophyll 'b'	Y=2159.177+2618.49** x	0.789**	Y=2337.269+3225.072** x	0.785**
21.	Chlorophyll 'c'	Y=4556.192+2496.029^{NS} x	0.526^{NS}	Y=1580.685+4605.029**x	0.927**

Table 4.19 : Results of regression analysis with correlation for Cyanophyceae (Y) in station I during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=1577.548+128.530^{NS} x	0.040^{NS}	Y=829.607+379.373 ^{NS} x	0.122^{NS}
2.	Visibility	Y=534.745+2884.675^{NS} x	0.257^{NS}	Y=6655.702-8806.125* x	-0.603*
3.	Temperature-Atmosphere	Y=29121.280-988.839* x	-0.593*	Y=10870.076-323.918^{NS} x	-0.241^{NS}
4.	Temperature-Surface	Y=18823.374-649.760^{NS} x	-0.489^{NS}	Y=2532.136-16.858^{NS} x	-0.009^{NS}
5.	Temperature-Bottom	Y=7361.965-203.234^{NS}x	-0.160^{NS}	Y=436.592+64.577^{NS} x	0.047^{NS}
6.	Salinity-Surface	Y=4406.335-200.358^{NS} x	-0.530^{NS}	Y=3196.079-102.999^{NS} x	-0.268^{NS}
7.	Salinity-Bottom	Y=4304.419-168.484^{NS} x	-0.534^{NS}	Y=3566.293-109.493^{NS} x	-0.328^{NS}
8.	Oxygen-Surface	Y=-4565.133+1413.628* x	0.607*	Y=-3685.455+1153.438 ^{NS} x	0.419^{NS}
9.	Oxygen-Bottom	Y=-4396.923+1462.495* x	0.613*	Y=-3444.713+1162.414 ^{NS} x	0.449^{NS}
10.	pH-Surface	Y=12616.960-1404.493^{NS} x	-0.235 ^{NS}	Y=11082.284-1218.074^{NS} x	-0.178^{NS}
11.	pH-Bottom	Y=17930.782-2092.363^{NS} x	-0.312 ^{NS}	Y=13750.774-1568.424^{NS} x	-0.221^{NS}
12.	H_2S-Surface	Y=4153.768-1012.793* x	-0.610*	Y=689.305-109.175* x	-0.643*
13.	H_2S-Bottom	Y=528.468+77.182^{NS} x	0.332	Y=2532.136-16.858^{NS} x	-0.009^{NS}
14.	Silicate	Y=-327.513+24.226^{NS} x	0.339^{NS}	Y=-62.228+20.312^{NS} x	0.268^{NS}
15.	Phosphorus	Y=-447.018+1590.210$^{NS\ x}$	0.380^{NS}	Y=1465.002+444.054^{NSx}	0.072^{NS}
16.	Phosphate	Y=-989.667+2503.527^{NS} x	0.382^{NS}	Y=165.173+1708.456^{NS} x	0.271 ^{NS}
17.	Nitrate	Y=318.685+219.213^{NS} x	0.312^{NS}	Y=545.660+224.914^{NS} x	0.288 ^{NS}
18.	Nitrite	Y=-131.962+6428.918$^{NS\ x}$	0.379^{NS}	Y=1252.874+2364.072^{NS} x	0.139^{NS}
19.	Gross production	Y=665.013+28.242 ^{NS} x	0.276^{NS}	Y=1245.275+16.026 ^{NS} x	0.084^{NS}
20.	Net production	Y=814.498+30.569 ^{NS} x	0.233^{NS}	Y=-639.456+67.780 ^{NS} x	0.273^{NS}
21.	Chlorophyll 'a'	Y=-225.139+941.696 ^{NS} x	0.377^{NS}	Y=9936.221-3061.024^{NS} x	-0.664*
22.	Chlorophyll 'b'	Y=486.940+1941.358 ^{NS} x	0.422^{NS}	Y=-515.448+1864.847 ^{NS} x	0.301^{NS}
23.	Chlorophyll 'c'	Y=104.009+1571.996^{NS} x	0.461 ^{NS}	Y=-267.238+1972.699^{NS} x	0.249^{NS}

Table 4.20 : Results of regression analysis with correlation for Cyanophyceae (Y) in station II during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=1450.572+647.175^{NS} x	0.205^{NS}	Y=1450.572+647.175^{NS} x	0.205^{NS}
2.	Visibility	Y=1537.345+1543.586^{NS} x	0.154^{NS}	Y=1537.345+1543.586^{NS} x	0.154^{NS}
3.	Temperature-Atmosphere	Y=4739.786-85.226^{NS} x	-0.072^{NS}	Y=4739.786-85.226^{NS}x	-0.072^{NS}
4.	Temperature-Surface	Y=9330.019-260.994^{NS} x	-0.241^{NS}	Y=9330.019-260.994^{NS} x	-0.241^{NS}
5.	Temperature-Bottom	Y=1474.436-32.381^{NS} x	-0.032^{NS}	Y=1474.436-32.381^{NS} x	-0.032^{NS}
6.	Salinity-Surface	Y=3079.296-78.037^{NS} x	-0.182^{NS}	Y=3079.296-78.037^{NS}x	-0.182^{NS}
7.	Salinity-Bottom	Y=3373.579-86.491^{NS} x	-0.271^{NS}	Y=3373.579-86.491^{NS} x	-0.271^{NS}
8.	Oxygen-Surface	Y=1422.472+195.654^{NS} x	0.111^{NS}	Y=1422.472+195.654^{NS} x	0.111^{NS}
9.	Oxygen-Bottom	Y=1812.264+122.753^{NS} x	0.069^{NS}	Y=1812.264+122.753^{NS} x	0.069^{NS}
10.	pH-Surface	Y=3484.48-147.906^{NS} x	-0.018^{NS}	Y=3484.48-147.906^{NS} x	-0.018^{NS}
11.	pH-Bottom	Y=9446.009-938.181^{NS} x	-0.130^{NS}	Y=9446.009-938.181^{NS} x	-0.130^{NS}
12.	Silicate	Y=2845.628-4.152^{NS} x	-0.073^{NS}	Y=439.915+22.229^{NS} x	0.253^{NS}
13.	Phosphorus	Y=892.865+854.922^{NS} x	0.252^{NS}	Y=3090.325+12.486^{NS} x	0.002^{NS}
14.	Phosphate	Y=2862.586-365.181^{NS} x	-0.067^{NS}	Y=995.615+1533.391^{NS} x	0.227^{NS}
15.	Nitrate	Y=2636.6-28.66^{NS} x	-0.049^{NS}	Y=1202.041+245.714* x	0.286^{NS}
16.	Nitrite	Y=2795.421-1062.646^{NS} x	-0.105^{NS}	Y=2882.522+529.987^{NS} x	0.038^{NS}
17.	Gross production	Y=1518.617+10.790^{NS} x	0.200^{NS}	Y=2492.078+6.463^{NS} x	0.094^{NS}
18.	Net production	Y=1374.407+16.484^{NS} x	0.235^{NS}	Y=1733.246+12.351^{NS} x	0.528^{NS}
19.	Chlorophyll 'a'	Y=1549.75+249.95^{NS} x	0.234^{NS}	Y=2642.001+108.2^{NS} x	0.075^{NS}
20.	Chlorophyll 'b'	Y=947.965+608.445^{NS} x	0.353^{NS}	Y=775.419+1081.852^{NS} x	0.351^{NS}
21.	Chlorophyll 'c'	Y=2140.45+127.035^{NS} x	0.066^{NS}		

Table 4.21 : Results of regression analysis with correlation for Cyanophyceae (Y) in station III during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=4474.06+135.846^{NS} x	0.032^{NS}	Y=-1183.224+2422.968 ^{NS} x	0.479^{NS}
2.	Visibility	Y=6225.048-210.939^{NS} x	-0.051^{NS}	Y=4475.756-4354.497^{NS} x	-0.445^{NS}
3.	Temperature-Atmosphere	Y=31844.480-893.74^{NS} x	-0.253^{NS}	Y=5544.76-107.804^{NS} x	-0.125^{NS}
4.	Temperature-Surface	Y=6713.678-56.116^{NS} x	-0.026^{NS}	Y=9091.709-245.879^{NS} x	-0.276^{NS}
5.	Temperature-Bottom	Y=11964.711-257.437^{NS}x	-0.128^{NS}	Y=9718.888-269.371^{NS} x	-0.299^{NS}
6.	Salinity-Surface	Y=3264.619+280.483^{NS} x	0.239^{NS}	Y=3227.446-147.910^{NS} x	-0.323^{NS}
7.	Salinity-Bottom	Y=3707.095+155.310^{NS} x	0.176^{NS}	Y=3184.906-97.913^{NS} x	-0.288^{NS}
8.	Oxygen-Surface	Y=4567.034+175.616^{NS} x	0.029^{NS}	Y=-9783.945+2199.646** x	0.740**
9.	Oxygen-Bottom	Y=3047.370+3781.799^{NS} x	0.128^{NS}	Y=-8588.939+2117.110**x	0.729**
10.	pH-Surface	Y=-15026.207+2738.447^{NS} x	0.120^{NS}	Y=2779.49-3417.713^{NS} x	-0.457^{NS}
11.	pH-Bottom	Y=-16734.212+2953.566^{NS}x	0.121^{NS}	Y=15026.315-1686.014^{NS} x	-0.304^{NS}
12.	Silicate	Y=6776.959-14.182^{NS}x	-0.112^{NS}	Y=933.955+11.91^{NS} x	0.329^{NS}
13.	Phosphorus	Y=8589.982-1645.207^{NS} x	-0.205^{NS}	Y=-328.141+1464.238^{NS} x	0.361^{NS}
14.	Phosphate	Y=9546.174-2931.119^{NS} x	-0.234^{NS}	Y=279.683+1453.215^{NS} x	0.364^{NS}
15.	Nitrate	Y=5938.609-67.778^{NS}x	-0.052^{NS}	Y=1114.556+146.324^{NS} x	0.327^{NS}
16.	Nitrite	Y=7658.494-5404.897^{NS} x	-0.258^{NS}	Y=2195.027+494.445^{NS} x	0.075^{NS}
17.	Gross production	Y=-2908.849+109.696* x	0.642*	Y=2626.33-2.295^{NS} x	-0.039^{NS}
18.	Net production	Y=-1570.125+120.920^{NS}x	0.488^{NS}	Y=2408.253+0.935^{NS} x	0.011^{NS}
19.	Chlorophyll 'a'	Y=-2451.313+2241.575** x	0.710*	Y=2596.404-41.744^{NS} x	-0.035^{NS}
20.	Chlorophyll 'b'	Y=4716.169+193.649^{NS} x	0.046^{NS}	Y=1834.578+266.123^{NS} x	0.157^{NS}
21.	Chlorophyll 'c'	Y=-2100.059+4670.0** x	0.777**	Y=2497.834-22.608^{NS} x	-0.011^{NS}

Table 4.22 : Results of regression analysis with correlation for Dinophyceae (Y) in station I during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=672.478+12.634^{NS} x	0.019^{NS}	Y=1221.382-145.122^{NS} x	-0.271^{NS}
2.	Visibility	Y=558.942+279.529^{NS} x	0.084^{NS}	Y=622.792+217.702^{NS} x	0.087^{NS}
3.	Temperature-Atmosphere	Y=-3466.194+152.659^{NS} x	0.433*	Y=1289.244-20.455^{NS} x	-0.089^{NS}
4.	Temperature-Surface	Y=-420.122+43.976^{NS} x	0.157^{NS}	Y=1836.384-42.951^{NS} x	-0.128^{NS}
5.	Temperature-Bottom	Y=35.555+25.947^{NS} x	0.097^{NS}	Y=1640.496-35.137^{NS} x	-0.150^{NS}
6.	Salinity-Surface	Y=581.611-11.373^{NS} x	-0.142^{NS}	Y=155.098+54.533** x	0.827**
7.	Salinity-Bottom	Y=536.864+13.302^{NS} x	0.199^{NS}	Y=74.761+49.333** x	0.862**
8.	Oxygen-Surface	Y=992.104-59.064^{NS} x	-0.120^{NS}	Y=1913.017-234.777^{NS} x	-0.497^{NS}
9.	Oxygen-Bottom	Y=735.938-4.387^{NS} x	-0.009^{NS}	Y=1789.099-220.898^{NS} x	-0.497^{NS}
10.	pH-Surface	Y=3423.458-358.991^{NS} x	-0.284^{NS}	Y=-2883.162+490.710^{NS} x	0.418^{NS}
11.	pH-Bottom	Y=3323.222-342.930^{NS} x	-0.242^{NS}	Y=-3147.277+522.687^{NS} x	0.430^{NS}
12.	H_2S-Surface	Y=413.045-160.327*x	0.665*	Y=864.004+63.1^{NS} x	0.225^{NS}
13.	H_2S-Bottom	Y=578.147+7.134^{NS} x	0.145^{NS}	Y=1836.384-42.951^{NS} x	-0.128^{NS}
14.	Silicate	Y=832.471-1.192^{NS} x	-0.079^{NS}	Y=1997.518-11.856** x	-0.912**
15.	Phosphorus	Y=996.182-179.657^{NS} x	-0.203^{NS}	Y=1769.980-723.471* x	-0.686*
16.	Phosphate	Y=1036.637-265.536^{NS} x	-0.192^{NS}	Y=1642.25-800.736** x	-0.740*
17.	Nitrate	Y=717.708-0.134^{NS} x	-0.001^{NS}	Y=1456.916-104.401** x	-0.781**
18.	Nitrite	Y=1004.97-858.473^{NS} x	-0.239^{NS}	Y=1568.307-2324.344** x	-0.799**
19.	Gross production	Y=413.358+6.243^{NS} x	0.288^{NS}	Y=-426.918+21.794* x	0.664*
20.	Net production	Y=328.028+9.798^{NS} x	0.353^{NS}	Y=-263.733+24.721* x	0.582*
21.	Chlorophyll 'a'	Y=558.281+66.224^{NS} x	0.125^{NS}	Y=-646.680+539.881* x	0.683*
22.	Chlorophyll 'b'	Y=789.264-91.509^{NS} x	-0.094^{NS}	Y=989.824-181.396^{NS} x	-0.171^{NS}
23.	Chlorophyll 'c'	Y=601.454+94.179^{NS} x	0.131^{NS}	Y=284.130+376.072^{NS} x	0.277^{NS}

Table 4.23 : Results of regression analysis with correlation for Dinophyceae (Y) in station II during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 – '91		1991 – '92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=813.827+188.017^{NS} x	0.177^{NS}	Y=2819.611-1314.464^{NS} x	-0.453^{NS}
2.	Visibility	Y=464.692+1129.789^{NS} x	0.336^{NS}	Y=811.481+1007.368^{NS} x	0.202^{NS}
3.	Temperature-Atmosphere	Y=3759.424-96.797^{NS} x	-0.243^{NS}	Y=127.762+41.123^{NS} x	0.115^{NS}
4.	Temperature-Surface	Y=1334.762-9.371^{NS} x	-0.026^{NS}	Y=535.046+28.526^{NS} x	0.060^{NS}
5.	Temperature-Bottom	Y=-1558.648+93.983^{NS} x	0.272^{NS}	Y=1195.406+2.997^{NS} x	0.008^{NS}
6.	Salinity-Surface	Y=924.416+18.107^{NS} x	0.125^{NS}	Y=617.826+94.662* x	0.652*
7.	Salinity-Bottom	Y=833.603+22.041^{NS} x	0.205^{NS}	Y=606.467+67.478* x	0.585*
8.	Oxygen-Surface	Y=1522.015-88.709^{NS} x	-0.150^{NS}	Y=6337.292-933.423** x	-0.725**
9.	Oxygen-Bottom	Y=1304.307-46.880^{NS} x	-0.079^{NS}	Y=5295.972-793.293* x	-0.584*
10.	pH-Surface	Y=-2467.898+478.185^{NS} x	0.176^{NS}	Y=-9185.724+1398.082* x	0.618*
11.	pH-Bottom	Y=-3701.569+636.074^{NS} x	0.263^{NS}	Y=-9035.270+1360.121* x	0.658*
12.	Silicate	Y=962.931+1.105^{NS} x	0.058^{NS}	Y=2936.301-13.776* x	-0.648*
13.	Phosphorus	Y=1121.994-20.951^{NS} x	-0.018^{NS}	Y=2904.629-1008.832* x	-0.592*
14.	Phosphate	Y=1436.812-268.925^{NS} x	-0.146^{NS}	Y=2783.186-1089.017* x	-0.668*
15.	Nitrate	Y=1057.937+3.135^{NS} x	0.016^{NS}	Y=2332.983-135.416* x	-0.652*
16.	Nitrite	Y=1373.087-745.583^{NS} x	-0.218^{NS}	Y=2386.385-2570.081** x	-0.753**
17.	Gross production	Y=554.083+6.614^{NS} x	0.364^{NS}	Y=107.54+12.269** x	0.739**
18.	Net production	Y=603.612+7.856^{NS} x	0.333^{NS}	Y=1282.707-0.01307^{NS} x	-0.002^{NS}
19.	Chlorophyll 'a'	Y=750.904+100.054^{NS} x	0.278^{NS}	Y=168.810+256.964** x	0.736**
20.	Chlorophyll 'b'	Y=724.499+152.769^{NS} x	0.263^{NS}	Y=657.971+288.778^{NS} x	0.387^{NS}
21.	Chlorophyll 'c'	Y=822.932+136.12^{NS} x	0.211^{NS}	Y=156.859+481.194** x	0.764**

Table 4.24 : Results of regression analysis with correlation for Dinophyceae (Y) in station III during 1990 – '91 and 1991 –'92.

S.No.	PARAMETERS (X)	1990 - '91		1991 –'92	
		REGRESSION	CORRELATION	REGRESSION	CORRELATION
1.	Depth	Y=-133.221+185.155* x	0.573*	Y=475.620-82.891^{NS} x	-0.131^{NS}
2.	Visibility	Y=179.729-5.206^{NS} x	-0.007^{NS}	Y=106.127+528.398^{NS} x	0.431^{NS}
3.	Temperature-Atmosphere	Y=959.025-26.210^{NS} x	-0.264^{NS}	Y=1468.261-39.005^{NS} x	-0.361^{NS}
4.	Temperature-Surface	Y=375.725-7.274^{NS} x	-0.119^{NS}	Y=1397.535-38.781^{NS} x	-0.348^{NS}
5.	Temperature-Bottom	Y=315.061-5.236^{NS} x	-0.092^{NS}	Y=1550.997-44.51^{NS} x	-0.395^{NS}
6.	Salinity-Surface	Y=167.708+1.372^{NS} x	0.042^{NS}	Y=258.343+17.806^{NS} x	0.311^{NS}
7.	Salinity-Bottom	Y=165.687+1.201^{NS} x	0.048^{NS}	Y=235.644+15.53^{NS} x	0.365
8.	Oxygen-Surface	Y=145.121+6.140^{NS} x	0.051^{NS}	Y=1237.392-159.265^{NS} x	-0.428^{NS}
9.	Oxygen-Bottom	Y=107.194+14.124^{NS} x	0.122^{NS}	Y=1140.515-151.305^{NS} x	-0.416^{NS}
10.	pH-Surface	Y=-1008.234+160.63^{NS} x	0.251^{NS}	Y=-726.370+145.422^{NS} x	0.155^{NS}
11.	pH-Bottom	Y=-1967.4+289.014^{NS} x	0.421^{NS}	Y=-1591.52+260.577^{NS} x	0.375^{NS}
12.	Silicate	Y=267.484-0.803^{NS} x	-0.226^{NS}	Y=499.934-1.164^{NS} x	-0.257^{NS}
13.	Phosphorus	Y=111.502+31.653^{NS} x	0.140^{NS}	Y=749.631-209.523^{NS} x	-0.413^{NS}
14.	Phosphate	Y=129.988+31.625^{NS} x	0.090^{NS}	Y=525.104-116.142^{NS} x	-0.232^{NS}
15.	Nitrate	Y=269.638-8.283^{NS} x	-0.227^{NS}	Y=559.347-22.699^{NS} x	-0.406^{NS}
16.	Nitrite	Y=254.007-167.834^{NS} x	-0.285^{NS}	Y=569.155-411.456^{NS} x Y=-32.464+5.201** x	-0.496^{NS}
17.	Gross production	Y=147.133+0.406^{NS} x	0.085^{NS}	Y=12.830+6.474* x	0.706**
18.	Net production	Y=48.873+2.296^{NS} x	0.31^{NS}	Y=9.459+102.359* x	0.611*
19.	Chlorophyll 'a'	Y=173.20+1.141^{NS} x	0.013^{NS}	Y=-26.797-161.545** x	0.688*
20.	Chlorophyll 'b'	Y=61.948+47.94^{NS} x	0.407^{NS}	Y=74.776+153.291* x	0.762**
21.	Chlorophyll 'c'	Y=208.094-19.89^{NS} x	-0.118^{NS}		0.598*

4.4.1.8. Discussion

In the present study, 78 species of phytoplankton were recorded. Among these, 42 species were Bacillariophyceae, 15 were Chlorophyceae, 12 were Cyanophyceae and 9 were Dinophyceae. The diatoms followed by green algae were dominating the total phytoplankton in station I and II. In the riverine zone (station III) Chlorophyceae became dominant.

Similar findings of the dominance of diatoms in the estuarine zone were made by Mathew and Nair (1981) and Gopinathan *et al.* (1970) in the Veli lake and Nair *et al.*(1987) in the Ashtamudi estuary. Devassy and Bhattathiri (1974) observed the dominance of diatoms in Cochin backwaters. In Vellar estuary, Santhanam (1976), Thangaraj *et al.* (1979) and Sivakumar (1982) recorded the dominance of diatoms among the phytoplankton. In Coleroon estuary, Jegadeesan (1986) and Prabha Devi (1986) observed the dominance of diatoms. Bruno and Staker (1978) and Bruno *et al.* (1981) had also recorded the diatom dominance in Black Island estuaries. In Muthupet estuary, Balusamy (1988) observed the dominance of diatoms. In Paravur lake, Shibu (1991) recorded similar dominance of diatoms.

In the present study, green algae were dominant in the riverine zone (Station III). This was in conformity with the findings of Mathew and Nair (1981) and Gopinathan (1975) in the freshwater zone of Veli lake, Balusamy (1988) in Muthupet estuary and Shibu (1991) in Paravur lake.

The successful development and maintenance of a population depend upon the harmonious ecological balance between environmental conditions and tolerance of organisms to variations in one or more of these conditions. This is true for plankton population which is much influenced by the varying environmental parameters.

In the present study, temperature had no direct influence on phytoplankton. The maximum and minimum densities of phytoplankton never coincided with the high and low temperatures. Gopinathan (1975) stated that temperature never acted as a limiting factor for the production of diatoms in tropical estuaries. Qasim (1972) also stated that the temperature of water is little direct importance to production and growth of phytoplankton in tropical seas. Similar observations were made by Mathew and Nair (1981) in Veli lake, Thangaraj (1984) in Vellar estuary and Shibu (1991) in Paravur lake. However, Ramadhas (1977) in Porto Novo waters, and Jegadeesan (1986) in Coleroon estuary recorded high density of phytoplankton with high temperature. Sivakumar (1982) was of the opinion that low temperature with low phytoplankton density was chiefly due to freshwater flow into the backwater and not due to low temperature.

Turbidity and light penetration along with other ecological factors were found to be influencing the phytoplankton density in aquatic systems. In the present investigation, light penetration was maximum during premonsoon and minimum during monsoon season. The phytoplankton density was also found to be maximum in premonsoon and minimum during monsoon season. Thus the population density showed a direct relationship with light penetration and an inverse relationship with turbidity which was maximum during monsoon season. Low concentration of phytoplankton during monsoon season was also attributed to the excessive turbulance, high turbidity and insufficient light penetration. This observation is in accordance with the findings of Dutt *et al.* (1954). Similar observations were also made by Qasim *et al.* (1968), Dehadrai (1970), Ramadhas (1977), Mathew and Nair (1981), Chandran (1982), Jegadeesan (1986) and Shibu (1991). Sinclair (1977) reported that the sharp decrease in turbidity of surface waters was probably due to the decreased freshwater input into the estuary and was important to the phytoplankton production.

Salinity plays the major role as an ecological factor in controlling the distribution of phytoplankton in estuaries. In the present study, a positive correlation was observed between phytoplankton density and salinity. This observation is in agreement with the findings of Rangarajan (1958), Santhakumari (1971), Vijayalakshmi and Venugopalan (1975), Ramadhas (1977), Chandran (1982) and Thangaraj (1984) from Vellar estuary; Qasim *et al.* (1972), Devassy and Bhattathiri (1974), Kumaran and Rao (1975), Joseph and Pillai (1975) and Pillai *et al.* (1975) from Cochin backwaters; Dutt *et al.* (1954) from Hooghli estuary; Gopinathan (1985) from Veli lake; Jegadeesan (1986) from Coleroon estuary; Balusamy

(1988) from Muthupet estuary and Shibu (1991) from Paravur lake. Smayda (1965) found that when the salinity was higher, phytoplankton density was also higher, probably these organisms were of typically marine nature.

The inorganic nutrients are the major limiting elements on phytoplankton growth and its production in an estuarine environment. In the present investigation, the phytoplankton density showed a negative correlation with all the nutrients. Low nutrient concentration during the premonsoon season was mainly due to the ceasation of freshwater flow and partly due to the utilization by the plankton population. This observation is in conformity with some of the previous studies. Jegadeesan (1986) in Coleroon estuary and Balusamy (1988) in Muthupet estuary recorded a negative correlation of nutrients with the abundance of phytoplankton. Krishnamurthy (1967) observed that phosphate peak corresponded with phytoplankton abundance in Vellar estuary. Silas and Pillai (1975) reported that the primary peak of phytoplankton abundance coincided with high nutrient concentration in Cochin backwater. Prabha Devi (1986) recorded a positive correlation between the phytoplankton and dissolved nutrients in Coleroon estuary. Shibu (1991) observed a similar finding in Paravur lake.

Margalef (1967) postulated that mixing of two water masses would result in an increase of species diversity index. The results of the present study supported this postulate. In the present study, the density and species composition were high at station II followed by III and I. Naturally, station I the estuarine zone should have recorded the maximum index followed by station II and III. But it recorded the minimum species diversity indices because it was affected by retting. However, station II recorded the highest indices because of the intrusion and mixing of sea water with estuarine water and more number of neritic phytoplankton species were recorded.

Vijayalakshmi and Venugopalan (1975) recorded high species diversity index in the estuarine zone in Vellar estuary. Sundararaj and Krishnamurthy (1973) had observed a high production in the Vellar estuary with high density of phytoplankton and species composition than at sea. Krishnamurthy *et al.* (1974) also noticed a high density of phytoplankton in the mouth of the Vellar estuary. Similar findings were also recorded by Jagadeesan (1986) in Coleroon estuary and Balusamy (1988) in Muthupet estuary.

The maximum species diversity values were recorded during premonsoon with phytoplankton peaks. Low diversity values were recorded during monsoon season. The diversity indices were found to be higher in the non-retting estuarine zone followed by riverine zone and retting estuarine zone.

Low species diversity indices were found at station III, the riverine zone, during monsoon period in both the years. The low species diversity at this station may be due to the unstable nature of the environmental conditions prevailed there and also due to low saline conditions caused by monsoon rain and more river discharge. The present observation is in conformity with the earlier reports of Devassy and Bhattathiri (1974) in Cochin backwater, Chandran (1982), Sivakumar (1982) and Thangaraj (1984) in Vellar estuary, Jegadeesan (1986) in Coleroon estuary and Balusamy (1988) in Muthupet estuary. Margalef (1968) reported that low value of species diversity in monsoon period in Ria Vigo was due to turbulance and at these times the population started to multiply and hence low diversity.

The primary peaks of phytoplankton were encountered in May at station I and II and in June at station III during 1990-'91 and in March at station I, in April at station II and in May at station III during 1991-'92. A secondary peak of phytoplankton occurred in August at station I, in September at station II and in October at station III during 1990-'91. During 1991-'92 the secondary peaks occurred in September at station I and II and in October at Station III. Thus the primary peaks occurred in the premonsoon season and secondary peak occurred in the postmonsoon season except station III the riverine zone where the secondary peaks occurred during the monsoon season. Such primary and secondary peaks of phytoplankton during premonsoon periods were recorded by Subbaraju and Krishnamurthy (1972), Santhanam *et al.* (1975), Vijayalakshmi and Vanugopalan (1975), Sundararaj (1978), Thangaraj *et al.* (1979) and Chandran (1982) in Vellar estuary, Jegadeesan (1986) in Coleroon estuary and Balusamy (1988) in Muthupet estuary.

4.4.2. Zooplankton

4.4.2.1. Population Density

The population density of zooplankton collected from Manakkudy estuary at station I, II and III during 1990-'91 and 1991-'92 is given in Fig. 4.4.

The population density of zooplankton at station I varied from a low density of 972 individuals /m^3 in September to a high density of 11444 individuals /m^3 in May during 1990-'91 and from a low density of 541 individuals /m^3 in October to a high density of 8747 individuals /m^3 in February during 1991-'92.

At station II the zooplankton fluctuated from 160 individuals /m^3 in November to 16691 individuals /m^3 in May during 1990-'91 and from 481 individuals /m^3 in November to 16362 individuals /m^3 in May during 1991-'92.

At station III the zooplankton varied from a minimum density of 140 individuals /m^3 in November to a maximum density of 12726 individuals /m^3 in May during 1990-'91 and from a minimum density of 478 individuals /m^3 in November to a maximum density of 13444 individuals /m^3 in May during 1991-'92.

The seasonal mean population density of zooplankton was maximum during premonsoon season and minimum during postmonsoon season at all the stations during both the years. The annual average population density was high at station II followed by station III and I during both the years. In general, the population density of zooplankton observed in 1990-'91 was lower than that of 1991-'92.

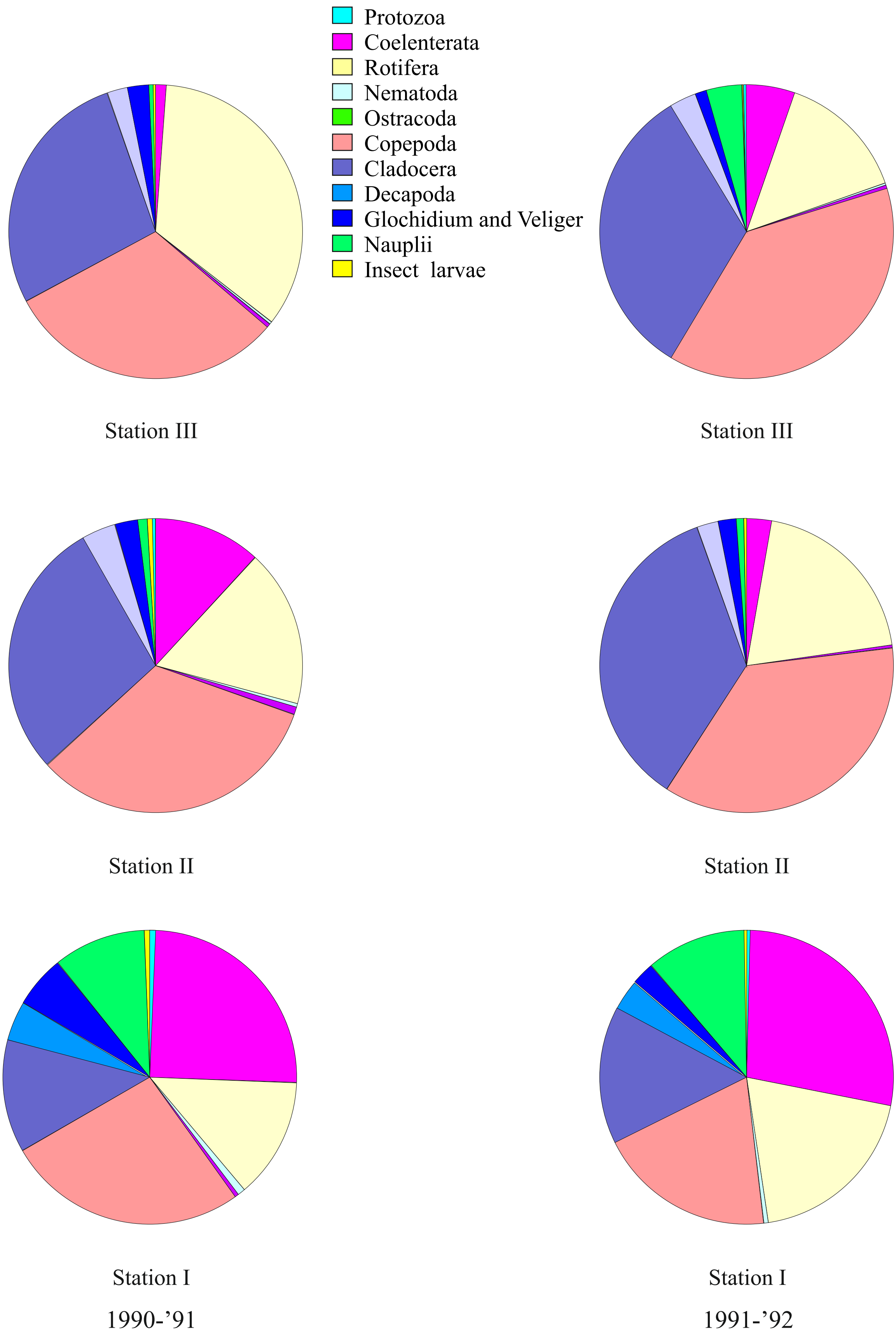

Fig 4.5 : Relative abundance of the various groups of zooplankton at station I, II and III in Manakkudy estuary during 1990-'91 and 1991-'92

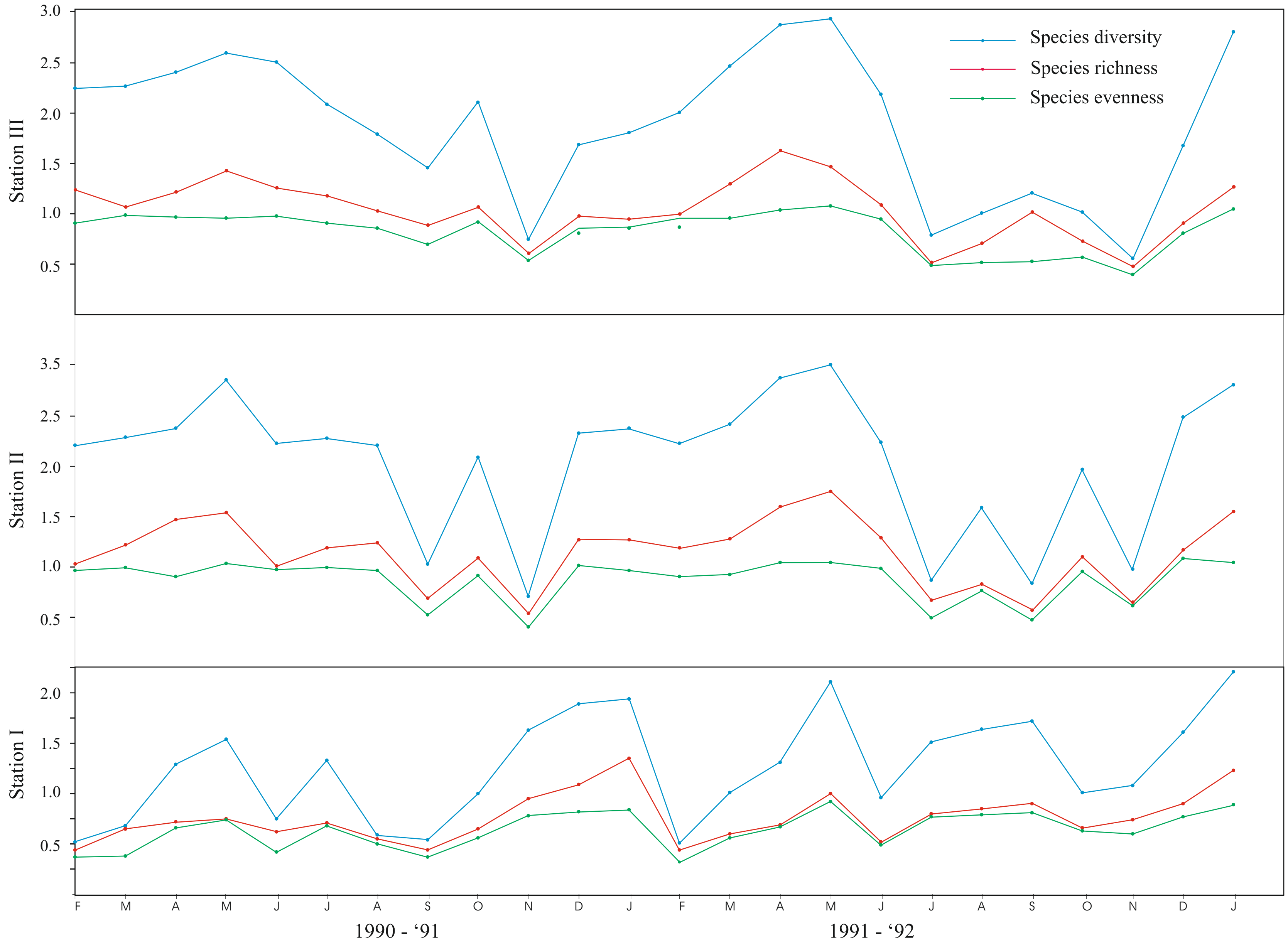

Fig. 4.6: The species diversity, species richness and species evenness of zooplankton at station I, II and III during 1990-'91 and 1991-'92.

4.4.2.2. Species Composition

The zooplankton population of Manakkudy estuary was composed of marine, estuarine and freshwater forms. In the present study, a total of 41 species of zooplankton were observed. It was composed of Protozoa, Coelenterata, Rotifera, Cladocera, Ostracoda, Copepoda, Decapoda, crustacean larvae, insect larvae , glochidium of bivalves, gastropod veliger and fish eggs and their larvae. Of these copepods followed by rotifers were the dominant groups in the zooplankton collection.

Among protozoans, *Tintinnopsis cylindrica* formed the dominant species. In addition *Tintinnopsis gracilis, Tintinnopsis minuta, Favella brevis* and *Globigerina* sp. were recorded.

Among hydromedusa, *Bougainvilla* sp. was abundant and *Eirena* sp. was rarely encountered.

Rotifers were dominated by *Brachionus calciflorus, B. quadridentatus and B. diversicornis.* Other commonly occurring *rotifers were B. falcatus, B. rubens, B. forficula* and *Keratella* sp. *Filinia* sp. and *Trichocera* sp. were rarely observed.

Cladocera and Ostracoda were poorly represented. They comprised of *Daphnia* sp., *Moina* sp., *Penilia* sp. and *Cypris* sp.

Copepoda was the dominant group represented mainly by copepod nauplii, *Acartia southwelli, A. spinicauda, Oithona brevicornis,* and *O. setigera.* Other copepods represented were *Acartia erythraea, A.longicornis, Eucalanus* sp., *Oithona rigida, Enteropine* sp. and *Microsetella* sp.

The Decapoda population included *Lucifer hanseni* and the larval forms of *Metapenaeus* sp., *Palaemon* sp., and *Penaeus indicus.* A check list of zooplankton observed at all the three stations throughout the study period is given in the Table 4.25.

Table 4.25 : Check list of zooplankton observed at Manakkudy estuary during 1990-'91 and 1991-'92.

Protozoa

Favella brevis	*T.gracilis*
Globigerina sp.	*T.minuta*
Tintinnopsis cylindrica	

Coelenterata

Bougainvilla sp.	*Eirena* sp.

Rotifera

Brachionus calciflorus	*B. rubens*
B. diversicornis	*Filinia* sp.
B. falcatus	*Keratella* sp.
B. forficula	*Trichocera* sp.
B. quadridentatus	

Cladocera

Daphnia sp.	*Penilia* sp.
Moina sp.	

Ostracoda

Cypris sp.

Copepoda

Calanoida

Acartia erythraea	*A.southwelli*
A. longicornis	*Eucalanus* sp.
A. spinicauda	

Cyclopoida

Oithona brevicornis *O. setigera*

O. rigida

Harpacticoidea

Enteropine sp. *Microsetella* sp.

Decapoda

Lucifer hanseni

Eggs and larvae

Polychaete setiger Crab megalopa

Copepod nauplii Insect larvae

Prawn nauplii Glochidium of bivalves

Mysis larva Gastropod veliger

Crab zoea Fish eggs and their larvae

4.4.2.3. Species Diversity

The species diversity for the zooplankton collected from Manakkudy estuary at station I, II and III during 1990-'91 and 1991-'92 is presented in the Fig. 4.6.

The species diversity at station I recorded a minimum value of 0.51 bits/individuals in September and a maximum value of 1.94 bits/individuals in January during 1990-'91 and a minimum value of 0.51 bits/individuals in February and a maximum value of 2.21 bits/individuals in January during 1991-'92.

At station II the species diversity fluctuated between 0.64 bits/individuals in November and 2.86 bits/individuals in May during 1990-'91 and between 0.84 bits/individuals in September and 3.01 bits/individuals in May during 1991-'92.

The species diversity at station III ranged from 0.75 bits/individuals in November to 2.60 bits/individuals in May during 1990-'91 and from 0.56 bits/individuals in November to 2.94 bits/individuals in May during 1991-'92.

The maximum diversity was obtained during premonsoon season while the minimum value was obtained during monsoon season. The diversity values were high during 1991-'92 and low during 1990-'91. The annual average values were higher in station II and lower in station I during both the years.

4.4.2.4. Species Richness

The species richness obtained for zooplankton at station I, II and III during 1990-'91 and 1991-'92 is presented in Fig. 4.6.

The species richness at station I showed variations between 0.44 bits/individuals (February and September) and 1.35 bits/individuals (January) during 1990-'91and during 1991-'92, it showed variations between 0.44 bits/individuals (February) and 1.23 bits/individuals (January) during 1991-'92.

At station II the species richness varied from 0.54 bits/individuals in November to 1.54 bits/individuals in May during 1990-'91 and from 0.57 bits/individuals in September to 1.75 bits/individuals in May during 1991-'92.

At station III species richness fluctuated between 0.61 bits/individuals (November) and 1.48 bits/individuals (May) during 1990-'91 and between 0.48 bits/individuals (November) and 1.63 bits/individuals (April) during 1991-'92.

In general high values of species richness were recorded during premonsoon months and low values during monsoon months. The annual average value was high at station II and low at station I. During 1990-'91 the species richness was low and during 1991-'92, it was high.

4.4.2.5. Species Evenness

The species evenness for zooplankton collected from Manakkudy estuary at station I, II and III during 1990-'91 and 1991-'92 is presented in Fig. 4.6.

The species evenness at station I fluctuated from 0.37 bits/individuals in February and September to 0.84 bits/individuals in January during 1990-'91 and from 0.32 bits/individuals in February to 1.92 bits/individuals in May during 1991-'92.

At station II it ranged between 0.40 bits/individuals (November) and 1.03 bits/individuals (May) during 1990-'91 and between 0.47 bits/individuals (September) and 1.08 bits/individuals (December) during 1991-'92.

At station III it varied from 0.54 bits/individuals in November to 0.99 bits/individuals in March during 1990-'91 and from 0.40 bits/individuals in November to 1.08 bits/individuals in May during 1991-'92.

The species evenness followed the same pattern as that of species richness. The seasonal variations were higher during premonsoon and lower during monsoon season. Station II recorded higher value and lower value was recorded in station I.

4.4.2.6. Comparative Study

In the present investigation the major peak of zooplankton density was observed in May at all stations during both the years except station II in 1991-'92 where the major peak was observed in April.

Out of 41 species of zooplankton recorded, 37 species were found in station I, 36 species at station II and 32 species at station III. The species diversity, species richness, species evenness and population density were higher at station II followed by station III and I.

Station I ranked first in having the maximum number of species. However, regarding population density, it ranked third, the first being station II followed by station III.

The maximum density of zooplankton at station I was contributed by copepods and hydrozoan medusae. Among copepods *Acartia spinicauda, A. southwelli, Oithona brevicornis* and *O. setigera* were dominant forms. Copepod nauplii were observed in all the collections. *Cyclops* sp. was observed during monsoon months. The hydrozoan medusa *Bougainvilla* sp. was found during postmonsoon and premonsoon months. The medusae were thickly populated especially when the bar mouth was artificially opened during these months.

Among Protozoa, *Tintinnopsis cylindrica* and *Tintinnopsis tubulosa* were observed during postmonsoon and premonsoon months.

During monsoon season the freshwater Cladocera *Daphnia* sp. and *Moina* sp. were recorded. But *Evadne* sp. and *Penilia* sp. were recorded in the premonsoon months.

The decapods were found in good numbers in this station. They showed their abundance during premonsoon months. Their population was thin during monsoon seasons. The decapod population consisted of *Lucifer hanseni*, larvae of *Metapenaeus* sp. and *Penaeus indicus*.

The setiger of polychaetes, veliger of gastropods, glochidium of bivalves, zoea of crabs and eggs of fishes had a sporadic appearance.

Station II recorded the maximum density of zooplankton population. The main bulk of the plankton was contributed by copepods and their nauplii. The copepods and their nauplii were recorded throughout the study period. The copepods showed two peaks of abundance. The primary peak was in May and the secondary peak was in February. Among copepods *Acartia southwelli, A. spinicauda, Oithona brevicornis* and *O. rigida* were frequently occurring.

The hydrozoan medusae appeared only during postmonsoon and premonsoon months. They disappeared during monsoon months.

The rotifers formed the third dominant group in this station. They were recorded throughout the study period except in the month of

February during 1990 - ’91. They registered in larger numbers during premonsoon seasons.

The tintinnids, polychaete setiger, decapods, ostracods, cladocerans, glochidium of bivalves, gastropod veliger and fish eggs their larvae exhibited rather an erratic appearance.

Station III was the castle for freshwater zooplankton. The plankton showed their peak of abundance in May during both the years. In general, the population densities were higher during premonsoon and postmonsoon months.

Protozoan ciliates were not recorded in this station. Hydrozoans made their appearance when the bar mouth was opened.

Rotifers showed their abundance and continuous existence at this station where freshwater condition prevailed for most of the period. This group formed 21.5% during 1990-’91 and 17.9% during 1991-’92. They ranked as the frist group during 1990-’91. However, during 1991-’92 they occupied the third place in abundance. In general, they showed maximum density during premonsoon season. The rotifer population consisted of nine species, namely *Brachionus calciflorus, B.falcatus, B. quadridentatus, B. rubens, B. forficula, Filinia* sp., *Keratella* sp. and *Trichocera* sp. Of these *B. calciflorus* was dominant.

Copepods formed the dominant group during 1991-’92. However, during 1990-’91 they occupied the second place, the first being copepods. They showed two peaks of abundance. The major peak occurred in may and the minor peak in February during both the years.

Polychaete setiger, ostracods, cladoceras, decapods, insect larvae, glochidium of bivalves, gastropod veliger and fish eggs and their larvae were sporadically recorded.

4.4.2.7. Statistical Treatment

The annual mean values of zooplankton density were high at station II and low at station I during both the years. The annual mean of zooplankton density was maximum during 1991-'92 and minimum during 1990-'91 (Table 4.26). The seasonal average values were maximum during premonsoon season and minimum during postmonsoon season (Table 4.3).

The annual mean values, seasonal mean values of species diversity, species richness and species evenness also followed the same pattern as that of population density except for the minimum seasonal mean values which occurred during monsoon season.

Simple correlation analysis of zooplankton density showed positive correlation with light penetration and salinity and negative correlation with all nutrients (Table 4.27).

Zooplankton was positively correlated with gross primary production, net primary production, chlorophyll 'b' and chlorophyll 'c' at station III during 1991-'92. It was positively associated with phytoplankton at station II and III during 1991-'92 and negatively associated at station I during 1990-'91 (Table 4.27).

Protozoa was not in existence in station III during both the years. The average value for station I and station II were on par in both the years (Table 4.26). The maximum recorded value was 65 individuals/

m^3 in station II during 1990-'91 and the minimum was 0 in all the stations in both the years.

The details regarding regression analysis with correlation for Protozoa are presented in Table 4.28 and 4.29.

In station I (Table 4.28) in 1990-'91 there was low atmospheric temperature than it was needed for Protozoa; hence an increase in the above could be considered to be favourable to Protozoa and phosphorus was already in excess and any more increase would be harmful to Protozoa. In 1991-'92 pH on the surface and bottom as well as chlorophyll 'c' were more needed so that an increase in these were more favourable for this where as a decrease in nitrate, nitrite and chlorophyll 'a' were found to be favouring Protozoa.

In station II (Table 4.29) in 1990-'91 an increase in chlorophylls 'a' and 'c' was found to be favourable where as a decrease in phosphorus also was found to favour Protozoa. In 1991-'92 an increase in pH at the two levels were found to be favourable where as decrease in nitrate and nitrite was found to be good for Protozoa.

In station III no data was available for both the years.

The computed average value of Coelenterata did not exhibit any significant difference among various stations in both the years (Table 4.26). The maximum value of 6425 individuals/m^3 was recorded in station I during 1990-'91 and the minimum was 0 in station I during 1991-'92, and both years in station II and station III.

The details of regression analysis with correlation for Coelenterata are shown in Table 4.30 to 4.32.

In station I in 1990-'91 increase in the temperature at the bottom, phosphate level, gross production, net primary production and chlorophylls 'a', 'b' and 'c' was found to favour this where as increase in depth and phosphorus was found to be most unfavourable. In 1991-'92 increase in the salinity at both the levels was found to favour Coelenterata; where as the same in oxygen levels, H_2S, phosphate, nitrate and nitrite levels were unfavourable to it.

In station II (Table 4.31) in 1990-'91 nitrate, gross production and net primary production and chlorophyll 'c' were found to be favourable where as silicate and phosphorus were unfavourable. In 1991-'92 salinity at surface and bottom, gross production, pH at both levels and chlorophyll 'c' were found to favour this where as depth, oxygen at both levels silicate, phosphorus, phosphate, nitrate and chlorophyll 'b' were unfavourable to it.

In station III (Table 4.32) in 1990-'91 depth and phosphorus were unfavourable due to excess availability and in 1991-'92 salinity at both levels, pH at both levels, gross production, net primary production, chlorophyll 'a' and chlorophyll 'c' were the favouring parameters and depth, oxygen at the surface, phosphorus, phosphate and nitrate were the unfavouring factors.

Rotifera had not exhibited any significant difference among its mean values over the three stations during 1991-'92 and during 1990-'91, station III had recorded the maximum average which was significantly higher than that in station I and was on par with that in station II (Table 4.26). Station I had the minimum average which was on par with that in station II (Table 4.26). The maximum recorded value was 4628 individuals/ m^3 in station III during 1990-'91 and the minimum was 0 in station I and station II during 1990-'91.

The results of regression analysis with correlation for Rotifera presented in Table 4.33 show that in station I in 1990-'91 no choice variable was able to express the behaviour of Rotifera. In 1991-'92 the table reveals that increase in the salinity at the two levels could bring considerable changes in Rotifera. At the same time only decreases in depth, oxygen and H_2S at the two levels, silicate, phosphorus, phosphate, nitrate and nitrite could help Rotifera.

In station II (Table 4.34) in 1990-'91 the increase in surface temperature, gross production, net primary production and chlorophyll 'c' were favourable factors and nothing seems to be unfavourable. In the second year only net primary production was favourable and oxygen at the bottom and phosphorus were in excess and unfavourable.

In station III (Table 4.35) in 1990-'91 the increase in surface temperature and net primary production were favourable where as the decreases in the two oxygen levels, nitrate and nitrite would be favourable.

In 1991-'92 increase in chlorophyll 'a' and 'b' seems to favour Rotifera where as decrease in temperature at the two levels would be more favourable.

During 1990-'91 Cladocera had the maximum average in station II which was significantly higher than that in station I but on par with that in station III (Table 4.26). However the averages in station I and III were also on par with each other. The maximum recorded value was 5463 individuals/m^3 in station II during 1991-'92 and the minimum was 0 in all the three stations in both the years.

The results of regression analysis with correlation for Cladocera exhibited in the Table 4.36 show that in station I in 1990-'91 increases in the chlorophyll 'a' and 'c' would be highly productive where as decreases in surface H_2S would be also productive. In 1991-'92 no parameter was able to give any information.

In station II (Table 4.37) in 1990-'91 increase in chlorophyll 'c' was favourable and decreases in salinity at the surface, phosphorus and nitrite would do good to this. In 1991-'92 increases in bottom temperature, salinity at all levels, pH at all levels, gross production, chlorophylls 'a' and 'c' would help this where as decreases in oxygen at all levels, silicate, phosphate, nitrate and nitrite would be favourable to this.

In station III (Table 4.38) in 1990 -'91 increases in surface salinity and atmospheric temperature would be favourable and decrease in chlorophyll 'b' would be favourable. In 1991-'92 increases in salinity at all levels, pH at all levels, gross production, net primary production and chlorophyll 'a' and 'c' would be favourable where as decreases in depth, oxygen at all levels, silicate, phosphorus, phosphate, nitrate and nitrite would be favourable to Cladocera.

The average value of Ostracoda (Table 4.26) showed consistancy over the three stations during 1990-'91. During 1991-'92 the average was maximum for station II, but which was on par with that in station III. Though station I had the least average it was on par with that in station III. The maximum recorded value was 266 individuals/m^3 in station II during 1990-'91 and the minimum was 0 in all the stations on both the years.

The results of regression analysis with correlation for Ostracoda presented in Table 4.39 reveal that in station I in 1990-'91 no parameter was able to provide any relationship where as in 1991-'92 increases in pH at all levels would be favourable and decrease in chlorophyll 'b' would add to Ostracoda.

In station II (Table 4.40) in 1990-'91 increase in salinity and pH at all levels would be favourable and decrease in silicate, phosphorus, phosphate, nitrate and nitrite would be favourable. In 1991-'92 also increase in salinity and pH at all levels would be more favourable where as decrease in surface oxygen, phosphate and nitrate would be advantageous for Ostracoda.

In station III (Table 4.41) in 1990-'91 increase in atmospheric temperature, salinity at all levels and surface pH was favourable and decrease in bottom oxygen, silicate, phosphorus and chlorophyll ‘b’ would be favourable. In 1991-’92, increase in salinity and pH at all levels and reductions in depth, oxygen at all levels, silicate, phosphorus, phosphate, nitrate and nitrite would favour Ostracoda.

During 1990-’91 the mean values of Copepoda had no significant difference over the three stations (Table 4.26). However during 1991-’92 the station I had recorded the minimum average significantly below the other two stations and the average in station II and III were on par with each other. The maximum recorded value was 6640 individuals/m^3 in station II during 1991-’92 and the minimum was 5 individuals/m^3 in station III during 1990-’91.

The results of regression analysis with correlation for Copepoda reveal that in station I (Table 4.42) in 1990-’91 only by decreasing the levels of silicate, nitrate and nitrite could improve Copepoda and increase in bottom temperature alone was favourable. In 1991-’92 increase in depth was favourable and decrease in atmospheric temperature and H_2S were also favourable.

In station II (Table 4.43) in 1990-’91 chlorophyll ‘a’ and ‘c’ would be favourable and decrease in phosphorus was also favourable to Copepoda. In 1991-’92 increases in the salinity and pH in all levels and chlorophyll ‘a’ and ‘c’ were favourable where as decreases in oxygen at all levels, silicate, phosphate, nitrate, nitrite and gross production would be favourable.

In station III (Table 4.44) in 1990-'91 increases in salinity at all levels and pH in the surface were more favourable. At the same time lowering the levels of silicate, phosphorus and phosphate would be favourable. In 1991-'92 salinity and pH at all levels, gross production, net primary production and chlorophylls 'a' and 'c' would be favourable and decreases in oxygen at all levels, silicate, phosphorus, phosphate, nitrate and nitrite would be favourable.

Decapoda had not showed any significant difference in any of its average values over all the three stations in both the years (Table 4.26). Numerically station II recorded the highest average in both the years. The maximum recorded value was 705 individuals/m^3 in station II during 1990-'91 and the minimum was 0 in all the three stations in both the years.

Results of regression analysis with correlation for Decapoda presented in Table 4.45 reveal that in station I in 1990-'91 increases in pH at all levels would be favourable and decreases in silicate, phosphorus, nitrate and nitrite would be favourable. In 1991-'92 increasing the depth and decreasing the H_2S and chlorophyll 'b' alone would be favourable.

In station II (Table 4.46) in 1990-'91 only reduction in phosphorus level would be favourable. In 1991-'92 increase in the bottom salinity and pH at all levels would be favourable where as the decreases in bottom oxygen, nitrate and nitrite also would be favourable.

In station III (Table 4.47) in 1990-'91 increases in surface temperature and salinity at the bottom would be favourable and decreases in oxygen at the bottom and phosphorus were favourable. In 1991-'92 increasing the salinity at all levels and decreasing the levels of oxygen at the bottom, silicate, phosphorus, phosphate, nitrate and nitrite would be favourable to Decapoda.

During 1990-'91 the average value of nauplii was the largest for station I which was significantly higher than that for station III, but on par with that in station II. Again the mean values were on par for station II and station III. During 1991-'92 again station I had the largest average which was on par with that in station II and both these were significantly higher than the average for station III (Table 4.26). The maximum recorded value was 1446 individuals/m^3 in station I during 1990-'91 and the minimum was 0 in all the stations in both the years.

The results of regression analysis with correlation for nauplii presented in Table 4.48 reveal that in station I in 1990-'91 increase in atmospheric temperature and chlorophyll 'a' and 'c' would favour this where as decreases in silicate, phosphorus and nitrate would do favour. In 1991-'92 increases in pH at all levels, gross production and the cholorophyll 'a' and 'c' would favour this.

In station II (Table 4.49) in 1990-'91 increases in net primary production and chlorophyll 'a' and 'c' would be favourable and decreases in silicate and phosphorus would be favourable. In 1991-'92 increase in pH at the two levels would be favourable to nauplii.

In station III (Table 4.50) in 1990-'91 decrease in phosphorus alone was favourable. In 1991-'92 no parameter was able to give any information.

Though during 1990-'91 station II had the greatest mean value of insect larvae and in 1991-'92 station III had the greatest mean value. No significant difference was obtained in any of the years among the mean of the three stations. The maximum recorded value was 85 individual/m^3 in station III during 1991-'92 and the minimim was 0 in all the stations in both the years (Table 4.26).

The results of regression analysis with correlation for insect larvae presented in Table 4.51 reveal that in station I in 1990-'91 increases in the temperature at all levels, salinity at all levels, gross production and net primary production would be more productive and decreases in H_2S, phosphate, nitrate, nitrite and chlorophyll 'c' would do the same. In 1991-'92 increases in pH at all levels was productive and decreases in temperature at all levels and H_2S at the bottom would be productive. In 1991-'92 increasing the pH at all levels would be productive and decreasing the temperature at all levels and H_2S at the bottom would be productive.

In station II (Table 4.52) in 1990-'91 increases in salinity at all levels, gross production, net primary production and chlorophyll 'c' would be more productive and decreases in oxygen at all levels, silicate, phosphorus, phosphate, nitrate and nitrite would be more productive. In 1991-'92 increases in depth and visibility and decreases in temperature at all levels would be more productive.

In station III (Table 4.53) in 1990-'91 increases in visibility, salinity and pH at all levels would be productive and decreases in oxygen at all levels, silicate, phhosphorus, phosphate, nitrate and nitrite would also be more productive. In 1991-'92 no parameter was having any association with this.

Though Glochidium and Veliger had recorded the highest average in station I on both the years none had shown any significant difference in any of the stations in both the years. The maximum recorded value was 414 individuals/m^3 in station I during 1990-'91 and the minimum was 0 in all the three stations in both the years (Table 4.26).

The results of regression analysis with correlation for molluscan larvae reveal that in station I (Table 4.54) during 1990-'91 increase in atmospheric temperature alone was favourable. During 1991-'92 increase in the temperature at all levels would be favourable where as decrease in oxygen at all levels, H_2S and phosphate would be favourable.

In station II (Table 4.55) in 1990-'91 increases in salinity at all levels and chlorophyll 'a' and 'c' would be favourable. In 1991-'92 increases in the temperature at all levels, salinity at all levels, pH at all levels, gross production, chlorophyll 'a' and 'c' would favour this group where as decreases in depth, surface oxygen, phosphorus, phosphate, nitrate and nitrite would do good to molluscan larvae.

In station III (Table 4.56) in 1990-'91 the increases in atmospheric temperature, salinity at all levels and pH at all levels would favour molluscan group. In 1991-'92 increase in temperature at the bottom, surface salinity, and surface pH would be favourable and decreases in silicate, phosphorus, phosphate and nitrate would be favourable.

The average value of fish eggs and their larvae during 1991-'92 was constant in all the stations and there was no significant difference among them, where as during 1990-'91 it had recorded significantly higher value in station I. Though the average on the other two stations were significantly lesser than this, both of them were on par with each other (Table 4.26). The maximum recorded value was 67 individuals/m^3 in station I in 1990-'91 and the minimum was 0 in all the stations in both the years.

The results of regression analysis with correlation for fish eggs and their larvae exhibited in Table 4.57 reveal that in station I in 1990-'91 addition in atmospheric temperature and salinity at the two levels seemed to favour fish eggs and their larvae where as further reduction in silicate, phosphorus and nitrite would be favourable. In 1991-'92 surface temperature and salinity at the two levels seemed to be conducive for adding more fish eggs and their larvae where as only reductions in depth, oxygen at the two levels, H_2S at the surface, phosphorus, phosphate, nitrate and nitrite would further help this.

In station II (Table 4.58) in 1990-'91 increase in salinity at the two levels could alone further help fish eggs and their larvae and only reductions in oxygen at the two levels and chlorophyll 'b' alone could help this group. In 1991-'92 increases in the salinity at the two levels, pH at bottom, nitrite, gross production, chlorophyll 'a' and 'c' could help fish eggs and their larvae where as decreases in oxygen at the bottom, phosphorus and phosphate would favour this.

In station III (Table 4.59) in 1990-'91 no parameter was able to provide any information to fish eggs and their larvae. In 1991-'92 increases in the salinity at the two levels and pH at the two levels would be favourable where as reductions in oxygen at the two levels, silicate, phosphorus, phosphate, nitrate and nitrite would help fish eggs and their larvae.

4.4.2.8. Discussion

Zooplankton constitutes the second trophic level of the food chain and forms the food for most of the pelagic fishes. The distribution of plankton differs in quality and quantity from place to place and time to time. In the present study, the distribution of zooplankton showed its high numerical abundance during the high saline premonsoon season. Similar results were obtained by Krishnamurthy and Santhanam (1975), Santhanam *et al.* (1975), Chandran (1982) and Thangaraj (1984) from Vellar estuary; Nair and Tranter (1971), Silas and Pillai (1975), Madhupratap (1978), Madhupratap and Rao (1979) and Nair *et al.* (1984) from Kadinamkulam backwaters; Arunachalam *et al.* (1982) in the Veli lake; Goswami and Singbal (1974) in the Mandovi and Zuari estuaries; Bayly (1980) in the Purari estuary, Jegadeesan (1986) in Muthupet estuary and Shibu (1991) in Paravur lake. However, Goswami *et al.* (1979) in Zuari estuary, Abdul Azis (1978) in Paravur lake, and Divakaran *et al.* (1982) in Ashtamudi estuary recorded high densities of zooplankton with low salinities.

In the zooplankton population the contribution of copepods was very high and they were the dominant forms throughout the study period. This observation was in conformity with the earlier observations. In Vellar estuary Subbaraju and Krishnamurthy (1972) noted that 91 percent of the zooplankton population was constituted by copepods. Similarly, Bhat and Gupta (1983) stated that in Nethravati- Gurupur estuary the main bulk of the zooplankton was formed by copepods. Such observations were also made by Dwivedi *et al.* (1974) and Goswami and Singbal (1974) from Mandovi and Zuari estuaries; Madhupratap *et al.* (1975) and Madhupratap (1978 , 1979) from Cochin backwaters, Abdul Azis (1978) from Edava-Nadayara backwaters, Divakaran *et al.* (1982) and Nair *et al.* (1985) from Ashtamudi estuary.

In the present investigation the calanoids contributed more species than the cyclopoids and harpacticoides in the zooplankton population. Among calanoids *Acartia southwelli* and *A.spinicauda* were the dominant forms. In cyclopoids *Oithona brevicornis* and *O. setigera* were the dominant forms. The harpacticoides had a sporadic occurrence. The dominance of *Acartia* species in the present investigation is in conformity with the observations of Chandramohan (1963) in Godavari estuary, Rao *et al.* (1975) and Madhupratap (1978) from Cochin backwaters, Goswami and Selvakumar (1977) and Goswami (1983) from Mandovi and Zuari estuaries, Sivakumar (1982) and Thangaraj (1984) from Vellar estuary, and Prabha Devi (1986) from Coleroon estuary. The dominance of *Oithona brevicornis* in the present investigation is in conformity with the observation of Goswami and Singbal (1974) from Mandovi estuary. Similarly Chong and Chua (1973) had also recorded the abundance of *Oithona* sp. from Chinese waters and suggested that it was mainly due to its high reproductive capacity. Grindley (1981) stated that although most of the taxonomic groups were present in the holoplankton of neritic seas and in estuaries, the copepods were the dominant forms in most of the estuaries in the world. Thus the present study is in conformity with the earlier observations regarding the composition of zooplankton.

The rotifers formed a beautiful and significant assemblage in the zooplankton population. Out of the 9 species of rotifers recorded, 6 species belonged to *Brachionus*. *Brachionus calciflorus* was occasionally found with eggs. *B. diversicornis* and *B. quadridentatus* were also common. They were dominant in the monsoon season especially at station III, the riverine zone. This observation is in agreement with the observations of Devassy and Gopinathan (1970) from Cochin backwaters, Chandran (1982) from Vellar estuary, Nair *et al.* (1984) from the Kadinamkulam backwater, Gopinathan (1985) from the Veli lake, Balusamy (1988) from Muthupet estuary and Shibu (1991) from Paravur lake.

A small fraction of the zooplankton population collected from Manakkudy estuary was contributed by neritic fauna. They included hydrozoan medusae, *Penilia* sp., *Lucifer* sp. and *Penaeus* sp. Most of these species existed during summer and postmonsoon months. They were abundantly recorded especially immediately after the artificial opening of the bar mouth when the estuary was at the full influence of neritic waters. This result was well supported by the observations made by Haridas (1975) in Cochin backwater, Chandran (1982) in Vellar estuary and Prabha Devi (1986) in Coleroon estuary.

The density of zooplankton showed clear fluctuation from season to season. Generally, the population density was high during premonsoon and it was low during postmonsoon season. During premonsoon season, the flow of freshwater into the estuary was minimum and the entire water body showed stable and uniform hydrographic conditions with high salinity and temperature values. This situation was congenial for the growth of the plankton population. The postmonsoon season brought in heavy rainfall which resulted in the heavy influx of freshwater into the estuarine system and this washed away the estuarine zooplankton population. Following the ceasation of monsoonal flow, many marine organisms migrate from the neritic environment and they gradually started to establish in the postmonsoon period. A gradual rise in salinity was noted during this period and it was reflected on the zooplankton population which was also gradually improving. This observation of high density of zooplankton during premonsoon season was in conformity with most of the estuaries in India (Pillai *et al.,* 1973; Rao *et al.* , 1975; Madhupratap *et al.* , 1977; Madhupratap, 1978; Nair *et al.,* 1984 and Balusamy, 1988).

On comparing the zooplankton population density of the three stations, the maximum density was observed at station II, the middle of the estuary, and the minimum density was recorded at station I, the mouth of the estuary. Station III, the riverine zone, ranked second in population density. Actually station I which lies close to the sea, might have recorded the maximum density because of its high salinity as it was observed in other estuaries (Pillai *et al.* 1973, Rao *et al.* 1975, Madhupratap *et al.* 1977 and Nair *et al.* 1984). But, in the present study station I, the estuarine zone, recorded low population density inspite of its high saline condition and its immediate contact with the neritic zone. The retting practices at the banks of the estuary at this zone and the liberation of hydrogen sulphide from the retting pits would have reduced the population. When the sand bar was opened, the stagnant water contaminated with hydrogen sulphide, was washed away and the estuary was refilled with uncontaminated neritic water with high density of plankton. When the bar mouth was closed, the stagnation began and the ret-liquor from the retting pit brought in hydrogen sulphide and the hydrogen sulphide content gradually increased resulting in the pollution of this zone. The increasing hydrogen sulphide resulted in the depletion of oxygen gradually. As a result the zooplankton population also started decreasing in its density. This depletion was going on until the opening of the sand bar or the influx of freshwater which also could dilute the hydrogen sulphide. In conformity with the present observation Abdul Azis (1978) observed a depletion in the biomass of zooplankton in the retting zones of the Edava Nadayara backwater. Similar depletion of zooplankton was reported by Remani *et al.*(1981) in Beypore estuary. The same type of results were also obtained by Bijoy Nandan (1991) in Kadinamkulam kayal and Shibu (1991) in Paravur lake.

In the present study the zooplankton population showed a major peak and a minor peak in each year. Similar observation was made by Krishnamurthy (1967), Subbaraju and Krishnamurthy (1972) and Santhanam (1976) from Vellar estuary, Dehadrai (1970) from Mandovi estuary and Panampunnayil and Desai (1975) from Cochin backwaters.