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CONTRIBUTION OF SIZE FRACTIONS OF PLANKTONIC ALGAE TO PRIMARY ORGANIC PRODUCTIVITY IN THE COASTAL WATERS OF COCHIN, SOUTH WEST COAST OF INDIA

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BY
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CERTIFICATE

This is to certify that this thesis entitled "Contribution of size fractions of planktonic algae to primary organic productivity in the coastal waters of Cochin, south west coast of India" is an authentic record of research work carried out by Akram. K. M. Alkershi, under our supervision and guidance in the Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, in partial fulfilment of the requirements for the Ph. D degree of the Cochin University of Science and Technology and no part of this has previously formed the basis for the award of any other degree in any University.

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DECLARATION

I hereby declare that the thesis entitled "Contribution of size fractions of planktonic algae to primary organic productivity in the coastal waters of Cochin, south west coast of India" is an authentic record of research carried out by me under the supervision and guidance of Prof. Dr. K. J. Joseph (Supervising Teacher), and Prof. Dr. N. R. Menon (Co-Guide), Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology and that no part of it has previously formed the basis for the award of any degree, diploma or associateship in any university.

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INTRODUCTION

INTRODUCTION

In marine ecosystems planktonic algae are the most important primary producers on which considerable attention is being given on account of their supreme status in the marine food chain.

The biological process which is carried out by the plants for forming high-energy organic matter using the abiotic components of the ecosystem is called the primary productivity. Primary productivity in the marine environment is of extreme importance since it is the initial trophic level in the marine food chain, on which the entire fishery resources are dependent. In considering the quantity of planktonic algae potentially available to the food chain in a particular location, we must take into consideration not only the amount available, but also the rate at which it is being produced. The amount of planktonic algae is termed the standing crop and it is usually expressed as the amount of living planktonic algae present in unit volume of water, or beneath unit area of water surface (mg / l or gm / m^3; gm / m^2). The rate of primary productivity is usually defined as the amount of inorganic carbon fixed photosynthetically in unit time per unit volume, or under unit area of water surface (mg C / m^3 / hr or gm C / m^2 /day). It is necessary to distinguish between the gross rate of primary productivity, which is the rate at which the plant carbon is produced photosynthetically, and the net rate, which is the gross rate less the rate of loss of carbon through respiration by plants.

Growth and productivity of planktonic algae depend on the hydrographic parameters of the particular environment, and since the hydrographic parameters such as light intensity, temperature, salinity, nutrients and grazing varies from place to place and season to season, the abundance and productivity of planktonic algae varies latitudinally and seasonally, and at any latitude, productivity of the coastal waters tends to be higher than that of the open sea.

Planktonic algae are composed of single cells or of relatively simply organized, small colonies of different forms. The major taxonomic classes which contribute significantly to the primary productivity in the marine environment are: Bacillariophyceae, Pyrrophyceae and Cyanophyceae. Other classes which are of less importance and may occur seasonally in certain localities are: Chlorophyceae, Prasinophyceae, Chrysophyceae, Haptophyceae and Cryptophyceae.

The continuous increase in the world population associated with shortage of food and other resources on land forced the scientists to look for new resources to satisfy the increasing demands of man for food, medicine, oil, minerals etc. Great attention was directed to the sea. Sea food (fish and shellfish) which begin with marine plants besides marine plants themselves were the proper solution. and the development of fisheries using modern technologies with intensive scientific research started to take wide strides for exploration and exploitation of the new resources.

The size of planktonic algae varies from less than 1 µm to more than 500 µm; either chain forming or colonial or solitary. Only very little is known on the seasonal variations and contributions of ultra plankton and picoplankton to primary productivity because they are not often seen under the microscope and also cannot be retained by the finest plankton nets. Generally these very small planktonic algae are green and brown flagellates, and sometimes grow very rapidly causing blooms and discolouration of seawater.

Various size groups of planktonic algae synthesize food at the primary trophic level and contributing to the organic production of the marine ecosystem. The relevance of contribution of various size fractions is more in the diet of consumers. The larvae of pelagic fishes and shellfish need very small size of planktonic algae, their requirement increase with the increasing size of larvae. Since the various size fractions of the algal flora forming the food of the different varieties of consumers, many of them being selective feeders, the study of different size fractions of planktonic algae and their relative contribution to the primary organic production is a useful tool for the estimation of the quantities and qualities of fisheries.

The study of primary production in the Indian Ocean started with DANA (1928-30), John Murray (1933-34), Discovery (1934) and Albatross (1947-48) expeditions which tried to evaluate productivity from nutrients and standing crop of phytoplankton. During Galathea expedition productivity was measured using C^{14} method in western Indian Ocean along the coast of Africa, equatorial part of Indian Ocean from Mombassa to Sri Lanka, Bay of Bengal and Indo-Malayan waters (Steeman Nielson 1952; 1954; Steeman Nielson and Jensen 1957). During the IIOE, between 1959 and 1965, the Arabian Sea along the 110^0 E longitude under the Australian programme was well studied (Ryther et al., 1966; Jitts 1969). Measurements of primary production onboard the Anton Bruun, showed that the western Indian Ocean is one of the most productive regions in the world (Ryther et al., 1966). In the eastern Indian Ocean, Wood (1966) found that the horizontal distribution of phytoplankton is related to land mass and up welling. Krey (1973) has given an account on the distribution of chlorophyll and potential assimilation in the Indian Ocean and Aruga (1973) has reviewed the relation of the primary production in the Indian Ocean to chlorophyll and other environmental factors. El Syed and Jitts (1973) studied the primary production and standing crop of plankton in the south-eastern Indian Ocean. Trevor Platt (1986) studied the primary production of the Ocean water column as a function of surface light intensity.

Prasad et al. (1970) studied the primary production in relation to the potential fishery resources of the Indian Ocean and Cushing (1971) for the up welling areas. Qasim (1976) reviewed the different aspects of the biological productivity of the Indian Ocean.

Several studies have been carried out in the coastal and off shore regions of the Indian seas. Subramanyan (1959) measured the standing crop of the phytoplankton by various methods and found that the production in the west coast of India is of high order comparable to some of the most productive areas in the temperate regions. Prasad and Nair (1960, 1963) studied the seasonal variations of primary production in the Gulf of Mannar in the south east coast of India. Nair et al. (1968) and Nair (1970, 1974) discussed the results of their investigations along the shelf regions of Indian seas and Lakshadweep Sea in relation to the potential living resources. Radhakrishna (1969) studied the primary production in the shelf waters off Alleppey in the south west coast of India during the post monsoon season. Shah (1973) reported the seasonal variations of phytoplankton pigments in the Lakshadweep Sea off Cochin.

Qasim et al. (1978) studied the productivity of the coastal waters of India up to 50 m depth and found that the larger phytoplankton contributed greater spatial variation in primary production than smaller forms. Radhakrishna (1978) and Radhakrishna et al. (1978) carried out quantitative investigations on some aspects of phytoplankton productivity in the coastal areas of the east coast. He also studied the primary production, chlorophyll *a* and related parameters in the shelf and oceanic regions in the northern Arabian Sea. The productivity of coral reefs (Nair and Pillai, 1972; Qasim et al.1972), of Sea grass beds (Qasim and Bhattathiri, 1971) and the relation between nitrogenous nutrients and primary production in Lakshadweep waters (Wafar et al. 1986) have also been studied.

During the last few decades several attempts were made to study the contribution of size fractions of planktonic algae to the primary production in different localities of the world ocean. Most of the studies concentrated to project the contribution of nanoplankton and net plankton to the productivity. Harvey (1950) showed that phytoplankton biomass quantified using fine meshed plankton nets often underestimate the total phytoplankton biomass. A similar conclusion was reached by Qasim et al (1969) for eutrophic Indian waters. Marshall and Raymont (1947) and Gross and Nutman (1950) found that nanoplankton formed a very important part of algal crop in shallow temperate waters. Yentsch and Ryther (1959) highlighted the importance of nanoplankton in waters off Woods Hole. Studies by Savage (1969) in Southampton waters demonstrated the outstanding importance of nanoplankton; the great majority of the crop in terms of chlorophyll (ca. 90 %) was attributed to the small phytoplankton (<55µm in size). Tundisi (1971) found that 87-93 % of primary production and 71-83 % of the standing crop of phytoplankton was the contribution of nanoplankton in the equatorial Atlantic. Malone (1971) in the Caribbean and eastern tropical Pacific found that nanoplankton was the dominant component of phytoplankton. So also it was found that the greater part of C^{14} assimilation (73 %) was due to nanoplankton. Further investigations by Parson (1972) confirmed the importance of the nanoplankton in the Celtic sea. In term of carbon fixed, nanoplankton contributed > 70 %. Revelante and Gilmartin (1976) showed that, the planktonic algae of less than 20 µm in diameter consisting mainly of microflagellates with some naviculoid diatoms and dinoflagellates dominated the phytoplankton of the northern Adriatic, averaging 74-88 % by number of the total phytoplankton. Burkill (1978), in Southampton waters confirmed that 89 % of the chlorophyll was that of < 50 µm in size group. Takahashi and Bienfang (1983) found that, in subtropical Hawaiian waters, ultraplankton (< 3 µm) nanoplankton (< 20 µm) and net plankton (> 20 µm) accounted for ca. 80, 98 and 2 % of the total chlorophyll respectively. Joseph (1988) showed that, in the coastal waters off the south-west coast of India around Cochin, 62.6 % of the total production is synthesized by planktonic algae of less than 60 µm in size. Gradinger et al. (1992) found that in the central Red Sea and the adjacent Gulf of Aden during February / March 1987, picoplankton (0.2 – 2 µm) was the dominant size fraction of phytoplankton, and chlorophyll *a* and primary productivity measurements revealed that they contributed 76 – 77 % of the total to both parameters, and their concentration exceeded 45 x 10^3 cell / ml. Gomes et al. (1992) reported that, in the Andaman Sea, of the total mean euphotic column production, 37 % was attributed to picoplankton, whereas nanophytoplankton and net phytoplankton contributed 40 % and 23 % respectively. Kawabata et al. (1993) revealed that, in the Vellar estuary and Pichavaram mangrove, south east coast of India, the largest quantity of chlorophyll *a* of phytoplankton was contributed by 5 – 10 µm size group, 3.6 mg/m^3 (33 %) at one site, and 6.5 mg/m^3 (51 %) at another site. Similarly, the highest gross production was found in the same size group (5 – 10 µm) at both stations; 49 mg C / m^3 / hr (20 %), and 32 mg C m^3 / hr (22 %) respectively. Liu et al. (1993) showed that, during the austral summer of 1989 / 1990, net phytoplankton with cells > 20 µm in the southern Atlantic Ocean having abundant nutrients accounted for 65 % of chlorophyll *a*, while in infertile southern Indian Ocean, picoplankton accounted for the highest proportion (47 %). Ning et al. (1993) found that, in the Indian sector of the Southern Ocean, during summer of 1990 – 1991, the contribution of both nanoplankton and picoplankton was estimated to be 53 % in term of biomass, and 69 % in term of productivity, indicating the dominance of these size fractions of phytoplankton in the Antarctic waters. Li et al. (1998) showed that, in the euphotic zone of The East China Sea in April 1994, picoplankton, nanoplankton and net plankton accounted on average for 47, 33 and 20 % of the total chlorophyll.

The present investigation aims at the elucidation of the specific contribution of >500, < 500-250, < 250-150, < 150-105, < 105-53, < 53-25, < 25-10 and <10 µm size fractions of planktonic algae to the standing crop, chlorophyll and primary organic productivity of the south west coast of India.

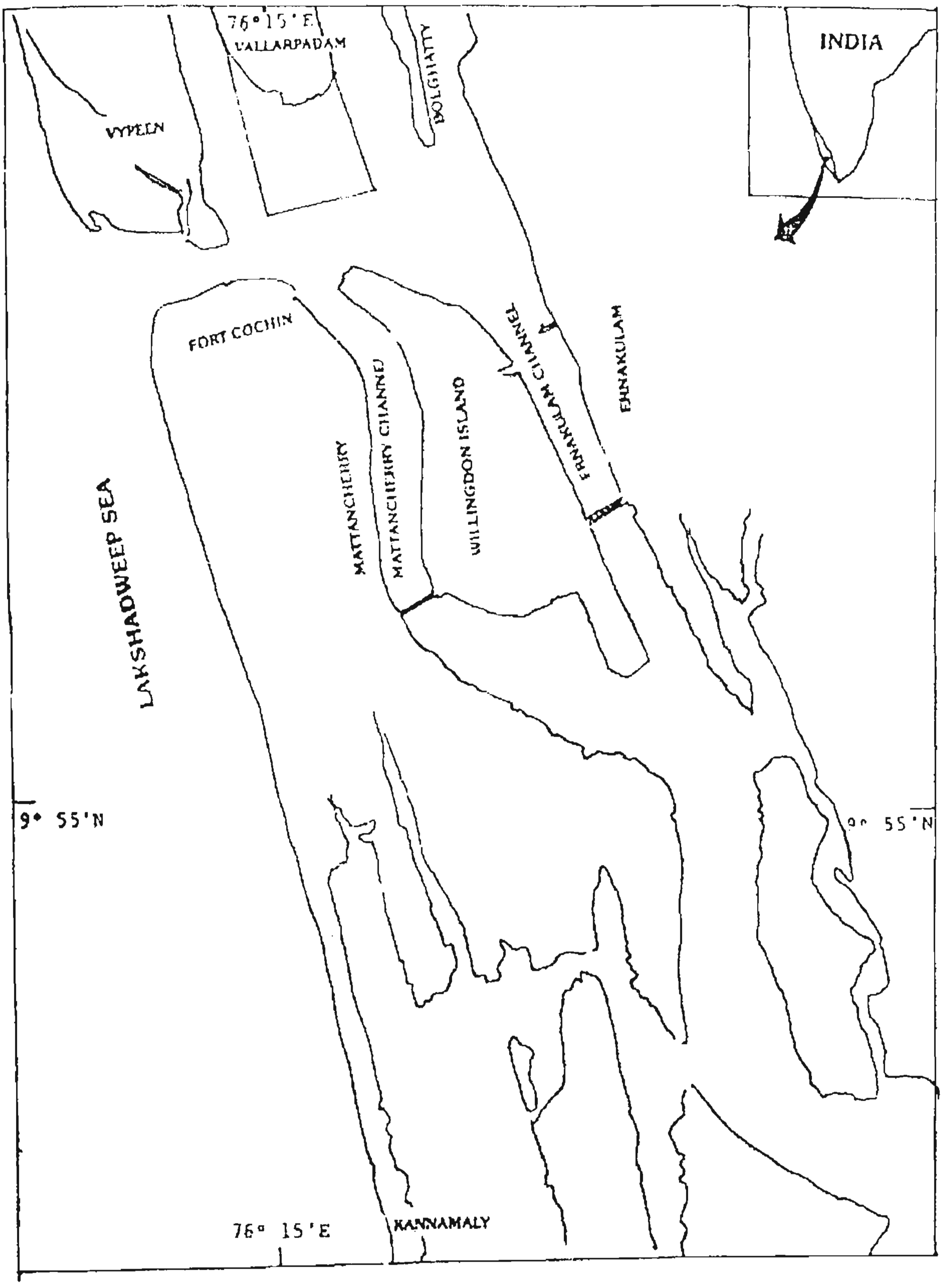


Figure 1 - Study Area

CHAPTER 1

METHODOLOGY

1) SAMPLING:

Surface water samples were collected using a non-metallic sampler from two selected stations in the south – west coast of India, stn.1 Kannamaly (9° 52' N; 76° 16.5' E) and stn. 2 Fort Cochin (about 10 nautical miles north of stn. 1), and transported immediately to the laboratory using 50 litres capacity black plastic containers. Monthly collections were made during the period from February 2000 to June 2001.

2) SEPARATION OF PLANKTONIC ALGAE:

Five litres of water samples were filtered through the separation tower which is comprised of seven sieves of 500, 250, 150, 105, 53, 25 and 10 µm from the top to the bottom respectively, and built on six litres capacity plastic container (Figure 2).

Each sieve was washed thoroughly in a wide – mouthed plastic tray with sea water collected from the same locality and filtered through GF/F filter paper and the volume is made to 500 ml. From the 500 ml, sub samples were taken for the estimation of primary productivity, chlorophyll *a* and for identification and enumeration of planktonic algae.

By filtering large volume of sea water (5 litres) and washing the sieve with 500 ml filtered sea water, the planktonic algae will be concentrated (10 times), so, even low productivity can be estimated. This would also render the estimation of chlorophyll, identification and enumeration of planktonic algae easier.

3) ANALYSIS OF SAMPLES:

A- PRIMARY PRODUCTIVITY

Measurements of primary productivity were made using Gaarder and Gran's light and dark bottles method (Strickland and Parsons, 1972). A series of three BOD bottles (60 ml) were used for the estimation of primary productivity of each size group. One bottle was used for the determination of the initial oxygen concentration. the second (the dark bottle) for measuring the respiration by planktonic algae and the third one (the light bottle) for the estimation of primary productivity. The three bottles were filled with water sample. and the dissolved oxygen concentration was fixed in the initial bottle The light and the dark bottles were incubated under the natural light for a period of three hours centred around the local noon. After the incubation, the concentration of the dissolved oxygen in the dark and the light bottles was fixed. The concentration of the dissolved oxygen in the three bottles was determined using Winkler's method.

The concentration of the dissolved oxygen was calculated using the following formula:

Oxygen concentration (mg / l) = $y \times x \times 8 \times (1000 \quad s \times (b - c) / b)$

Where:

y = normality of sodium thiosulphate solution.

x = volume of sodium thiosulphate solution.

s = volume of sample titrated.

b = volume of BOD bottle.

c = volume of reagents added (Winkler's A & B).

The difference in the concentration of oxygen in the three bottles was used for the estimation of respiration, net and gross primary production in terms of oxygen as shown below.

Respiration = Ib – Db

Net primary production = Lb – Ib

Gross primary production = Lb – Db

Where Ib, Db and Lb are the concentrations of oxygen (mg / l) in the initial, the dark and the light bottles, respectively.

And in terms of carbon fixed:

Net primary production (mg C/ m^3/ hr) = ((Lb – Ib) X 375) / (t X 1.2) -----------1

Gross primary production (mg C/ m^3/ hr) = ((Lb – Db) X 375) / (t X1.2) --------2

Where:

375= is a factor for the conversion from mg O_2 / l to mg C / m^3

t= the incubation time (hours).

1.2= the photosynthetic quotient.

The actual primary productivity of each size group is 1/10th of that was obtained from the equations 1 and 2, that is, because each size group was concentrated 10 times before measuring primary productivity.

B- CHLOROPHYLL *a*

Chlorophyll *a* was estimated using Strickland and Parsons (1972) method. The water sample (200 ml) containing the specific size group of planktonic algae was filtered through GF/F filter paper under moderate vacuum, and the filter paper then transferred into a clean stoppered - test tube and 10 ml of 90 % acetone was added. The test tube was placed in a refrigerator for about 24 hours in order to facilitate the complete extraction of chlorophyll. The chlorophyll-acetone solution was centrifuged for about 20 minutes at 5000 rpm. and the absorbance of the clear chlorophyll-acetone solution was measured at 664, 647 and 630 nm wavelengths using U – 2001 spectrophotometer. and 90 % acetone solution as a blank. The correction has been done by subtracting the absorbance value at 750 nm from the values obtained at 664. 647 and 630 nm wavelengths.

CALCULATIONS:

$Ca = 11.85\ E_{664} - 1.54\ E_{647} - 0.08\ E_{630}$ ------------------- 1

Where E is the absorbance at the respective wavelength.

Chlorophyll *a* $(mg / m^3) = (Ca \times v) / (V \times l)$

Where:

Ca = the calculated value of equation 1.

v = volume of acetone (ml).

V = volume of water sample filtered (litre).

l = path length of the cuvette (Cm).

C- IDENTIFICATION AND ENUMERATION OF PLANKTONIC ALGAE

After preliminary observation of the live material, samples were transferred to polythene bottles and preserved with Lugol's solution (Lugol's solution was added, so that. the concentration in the sample will be 1 %), and the organisms were identified microscopically.

Enumeration of microalgae was done using a Sedgwick – Rafter counting cell. The concentrated sample was mixed very well, and 1 ml was taken and transferred into the counting cell, and made to cover the all squares (1000 squares). Planktonic algae in 200 squares were counted using a microscope. Each size group was counted three times and the average was recorded.

4) MEASUREMENTS OF THE HYDROGRAPHIC PARAMETERS:

Temperature, transparency, salinity and nutrients were measured using standard methods.

A- TEMPERATURE:

Surface water samples were collected using an ordinary plastic container, and temperature was measured in the shadow, in a place protected from air currents using precision mercury thermometer.

B- TRANSPARENCY:

Light intensity at the sea surface was measured using a calibrated lux meter (LUX-101). Transparency was measured using Secchi disc, which was lowered vertically from the sunny side of the ship, and the depth at which the disc was disappeared recorded. The depth of the euphotic zone then calculated using the following formula:

$$\text{The depth of the euphotic zone (meters)} = (\ln 100 - \ln 1) / K$$

$$K = 1.7 / D$$

Where: ln = the natural logarithm.

K= the extinction coefficient

D = Secchi disc depth (meters)

C- SALINITY:

Salinity was estimated immediately after collection using a calibrated salinometer.

D- NUTRIENTS:

1- NITRATE ($NO_3 - N$)

Nitrate was reduced to nitrite (Grasshoff, 1970), and estimated spectrophotometrically

2- NITRITE ($NO_2 - N$)

The determination of nitrite concentration in sea water was done using Bendschneider and Robinson (1952) method.

3- PHOSPHATE ($PO_4 - P$)

The concentration of inorganic phosphate in sea water was determined spectrophotometrically using the method of Murphy and Riley (1962) as modified by Koroleff (1963) and Koroleff (1968)

4- SILICATE ($SiO_4 - Si$)

Silicate concentration in water samples was estimated spectrophotometrically using Koroleff (1971) method.

Figure 2- The separation tower

CHAPTER 2

THE HYDROGRAPHIC PARAMETERS

The hydrographic parameters in the coastal waters vary to a great extent, controlled by the climate, tidal activities, up welling and the fresh water influx. Knowledge of the hydrographic parameters prevailing in the coastal waters is of utmost importance for better understanding of the growth and productivity of planktonic algae. Factors like temperature, light intensity, salinity, nutrients etc. are influenced to a great extent by seasonal changes.

India is characterized by a steady, annually occurring phenomenon, viz., the "monsoon" or the rainy season due to its geographical location (a triangular land mass extending into the Indian Ocean). Accordingly, the climatic seasons in India are divided into: 1) the pre-monsoon season (February – May), 2) the monsoon season (June – September) and 3) the post-monsoon season (October – January). Each season has its own environmental features. Fluctuations in salinity, temperature, nutrients and illumination seem to be closely correlated with growth and productivity of planktonic algae. Hence, variations of these parameters in the coastal waters of the south-west coast of India are briefly discussed below.

TEMPERATURE:

Temperature is an important physical factor controlling growth and distribution of planktonic algae. High temperatures inhibit photosynthesis by causing damage to enzymes and cell structure. Temperature may have an indirect effect on growth and productivity of planktonic algae via its effects on the stability of the water column. However, in the south-west coast of India, temperature has been found to be within the limits of tolerance throughout the year, and does not have a significant effect on growth and productivity of planktonic algae. At station 1, the maximum values were recorded during the pre-monsoon season with average value of 31°C, and the minimum values were observed during the monsoon season with average value of 26°C. Intermediate values have been recorded during the post-monsoon season with average value of 29°C. At station 2, the same trend was noticed, with an average temperature values of 31°C, 26°C and 30°C during the pre-monsoon, the monsoon and the post-monsoon seasons, respectively.

Temperature (°C)

Station	pre-monsoon	monsoon	post-monsoon
1	31	26	29
2	31	26	30

Low temperature during the monsoon season is occurring due to the cloud cover associated with rains and fresh water influx. The up welling of subsurface cold-nutrient rich waters, which occurs during the monsoon season, is also an important factor, responsible for lowering surface water temperature.

LIGHT:

Light is the energy source powering photosynthesis. The quantity and quality of the ambient light have a great influence on the growth and productivity of planktonic algae. The penetration of light into the coastal waters depends largely on the turbidity, which is greater than that of the open sea. In the south-west coast of India, although there is a reduction in the quantity of light falling on and penetrating the surface layer during the monsoon season, due to the cloud cover and high turbidity, light is not a limiting factor controlling growth and productivity of microalgae. The sea surface has been found to receive sufficient light throughout the year, but the thickness of the euphotic zone vary from 1.4

meters during the monsoon season to about 14 meters during the pre-monsoon and post-monsoon seasons. The quantity of light falling on the water surface has been found on averages to be 93, 56 and 68 Klux during the pre-monsoon, the monsoon and the post-monsoon seasons respectively

SALINITY:

Salinity is an important hydrographic parameter effecting growth, distribution, species succession and productivity in the marine environment, especially in the coastal waters that are more subjected to variations in salinity as compared with the offshore waters. Salinity is a function of evaporation, precipitation, land-runoff, melting of ice and up welling. Some species, particularly diatoms, grow poorly at salinities greater than 35 ‰ and this perhaps explains their preference for coastal waters (Hulbert and Rodman, 1963). According to Braarud (1962) the density changes produced in the coastal waters by variations of temperature and salinity may indirectly affect the phytoplankton species succession by causing certain species to sink. In the south west coast of India, small variations of salinity were observed, and the fluctuations of salinity were ranged between 31 and 36 ‰ throughout the year. At station 1, highest salinity values were recorded during the monsoon season with average value of 36 ‰, and lowest values during the post-monsoon season with average value of 33 ‰. During the pre-monsoon season, the average value of salinity was 34.4 ‰. Similarly, at station 2, the maximum values observed in the monsoon season with average of 34 ‰, and the minimum salinity values were recorded in the post-monsoon season with average value of 31 ‰. In the pre-monsoon season, average value of salinity recorded was 33 ‰.

Salinity (‰)

Station	pre-monsoon	monsoon	post-monsoon
1	34.4	36	33
2	33	34	3[illegible]

High salinity values during the monsoon season in the south-west coast of India associated with low temperature and high nutrient-salts concentration is an indication of the occurrence of up welling during this season of the year The lower values during the post-monsoon season exist due to the higher effect of the land-runoff and fresh water influx from the backwaters along Kerala coast during this season.

Salinity appears to have little or no significant role on the growth and productivity of planktonic algae in the south-west coast of India.

NUTRIENTS:

For healthy growth marine planktonic algae require a supply of certain chemical elements, which are utilized from sea water as simple inorganic salts (nitrate. nitrite. phosphate, silicate etc.). These nutrients are introduced into the coastal waters through land-runoff or as a result of microbial decomposition of the dead bodies of the marine organisms and their waste products. The microbial decomposition occurs often at the intermediate depths or on the bottom of the sea, and the resultant nutrients are brought up to the surface layer (the euphotic zone), to be used by planktonic algae, with the help of the vertical mixing (turbulent mixing, convection currents and up welling). Coastal waters are usually richer in nutrients than the open sea. The differences in nutrients concentration in coastal waters and the requirements of planktonic algae may have an important influence on the distribution and succession of planktonic algal species in the sea. In the south-west coast of India, nutrients have been found to be the most important ecological factor controlling growth and productivity of planktonic algae.

NITRATE (NO_3- N):

Nitrate is an important source of nitrogen in the coastal waters of the south-west coast of India. At station 1, its concentration has been found to show seasonal variations, with highest values during the monsoon season, averaged 4.14 µg. at /l. Lowest values were observed during the post-monsoon season, averaged 1.08 µg. at /l. At station 2, same trend has been found with averages of 5.89 µg. at /l, and 1.44 µg. at /l during the monsoon and the post-monsoon seasons respectively. At both stations, intermediate values were recorded during the pre-monsoon season, with averages of 3.21 µg at /l at station 1, and 2.92 µg. at /l at station 2.

$NO_3 - N$ (µg. at /l)

Station	pre-monsoon	monsoon	post-monsoon
1	3.21	4.14	1.08
2	2.92	5.89	1.44

NITRITE (NO_2 – N):

Nitrite is another important source of nitrogen. Its concentration in the coastal waters is less than that of nitrate, but has also shown seasonal variations. At station 1, highest values were found in the monsoon season, with average value of 1.28 µg. at /l, the lowest values were recorded in the pre-monsoon season, averaging 0.32 µg. at /l. At station 2, maximum values were also recorded in the monsoon season with average value of 1.77 µg. at /l, but the minimum values have been found during the post-monsoon season, averaging 0.52 µg. at /l. Moderate concentrations recorded were 0.83 µg. at /l during the post-monsoon season at station 1, and 0.56 µg. at /l during the pre-monsoon season at station 2.

$NO_2 - N$ (µg. at /l)

Station	pre-monsoon	monsoon	post-monsoon
1	0.32	1.28	0.83
2	0.56	1.77	0.52

PHOSPHATE ($PO_4 - P$):

Among all nutrients, inorganic phosphate has been found to be the most important nutrient salt effecting growth and productivity of planktonic algae in the coastal waters of the south-west coast of India. The concentration of inorganic phosphate has been found to be subjected to seasonal variations, and to correlate positively with the primary organic productivity in this area of investigation.

At station 1, maximum values were recorded during the monsoon season, with average concentration of 2.71 µg. at /l; the minimum concentrations were recorded in the pre-monsoon season with average value of 0.27 µg. at /l. The average concentration recorded during the post-monsoon season was 1.13 µg. at /l. At station 2, the highest values were also observed in the monsoon season with average concentration of 2.68 µg. at /l. During the pre-monsoon and the post-monsoon seasons, phosphate concentrations have shown lower values, with nearly same averages of 1.05 µg. at /l, and 0.98 µg. at /l, respectively.

$PO_4 - P$ (µg. at /l)

Station	pre-monsoon	monsoon	post-monsoon
1	0.27	2.71	1.13
2	1.05	2.68	0.98

SILICATE (SiO_4 – Si):

Silicate is an important nutrient salt required by diatoms and silicoflagellates. which constitute 77 % of the total planktonic algae in the coastal waters of the south west coast of India. Silicate concentration also showed seasonal variations with highest values during the monsoon season. and lowest values during the post-monsoon season. The concentrations recorded at station 1 were 25.40 µg. at /l in the monsoon season. and 8.58 µg. at /l during the post-monsoon season. In the pre-monsoon season, the average value found was 9.71 µg. at /l. At station 2. the average values recorded were 31.95 µg. at /l during the monsoon season. and 9.76 µg. at /l in the post monsoon season. The average concentration recorded during the pre-monsoon season was 11.08 µg. at /l.

SiO_4 – Si (µg. at /l)

Station	pre-monsoon	monsoon	post-monsoon
1	9.71	25.40	8.58
2	11.08	31.95	9.76

Higher concentrations of nutrient salts during the monsoon season in the coastal waters of the south west coast of India occur due to the up welling of subsurface cold-nutrient rich waters, and also as a result of land-run off associated with heavy rains during this season.

CHAPTER 3

SPECIES COMPOSITION OF PLANKTONIC ALGAE

INTRODUCTION:

Species composition of planktonic algae and the size of the standing crop are of great importance in the marine ecosystem, and though nearly all species of planktonic algae are utilized as food by some marine organisms, certain herbivorous zooplankton exhibit considerable selectivity in their diet. A suitable quantity of food organisms of the right type at the appropriate time is very important for the survival of a brood of zooplankton.

In some regions the species composition of planktonic algae is relatively stable. Some algae are fairly sharply restricted to particular areas of the ocean, the distribution being limited most obviously by temperature and salinity characteristics. Intensity and quality of light as well as nutrients concentration affect the floristic composition in aquatic ecosystems.

In temperate latitudes, where there may be considerable variations in temperature, light and nutrients concentration throughout the year, there is frequently a marked change in species composition of planktonic algae, accompanying fluctuations in standing crop. This seasonal succession is also well known at high latitudes. Even in low latitudes where usually environmental variations are smaller, the species composition of planktonic algae often shows what might be described as a seasonal succession. The changes in species composition may sometimes be recognized as associated with changing environmental conditions; as evidenced by their remarkable change during monsoons and seasonal up welling.

In tropical inshore waters Smayda (1963, 1966) found that the microalgae was remarkably constant in composition over the Gulf of Panama and was dominated by diatoms.

The marked seasonal variations in microalgae which may occur in tropical seas related to monsoonal changes are demonstrated by the investigations of Subramanyan and Sarma (1965) off Calicut, south-west coast of India. They found a very large standing crop, especially during the south-west monsoon period. Although in some occasions (June 1959, August 1960) nanoplankton comprised more than 80 % of the standing crop, on average it constituted only 40 %. Seasonal fluctuations of the nanoplankton off the west coast of India were not so pronounced as that of the net plankton. Small diatoms and dinoflagellates predominated in the nanoplankton.

Krey (1973), describing phytoplankton geographical regions of the Indian Ocean, points out that the rich regions (Antarctic, sub-Antarctic, west wind drift and major up welling areas) are dominated by diatoms and may have concentrations of 10^4 to 10^5 cell / l; less rich areas (Arabian sea and equatorial current areas) have a great proportion of dinoflagellates often with coccolithophorids with concentrations of about 10^4 cell / l; the poorest areas include the south sub-tropical gyre and central part of the Bay of Bengal, with mostly dinoflagellates and coccolithophorids amounting to less than 5×10^3 cell/l.

RESULTS:

In the coastal waters of Cochin, south west coast of India, planktonic algal community composed mainly of the diatoms, the dinoflagellates, the blue-green algae and the silicoflagellates. The presence of a specific group of organisms at a certain locality at a particular season is directly linked to its requirements to suitable environmental conditions which enhance their growth and reproduction.

At station 1, during the pre-monsoon season (February – May), the planktonic algal community recorded were:

DIATOMS: 23 genera and 33 species

Thalassiothrix longissima. Thalassiothrix frauenfeldii. Chaetoceros curvisetus. Chaetoceros brevis. Chaetoceros affinis. Chaetoceros leave. Asterionella japonica. Rhizosolenia alata. Rhizosolenia setigera. Rhizosolenia stolterfothii. Rhizosolenia styliformis. Nitzschia longissima. Nitzschia delicatissima. Schroderella delicatula. Bacteriastrum varians. Guinardia flaccida. Ditylum sol. Streptotheca thamensis. Pleurosigma directum. Biddulphia mobiliensis. Biddulphia heteroceros. Hemiaulus sp. Corethron inerme. Coscinodiscus radiatus. Navicula hennedyii. Thalassiosira subtilis. Thalassiosira coramandeliana. Planktoniella sol. Amphiprora gigantae. Stephanopyxis palmeriana. Thalassionema nitzschioides. Skeletonema costatum and *Leptocylindrus danicus.*

DINOFLAGELLATES: 6 genera and 9 species

Ceratium furca. Dinophysis caudata. Peridinium depressum. Peridinium tuba. Peridinium pellucidum. Pyrophacus horologicum. Prorocentrum micans. Prorocentrum gracile and *Gonyaulax sp.*

BLUE-GREEN ALGAE: 2 genera and 2 species

Oscillatoria nigroviridis and *Johannesbaptistia pellucida.*

SILICOFLAGELLATES: 1 genus and 1 species

Dictyocha fibula.

Diatoms have been found to constitute 73.4 %, the dinoflagellates 20 %, the blue-green algae 4.4 % and the silicoflagellates 2.2 % of the total number of species of planktonic algae (table 3.1). The distribution of the different taxa of planktonic algae among the various size groups at station 1, during the pre-monsoon season is discussed.

The planktonic algae in the size group of > 500 µm consisted of diatoms *Chaetoceros curvisetus* and *Thalassiothrix longissima*. The size group of < 500 – 250 µm included the diatoms *Chaetoceros curvisetus. Chaetoceros affinis. Thalassiothrix longissima* and *Asterionella japonica.* The size group of < 250 – 150 µm was dominated by the diatoms *Thalassiothrix longissima* and *Chaetoceros curvisetus.* The other planktonic algae were *Chaetoceros brevis. Chaetoceros affinis. Rhizosolenia alata. Rhizosolenia setigera. Asterionella japonica.* and the blue-green algae *Oscillatoria nigroviridis.* In the size group of < 150 – 105 µm, *Chaetoceros curvisetus* was the dominant species. The other planktonic algae were *Chaetoceros brevis. Chaetoceros affinis. Chaetoceros leave. Rhizosolenia alata. Rhizosolenia setigera. Asterionella japonica. Nitzschia delicatissima. Nitzschia longissima. Schroderella delicatula. Bacteriastrum varians. Guinardia flaccida. Ditylum sol. Thalassiothrix longissima. Thalassiothrix frauenfeldii. Streptotheca thamensis. Pleurosigma directum. Thalassiosira coramandeliana.* and *Biddulphia mobiliensis.* The planktonic algae of the size group of < 105 – 53 µm were dominated by the diatoms *Chaetoceros curvisetus.*, the other diatoms included were *Chaetoceros brevis. Chaetoceros leave. Thalassiosira coramandeliana, Bacteriastrum varians. Hemiaulus sp. Asterionella japonica. Schroderella delicatula. Biddulphia mobiliensis. Nitzschia longissima, Nitzschia delicatissima, Corethron inerme, Pleurosigma directum. Coscinodiscus radiatus. Planktoniella sol. Ditylum sol. Thalassiothrix longissima, Rhizosolenia alata* and *Rhizosolenia setigera.* The dinoflagellates present were *Ceratium furca. Dinophysis caudata. Peridinium depressum. Peridinium tuba* and *Pyrophacus horologicum.* The planktonic algae in the size range of < 53 – 25 µm included the diatoms *Thalassiosira coramandeliana* and *Rhizosolenia setigera* as the dominant species. The other diatoms recorded were *Chaetoceros curvisetus, Hemiaulus sp,* *Schroderella delicatula*, *Amphiprora gigantae*, *Coscinodiscus radiatus*, *Asterionella japonica*, *Biddulphia mobiliensis*, *Nitzschia delicatissima*, *Stephanopyxis palmeriana*, *Rhizosolenia stolterfothii*, *Thalassionema nitzschioides*, *Pleurosigma directum* and *Chaetoceros brevis*; the dinoflagellates were represented by *Ceratium furca*, *Peridinium pellucidum*, *Peridinium tuba*, *Prorocentrum gracile* and *Dinophysis caudata*; the silicoflagellate *Dictyocha fibula* was also present in addition to the blue-green algae *Johannesbaptistia pellucida*. In the size group of < 25 – 10 μm, small and unicellular planktonic algae were present, these included the diatoms *Skeletonema costatum* which was the dominant species, *Nitzschia longissima*, *Nitzschia delicatissima*, *Amphiprora gigantae*, *Schroderella delicatula*, *Thalassiosira subtilis*, *Thalassiosira coramandeliana*, *Rhizosolenia alata*, *Rhizosolenia stolterfothii*, *Rhizosolenia styliformis*, *Stephanopyxis palmeriana*, *Leptocylindrus danicus*, *Pleurosigma directum*, *Corethron inerme*, *Biddulphia heteroceros*, *Hemiaulus sp.*, *Coscinodiscus radiatus* and *Thalassionema nitzschioides*; the dinoflagellates were *Ceratium furca*, *Prorocentrum micans* and *Gonyaulax sp.*, the silicoflagellates and the blue-green algae were represented by one species each, *Dictyocha fibula* and *Johannesbaptistia pellucida* respectively. The smallest size group of < 10 μm in size included *Fragilaria oceanica*, *Navicula hennedyii* and *Thalassiosira coramandeliana* (as the dominant species) the other forms were *Skeletonema costatum*, *Nitzschia longissima* and *Leptocylindrus danicus*; the blue-green alga *Johannesbaptistia pellucida* was also recorded in this size group.

In the monsoon season (June – September), species composition was slightly different, as shown below.

<u>DIATOMS</u>: 20 genera and 28 species

Thalassiothrix longissima, *Thalassiothrix frauenfeldii*, *Chaetoceros curvisetus*, *Chaetoceros brevis*, *Chaetoceros lorenzianus*, *Asterionella japonica*, *Rhizosolenia setigera*, *Rhizosolenia stolterfothii*, *Rhizosolenia styliformis*, *Nitzschia delicatissima*, *Nitzschia longissima*, *Bacteriastrum varians*, *Guinardia flaccida*, *Ditylum sol*, *Pleurosigma directum*, *Biddulphia mobiliensis*, *Hemiaulus sp*, *Corethron inerme*, *Coscinodiscus radiatus*, *Coscinodiscus spp*, *Thalassiosira subtilis*, *Thalassiosira coramandeliana*, *Thalassionema nitzschioides*, *Skeletonema costatum*, *Navicula hennedyii*, *Fragilaria oceanica*, *Eucampia zoodiacus* and *Licmophora sp*.

DINOFLAGELLATES: 3 genera and 3 species

Dinophysis caudata, *Peridinium depressum* and *Prorocentrum micans*.

BLUE-GREEN ALGAE: 2 genera and 2 species

Oscillatoria nigroviridis and *Johannesbaptistia pellucida*.

SILICOFLAGELLATES: 1genus and 1 species

Dictyocha fibula.

Of the total number of species, diatoms were contributing 82.4 %, dinoflagellates 8.8 %, blue-green algae 5.9 % and silicoflagellates 2.9 % (table 3.1).

The planktonic algae of the size group of > 500 µm were *Eucampia zoodiacus*, *Asterionella japonica* and *Oscillatoria nigroviridis*. In the size group of < 500 – 250 µm, *Asterionella japonica* and the chain forming diatom *Fragilaria oceanica* have been recorded. *Asterionella japonica* was the dominant species in the size group of < 250 – 150 µm, the other forms were *Bacteriastrum varians*, *Hemiaulus sp*, *Nitzschia delicatissima*, *Nitzschia longissima*, *Thalassiosira coramandeliana*, *Rhizosolenia styliformis*, *Thalassiothrix frauenfeldii*, *Chaetoceros curvisetus*, *Thalassiothrix longissima* and *Fragilaria oceanica*. The planktonic algae in the size range of < 150 – 105 µm were also dominated by *Asterionella japonica*, the other diatoms were *Ditylum sol*, *Chaetoceros curvisetus*, *Chaetoceros lorenzianus*, *Chaetoceros brevis*, *Eucampia zoodiacus*, *Nitzschia longissima*, *Nitzschia delicatissima*, *Fragilaria oceanica*, *Rhizosolenia setigera. Rhizosolenia sp. Pleurosigma directum* and *Thalassiothrix longissima;* the blue-green algae *Oscillatoria nigroviridis* was also present in this size group. The size group of < 105 – 53 µm showed the dominance of *Asterionella japonica*, the other members of this group were *Nitzschia longissima. Nitzschia delicatissima. Eucampia zoodiacus. Rhizosolenia setigera. Rhizosolenia stolterfothii. Chaetoceros curvisetus. Ditylum sol. Thalassionema nitzschioides. Thalassiothrix frauenfeldii. Thalassiothrix longissima. Thalassiosira subtilis, Thalassiosira coramandeliana. Skeletonema costatum. Biddulphia mobiliensis. Guinardia flaccida. Planktoniella sol. Coscinodiscus radiatus. Hemiaulus sp, Pleurosigma directum. Fragilaria oceanica* and *Bacteriastrum varians; Oscillatoria nigroviridis* was also found in this size group. In the size range of < 53 – 25 µm the dominant species was *Asterionella japonica*. other species being *Thalassiosira coramandeliana, Thalassionema nitzschioides, Nitzschia delicatissima. Nitzschia longissima. Pleurosigma directum, Rhizosolenia setigera, Rhizosolenia stolterfothii. Thalassiothrix longissima. Thalassiothrix frauenfeldii, Skeletonema costatum. Eucampia zoodiacus. Fragilaria oceanica. Corethron inerme. Thalassiosira subtilis. Coscinodiscus sp* and *Biddulphia mobiliensis;* the recorded dinoflagellates were *Peridinium depressum* and *Dinophysis caudata;* the silicoflagellate *Dictyocha fibula* and the blue-green algae *Johannesbaptistia pellucida* were also recorded in this size group. *Nitzschia longissima* was the dominant planktonic algae in the size fraction of < 25 – 10 µm, the diatoms *Asterionella japonica. Thalassiosira coramandeliana. Pleurosigma directum. Rhizosolenia setigera. Rhizosolenia stolterfothii. Thalassiothrix frauenfeldii. Thalassionema nitzschioides. Nitzschia delicatissima, Skeletonema costatum. Fragilaria oceanica. Eucampia zoodiacus. Licmophora sp. Coscinodiscus radiatus. Biddulphia mobiliensis* and *Navicula hennedyii* have been recorded in this size group along with the dinoflagellates *Prorocentrum micans.* The smallest size fraction of < 10 µm in size included small and unicellular forms viz., *Skeletonema costatum. Thalassiosira coramandeliana. Rhizosolenia stolterfothii,* *Fragilaria oceanica. Nitzschia longissima. Navicula hennedyii. Thalassionema nitzschioides* and *Johannesbaptistia pellucida.*

During the post-monsoon season (October – January), the following planktonic algae were observed.

DIATOMS: 21 genera and 33 species

Thalassiothrix longissima. Thalassiothrix frauenfeldii. Chaetoceros curvisetus. Chaetoceros affinis. Chaetoceros atlanticus. Chaetoceros lorenzianus. Chaetoceros diversus. Chaetoceros tortissimum. Asterionella japonica. Rhizosolenia alata. Rhizosolenia setigera. Rhizosolenia stolterfothii. Rhizosolenia calcar-vis. Nitzschia delicatissima. Nitzschia longissima. Bacteriastrum varians. Guinardia flaccida. Ditylum sol. Streptotheca thamensis. Pleurosigma directum. Biddulphia mobiliensis. Hemiaulus sp. Coscinodiscus radiatus. Coscinodiscus sp. Thalassiosira subtilis. Thalassiosira coramandeliana. Amphiprora gigantae. Thalassionema nitzschioides. Skeletonema costatum. Leptocylindrus danicus. Eucampia zoodiacus. Navicula hennedyii and *Diplonies sp.*

DINOFLAGELLATES: 6 genera and 7 species

Ceratium furca. Ceratium fusus. Peridinium depressum. Prorocentrum micans. Gonyaulax sp. Pyrocystis fusiformis and *Gymnodinium veneficum.*

BLUE-GREEN ALGAE: 1genus and 1 species

Oscillatoria nigroviridis.

SILICOFLAGELLATES: 1genus and 1 species

Dictyocha fibula.

Diatoms have been found to contribute 78.6 %, the dinoflagellates 16.6 %, the blue-green algae and silicoflagellates 2.4 % each, to the total number of species at this season of the year (table 3.1).

The planktonic algae of > 500 µm in size were *Thalassiothrix longissima* (dominant), *Chaetoceros curvisetus*, *Nitzschia delicatissima* and *Asterionella japonica*. The size group of < 500 – 250 µm was represented by the dominant species of *Thalassiothrix longissima*. The other species were *Nitzschia delicatissima*, *Chaetoceros atlanticus*, *Asterionella japonica* and *Bacteriastrum varians*. The organisms in the size range of < 250 – 150 µm were *Chaetoceros curvisetus*, *Chaetoceros lorenzianus*, *Chaetoceros atlanticus*, *Nitzschia delicatissima*, *Nitzschia longissima*, *Rhizosolenia stolterfothii*, *Thalassiothrix longissima*, *Asterionella japonica*, *Biddulphia mobiliensis*, *Bacteriastrum varians* and *Skeletonema costatum* beside the filamentous blue-green algae *Oscillatoria nigroviridis*. In the size fraction of < 150 – 105 µm, *Chaetoceros curvisetus* was the dominant species, other species being *Chaetoceros affinis*, *Chaetoceros lorenzianus*, *Chaetoceros atlanticus*, *Chaetoceros diversus*, *Chaetoceros tortissimum*, *Nitzschia delicatissima*, *Nitzschia longissima*, *Asterionella japonica*, *Streptotheca thamensis*, *Rhizosolenia stolterfothii*, *Rhizosolenia alata*, *Rhizosolenia sp*, *Thalassiothrix longissima*, *Bacteriastrum varians*, *Biddulphia mobiliensis*, *Skeletonema costatum* and *Leptocylindrus danicus*, the dinoflagellate *Ceratium fusus* and the blue-green alga *Oscillatoria nigroviridis*. The dominant species in the size group of < 105 – 53 µm was also *Chaetoceros curvisetus*, the other diatoms recorded were *Chaetoceros lorenzianus*, *Chaetoceros diversus*, *Chaetoceros atlanticus*, *Asterionella japonica*, *Nitzschia longissima*, *Nitzschia delicatissima*, *Ditylum sol*, *Eucampia zoodiacus*, *Thalassiosira subtilis*, *Navicula hennedyii*, *Skeletonema costatum*, *Rhizosolenia stolterfothii*, *Rhizosolenia calcar-avis*, *Thalassionema nitzschioides*, *Amphiprora gigantae*, *Diplonies sp*, *Thalassiothrix longissima*, *Bacteriastrum varians*, *Biddulphia mobiliensis* and *Leptocylindrus danicus*. The dinoflagellates present were *Ceratium fusus*. *Ceratium furca*. *Gonyaulax sp.* *Peridinium depressum* and *Pyrocystis fusiformis*. The blue green alga represented in this size group was *Oscillatoria nigroviridis*. The dominant species in the size group of < 53 – 25 µm was the diatom *Skeletonema costatum;* the other diatoms were *Asterionella japonica*, *Guinardia flaccida*, *Rhizosolenia stolterfothii*, *Rhizosolenia setigera*, *Rhizosolenia calcar-avis*, *Chaetoceros curvisetus*, *Thalassiothrix frauenfeldii*, *Nitzschia longissima*, *Nitzschia delicatissima*, *Thalassionema nitzschioides*, *Thalassiosira subtilis*, *Thalassiosira coramandeliana*, *Biddulphia mobiliensis*, *Navicula hennedyii*, *Pleurosigma directum*, *Coscinodiscus radiatus*, *Leptocylindrus danicus*, *Schroderella delicatula* and *Amphiprora gigantae;* the dinoflagellates included *Ceratium furca* and *Gymnodinium veneficum;* the silicoflagellate *Dictyocha fibula* was also present. The planktonic algae of the size group of < 25 – 10 µm were the diatoms *Skeletonema costatum* which was forming 44.8 % of the total planktonic algae; the other species were *Nitzschia longissima*, *Nitzschia delicatissima*, *Leptocylindrus danicus*, *Hemiaulus sp.* *Thalassionema nitzschioides*. *Rhizosolenia stolterfothii*, *Rhizosolenia setigera*, *Navicula hennedyii*, *Thalassiothrix frauenfeldii* and *Thalassiosira coramandeliana;* and the dinoflagellates *Prorocentrum micans* and *Gymnodinium veneficum*. In the size group of < 10 µm the flora present were the diatoms *Skeletonema costatum*, *Nitzschia longissima* *Navicula hennedyii*, *Rhizosolenia setigera*, *Rhizosolenia stolterfothii*, *Thalassiosira coramandeliana*. *Thalassionema nitzschioides* and the dinoflagellate *Gymnodinium veneficum*.

At station 2, during the pre-monsoon season, the planktonic algae found were:

<u>DIATOMS</u>: 22 genera and 32 species

Thalassiothrix longissima, *Thalassiothrix frauenfeldii*. *Chaetoceros curvisetus*, *Chaetoceros brevis*, *Chaetoceros affinis*, *Chaetoceros lorenzianus*.

Bacteriastrum varians. Asterionella japonica. Hemiaulus sp. Thalassiosira subtilis. Thalassiosira coramandeliana. Skeletonema costatum. Fragilaria oceanica. Rhizosolenia setigera. Rhizosolenia stolterfothii. Rhizosolenia styliformis. Rhizosolenia clevei. Thalassionema nitzschioides. Nitzschia delicatissima. Nitzschia longissima. Schroderella delicatula. Pleurosigma directum. Biddulphia mobiliensis. Biddulphia sinensis. Streptotheca thamensis. Eucampia zoodiacus. Planktoniella sol. Coscinodiscus radiatus. Leptocylindrus danicus. Corethron inerme. Amphiprora gigantae and *Navicula hennedyii.*

DINOFLAGELLATES: 5 genera and 7 species

Peridinium depressum. Peridinium tuba. Ceratium furca. Ceratium tripos, Pyrophacus horologicum. Dinophysis caudata and *Gonyaulax sp.*

BLUE-GREEN ALGAE: 2 genera and 2 species

Oscillatoria nigroviridis and *Johannesbaptistia pellucida.*

SILICOFLAGELLATES: 1 genus and 1 species

Dictyocha fibula.

The contribution of the various taxa to the total number of species was 76.2 % diatoms. 16.6 % dinoflagellates, 4.8 % blue-green algae and 2.4 % silicoflagellates (table 3.2).

The planktonic algae in the size group of > 500 µm were *Thalassiothrix longissima* which was the dominant species; the other species were *Chaetoceros curvisetus* and *Bacteriastrum varians.* In the size range of < 500 – 250 µm. *Thalassiothrix longissima, Asterionella japonica* and *Oscillatoria nigroviridis* were found. The size fraction of < 250 – 150 µm was including the following diatoms. *Chaetoceros curvisetus. Thalassiothrix longissima, Chaetoceros brevis. Chaetoceros affinis, Chaetoceros lorenzianus. Asterionella japonica. Hemiaulus sp. Thalassiothrix frauenfeldii. Thalassiosira coramandeliana. Bacteriastrum varians. Skeletonema costatum, Fragilaria* *oceanica* and *Rhizosolenia setigera*. The size group of < 150 – 105 µm was dominated by the diatoms *Chaetoceros curvisetus* and *Thalassiothrix longissima*, the other forms were *Chaetoceros brevis*, *Chaetoceros lorenzianus*, *Chaetoceros affinis*, *Thalassionema nitzschioides*, *Nitzschia delicatissima*, *Nitzschia longissima*, *Asterionella japonica*, *Schroderella delicatula*, *Hemiaulus sp*, *Bacteriastrum varians*, *Rhizosolenia stolterfothii*, *Rhizosolenia setigera*, *Rhizosolenia styliformis*, *Fragilaria oceanica*, *Thalassiothrix frauenfeldii*, *Thalassiosira coramandeliana*, *Pleurosigma directum*, *Skeletonema costatum*, *Biddulphia mobiliensis*, *Streptotheca thamensis* and *Eucampia zoodiacus;* the blue-green alga *Oscillatoria nigroviridis* was also found in this size fraction. Within the size range of < 105 – 53 µm, the dominant species was the diatom *Chaetoceros curvisetus*, the other diatoms were *Chaetoceros affinis*, *Chaetoceros brevis*, *Skeletonema costatum*, *Asterionella japonica*, *Bacteriastrum varians*, *Schroderella delicatula*, *Biddulphia mobiliensis*, *Biddulphia sinensis*, *Rhizosolenia setigera*, *Rhizosolenia stolterfothii*, *Rhizosolenia clevei*, *Planktoniella sol*, *Thalassiosira coramandeliana*, *Nitzschia longissima*, *Nitzschia delicatissima*, *Coscinodiscus radiatus*, *Thalassiothrix frauenfeldii*, *Thalassionema nitzschioides*, *Eucampia zoodiacus*, *Pleurosigma directum*, *Leptocylindrus danicus*, *Fragilaria oceanica* and *Hemiaulus sp:* the dinoflagellates were *Peridinium depressum*, *Ceratium furca*, *Ceratium tripos* and *Pyrophacus horologicum; Oscillatoria nigroviridis* was the only species of blue green algae present. The dominant species in the size group of < 53 – 25 µm were the diatoms *Thalassiosira subtilis*, *Thalassiosira coramandeliana* and *Rhizosolenia setigera*, the other forms of diatoms were *Skeletonema costatum*, *Corethron inerme*, *Schroderella delicatula*, *Chaetoceros curvisetus*, *Nitzschia longissima*, *Nitzschia delicatissima*, *Biddulphia mobiliensis*, *Asterionella japonica*, *Hemiaulus sp*, *Bacteriastrum varians*, *Amphiprora gigantae*, *Rhizosolenia stolterfothii*, *Rhizosolenia clevei*, *Pleurosigma directum*, *Coscinodiscus radiatus*, *Thalassionema nitzschioides*, *Eucampia zoodiacus*, *Thalassiothrix frauenfeldii* and *Fragilaria oceanica:* the dinoflagellates of this size group were *Peridinium tuba. Ceratium furca. Dinophysis caudata. Pyrophacus horologicum* and *Gonyaulax sp:* the silicoflagellate *Dictyocha fibula* was also seen in this size group. The size group of < 25 – 10 µm was found to include the diatoms, *Nitzschia delicatissima. Skeletonema costatum. Thalassiosira coramandeliana* (dominant species). *Nitzschia longissima. Leptocylindrus danicus. Asterionella japonica. Schroderella delicatula. Thalassionema nitzschioides. Rhizosolenia stolterfothii. Rhizosolenia setigera. Corethron inerme. Amphiprora gigantae. Hemiaulus sp* and *Pleurosigma directum* along with the blue-green alga *Johannesbaptistia pellucida.* The smallest size group of < 10 µm in size was represented by diatoms such as *Thalassiosira coramandeliana. Nitzschia longissma Navicula hennedyii. Rhizosolenia stolterfothii* and the blue green alga *Johannesbaptistia pellucida.*

During the monsoon season, the planktonic algal community was composed of:

<u>DIATOMS:</u> 17 genera and 22 species

Thalassiothrix longissima. Thalassiothrix frauenfeldii. Chaetoceros curvisetus. Chaetoceros lorenzianus. Asterionella japonica. Hemiaulus sp. Thalassiosira subtilis. Thalassiosira coramandeliana. Skeletonema costatum. Fragilaria oceanica. Rhizosolenia setigera. Rhizosolenia Stolterfothii. Thalassionema nitzschioides. Nitzschia longissima. Nitzschia delicatissima. Pleurosigma directum. Biddulphia mobiliensis. Eucampia zoodiacus. Coscinodiscus radiatus. Leptocylindrus danicus. Navicula hennedyii and *Guinardia flaccida.*

<u>DINOFLAGELLATES:</u> 1 genus and 1 species

Dinophysis caudata

<u>BLUE-GREEN ALGAE:</u> 1 genus and 1 species

Oscillatoria nigroviridis

SILICOFLAGELLATES: 1 genus and 1 species

Dictyocha fibula

Diatoms contributed 88 % of the total number of species. the dinoflagellates, the blue green algae and the silicoflagellates 4 % each (table 3.2).

The diatom *Asterionella japonica* has been recorded alone in the size group of > 500 µm. In the size fraction of < 500 – 250 µm, this diatom was dominating and the other forms were *Thalassiothrix longissima. Chaetoceros curvisetus* and *Oscillatoria nigroviridis*. Similarly. in the size range of < 250 – 150 µm, *Asterionella japonica* was the dominant species, the others were *Nitzschia longissima. Nitzschia delicatissima. Chaetoceros curvisetus. Thalassiothrix longissima. Fragilaria oceanica* and *Oscillatoria nigroviridis. Asterionella japonica* was the dominant species in the size group of < 150 – 105 µm, and the other planktonic algae were *Nitzschia longissima, Nitzschia delicatissima, Chaetoceros curvisetus. Chaetoceros lorenzianus. Pleurosigma directum. Thalassiothrix longissima* and *Oscillatoria nigroviridis*. The size group of < 105 – 53 µm was dominated by the diatom *Asterionella japonica*, the other diatoms were *Nitzschia longissima. Nitzschia delicatissima. Chaetoceros curvisetus. Thalassiosira coramandeliana. Rhizosolenia setigera, Rhizosolenia stolterfothii. Biddulphia mobiliensis. Skeletonema costatum, Thalassionema nitzschioides. Pleurosigma directum. Planktoniella sol, Thalassiothrix longissima. Eucampia zoodiacus, Fragilaria oceanica* and *Coscinodiscus radiatus*. The blue green algae were represented by *Oscillatoria nigroviridis*. The planktonic algae within the size range of < 53 – 25 µm were dominated by the species, *Thalassiosira subtilis. Thalassiosira coramandeliana* and *Asterionella japonica*, the diatoms *Thalassionema nitzschioides. Pleurosigma directum, Skeletonema costatum. Rhizosolenia stolterfothii, Rhizosolenia setigera,* *Hemiaulus sp*, *Fragilaria oceanica*, *Biddulphia mobiliensis*, *Nitzschia longissima*, *Nitzschia delicatissima*, *Eucampia zoodiacus*, *Thalassiothrix longissima*, *Thalassiothrix frauenfeldii*, *Chaetoceros curvisetus*, *Coscinodiscus radiatus* and *Leptocylindrus danicus*; the dinoflagellate *Dinophysis caudata*; the silicoflagellate *Dictyocha fibula* and the blue-green alga *Oscillatoria nigroviridis* were also recorded in this size group. In the size group of < 25 – 10 µm, the dominant forms were *Asterionella japonica*, *Skeletonema costatum*, *Thalassiosira coramandeliana* and *Nitzschia delicatissima*; the other species being *Nitzschia longissima*, *Guinardia flaccida*, *Pleurosigma directum*, *Rhizosolenia stolterfothii*, *Rhizosolenia setigera*, *Thalassiothrix longissima*, *Thalassiothrix frauenfeldii*, *Hemiaulus sp*, *Thalassionema nitzschioides*, *Fragilaria oceanica*, *Navicula hennedyii* and *Coscinodiscus radiatus*. The smallest planktonic algae of the size group of < 10 µm included dominant species such as *Nitzschia longissima*, *Skeletonema costatum* and *Navicula hennedyii*. *Thalassiosira coramandeliana*, *Rhizosolenia setigera* and *Fragilaria oceanica* were also found in this size group.

During the post-monsoon season, the following planktonic algae have been recorded:

<u>DIATOMS</u>: 20 genera and 28 species

Thalassiothrix longissima, *Thalassiothrix frauenfeldii*, *Chaetoceros curvisetus*, *Chaetoceros affinis*, *Chaetoceros lorenzianus*, *Chaetoceros diversus*, *Chaetoceros atlanticus*, *Bacteriastrum varians*, *Asterionella japonica*, *Thalassiosira coramandeliana*, *Skeletonema costatum*, *Fragilaria oceanica*, *Thalassionema nitzschioides*, *Nitzschia delicatissima*, *Nitzschia longissima*, *Rhizosolenia stolterfothii*, *Rhizosolenia alata*, *Pleurosigma directum*, *Biddulphia mobiliensis*, *Streptotheca thamensis*, *Eucampia zoodiacus*, *Coscinodiscus radiatus*, *Coscinodiscus spp*, *Leptocylindrus danicus*, *Corethron inerme*, *Navicula hennedyii*, *Ditylum sol* and *Guinardia flaccida*.

DINOFLAGELLATES: 5 genera and 6 species

Ceratium furca, Ceratium fusus, Peridinium tuba, Dinophysis caudata, Gonyaulax sp and *Pyrocystis fusiformis.*

BLUE-GREENALGAE: 2 genera and 2 species

Oscillatoria nigroviridis and *Johannesbaptistia pellucida.*

The contribution of the diatoms, the dinoflagellates and the blue-green algae to the total number of species was 77.8 %, 16.6 % and 5.5 % respectively (table 3.2).

The only planktonic algae found in the size group of > 500 µm was the diatom *Thalassiothrix longissima.* The organisms in the size range of < 500 – 250 µm included the dominant diatoms *Nitzschia delicatissima, Thalassiothrix longissima* and *Asterionella japonica,* the other species being *Chaetoceros diversus* and *Chaetoceros lorenzianus.* The dinoflagellate *Pyrocystis fusiformis* was also found in this size range. *Chaetoceros curvisetus, Asterionella japonica* and *Skeletonema costatum* were the dominant species in the size fraction of < 250 – 150 µm; the other forms were *Chaetoceros lorenzianus, Chaetoceros affinis, Chaetoceros atlanticus, Ditylum sol, Bacteriastrum varians, Thalassiothrix longissima, Biddulphia mobiliensis* and *Nitzschia delicatissima.* In the size group of < 150 – 105 µm, *Chaetoceros curvisetus* and *Asterionella japonica* were the dominant species, the other species being *Chaetoceros lorenzianus, Bacteriastrum varians, Streptotheca thamensis, Chaetoceros diversus, Chaetoceros affinis, Nitzschia delicatissima, Thalassiothrix longissima, Rhizosolenia alata, Biddulphia mobiliensis, Guinardia flaccida, Leptocylindrus danicus, Skeletonema costatum* and *Oscillatoria nigroviridis.* In the size group of < 105 – 53 µm, the dominant species were *Chaetoceros curvisetus* and *Asterionella japonica.* The other diatoms present in comparatively low concentration being *Chaetoceros affinis, Chaetoceros lorenzianus, Chaetoceros diversus, Rhizosolenia stolterfothii, Nitzschia longissima, Nitzschia delicatissima,* *Skeletonema costatum. Thalassiothrix longissima. Ditylum sol, Thalassiosira coramandeliana. Eucampia zoodiacus. Biddulphia mobiliensis. Streptotheca thamensis. Bacteriastrum varians. Guinardia flaccida* and *Coscinodiscus radiatus* along with the dinoflagellates *Ceratium furca* and *Ceratium fusus* were recorded in this size range. Within the size group of < 53 – 25 µm, *Skeletonema costatum* was the dominant species. the other diatoms being *Asterionella japonica. Nitzschia delicatissima, Nitzschia longissima. Rhizosolenia stolterfothii. Thalassiosira coramandeliana. Thalassiothrix frauenfeldii. Navicula hennedyii. Thalassionema nitzschioides. Biddulphia mobiliensis. Pleurosigma directum. Coscinodiscus radiatus. Leptocylindrus danicus. Corethron inerme. Chaetoceros curvisetus* and *Guinardia flaccida.* The dinoflagellates present were *Peridinium tuba. Ceratium furca. Dinophysis caudata* and *Gonyaulax sp.* The size fraction of < 25 – 10 µm was dominated by *Skeletonema costatum.* the other planktonic algae were, the diatoms *Rhizosolenia stolterfothii. Leptocylindrus danicus, Pleurosigma directum. Thalassiosira coramandeliana. Thalassiothrix frauenfeldii. Nitzschia longissima. Nitzschia delicatissima. Thalassionema nitzschioides. Navicula hennedyii. Nitzschia longissima* and *Coscinodiscus radiatus.* The dinoflagellate *Dinophysis caudata* was also found here. The smallest microalgae of < 10 µm in size were *Skeletonema costaum. Nitzschia longissima* and *Navicula hennedyii* as the dominant species, along with species such as *Nitzschia spp. Fragilaria oceanica. Rhizosolenia stolterfothii. Thalassiosira coramandeliana* and *Johannesbaptistia pellucida.*

DISCUSSION:

The diatoms and the dinoflagellates are the dominant planktonic algae in the coastal waters of Cochin, south west coast of India, and exhibiting qualitative and quantitative fluctuations influenced by seasonal and spatial fluctuations of physico-chemical parameters.

During the pre-monsoon season, 33 species of diatoms were recorded at station 1, and 32 species at station 2, contributing 73.4 % and 76.2 % of the total number of species at both stations, respectively. Dinoflagellates have been found to be composed of 9 species (20 %) at station 1; and 7 species (16.6 %) at station 2. The blue-green algae were formed of 2 species, contributing 4.4 % and 4.8 % to the total number of species at both stations, respectively. One species of silicoflagellates has been found at each station during this season, contributing 2.2 % at station 1 and 2.4 % at station 2 respectively.

In the monsoon season, the species composition of planktonic algae was found to be slightly different with only 28 species of diatoms (82.4 %) at station 1; and 22 species (88 %) at station 2. A sharp decline in the number of species of dinoflagellates was noticed during this season with 3 species (8.8 %) at station 1; and only 1 species (4 %) at station 2. Two species (5.9 %) of the blue-green algae were reported at station 1; and only 1 species (4 %) at station 2. The silicoflagellates were represented by one species contributing 2.9 % at station 1; and 4 % of the total number of species at station 2.

During the post-monsoon season, there were 33 species of diatoms (78.6 %) at station 1; and 28 species (77.8 %) at station 2. The dinoflagellates included 7 species (16.6 %) at station 1; and 6 species (16.6 %) at station 2. Only one species of the blue-green algae (2.4 %) has been found at station 1, while at station 2, two species (5.6 %) have been seen. At station 1, only one species of the silicoflagellates (2.4 %) was observed, while at station 2, the silicoflagellates were absent during this season.

The maximum numbers of species of diatoms at station 1 and station 2 were found in the pre-monsoon season, 33 species and 32 species respectively comprising 73.4 % and 76.2 % of the total planktonic algae. This highest diversity was inversely correlated with the standing crop of planktonic algae. The minimum number of species of diatoms was observed during the monsoon season, 28 species at station 1; and 22 species at station 2, 82.4 % and

88.0 % of the total flora respectively (tables 3.1& 3.2). associated with the highest standing crop of microalgae.

- Table 3.1- Seasonal composition of planktonic algae at station 1.

Seasons ►	Pre-monsoon	Monsoon	Post-monsoon
No. of species of diatoms	33	28	33
%	73.4	82.4	78.6
No. of species of dinoflagellates	9	3	7
%	20	8.8	16.6
No. of species of blue-green algae	2	2	1
%	4.4	5.9	2.4
No. of species of silicoflagellates	1	1	1
%	2.2	2.9	2.4

- Table 3.2- Seasonal composition of planktonic algae at station 2.

Seasons ►	Pre-monsoon	Monsoon	Post-monsoon
No. of species of diatoms	32	22	28
%	76.2	88	77.8
No. of species of dinoflagellates	7	1	6
%	16.6	4	16.6
No. of species of blue-green algae	2	1	2
%	4.8	4	5.6
No. of species of silicoflagellates	1	1	-
%	2.4	4	-

In the coastal waters of Cochin, south-west coast of India, diatoms were found to be the dominant group of planktonic algae throughout the year. Their contribution to the total number of species was maximum during the monsoon season. This can be attributed to the higher concentration of nutrients in the coastal waters during the monsoon, which is more suitable for diatoms and favourable for their growth and reproduction over the other groups of planktonic algae. Krey (1973), describing phytoplankton geographical regions of the Indian Ocean, points out that the rich regions are dominated by diatoms and less rich areas have a great proportion of dinoflagellates. However, not all dinoflagellates have low nutrients requirements (Ryther, 1954). Land run-off, in addition to coastal up welling off the south-west coast of India during the south-west monsoon season, leads to a general richness of the planktonic algal standing crop at this time of the year.

Dinoflagellates have been found to be more abundant during the pre-monsoon season with 9 species at station 1; and 7 species at station 2. The lowest number of species of the dinoflagellates was recorded during the monsoon season with 3 species at station 1; and only 1 species at station 2 (tables 3.1&3.2). During the pre-monsoon season, the lowest concentration of nutrients was recorded in the south-west coast of India. Taylor (1973) found that, many of the dinoflagellates are apparently able to tolerate remarkably low inorganic nutrients level. This may be attributed to their greater efficiency in nutrients uptake, due to their small size and perhaps also related to their motility. The observations of Qasim (1973) that the photosynthetic rate of a species of *Ceratium* was depressed by an increase of nitrate in culture relative to diatoms, suggests that a difference in metabolism may also be involved in some tropical species.

There were no significant seasonal variations in the species composition of the blue-green algae and the silicoflagellates, with the presence of 2 species of the blue-greens and only 1 species of silicoflagellates, mostly at the same per centages throughout the year.

The maximum number of species of planktonic algae was recorded in the pre-monsoon season, with 45 species at station 1; and 42 species at station 2 (table 3.3), this may be due to stability of the coastal waters during this season which enhance equal chances for existence and growth of a large number of species. The minimum number of species has been found at both stations during the monsoon season, with 34 species at station 1; and 25 species at station 2 (table 3.3), this may be due to the unstable environmental conditions in the coastal waters during this time of the year. In such conditions, only a small number of species of planktonic algae, which can tolerate and survive the environmental stress can grow and reproduce with higher efficiency producing a large number of cells.

- Table 3.3-The total number of species of planktonic algae at various seasons.

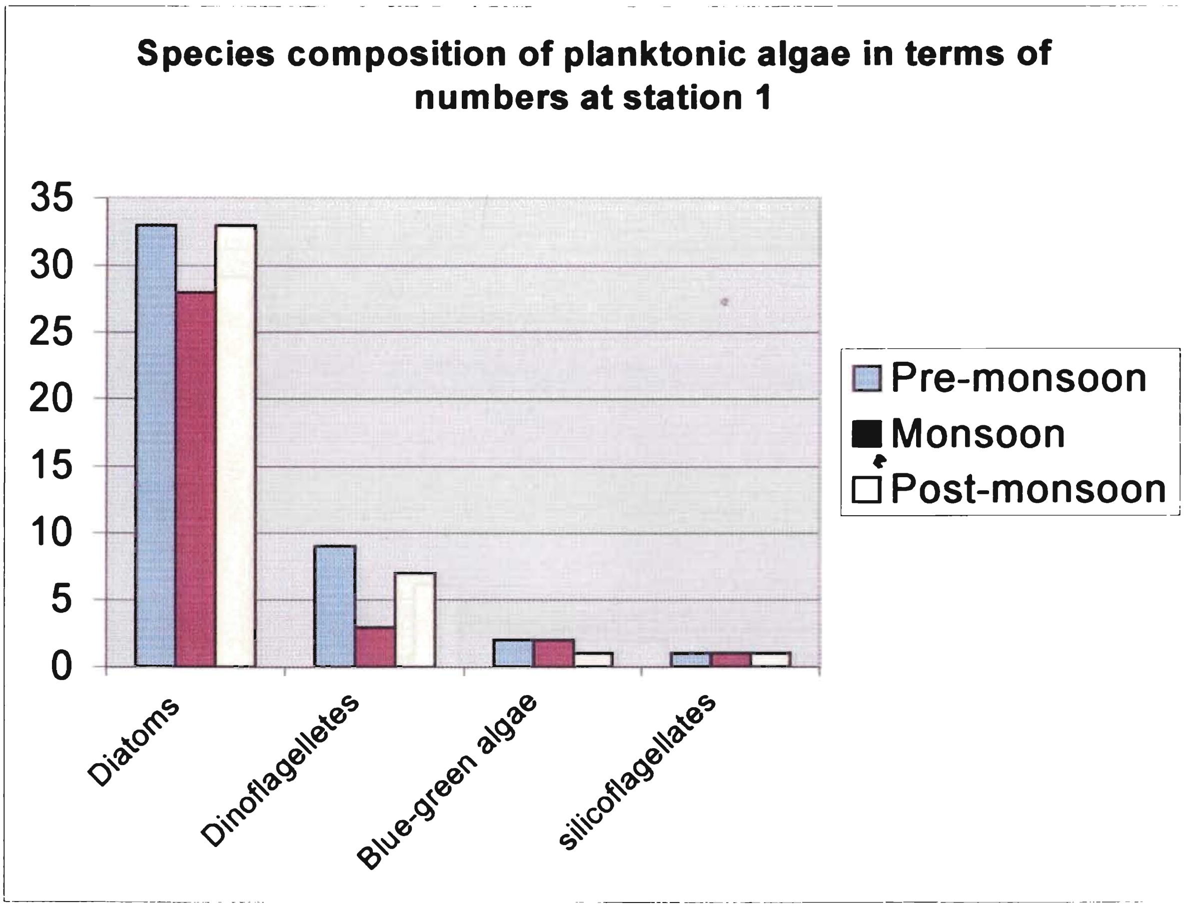
Seasons ▶	Pre-monsoon	Monsoon	Post-monsoon
Station 1	45	34	42
Station 2	42	25	36

In the coastal waters of Cochin, south-west coast of India, the highest species diversity was observed in the pre-monsoon season and the lowest species diversity is a common phenomenon during the monsoon season.

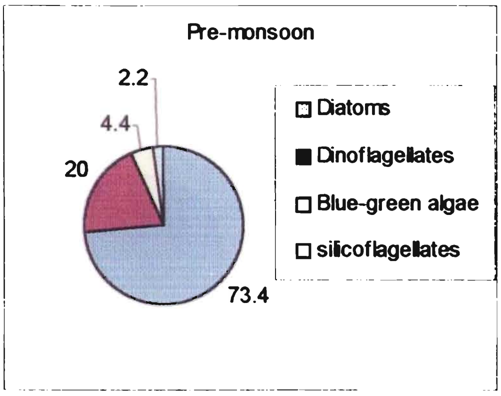
It is noteworthy to mention that, station 1 is having higher species diversity of planktonic algae during all the three seasons as compared with station 2. This is due to the closeness of station 2 to the Cochin backwaters and the mutual effect of both environments on each other producing environmental stress at station 2 resulting in lower species diversity at this station.

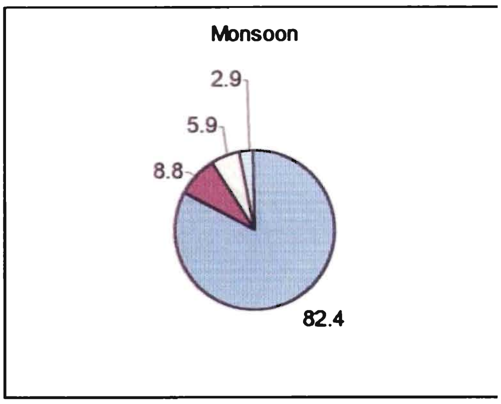
Generally, the size groups of planktonic algae greater than 53 µm are dominated by filamentous, chain forming and colonial diatoms, while the size groups smaller than 53 µm usually formed of small and unicellular pennate and centric diatoms, dinoflagellates and some other flagellates and blue-green algae. Furnas (1983) showed that in the Narragansett Bay, a significant number of small diatoms and dinoflagellates were found in the 10 – 8 µm size fraction.

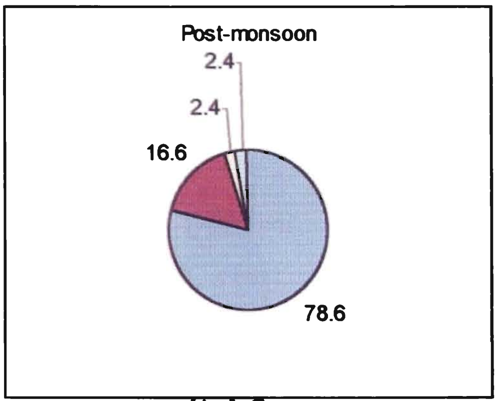
In the coastal waters of the south-west coast of India, during the pre-monsoon season, the chain forming diatom *Chaetoceros curvisetus* was found to be the dominant planktonic algae, whereas in the monsoon season, the colonial diatom *Asterionella japonica* was the dominant species.

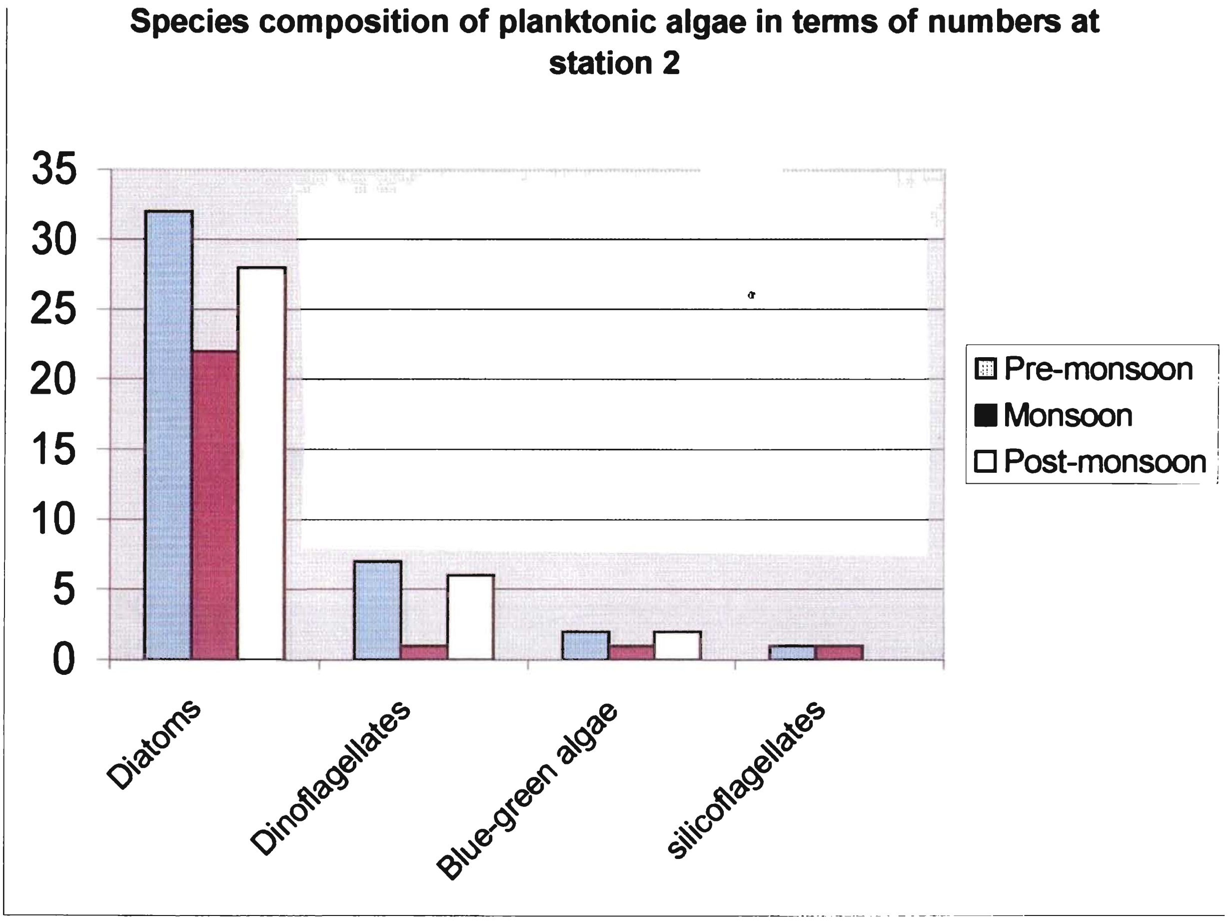


- Species composition of planktonic algae in terms of percentage at station 1.

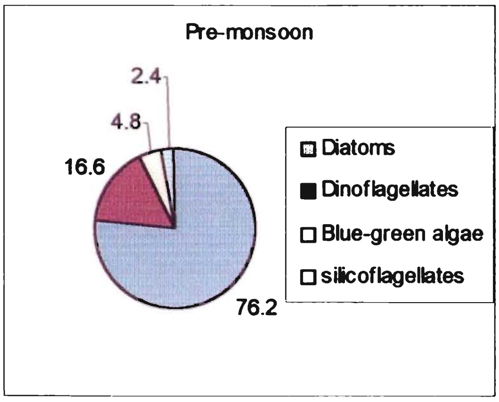


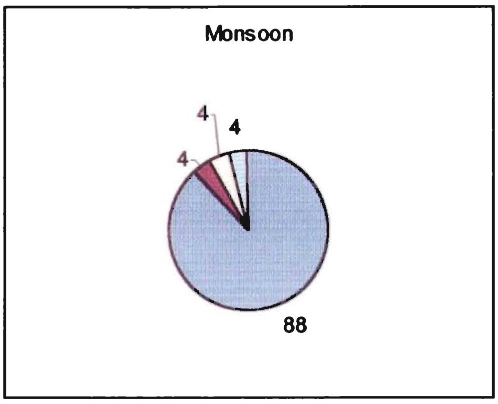


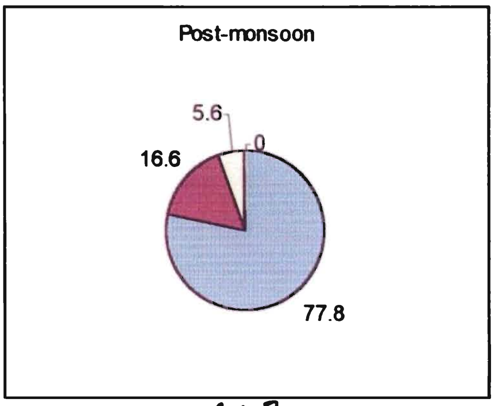


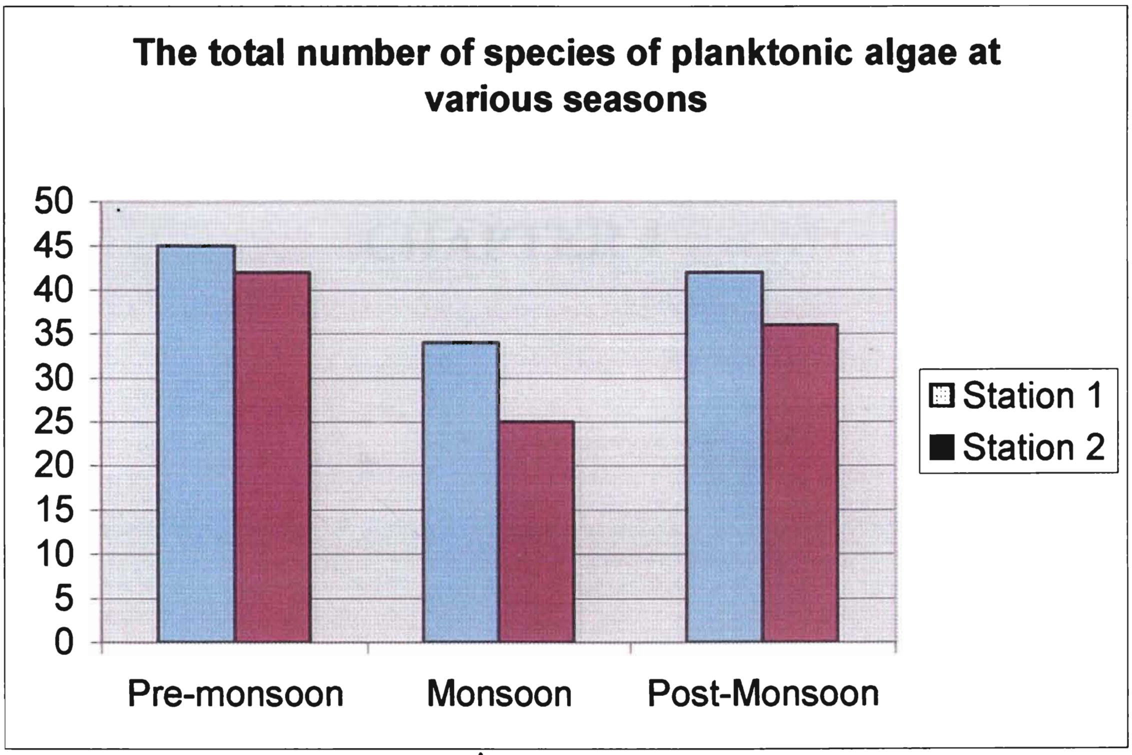


- Species composition of planktonic algae in terms of percentages at station 2








The total number of species of planktonic algae at various seasons
50
45
40
35
30
25
20
15
10
5
0
Pre-monsoon
Monsoon
Post-Monsoon
Station 1
Station 2

41 c

CHAPTER 4

ABUNDANCE, SPECIES DIVERSITY AND SPECIES DOMINANCE

-INTRODUCTION:

Comprehension of quantitative distribution of planktonic algae is of utmost importance for studying their ecology, community structure, species diversity and species dominance and is useful for the assessment of potential productivity. The study of community structure, species diversity and species dominance of planktonic algae is very significant for interpreting the fluctuations in fisheries. An understanding of the phenomenon of the selective grazing of certain fishes and shellfishes especially their larval stages which feed exclusively on certain species of microalgae, would be useful for the prediction of the occurrence of specific type of fishes or a particular fishery.

Wide fluctuations exist among the planktonic algal densities of various regions. Generally, oceanic regions in temperate and moderately high latitudes have high densities whereas low latitudes especially the central areas of oceanic gyres, are marked by low densities. At any latitude, the planktonic algae near the coast are normally richer than that of the off shore and oceanic areas. The generally much greater density of planktonic algae at high latitudes was demonstrated by early data from Hart (1934) which show a remarkable fall in crop, as cell counts, on proceeding to lower latitudes. Motoda, Taniguchi and Ikeda (1974) reported crops of about 10^4 to 10^6 cells / l in sub-Arctic waters of the western north Pacific. A different flora occupies a transition zone with 10^3 to 10^4 cells / l between the Oyashio and Kuroshio currents. To the south from the Kuroshio to the equator the planktonic algae is comparatively uniform and less rich, viz. 10^2 to 10^3 cells / l (Raymont, 1980). Whereas in lower latitudes the crop over the year shows relatively small variations, at high latitudes there are very marked seasonal fluctuations with high crops during the productive period of the year, particularly in the spring, contrasting sharply with the low crops during winter.

Krey (1973), describing phytoplankton geographical regions of the Indian Ocean, points out that the rich regions (Antarctic, sub-Antarctic, west wind drift and major upwelling areas) are dominated by diatoms and may have concentrations of 10^4 to 10^5 cells / l; less rich areas (Arabian Sea, equatorial current areas) have a great proportion of dinoflagellates, often with coccolithophorids with concentrations of ca. 10^4 cells / l; the poorest areas include the south sub-tropical gyre and central part of the Bay of Bengal, with mostly dinoflagellates and coccolithophorids amounting to $< 5 \times 10^3$ cells / l. In the Laccadive Sea off Cochin, the composition of phytoplankton changed considerably with time and depth, the total count being between 1.2×10^5 and 2.9×10^5 cells / l (Shah, 1969).

Little work has been done on the contribution of various size fractions of planktonic algae in terms of their standing crop, chlorophyll and production. This is due to the difficulty in identification and enumeration of the smaller size groups. Booth et al (1989) found that, in the Hauraki gulf, New Zealand, the picoplankton were composed of chroococcoid cyanobacterial cells, 0.7 – 1.2 μm in diameter, at densities between 10^3 and 10^4 / ml together with larger (1 – 2 μm) eukaryotic cells at densities up to 10^3 / ml. Using flow cytometry and epifluorescence microscopy Detmer et al (1997) showed that, during spring in the Atlantic sector of the southern ocean, the abundance of autotrophic pico- and nanoplankton ranged from < 1.0 to > 20.0×10^6 cells / l in the upper 100 m. However, no concrete study has been done on the distribution and abundance of various size fractions of planktonic algae in the Indian Seas.

The present chapter is concentrated on the abundance, species diversity and species dominance within the different size fractions of planktonic algae in the coastal waters of Cochin, south-west coast of India.

-RESULTS:-

- ABUNDANCE OF PLANKTONIC ALGAE:

The quantity and quality of various size fractions of planktonic algae at any locality depend mainly on the hydrographic conditions in the area under study.

In the coastal waters of Cochin, south west coast of India, at station 1, during the pre-monsoon season, the density of the largest size group of > 500 µm, has been found to be 1.3×10^3 / l, *Thalassiothrix longissima* was contributing 77 %. The size group of < 500 – 250 µm was 2.3×10^3 / l, *Thalassiothrix longissima* being the dominant, contributing about 65.2 % of this size group. The size group of < 250 – 150 µm has been found to be 4.2×10^3 / l, the major contribution was that of the diatoms *Thalassiothrix longissima*, 28.6 % and *Chaetoceros curvisetus*, 20.7 %. In the size group of < 150 – 105 µm, the total count was 1.1×10^4 / l, the major contributors were *Chaetoceros curvisetus*, 33.6 %; *Asterionella japonica*, 20.9 % and *Thalassiothrix longissima*, 11.8 %. The density of the planktonic algae of the size group of < 105 – 53 µm was 2.6×10^4 / l, 42.3 % of which was contributed by *Chaetoceros curvisetus*. The total count of the size group of < 53 – 25 µm was found to be 1.4×10^4 / l, the major contributors were *Thalassiosira coramandeliana*, 20.7 % and *Rhizosolenia setigera*, 10.0 % of the total number of this size group. The microalgae within the size range of < 25 – 10 µm counted 1.8×10^4 / l, *Skeletonema costatum*, *Thalassiosira subtilis*, *Rhizosolenia setigera* and *Thalassiosira coramandeliana* were contributing 22.2 %, 12.8 %, 12.8 % and 12.2 % to the total number of this size group respectively. The smallest size group of < 10 μm was counted 6.1 x 10^3 / l, *Fragilaria oceanica*, *Thalassiosira coramandeliana* and *Navicula hennedyii* were the major contributors, contributing 41.0 %, 16.4 % and 21.3 % respectively (table 4.1).

During the monsoon season, the concentration of the largest size group of > 500 μm has been found to be 1.6 x 10^3 / l, 75.0 % of which was contributed by *Asterionella japonica*. The size group of < 500 – 250 μm was counted 2.8 x 10^3 / l, here also the major contribution was attributed to *Asterionella japonica* which contributed 96.0 %. The number of planktonic algae within the size range Of < 250 – 150 μm was found to be 1.4 x 10^4 / l, of which 71.4 % was contributed by *Asterionella japonica* alone. The density of microalgae within the size group of < 150 – 105 μm was 5.7 x 10^4 / l, here also the highest number was that of *Asterionella japonica*, 84.2 %. The size fraction of < 105 – 53 μm was having the highest count among all size groups, with density of 1.9 x 10^5 / l, of which 78.9 % was contributed by *Asterionella japonica*. The microflora of the size group of < 53 – 25 μm were counted 6.4 x 10^4 / l, here the contribution of *Asterionella japonica* falls to only 25.0 % of the total count of this size group. The planktonic algae within the size fraction of < 25 – 10 μm were counted 9.4 x 10^4 / l, the major contribution was that of the pennate diatom *Nitzschia longissima* which contributes 62.8 %. The smallest size fraction of < 10 μm has been found to count 2.8 x 10^4 / l, the major contributors in this size group were *Nitzschia spp*. *Navicula spp* and *Thalassiosira spp*, with average contributions of 42.9 %, 26.1 % and 16.8 % respectively (table 4.2).

In the post-monsoon season, the number of planktonic algae of the largest size group of > 500 μm has been found to be 1.3 x 10^3 / l, *Thalassiothrix longissima* was contributing 38.5 %. The size group of < 500 – 250 μm was 1.5 x 10^3 / l, 30.7 % of which was *Thalassiothrix longissima*. The density of planktonic algae of the size group of < 250 – 150 μm was 6.6 x 10^3 / l, the major contribution was that of *Chaetoceros curvisetus*, 30.3 %; *Chaetoceros lorenzianus*, 15.2 % and *Asterionella japonica*, 15.2 %. The planktonic algae within the size fraction of < 150 – 105 µm have been found to count 1.7 x 10^4 / l, *Chaetoceros curvisetus* was contributing 31.2 %, *Asterionella japonica* 16.5 % and *Chaetoceros lorenzianus* 13.5 %. The count of the size group of < 105 – 53 µm was 1.9 x 10^4 / l, the major contribution was that of *Chaetoceros curvisetus*, 30.5 %; *Nitzschia delicatissima*, 8.4 %; *Thalassiosira subtilis*, 7.9 % and *Skeletonema costatum*, 7.4 %. The microalgae of the size group of < 53 – 25 µm contributed 2.0 x 10^4 / l, to the total count of planktonic microalgae, the major contributors were *Skeletonema costatum*, 21.0 %; *Rhizosolenia stolterfothii*, 10.0 %; *Asterionella japonica*, 9.0 % and *Nitzschia longissima*, 8.0 %. The size group of < 25 – 10 µm has been found to include 2.9 x 10^4 / l, the dominant species was *Skeletonema costatum*, 44.8 %. The smallest size group of < 10 µm was recorded 9.6 x 10^3 / l, the major flora being *Nitzschia spp*, 50.0 % and *Navicula spp*, 12.5 % (table 4.3).

At station 2, during the pre-monsoon season, the concentration of the largest size group of > 500 µm was 1.1 x 10^3 / l, *Thalassiothrix longissima* was contributing 65.5 % of the total flora in this size group. The size group of < 500 – 250 µm was having 1.7 x 10^3 / l, the major contribution was that of *Thalassiothrix longissima*, recording 76.5 % of the standing stock. The number of planktonic algae within the size fraction of < 250 – 150 µm was 3.5 x 10^3 / l, *Chaetoceros curvisetus* and *Thalassiothrix longissima* were contributing 31.4 % each. The density of planktonic algae in the size fraction of < 150 – 105 µm was found to be 6.3 x 10^3 / l, the major flora were *Chaetoceros curvisetus* and *Thalassiothrix longissima*, recording 23.8 % and 15.9 % respectively. The number of planktonic algae of the size group of < 105 – 53 µm was 1.8 x 10^4 / l, *Chaetoceros curvisetus* was contributing 55.6 % of the standing stock. The size group of < 53 – 25 µm was 1.4 x 10^4 / l, the major flora being *Thalassiosira subtilis*, 12.9 %; *Thalassiosira coramandeliana*, 9.3 %; *Rhizosolenia setigera*, 10.7 % and *Asterionella japonica* and *Schroderella delicatula*, 7.1 % each. The density of planktonic algae of the size group of < 25 – 10 µm was 2.2 x 10^4 / l, the major contributors were *Nitzschia delicatissima*, 20.9 %; *Skeletonema costatum*, 19.5 % and *Thalassiosira coramandeliana*, 11.4 %. The count of the smallest size group of < 10 µm was found to be 4.9 x 10^3 / l. the dominant species was *Thalassiosira coramandeliana*, with 49.0 % of the total planktonic algae of this size group (table 4.4).

In the monsoon season, at station 2, *Asterionella japonica* was the only species in the size group of > 500 µm, its number was 2.5 x 10^2 / l. The size group of < 500 – 250 µm was 2.6 x 10^3 / l, *Asterionella japonica* was contributing 57.7 %. The count of planktonic algae within the size range of < 250 – 150 µm was found to be 8.9 x 10^3 / l, of which 73.0 % was contributed by *Asterionella japonica*. Within the size group of < 150 – 105 µm, the concentration of planktonic algae was 1.8 x 10^4 / l. *Asterionella japonica* alone contributed 77.8 % of the total standing stock. The size group of < 105 – 53 µm was having 5.6 x 10^4 / l, here also the major contribution was that of *Asterionella japonica*, 76.8 %. The density of microalgae within the size fraction of < 53 – 25 µm has been found to be 4.4 x 10^4 / l, the main contributors in this size group were *Thalassiosira subtilis*, 29.5 %; *Thalassiosira coramandeliana*, 16.6 % and *Asterionella japonica*, 13.0 %. The size group of < 25 – 10 µm was found to include 3.5 x 10^4 / l, the major contribution was that of *Asterionella japonica*, 16.6 %; *Skeletonema costatum*, 14.3 %; *Thalassiosira coramandeliana*, 10.3 %; *Nitzschia delicatissima*, 9.7 % and *Nitzschia longissima*, 8.9 %. The smallest size group of < 10 µm was 9.8 x 10^3 / l, the dominant flora included *Nitzschia spp*, *Skeletonema costatum* and *Navicula spp* with 45.9 %, 19.4 % and 15.3 % respectively (table 4.5).

In the post monsoon season, the size group of > 500 µm was represented by the single species *Thalassiothrix longissima* with a concentration of 5.0 x 10^2 / l. The concentration of the size group of < 500 – 250 µm was 2.4 x 10^3 / l, the diatom *Nitzschia delicatissima* contributed 31.3 %, *Thalassiothrix longissima* and *Asterionella japonica* represented 20.8 % each. The size fraction of < 250 – 150 μm recorded 1.1 x 10^4 / l, of which 30.9 % was the contribution of *Chaetoceros curvisetus*, while *Asterionella japonica* and *Skeletonema costatum* contributed 18.2 % each. The density of the planktonic algae of the size group of < 150 – 105 μm was 2.9 x 10^4 / l, the dominant species were those of *Chaetoceros curvisetus*, 34.5 % and *Asterionella japonica*, 33.8 %. The concentration of the size fraction of < 105 – 53 μm was found to be 3.1 x 10^4 / l, with the dominant species of *Chaetoceros curvisetus*, 38.7 % and *Asterionella japonica*, 15.5 %. The number of microalgae within the size group of < 53 – 25 μm was 2.3 x 10^4 / l, the single dominant species being *Skeletonema costatum*, with 37.0 % of the total count of this size fraction. The concentration of the microflora within the size range of < 25 – 10 μm was 5.7 x 10^4 / l. 70.2 % of the total count of this size group contributed by *Skeletonema costatum*. The number of planktonic algae of the smallest size group of < 10 μm was 1.6 x 10^4 / l, the dominant species being *Skeletonema costatum*, *Nitzschia spp* and *Navicula spp*. contributing 42.5 %, 26.9 % and 21.9 %, respectively (table 4.6).

At station 1, in the pre-monsoon season, the density of planktonic algae increases from 1.3 x 10^3 / l, (1.6 % at the largest size group of > 500 μm) to 2.6 x 10^4 / l, (31.3 % at the size group of < 105 – 53 μm), then decreases at the size groups of < 53 – 25 μm and < 25 – 10 μm to 1.4 x 10^4 / l, 16.9 % and 1.8 x 10^4 / l, 21.7 % respectively. The number of planktonic algae of the smallest size group of < 10 μm was 6.1 x 10^3 / l, which formed 7.4 % of the standing crop. The total number of planktonic algae during the pre-monsoon period was relatively small, 8.3 x 10^4 / l (Table 4.7).

During the monsoon season, the same trend was also observed, with gradual increase from 1.6 x 10^3 / l, (0.4 % at the largest size group of > 500 μm) to 1.9 x 10^5 / l, (42.1 % at the size group of < 105 – 53 μm), then decreases to 6.4 x 10^4 / l, 14.2 % and 9.4 x 10^4 / l, 20.8 % at the size groups of < 53 – 25 μm and < 25 – 10 μm respectively. The number of planktonic algae in the smallest size group of < 10 μm was only 2.8×10^4 / l, 6.2 % of the total planktonic algae. The total number of planktonic algae recorded was the highest during the monsoon season, with 4.5×10^5 / l (Table 4.7).

In the post-monsoon season, the number of planktonic algae was gradually increases from 1.3×10^3 / l, (1.3 % at the largest size fraction of > 500 μm) to 2.9×10^4 / l, (28.0 % at the size group of < 25 – 10 μm). The microalgae in the smallest size group of < 10 μm was 9.6×10^3 cells / l, which was 9.2 % of the total flora. The total number of planktonic algae during the post-monsoon season was higher than that of the pre-monsoon season, but lower than that of the monsoon period, with average number of 1.0×10^5 / l (Table 4.7).

At station 2, during the pre-monsoon season, the concentration of planktonic algae increases from 1.1×10^3 / l, (1.5 % in the largest size group of > 500 μm) to 1.8×10^4 / l, (25.2 % in the size group of < 105 – 53 μm), then decreases in the smaller size group of < 53 – 25 μm to 1.4×10^4 / l, (19.6 %), then increases again to 2.2×10^4 / l, (30.8 % at the size fraction of < 25 – 10 μm). The number of microalgae in the smallest size group of < 10 μm was 4.9×10^3 / l, 6.9 % of the total number. The total number of planktonic algae during this season was 7.2×10^4 / l, which was low compared to those of other seasons (Table 4.8).

In the monsoon season, the abundance of planktonic algae also increases from 2.5×10^2 / l, (0.1 % at the largest size group of > 500 μm) to 5.6×10^4 / l, (32.1 % at the size group of < 105 – 53 μm), and then gradually decreases to reach 3.5×10^4 / l, (20.1 % in the size group of < 25 – 10 μm). The microalgae within the size group of < 10 μm recorded only 9.8×10^3 / l, 5.6 %. The highest relative abundance of planktonic algae was recorded during this season, with total number of 1.7×10^5 / l (Table 4.8).

During the post-monsoon season, the number of planktonic algae increases gradually from 5.0×10^2 / l, (0.3 % at the largest size group of > 500 μm) to 3.1×10^4 / l, (18.2 % at < 105 – 53 μm size fraction), then decreases in the next size group of < 53 – 25 μm recording only 2.3×10^4 / l, 13.5 %, then increases again to reach 5.7×10^4 / l, (33.6 % in the size group of < 25 – 10 μm). The microalgae of the smallest size group of < 10 μm was only 1.6×10^4 cells / l, which was 9.4 % of the total planktonic algae. The total count has been found to be slightly less than that of the monsoon season, recording 1.6×10^5 / l (Table 4.8).

- SPECIES DOMINANCE AND SPECIES DIVERSITY:

All the species are not equally important in determining the nature and the function of the community. Thus out of tens of species inhabiting the biocoenose there may be a few species which form the greater part or which control the flow of energy in the system, due to their large number, large volume, increased fecundity etc. such species are named Dominants. These control the natural balance of the community and are usually present in large numbers throughout the whole year or during their active reproductive season. The dominance in the community can be determined by Simpson index of dominance, the maximum value is 1 and means complete dominance.

$$D = \sum (n_i / N)^2$$

where: n_i = the number of individuals of species i.
N = total number of individuals of all species.

It is important to note that while the energy flow in the community depends to a large extent on the dominant species, the species diversity depends on the total number of species particularly those of less importance or rare species. Species diversity decreases in systems controlled by strong physico-chemical limiting factors while the diversity of species increases in biologically controlled communities and is directly proportional to the stability of the system. The diversity of species in the community can be determined by Shannon index of general diversity H. The higher the value the greater the diversity.

$$H = -\sum(n_i / N)\ln(n_i / N)$$ where: n_i = the number of individuals of species $_i$. N = the total number of individuals of all species.

It is to be noted that species diversity comprises a number of components each of which would respond with different degrees to the variations in the structural, geographical or physical factors. One of these components is the species richness which is the ratio between the number of species and the total number of individuals (S / N) or $R = (S - 1) / \ln N$. The higher the value the higher the diversity. The other component is evenness or equitability "e " for example: two systems each may contain 10 species represented by 100 individuals, so (S / N) will be the same for both, but each may have different evenness index depending on the mode of distribution of the 100 individuals. Each species may have 10 individuals or 1 species may be represented by 91 individuals and the others, each with 1 organism. The "e" index may be a measure of this component.

$$e = H / \ln S$$ where: H = Shannon index. S = number of species.

At station 1, during the pre-monsoon season, the minimum species diversity was found in the largest size group of > 500 µm which was having the values of 0.500 and 0.140 as Shannon index and richness index, respectively. In this size group the maximum dominance was observed, with the maximum value of Simpson index, 0.680. The evenness index value in this size fraction was found to be 0.722. The highest species diversity has been observed in the size group of < 53 – 25 µm which was having the highest values of Shannon index, 2.978 and richness index 2.932. The evenness index value was relatively high, 0.884. The minimum species dominance was recorded in this size group. with 0.077 Simpson index value (Table 4.9).

In the monsoon season, the lowest species diversity was recorded in the size group of < 500 – 250 µm which was having the values 0.186, 0.126 and 0.269 for Shannon index, species richness and evenness index, respectively. This size fraction was also having the maximum value of Simpson index, 0.912. The highest values of Shannon index, 2.787 and evenness index, 0.947 were recorded in the size group of < 25 – 10 µm, while the highest richness index value. 1.988 was noticed in the size group of < 53 – 25 µm, in which the minimum value of Simpson index of dominance. 0.145 was recorded (Table 4.10).

During the post-monsoon season, the lowest diversity was recorded in the largest size group of > 500 µm in which the lowest values of Shannon index, 1.332 and richness index, 0.421were found. The evenness index value, 0.961 was relatively high in this size group and its Simpson index value, 0.280 was also high. The highest species diversity was observed in the size group of < 53 – 25 µm, as indicated by the highest value, 2.778 of Shannon index. The lowest species dominance was also reported in this size group, with the lowest value of Simpson index, 0.090. Richness index value, 2.530 and evenness index value, 0.853 were also high in this size fraction (Table 4.11).

At station 2, during the pre-monsoon season, the lowest diversity was seen in the size group of < 500 – 250 µm in which the minimum values of Shannon index, 0.691; richness index, 0.269 and evenness index, 0.629 were recorded. Simpson index of species dominance shows its maximum value, 0.620 in this size fraction. The highest species diversity has been found in the size group of < 53 – 25 µm where maximum values of Shannon index. 2.942; richness index, 2.734 and evenness index, 0.893 were recorded. The lowest species dominance was also found in this size group, with the lowest Simpson index value of 0.068 (Table 4.12).

In the monsoon season, nil values of diversity indices i.e. zero values were found for the largest size group of > 500 µm composing of only single species, indicating no diversity at all. On the other hand, the dominance was complete with the highest value of Simpson index, 1. The highest values of Shannon and evenness indices were found in the size group of < 25 – 10 µm, while the highest value of richness index was recorded for the size fraction of < 53 – 25 µm. The lowest species dominance was seen for the size group of < 25 – 10 µm, with the lowest dominance index of 0.096 (Table 4.13).

During the post-monsoon season, the largest size group of > 500 µm was having only one species, so the absence of species diversity and the complete dominance were recorded in this size group. The highest species diversity was observed in the size fraction of < 53 – 25 µm, as it was indicated from the highest values of Shannon index, 2.559 and richness index, 2.289; the evenness index value was also high, 0.805. The minimum species dominance was found in this size group with Simpson index value of 0.157 (Table 4.14).

- DISCUSSION:

The abundance, species diversity and species dominance of planktonic algae as a whole or at any size group depend mainly upon the hydrographic parameters of the locality under study, which in turn varies spatially and seasonally.

In the coastal waters of Cochin, south-west coast of India, at station 1, during the pre-monsoon season, in which high temperature, high light intensity, high salinity and low nutrient salts concentration prevail, the pennate diatom *Thalassiothrix longissima* was the dominant species of planktonic algae > 150 µm, while the centric diatom *Chaetoceros curvisetus* was the dominant species in the size fraction of < 150 – 53 µm. The microalgae < 53 µm were dominated by *Thalassiosira subtilis*, *Thalassiosira coramandeliana*, *Rhizosolenia setigera*, *Skeletonema costatum*, *Fragilaria oceanica* and *Navicula hennedyii*. So, these species have greater ability to survive and grow during the pre-monsoon season.

In the monsoon season, at low temperature, low light intensity, high salinity (due to the up welling) and high concentration of nutrients, the pennate diatom *Asterionella japonica* was the dominant species of planktonic algae > 25 µm in size. The dominant species of microalgae < 25 µm were *Nitzschia longissima*, *Nitzschia spp*, *Navicula hennedyii* and *Thalassiosira spp*.

During the post-monsoon season, when the coastal waters is having high temperature, high light intensity, relatively low salinity and low concentration of nutrients, *Thalassiothrix longissima* was found to be the dominant species among the planktonic algae > 250 µm; the centric diatom *Chaetoceros curvisetus* was the most important species of planktonic algae within the size range of < 250 – 53 µm. The microflora < 53 µm were dominated by *Skeletonema costatum* and *Nitzschia spp*.

At station 2, in the pre-monsoon period, which is characterized with high temperature, high light intensity, high salinity and low concentration of nutrients, *Thalassiothrix longissima* was the most abundant species among the planktonic algae > 250 µm. In the size fraction of < 250 – 150 µm, *Chaetoceros curvisetus* and *Thalassiothrix longissima* were abundant. *Chaetoceros curvisetus* was the most abundant species of planktonic algae within the size fraction of < 150 – 53 µm. The planktonic algae < 53 µm were dominated by *Thalassiosira subtilis*, *Thalassiosira coramandeliana*, *Nitzschia delicatissima* and *Skeletonema costatum*.

During the monsoon season, with its characteristic features of low temperature, low light intensity, high salinity and high concentration of nutrients, *Asterionella japonica* was the most abundant species of planktonic algae > 53 µm.

The planktonic algae < 53 µm were dominated by the species *Thalassiosira subtilis*. *Asterionella japonica*. *Nitzschia spp*. *Navicula hennedyii* and *Skeletonema costatum*.

In the post-monsoon season, when the coastal waters is having high temperature, high light intensity, low salinity and relatively low concentration of nutrients, the most abundant species of planktonic algae > 250 µm was *Thalassiothrix longissima*. The planktonic algae within the size fraction of < 250 – 53 µm were dominated by *Chaetoceros curvisetus*. *Skeletonema costatum*. *Nitzschia spp* and *Navicula hennedyii* were the most abundant species among the planktonic algae < 53 µm in size.

Generally, in the coastal waters of Cochin, south-west coast of India, during the pre-monsoon season, species which favour high temperature, high light intensity, high salinity and can survive the low concentration of nutrients grow and reproduce with higher efficiency than the other forms and dominate the community. In the monsoon season, the coastal water is characterized by low temperature, low light intensity, high salinity and high concentration of nutrients, so the species which require such conditions proliferate and dominate the other planktonic algae. The post-monsoon period with its intermediate hydrographic conditions, support microflora which are able to grow well and outnumber the other species of planktonic algae.

At station 1, in the pre-monsoon season, the number of planktonic algae increases from 1.3×10^3 / l at the largest size group of > 500 µm to 2.6×10^4 / l at the size group of < 105 – 53 µm, then decreases at the size groups of < 53 – 25 µm and < 25 – 10 µm to 1.4×10^4 / l and 1.8×10^4 / l, respectively. The low density of planktonic algae at the size groups of < 53 – 25 µm and < 25 – 10 µm might have been due to the selective grazing by zooplankton. The total number of planktonic algae during the pre-monsoon season was relatively small, 8.3×10^4 / l, which can be attributed to the low concentration of nutrients in the coastal waters.

During the monsoon season, gradual increase in the number of planktonic algae was observed, from 1.6×10^3 / l at the largest size group of > 500 µm to 1.9×10^5 / l at the size group of < 105 – 53 µm, then decreases to 6.4×10^4 / l and 9.4×10^4 / l at the size groups of < 53 – 25 µm and < 25 – 10 µm, respectively. Here also the effect of grazing could be seen in the latter two size groups. The total count of planktonic algae was found to be the highest during the monsoon period, 4.5×10^5 / l. The high concentration of planktonic algae was due to the availability of high concentrations of nutrients in the coastal waters which enhance the growth and reproduction of planktonic algae during the monsoon months.

In the post-monsoon season, the density of planktonic algae was gradually increases from 1.3×10^3 / l at the largest size group of > 500 µm to 2.9×10^4 / l at the size group of < 25 – 10 µm, indicating the decreased grazing intensity during this season of the year especially on the size group of < 53 – 25 µm, or the shifted grazing intensity to the size fraction of microalgae < 25 µm in size. The total number of planktonic algae during the post-monsoon season, 1.0×10^5 / l, was higher than that of the pre-monsoon season, but lower than that of the monsoon period, indicating the significant role of nutrients, especially phosphate in determining and limiting growth and productivity of planktonic algae in the coastal waters of the south-west coast of India.

At station 2, during the pre-monsoon season, the density of planktonic algae increases from 1.1×10^3 / l at the largest size group of > 500 µm to 1.8×10^4 / l in the size fraction of < 105 – 53 µm, then decreases in the size group of < 53 – 25 µm to 1.4×10^4 / l, then increases again to 2.2×10^4 / l at the size group of < 25 – 10 µm. The low number within the size fraction of < 53 – 25 µm may be attributed to the selective grazing of zooplankton. The total number of planktonic algae during this season was relatively low, 7.2×10^4 / l, due to the low concentration of nutrients accompanied with intensive grazing effect by zooplankton.

In the monsoon season, the count of planktonic algae also increases from 2.5×10^2 / l for the largest size group of > 500 µm to 5.6×10^4 / l at the size group of < 105 – 53 µm, and then gradually decreases to reach 3.5×10^4 / l in the size group of < 25 – 10 µm. The low density of microalgae in the size groups of < 53 – 25 µm and < 25 – 10 µm may be duo to the selective grazing by zooplankton. The total count of planktonic algae was the highest during the monsoon period, 1.7×10^5 / l; this can be attributed to the high concentration of nutrients in the coastal waters of the south-west coast of India during the monsoon months.

During the post-monsoon period, the concentration of planktonic algae increases gradually from 5.0×10^2 / l for the largest size group of > 500 µm to 3.1×10^4 / l for the size fraction of < 105 – 53 µm, then decreases for the size group of < 53 – 25 µm to 2.3×10^4 / l, then increases to 5.7×10^4 / l for the size group of < 25 – 10 µm. The low concentration of microalgae within the size range of < 53 – 25 µm can be attributed also to the selective grazing of zooplankton. The total number of planktonic algae was relatively high, 1.6×10^5 / l; this may be occurred due to the decreased grazing intensity during the post-monsoon season at station 2.

At both stations, on average, the abundance of planktonic algae < 53 µm in size, tends to be higher than that of planktonic algae > 53 µm during the pre and the post-monsoon seasons, while the density of planktonic algae > 53 µm becomes significant during the monsoon season, this may be related to the concentration of nutrients. During the pre and the post-monsoon seasons the concentration of nutrients in the coastal waters is normally low, and in such conditions, the smaller planktonic algae with their higher efficiency of nutrients utilization grow and reproduce well and outnumber the larger planktonic algae; while during the monsoon season, when the concentration of nutrients is high, the chance is more favorable for the larger planktonic algae to grow and reproduce with higher efficiency and outnumber the smaller size fractions.

It is very important to note that, while the smallest size group of < 10 µm contribute significantly to the primary production and biomass (in terms of chlorophyll), the observed standing crop of microalgae < 10 µm in size (in term of numbers) can be far from approximation as many of them are too small to be identified and enumerated. The underestimation in the standing crop of this size group would render the evaluation of the total standing crop (in terms of numbers) apparent rather than real.

At station 1, during the pre and post-monsoon seasons, the lowest species diversity was found in the largest size group of > 500 µm, while the highest species diversity and the lowest species dominance have been reported in the size group of < 53 – 25 µm. So, during the pre and the post-monsoon seasons the planktonic algae within the size fraction of < 53 – 25 µm become the most important among all other size groups in providing food for a large number of species of consumers in the coastal waters of the south-west coast of India.

In the monsoon season, the lowest species diversity was observed in the size group of < 500 – 250 µm, in which the highest species dominance was recorded. High diversity was seen in the size groups of < 53 – 25 µm and < 25 – 10 µm, so they might be a significant source of food for a large number of species of marine organisms.

Station 2, showed the same trend, with the highest species diversity in the size fraction of < 53 – 25 µm during the pre and the post-monsoon seasons, and within the size groups of < 53 – 25 µm and < 25 – 10 µm in the monsoon season. So, the size groups of < 53 – 25 µm, during the pre and the post-monsoon seasons, and with the size fraction of < 25 – 10 µm during the monsoon season, serve as a very important source of food for a large number of marine organisms inhabiting the coastal waters of the south-west coast of India.

-Table 4.1- Average concentration of planktonic algae of various size groups during the pre-monsoon season at station 1.

Size groups	Species	No. / l	Total
> 500 µm	*Chaetoceros curvisetus*	2.5 x 10^2	
	Thalassiothrix longissima	1.0 x 10^3	1.3 x 10^3
<500 – 250 µm	*Chaetoceros curvisetus*	3.8 x 10^2	
	Thalassiothrix longissima	1.5 x 10^3	
	Asterionella japonica	2.5 x 10^2	
	Chaetoceros affinis	1.3 x 10^2	2.3 x 10^3
<250 – 150 µm	*Chaetoceros curvisetus*	8.7 x 10^2	
	Asterionella japonica	5.7 x 10^2	
	Chaetoceros brevis	6.9 x 10^2	
	Thalassiothrix longissima	1.2 x 10^3	
	Chaetoceros lorenzianus	3.8 x 10^2	
	Rhizosolenia setigera	1.3 x 10^2	
	Chaetoceros affinis	3.8 x 10^2	4.2 x 10^3
<150 – 105 µm	*Chaetoceros curvisetus*	3.7 x 10^3	
	Chaetoceros laevis	2.5 x 10^2	
	Asterionella japonica	2.3 x 10^3	
	Nitzschia delicatissima	2.5 x 10^2	
	Nitzschia longissima	2.5 x 10^2	
	Chaetoceros affinis	4.4 x 10^2	
	Schroderella delicatula	3.8 x 10^2	
	Chaetoceros brevis	8.8 x 10^2	
	Bacteriastrum varians	1.3 x 10^2	
	Guinardia flaccida	1.3 x 10^2	
	Thalassiothrix longissima	1.3 x 10^3	
	Thalassiothrix frauenfeldii	1.3 x 10^2	
	Ditylum sol	1.3 x 10^2	
	Streptotheca thamensis	2.5 x 10^2	
	Rhizosolenia setigera	1.3 x 10^2	
	Rhizosolenia stolterfothii	1.3 x 10^2	
	Thalassiosira coramandeliana	2.5 x 10^2	
	Biddulphia mobiliensis	5.0 x 10^2	
	Pleurosigma directum	2.5 x 10^2	1.1 x 10^4
<105 – 53 µm	*Chaetoceros curvisetus*	1.1 x 10^4	
	Bacteriastrum varians	1.0 x 10^3	

	Hemiaulus sp	1.3×10^2	
	Asterionella japonica	2.6×10^3	
	Schroderella delicatula	5.0×10^2	
	Chaetoceros laevis	1.3×10^2	
	Biddulphia mobiliensis	1.5×10^3	
	Nitzschia longissima	1.3×10^2	
	Corethron inerme	1.3×10^2	
	Pleurosigma directum	2.5×10^2	
	Nitzschia delicatissima	2.5×10^2	
	Planktoniella sol	3.8×10^2	
	Dinophysis caudata	1.7×10^2	
	Ditylum sol	2.5×10^2	
	Thalassiosira coramandeliana	3.8×10^3	
	Streptotheca thamensis	1.3×10^2	
	Thalassiothrix frauenfeldii	1.3×10^2	
	Chaetoceros brevis	5.1×10^2	
	Rhizosolenia setigera	7.1×10^2	
	Thalassiothrix longissima	5.7×10^2	
	Peridinium depressum	1.3×10^2	
	Thalassiosira subtilis	6.3×10^2	
	Peridinium tuba	1.3×10^2	
	Ceratium furca	1.9×10^2	
	Chaetoceros affinis	6.3×10^2	
	Pyrophacus horologicum	1.3×10^2	
	Rhizosolenia alata	1.9×10^2	2.6×10^4
<53 – 25 µm	*Chaetoceros curvisetus*	4.4×10^2	
	Hemiaulus sp	2.5×10^2	
	Schroderella delicatula	2.3×10^2	
	Ceratium furca	8.7×10^2	
	Dictyocha fibula	2.1×10^2	
	Amphiprora gigantae	4.2×10^2	
	Coscinodiscus radiatus	2.5×10^2	
	Asterionella japonica	3.8×10^2	
	Biddulphia mobiliensis	5.0×10^2	
	Thalassiosira coramandeliana	2.9×10^3	
	Nitzschia delicatissima	3.0×10^2	
	Peridinium pellucidum	2.5×10^2	
	Stephanopyxis palmeriana	1.3×10^2	
	Rhizosolenia setigera	1.4×10^3	
	Chaetoceros danicus	1.0×10^2	

	Thalassiothrix frauenfeldii	6.3 x 10^2	
	Thalassiothrix longissima	8.2 x 10^2	
	Nitzschia longissima	2.5 x 10^2	
	Peridinium tuba	1.9 x 10^2	
	Dinophysis caudata	5.0 x 10^2	
	Planktoniella sol	1.3 x 10^2	
	Thalassionema nitzschioides	2.5 x 10^2	
	Pleurosigma directum	7.5 x 10^2	
	Oscillatoria nigroviridis	2.5 x 10^2	
	Johannesbaptistia pellucida	2.5 x 10^2	
	Thalassiosira subtilis	7.5 x 10^2	
	Rhizosolenia stolterfothii	1.3 x 10^2	
	Chaetoceros brevis	2.5 x 10^2	
	Prorocentrum gracile	2.5 x 10^2	1.4 x 10^4
<25 – 10 µm	*Skeletonema costatum*	4.0 x 10^3	
	Nitzschia longissima	2.9 x 10^2	
	Nitzschia delicatissima	6.7 x 10^2	
	Nitzschia spp	2.5 x10^2	
	Amphiprora gigantae	2.5 x 10^2	
	Schroderella delicatula	3.8 x 10^2	
	Thalassiosira coramandeliana	2.2 x 10^3	
	Rhizosolenia alata	2.5 x 10^2	
	Stephanopyxis palmeriana	2.5 x 10^2	
	Leptocylindrus danicus	4.2 x 10^2	
	Rhizosolenia stolterfothii	1.1 x 10^3	
	Pleurosigma directum	5.7 x 10^2	
	Ceratium furca	1.3 x 10^2	
	Corethron inerme	1.3 x 10^2	
	Biddulphia heteroceros	1.3 x 10^2	
	Hemiaulus sp	1.3 x 10^2	
	Dictyocha fibula	1.3 x 10^2	
	Prorocentrum micans	1.3 x 10^2	
	Rhizosolenia setigera	2.3 x 10^3	
	Thalassiothrix longissima	9.4 x 10^2	
	Chaetoceros danicus	5.0 x 10^2	
	Thalassionema nitzschioides	2.5 x 10^2	
	Johannesbaptistia pellucida	2.5 x 10^2	
	Thalassiosira subtilis	2.3 x 10^3	
	Rhizosolenia styliformis	1.3 x10^2	
	Gonyaulax sp	1.3 x 10^2	1.8 x 10^4

< 10 µm	*Fragilaria oceanica*	2.5×10^3	
	Thalassiosira coramandeliana	1.0×10^3	
	Nitzschia spp	5.0×10^2	
	Navicula hennedyii	1.3×10^3	
	Johannesbaptistia pellucida	2.5×10^2	
	Thalassiothrix frauenfeldii	2.5×10^2	
	Leptocylindrus danicus	2.5×10^2	6.1×10^3 *

* Observed number

-Table 4.2- Average concentration of planktonic algae of various size groups during the monsoon season at station 1.

Size groups	Species	No. / l	Total
> 500 µm	*Asterionella japonica*	1.2×10^3	
	Eucampia zoodiacus	2.5×10^2	
	Oscillatoria nigroviridis	1.3×10^2	1.6×10^3
<500 – 250 µm	*Asterionella japonica*	2.7×10^3	
	Fragilaria oceanica	1.3×10^2	2.8×10^3
<250 – 150 µm	*Asterionella japonica*	1.0×10^4	
	Bacteriastrum varians	2.5×10^2	
	Hemiaulus sp	2.5×10^2	
	Nitzschia delicatissima	2.5×10^2	
	Thalassiosira coramandeliana	7.5×10^2	
	Rhizosolenia styliformis	2.5×10^2	
	Thalassiothrix frauenfeldii	2.5×10^2	
	Chaetoceros curvisetus	2.5×10^2	
	Nitzschia longissima	9.2×10^2	
	Fragilaria oceanica	3.8×10^2	
	Thalassiothrix longissima	2.5×10^2	1.4×10^4
<150 – 105 µm	*Asterionella japonica*	4.8×10^4	
	Ditylum sol	2.5×10^2	
	Chaetoceros curvisetus	2.3×10^3	
	Eucampia zoodiacus	2.5×10^2	
	Chaetoceros lorenzianus	7.5×10^2	
	Nitzschia longissima	1.8×10^3	
	Fragilaria oceanica	2.1×10^2	
	Rhizosolenia spp	2.5×10^2	
	Nitzschia delicatissima	2.5×10^2	
	Chaetoceros brevis	1.3×10^2	

	Pleurosigma directum	8.8×10^2	
	Rhizosolenia setigera	2.5×10^2	
	Thalassiothrix longissima	7.5×10^2	
	Oscillatoria nigroviridis	3.2×10^2	5.7×10^4
<105 – 53 µm	*Asterionella japonica*	1.5×10^5	
	Nitzschia delicatissima	1.8×10^3	
	Eucampia zoodiacus	3.3×10^3	
	Rhizosolenia setigera	5.7×10^2	
	Chaetoceros curvisetus	5.3×10^3	
	Ditylum sol	5.0×10^2	
	Thalassionema nitzschioides	2.5×10^3	
	Thalassiothrix frauenfeldii	2.3×10^3	
	Nitzschia longissima	3.7×10^3	
	Thalassiosira coramandeliana	5.3×10^3	
	Skeletonema costatum	1.0×10^3	
	Biddulphia mobiliensis	6.9×10^2	
	Guinardia flaccida	5.0×10^2	
	Planktoniella sol	5.0×10^2	
	Coscinodiscus radiatus	8.6×10^2	
	Rhizosolenia stolterfothii	7.5×10^2	
	Thalassiothrix longissima	9.3×10^2	
	Hemiaulus sp	2.5×10^2	
	Pleurosigma directum	9.6×10^2	
	Oscillatoria nigroviridis	6.3×10^2	
	Thalassiosira subtilis	4.0×10^3	
	Fragilaria oceanica	7.2×10^2	
	Bacteriastrum varians	2.5×10^2	1.9×10^5
<53 – 25 µm	*Asterionella japonica*	1.6×10^4	
	Nitzschia longissima	3.5×10^3	
	Thalassiosira coramandeliana	4.6×10^3	
	Thalassionema nitzschioides	3.5×10^3	
	Nitzschia delicatissima	1.8×10^3	
	Pleurosigma directum	2.8×10^3	
	Rhizosolenia setigera	7.2×10^2	
	Thalassiothrix longissima	5.8×10^2	
	Skeletonema costatum	2.4×10^3	
	Johannesbaptistia pellucida	7.5×10^2	
	Biddulphia mobiliensis	1.9×10^3	
	Eucampia zoodiacus	1.3×10^3	

	Hemiaulus sp	7.5×10^2	
	Thalassiothrix frauenfeldii	2.0×10^3	
	Fragilaria oceanica	8.3×10^2	
	Corethron inerme	2.5×10^2	
	Rhizosolenia stolterfothii	2.5×10^2	
	Thalassiosira subtilis	1.6×10^4	
	Coscinodiscus radiatus	2.8×10^3	
	Dinophysis caudata	2.5×10^2	
	Peridinium depressum	2.5×10^2	
	Dictyocha fibula	2.5×10^2	
	Oscillatoria nigroviridis	5.0×10^2	6.4×10^4
<25 – 10 µm	*Asterionella japonica*	5.4×10^3	
	Nitzschia longissima	5.9×10^4	
	Pleurosigma directum	1.3×10^3	
	Rhizosolenia setigera	5.0×10^2	
	Thalassiothrix frauenfeldii	9.0×10^2	
	Thalassionema nitzschioides	1.7×10^3	
	Nitzschia delicatissima	8.0×10^3	
	Thalassiosira coramandeliana	5.0×10^3	
	Rhizosolenia stolterfothii	1.8×10^3	
	Skeletonema costatum	1.8×10^3	
	Fragilaria oceanica	3.2×10^3	
	Eucampia zoodiacus	1.0×10^3	
	Licmophora sp	2.5×10^2	
	Thalassiosira subtilis	1.4×10^3	
	Coscinodiscus radiatus	3.8×10^2	
	Prorocentrum micans	5.0×10^2	
	Thalassiothrix longissima	3.8×10^2	
	Biddulphia mobiliensis	5.0×10^2	
	Navicula hennedyii	5.0×10^2	
	Oscillatoria nigroviridis	1.0×10^3	9.4×10^4
< 10 µm	*Nitzschia longissima*	1.2×10^4	
	Navicula hennedyii	7.3×10^3	
	Thalassiosira coramandeliana	4.7×10^3	
	Thalassiothrix frauenfeldii	2.3×10^3	
	Fragilaria oceanica	7.5×10^2	
	Johannesbaptistia pellucida	5.0×10^2	2.8×10^4 *

* Observed number

Table 4.3- Average concentration of planktonic algae of various size groups during the post-monsoon season at station 1

Size groups	Species	No. / l	Total
> 500 µm	*Chaetoceros curvisetus*	2.5×10^2	
	Thalassiothrix longissima	5.0×10^2	
	Nitzschia delicatissima	2.5×10^2	
	Asterionella japonica	2.5×10^2	1.3×10^3
<500 – 250 µm	*Thalassiothrix longissima*	4.6×10^2	
	Nitzschia delicatissima	2.5×10^2	
	Chaetoceros atlanticus	2.5×10^2	
	Asterionella japonica	2.5×10^2	
	Bacteriastrum varians	2.5×10^2	1.5×10^3
<250 – 150 µm	*Chaetoceros curvisetus*	2.0×10^3	
	Nitzschia delicatissima	2.5×10^2	
	Rhizosolenia stolterfothii	2.5×10^2	
	Thalassiothrix longissima	6.4×10^2	
	Chaetoceros lorenzianus	1.0×10^3	
	Asterionella japonica	1.0×10^3	
	Chaetoceros atlanticus	2.5×10^2	
	Nitzschia longissima	2.5×10^2	
	Biddulphia mobiliensis	2.5×10^2	
	Bacteriastrum varians	2.5×10^2	
	Skeletonema costatum	2.5×10^2	
	Oscillatoria nigroviridis	2.5×10^2	6.6×10^3
<150 – 105 µm	*Chaetoceros curvisetus*	5.3×10^3	
	Nitzschia longissima	1.0×10^3	
	Chaetoceros affinis	2.5×10^2	
	Chaetoceros lorenzianus	2.3×10^3	
	Asterionella japonica	2.8×10^3	
	Streptotheca thamensis	2.5×10^2	
	Chaetoceros atlanticus	2.5×10^2	
	Rhizosolenia stolterfothii	2.5×10^2	
	Nitzschia delicatissima	3.8×10^2	
	Chaetoceros diversus	1.3×10^2	
	Thalassiothrix longissima	7.3×10^2	
	Rhizosolenia hebetate	5.0×10^2	
	Bacteriastrum varians	2.5×10^2	
	Chaetoceros tortissimum	2.5×10^2	

	Biddulphia mobiliensis	1.3×10^2	
	Ceratium fusus	1.3×10^2	
	Skeletonema costatum	1.3×10^2	
	Rhizosolenia alata	1.3×10^2	
	Leptocylindrus danicus	1.3×10^2	
	Oscillatoria nigroviridis	1.3×10^2	1.7×10^4
<105 – 53 µm	*Chaetoceros curvisetus*	5.8×10^3	
	Nitzschia delicatissima	1.6×10^3	
	Asterionella japonica	1.1×10^3	
	Chaetoceros lorenzianus	2.5×10^2	
	Ditylum sol	4.4×10^2	
	Eucampia zoodiacus	2.5×10^2	
	Thalassiosira subtilis	1.5×10^3	
	Navicula hennedyii	5.0×10^2	
	Skeletonema costatum	1.4×10^3	
	Chaetoceros diversus	6.3×10^2	
	Rhizosolenia stolterfothii	1.3×10^2	
	Nitzschia longissima	5.7×10^2	
	Thalassionema nitzschioides	7.5×10^2	
	Amphiprora gigantae	2.5×10^2	
	Diplonies sp	2.5×10^2	
	Chaetoceros atlanticus	5.0×10^2	
	Thalassiothrix longissima	6.7×10^2	
	Bacteriastrum varians	5.0×10^2	
	Biddulphia mobiliensis	5.0×10^2	
	Ceratium fusus	5.0×10^2	
	Ceratium furca	2.5×10^2	
	Gonyaulax sp	2.5×10^2	
	Peridinium depressum	2.5×10^2	
	Chaetoceros tortissimum	2.5×10^2	
	Chaetoceros brevis	1.3×10^2	
	Pyrocystis fusiformis	3.8×10^2	
	Leptocylindrus danicus	1.3×10^2	
	Oscillatoria nigroviridis	3.2×10^2	1.9×10^4
<53 – 25 µm	*Skeletonema costatum*	4.2×10^3	
	Asterionella japonica	1.8×10^3	
	Guinardia flaccida	1.9×10^2	
	Rhizosolenia stolterfothii	2.0×10^3	
	Chaetoceros curvisetus	5.0×10^2	

	Thalassiothrix frauenfeldii	1.0×10^3	
	Nitzschia delicatissima	1.1×10^3	
	Thalassionema nitzschioides	7.2×10^2	
	Nitzschia longissima	1.6×10^3	
	Thalassiosira subtilis	1.3×10^3	
	Thalassiothrix longissima	4.7×10^2	
	Ceratium furca	7.2×10^2	
	Biddulphia mobiliensis	5.0×10^2	
	Navicula hennedyii	7.5×10^2	
	Gymnodinium veneficum	2.5×10^2	
	Rhizosolenia setigera	2.5×10^2	
	Pleurosigma directum	2.9×10^2	
	Thalassiosira coramandeliana	3.8×10^2	
	Rhizosolenia calcar-avis	1.3×10^2	
	Coscinodiscus radiatus	1.3×10^2	
	Dictyocha fibula	2.5×10^2	
	Leptocylindrus danicus	3.8×10^2	
	Rhizosolenia imbricate	1.3×10^2	
	Schroderella delicatula	1.3×10^2	
	Amphiprora gigantae	1.3×10^2	
	Chaetoceros diversus	2.5×10^2	2.0×10^4
<25 – 10 µm	*Skeletonema costatum*	1.3×10^4	
	Nitzschia longissima	2.0×10^3	
	Nitzschia delicatissima	2.0×10^3	
	Leptocylindrus danicus	2.3×10^3	
	Hemiaulus sp	2.5×10^2	
	Thalassiothrix longissima	9.3×10^2	
	Thalassionema nitzschioides	5.0×10^2	
	Rhizosolenia stolterfothii	1.6×10^3	
	Pleurosigma directum	4.6×10^2	
	Navicula hennedyii	5.0×10^2	
	Thalassiothrix frauenfeldii	3.2×10^2	
	Rhizosolenia setigera	3.0×10^3	
	Thalassiosira coramandeliana	7.5×10^2	
	Thalassiosira subtilis	7.5×10^2	
	Prorocentrum micans	2.5×10^2	
	Oscillatoria nigroviridis	5.0×10^2	2.9×10^4

< 10 µm	*Skeletonema costatum*	1.0 x 10^{3}	
	Rhizosolenia setigera	7.5 x 10^{2}	
	Nitzschia longissima	4.8 x 10^{3}	
	Navicula hennedyii	1.2 x 10^{3}	
	Thalassiosira coramandeliana	7.5 x 10^{2}	
	Rhizosolenia stolterfothii	1.3 x 10^{2}	
	Thalassionema nitzschioides	1.0 x 10^{3}	9.6 x 10^{3} *

* Observed number

- Table 4.4-Average concentration of planktonic algae of various size groups during the pre-monsoon season at station 2.

Size groups	Species	No. / l	Total
> 500 µm	*Thalassiothrix longissima*	7.2 x 10^{2}	
	Chaetoceros curvisetus	1.3 x 10^{2}	
	Bacteriastrum varians	2.5 x 10^{2}	1.1 x 10^{3}
<500 – 250 µm	*Thalassiothrix longissima*	1.3 x 10^{3}	
	Asterionella japonica	2.5 x 10^{2}	
	Oscillatoria nigroviridis	1.4 x 10^{2}	1.7 x 10^{3}
<250 – 150 µm	*Chaetoceros curvisetus*	1.1 x 10^{3}	
	Chaetoceros brevis	3.2 x 10^{2}	
	Asterionella japonica	2.9 x 10^{2}	
	Hemiaulus sp	1.3 x 10^{2}	
	Thalassiothrix longissima	1.1 x 10^{3}	
	Thalassiosira spp	1.9 x 10^{2}	
	Bacteriastrum varians	1.3 x 10^{2}	
	Chaetoceros affinis	1.3 x 10^{2}	
	Chaetoceros lorenzianus	1.3 x 10^{2}	3.5 x 10^{3}
<150 – 105 µm	*Chaetoceros curvisetus*	1.5 x 10^{3}	
	Thalassiothrix longissima	1.0 x 10^{3}	
	Thalassionema nitzschioides	1.3 x 10^{2}	
	Nitzschia delicatissima	2.5 x 10^{2}	
	Asterionella japonica	4.6 x 10^{2}	
	Schroderella delicatula	2.5 x 10^{2}	
	Hemiaulus sp	1.3 x 10^{2}	
	Bacteriastrum varians	3.8 x 10^{2}	
	Chaetoceros brevis	3.8 x 10^{2}	

	Rhizosolenia stolterfothii	1.3×10^{2}	
	Fragilaria oceanica	1.3×10^{2}	
	Chaetoceros lorenzianus	2.5×10^{2}	
	Guinardia flaccida	1.3×10^{2}	
	Rhizosolenia styliformis	2.5×10^{2}	
	Chaetoceros affinis	2.5×10^{2}	
	Rhizosolenia setigera	1.3×10^{2}	
	Thalassiosira coramandeliana	3.8×10^{2}	
	Pleurosigma directum	1.3×10^{2}	6.3×10^{3}
<105 – 53 µm	*Chaetoceros curvisetus*	1.0×10^{4}	
	Asterionella japonica	1.0×10^{3}	
	Chaetoceros affinis	1.0×10^{2}	
	Bacteriastrum varians	1.0×10^{3}	
	Schroderella delicatula	5.0×10^{2}	
	Chaetoceros brevis	6.3×10^{2}	
	Biddulphia mobiliensis	2.5×10^{2}	
	Rhizosolenia setigera	8.7×10^{2}	
	Planktoniella sol	1.3×10^{2}	
	Thalassiosira coramandeliana	1.1×10^{3}	
	Nitzschia delicatissima	1.3×10^{2}	
	Coscinodiscus radiatus	1.3×10^{2}	
	Thalassiothrix longissima	1.1×10^{3}	
	Peridinium depressum	2.5×10^{2}	
	Thalassiothrix frauenfeldii	2.5×10^{2}	
	Thalassionema nitzschioides	2.5×10^{2}	
	Rhizosolenia stolterfothii	2.5×10^{2}	
	Ceratium furca	1.3×10^{2}	
	Ceratium tripos	1.3×10^{2}	
	Rhizosolenia clevei	1.3×10^{2}	
	Pyrophacus horologicum	1.3×10^{2}	1.8×10^{4}
<53 – 25 µm	*Thalassiosira subtilis*	1.8×10^{3}	
	Thalassiosira coramandeliana	1.3×10^{3}	
	Schroderella delicatula	1.0×10^{3}	
	Corethron inerme	2.5×10^{2}	
	Chaetoceros curvisetus	7.5×10^{2}	
	Nitzschia delicatissima	5.0×10^{2}	
	Ceratium furca	8.8×10^{2}	
	Biddulphia mobiliensis	2.6×10^{2}	
	Nitzschia longissima	3.8×10^{2}	

	Asterionella japonica	1.0 x 10^3	
	Hemiaulus sp	2.5 x 10^2	
	Bacteriastrum varians	1.3 x 10^2	
	Skeletonema costatum	1.9 x 10^2	
	Amphiprora gigantae	1.3 x 10^2	
	Rhizosolenia stolterfothii	5.1 x 10^2	
	Thalassiothrix longissima	5.7 x 10^2	
	Peridinium tuba	1.3 x 10^2	
	Chaetoceros danicus	5.0 x 10^2	
	Pleurosigma directum	3.2 x 10^2	
	Dictyocha fibula	2.5 x 10^2	
	Rhizosolenia setigera	1.5 x 10^3	
	Coscinodiscus radiatus	1.3 x 10^2	
	Dinophysis caudata	1.3 x 10^2	
	Pyrophacus horologicum	2.5 x 10^2	
	Rhizosolenia clevei	1.3 x 10^2	
	Gonyaulax sp	1.3 x 10^2	
	Thalassionema nitzschioides	1.3 x 10^2	1.4 x 10^4
<25 – 10 µm	*Nitzschia delicatissima*	4.6 x 10^3	
	Nitzschia longissima	2.1 x 10^3	
	Leptocylindrus danicus	4.6 x 10^2	
	Asterionella japonica	1.9 x 10^2	
	Schroderella delicatula	2.0 x 10^3	
	Thalassionema nitzschioides	3.8 x 10^2	
	Skeletonema costatum	4.3 x 10^3	
	Rhizosolenia stolterfothii	6.8 x 10^2	
	Corethron inerme	1.3 x 10^2	
	Amphiprora gigantae	1.3 x 10^2	
	Hemiaulus sp	2.5 x 10^2	
	Thalassiosira coramandeliana	2.5 x 10^3	
	Thalassiothrix longissima	1.9 x 10^3	
	Pleurosigma directum	5.0 x 10^2	
	Rhizosolenia setigera	1.4 x 10^3	
	Johannesbaptistia pellucida	2.5 x 10^2	2.2 x 10^4
< 10 µm	*Thalassiosira coramandeliana*	2.4 x 10^3	
	Nitzschia longissima	1.0 x 10^3	
	Navicula hennedyii	1.0 x 10^3	
	Rhizosolenia stolterfothii	5.0 x 10^2	4.9 x 10^3 *

* Observed number

- Table 4.5-Average concentration of planktonic algae of various size groups during the monsoon season at station 2.

Size groups	Species	No. / l	Total
> 500 µm	*Asterionella japonica*	2.5×10^2	2.5×10^2
<500 – 250 µm	*Asterionella japonica*	1.5×10^3	
	Thalassiothrix longissima	6.3×10^2	
	Chaetoceros curvisetus	2.5×10^2	
	Oscillatoria nigroviridis	2.5×10^2	2.6×10^3
<250 – 150 µm	*Asterionella japonica*	6.5×10^3	
	Nitzschia delicatissima	2.5×10^2	
	Thalassiothrix longissima	8.5×10^2	
	Nitzschia longissima	1.9×10^2	
	Chaetoceros curvisetus	2.5×10^2	
	Coscinodiscus radiatus	1.3×10^2	
	Fragilaria oceanica	2.5×10^2	
	Oscillatoria nigroviridis	5.0×10^2	8.9×10^3
<150 – 105 µm	*Asterionella japonica*	1.4×10^4	
	Nitzschia delicatissima	1.0×10^3	
	Chaetoceros curvisetus	2.5×10^2	
	Pleurosigma directum	2.5×10^2	
	Nitzschia longissima	5.4×10^2	
	Thalassiothrix longissima	1.4×10^3	
	Fragilaria oceanica	5.0×10^2	
	Chaetoceros lorenzianus	2.5×10^2	
	Oscillatoria nigroviridis	2.5×10^2	1.8×10^4
<105 – 53 µm	*Asterionella japonica*	4.3×10^4	
	Nitzschia delicatissima	2.3×10^3	
	Chaetoceros curvisetus	2.3×10^3	
	Thalassiosira coramandeliana	5.0×10^2	
	Rhizosolenia setigera	7.5×10^2	
	Biddulphia mobiliensis	7.8×10^2	
	Skeletonema costatum	9.2×10^2	
	Nitzschia longissima	5.8×10^2	
	Rhizosolenia stolterfothii	2.5×10^2	
	Thalassionema nitzschioides	1.9×10^2	
	Fragilaria oceanica	2.5×10^2	
	Pleurosigma directum	3.8×10^2	

	Planktoniella sol	5.0 x 10^2	
	Thalassiothrix longissima	1.5 x 10^3	
	Eucampia zoodiacus	2.5 x 10^2	
	Coscinodiscus radiatus	7.5 x 10^2	
	Thalassiosira subtilis	7.5 x 10^2	
	Oscillatoria nigroviridis	2.5 x 10^2	5.6 x 10^4
<53 – 25 µm	*Asterionella japonica*	5.7 x 10^3	
	Thalassiosira subtilis	1.3 x 10^4	
	Thalassionema nitzschioides	1.3 x 10^3	
	Pleurosigma directum	6.7 x 10^2	
	Thalassiosira coramandeliana	7.3 x 10^3	
	Skeletonema costatum	2.1 x 10^3	
	Rhizosolenia stolterfothii	2.5 x 10^2	
	Hemiaulus sp	2.5 x 10^2	
	Fragilaria oceanica	7.5 x 10^2	
	Biddulphia mobiliensis	1.6 x 10^3	
	Nitzschia delicatissima	1.3 x 10^3	
	Nitzschia longissima	7.5 x 10^2	
	Eucampia zoodiacus	5.0 x 10^2	
	Thalassiothrix frauenfeldii	1.3 x 10^3	
	Chaetoceros curvisetus	7.5 x 10^2	
	Rhizosolenia setigera	7.5 x 10^2	
	Coscinodiscus radiatus	2.7 x 10^3	
	Dictyocha fibula	2.5 x 10^2	
	Thalassiothrix longissima	2.2 x 10^3	
	Leptocylindrus danicus	2.5 x 10^2	
	Chaetoceros spp	2.5 x 10^2	
	Dinophysis caudata	2.5 x 10^2	
	Oscillatoria nigroviridis	3.2 x 10^2	4.4 x 10^4
<25 – 10 µm	*Asterionella japonica*	5.8 x 10^3	
	Nitzschia longissima	3.1 x 10^3	
	Thalassiosira coramandeliana	3.6 x 10^3	
	Guinardia flaccida	2.5 x 10^2	
	Pleurosigma directum	5.8 x 10^2	
	Nitzschia delicatissima	3.4 x 10^3	

	Skeletonema costatum	5.0×10^3	
	Rhizosolenia stolterfothii	7.5×10^2	
	Thalassiothrix longissima	1.2×10^3	
	Thalassiothrix frauenfeldii	2.5×10^2	
	Hemiaulus sp	2.5×10^2	
	Thalassionema nitzschioides	2.5×10^2	
	Fragilaria oceanica	1.3×10^3	
	Thalassiosira subtilis	3.3×10^3	
	Navicula hennedyii	1.5×10^3	
	Diplonies sp	2.5×10^2	
	Coscinodiscus radiatus	3.0×10^3	
	Rhizosolenia setigera	5.0×10^2	
	Oscillatoria nigroviridis	2.5×10^2	3.5×10^4
< 10 µm	*Skeletonema costatum*	1.9×10^3	
	Navicula hennedyii	1.5×10^3	
	Nitzschia longissima	4.5×10^3	
	Thalassiosira coramandeliana	8.8×10^2	
	Fragilaria oceanica	5.0×10^2	
	Rhizosolenia setigera	5.0×10^2	9.8×10^3 *

* Observed number

- Table 4.6-Average concentration of planktonic algae of various size groups during the post-monsoon season at station 2.

Size groups	Species	No. / l	Total
> 500 µm	*Thalassiothrix longissima*	5.0×10^2	5.0×10^2
<500 – 250 µm	*Thalassiothrix longissima*	5.0×10^2	
	Chaetoceros diversus	2.5×10^2	
	Nitzschia delicatissima	7.5×10^2	
	Chaetoceros lorenzianus	1.3×10^2	
	Asterionella japonica	5.0×10^2	
	Pyrocystis fusiformis	2.5×10^2	2.4×10^3
<250 – 150 µm	*Chaetoceros curvisetus*	3.4×10^3	
	Chaetoceros affinis	2.5×10^2	
	Asterionella japonica	2.0×10^3	
	Ditylum sol	2.5×10^2	
	Bacteriastrum varians	2.5×10^2	
	Chaetoceros lorenzianus	1.0×10^3	

	Chaetoceros atlanticus	7.8 x 10^2	
	Thalassiothrix longissima	3.8 x 10^2	
	Leptocylindrus danicus	2.5 x 10^2	
	Biddulphia mobiliensis	2.5 x 10^2	
	Nitzschia delicatissima	5.0 x 10^2	
	Skeletonema costatum	2.0 x 10^3	1.1 x 10^4
<150 – 105 µm	*Chaetoceros curvisetus*	1.0 x 10^4	
	Asterionella japonica	9.8 x 10^3	
	Bacteriastrum varians	2.5 x 10^2	
	Chaetoceros danicus	1.0 x 10^3	
	Chaetoceros affinis	7.5 x 10^2	
	Chaetoceros lorenzianus	1.5 x 10^3	
	Streptotheca thamensis	2.5 x 10^2	
	Chaetoceros diversus	7.5 x 10^2	
	Nitzschia delicatissima	1.2 x 10^3	
	Thalassiothrix longissima	8.8 x 10^2	
	Rhizosolenia alata	2.5 x 10^2	
	Biddulphia mobiliensis	2.5 x 10^2	
	Leptocylindrus danicus	5.0 x 10^2	
	Skeletonema costatum	5.0 x 10^2	
	Guinardia flaccida	5.0 x 10^2	
	Oscillatoria nigroviridis	5.0 x 10^2	2.9 x 10^4
<105 – 53 µm	*Chaetoceros curvisetus*	1.2 x 10^4	
	Asterionella japonica	4.8 x 10^3	
	Rhizosolenia stolterfothii	1.0 x 10^3	
	Nitzschia longissima	3.8 x 10^2	
	Nitzschia delicatissima	1.7 x 10^3	
	Skeletonema costatum	1.8 x 10^3	
	Chaetoceros affinis	5.0 x 10^2	
	Thalassiothrix longissima	8.3 x 10^2	
	Chaetoceros lorenzianus	1.5 x 10^3	
	Ditylum sol	6.3 x 10^2	
	Ceratium furca	2.5 x 10^2	
	Chaetoceros diversus	5.0 x 10^2	
	Thalassiosira coramandeliana	2.5 x 10^2	
	Eucampia zoodiacus	2.5 x 10^2	
	Biddulphia mobiliensis	5.0 x 10^2	
	Streptotheca thamensis	2.5 x 10^2	
	Bacteriastrum varians	1.0 x 10^3	

	Ceratium fusus	2.5×10^2	
	Guinardia flaccida	5.0×10^2	
	Coscinodiscus radiatus	2.0×10^3	
	Leptocylindrus danicus	5.0×10^2	3.1×10^4
<53 – 25 µm	*Skeletonema costatum*	8.5×10^3	
	Ceratium furca	7.5×10^2	
	Asterionella japonica	1.3×10^3	
	Nitzschia delicatissima	9.3×10^2	
	Thalassiothrix longissima	4.2×10^2	
	Peridinium tuba	5.0×10^2	
	Peridinium spp	5.0×10^2	
	Rhizosolenia stolterfothii	6.3×10^2	
	Thalassiosira subtilis	2.5×10^2	
	Thalassiothrix frauenfeldii	6.3×10^2	
	Navicula hennedyii	7.8×10^2	
	Thalassionema nitzschioides	2.5×10^2	
	Nitzschia longissima	2.5×10^2	
	Dinophysis caudata	2.5×10^2	
	Biddulphia mobiliensis	5.0×10^2	
	Gonyaulax sp	2.5×10^2	
	Pleurosigma directum	6.3×10^2	
	Amphiprora gigantae	2.5×10^2	
	Coscinodiscus radiatus	1.0×10^3	
	Leptocylindrus danicus	1.0×10^3	
	Corethron inerme	5.0×10^2	
	Chaetoceros curvisetus	1.0×10^3	
	Chaetoceros danicus	1.0×10^3	
	Guinardia flaccida	1.0×10^3	2.3×10^4
<25 – 10 µm	*Skeletonema costatum*	4.0×10^4	
	Rhizosolenia stolterfothii	5.1×10^3	
	Thalassiothrix longissima	6.3×10^2	
	Leptocylindrus danicus	2.9×10^3	
	Chaetoceros curvisetus	2.5×10^2	
	Pleurosigma directum	3.8×10^2	
	Thalassiosira coramandeliana	5.0×10^2	
	Thalassiothrix frauenfeldii	5.0×10^2	
	Nitzschia delicatissima	1.7×10^3	
	Nitzschia longissima	1.4×10^3	
	Thalassionema nitzschioides	2.5×10^2	

	Dinophysis caudata	2.5 x 10^2	
	Navicula hennedyii	5.0 x 10^2	
	Fragilaria oceanica	1.0 x 10^3	
	Coscinodiscus radiatus	5.0 x 10^2	
	Nitzschia sp	1.0 x 10^3	
	Oscillatoria nigroviridis	2.5 x 10^2	5.7 x 10^4
< 10 µm	*Skeletonema costatum*	6.8 x 10^3	
	Fragilaria oceanica	2.5 x 10^2	
	Navicula hennedyii	3.5 x 10^3	
	Nitzschia longissima	4.3 x 10^3	
	Rhizosolenia stolterfothii	2.5 x 10^2	
	Thalassiosira coramandeliana	7.5 x 10^2	1.6 x 10^4 *

* Observed number

- Table 4.7-Abundance of various size fractions of planktonic algae (No. / l) during the different seasons at station 1.

Size groups ▼	Pre-monsoon	%	Monsoon	%	Post-monsoon	%
> 500 μm	1.3 x 10^3	1.6	1.6 x 10^3	0.4	1.3 x 10^3	1.3
<500 – 250 μm	2.3 x 10^3	2.8	2.8 x 10^3	0.6	1.5 x 10^3	1.4
<250 – 150 μm	4.2 x 10^3	5.0	1.4 x 10^4	3.1	6.6 x 10^3	6.3
<150 – 105 μm	1.1 x 10^4	13.3	5.7 x 10^4	12.6	1.7 x 10^4	16.3
<105 – 53 μm	2.6 x 10^4	31.3	1.9 x 10^5	42.1	1.9 x 10^4	18.3
<53 – 25 μm	1.4 x 10^4	16.9	6.4 x 10^4	14.2	2.0 x 10^4	19.2
<25 – 10 μm	1.8 x 10^4	21.7	9.4 x 10^4	20.8	2.9 x 10^4	28.0
< 10 μm	6.1 x 10^3 *	7.4	2.8 x 10^4 *	6.2	9.6 x 10^3 *	9.2
Total	8.3 x 10^4	100	4.5 x 10^5	100	1.0 x 10^5	100

* Observed number

- Table 4.8-Abundance of various size fractions of planktonic algae (No. / l) during the different seasons at station 2.

Size groups ▼	Pre-monsoon	%	Monsoon	%	Post-monsoon	%
> 500 μm	1.1 x 10^3	1.5	2.5 x 10^2	0.1	5.0 x 10^2	0.3
<500 – 250 μm	1.7 x 10^3	2.3	2.6 x 10^3	1.5	2.4 x 10^3	1.4
<250 – 150 μm	3.5 x 10^3	4.9	8.9 x 10^3	5.1	1.1 x 10^4	6.5
<150 – 105 μm	6.3 x 10^3	8.8	1.8 x 10^4	10.3	2.9 x 10^4	17.1
<105 – 53 μm	1.8 x 10^4	25.2	5.6 x 10^4	32.1	3.1 x 10^4	18.2
<53 – 25 μm	1.4 x 10^4	19.6	4.4 x 10^4	25.2	2.3 x 10^4	13.5
<25 – 10 μm	2.2 x 10^4	30.8	3.5 x 10^4	20.1	5.7 x 10^4	33.6
< 10 μm	4.9 x 10^3 *	6.9	9.8 x 10^3 *	5.6	1.6 x 10^4 *	9.4
Total	7.2 x 10^4	100	1.7 x 10^5	100	1.6 x 10^5	100

* Observed number

- Table 4.9-Diversity indices for station 1 during the pre-monsoon season.

Size groups ▼	Shannon index	Simpson index	Richness index	Evenness index
> 500 µm	0.500	0.680	0.140	0.722
<500 – 250 µm	0.979	0.484	0.388	0.707
<250 – 150 µm	1.790	0.186	0.719	0.920
<150 – 105 µm	2.276	0.162	1.920	0.773
<105 – 53 µm	2.222	0.217	2.558	0.674
<53 – 25 µm	2.978	0.077	2.932	0.884
<25 – 10 µm	2.631	0.107	2.548	0.808
< 10 µm	1.594	0.256	0.689	0.819

- Table 4.10-Diversity indices for station 1 during the monsoon season.

Size groups ▼	Shannon index	Simpson index	Richness index	Evenness index
> 500 µm	0.706	0.609	0.272	0.643
<500 – 250 µm	0.186	0.912	0.126	0.269
<250 – 150 µm	1.178	0.520	1.047	0.491
<150 – 105 µm	0.744	0.712	1.187	0.282
<105 – 53 µm	1.038	0.626	1.810	0.331
<53 – 25 µm	2.390	0.145	1.988	0.762
<25 – 10 µm	2.787	0.173	1.752	0.947
< 10 µm	1.387	0.288	0.488	0.774

- Table 4.11-Diversity indices for station 1 during the post- monsoon season.

Size groups ▼	Shannon index	Simpson index	Richness index	Evenness index
> 500 µm	1.332	0.280	0.421	0.961
<500 – 250 µm	1.573	0.217	0.549	0.977
<250 – 150 µm	2.145	0.157	1.249	0.863
<150 – 105 µm	2.168	0.184	1.970	0.724
<105 – 53 µm	2.767	0.113	2.726	0.830
<53 – 25 µm	2.778	0.090	2.530	0.853
<25 – 10 µm	1.937	0.234	1.459	0.699
< 10 µm	1.533	0.298	0.654	0.788

- Table 4.12- Diversity indices for station 2 during the pre- monsoon season.

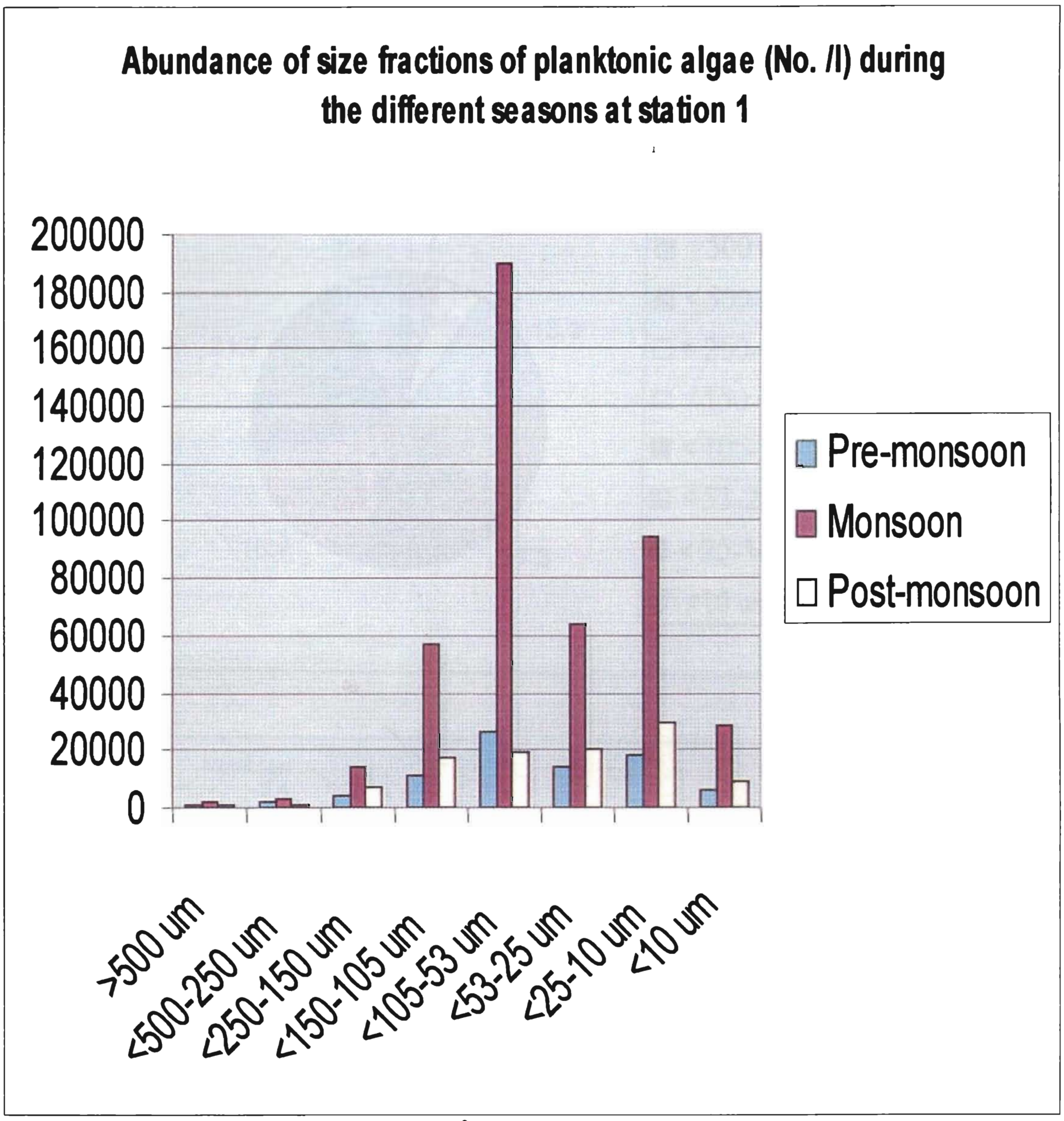
Size groups ▼	Shannon index	Simpson index	Richness index	Evenness index
> 500 µm	0.867	0.494	0.286	0.789
<500 – 250 µm	0.691	0.620	0.269	0.629
<250 – 150 µm	1.795	0.219	0.979	0.817
<150 – 105 µm	2.544	0.110	1.945	0.880
<105 – 53 µm	1.925	0.327	2.041	0.632
<53 – 25 µm	2.942	0.068	2.734	0.893
<25 – 10 µm	2.284	0.129	1.502	0.824
< 10 µm	1.231	0.334	0.353	0.888

- Table 4.13- Diversity indices for station 2 during the monsoon season.

Size groups ▼	Shannon index	Simpson index	Richness index	Evenness index
> 500 µm	0.000	1.000	0.000	0.000
<500 – 250 µm	1.110	0.401	0.381	0.801
<250 – 150 µm	1.060	0.546	0.769	0.510
<150 – 105 µm	0.997	0.617	0.816	0.454
<105 – 53 µm	1.145	0.595	1.555	0.396
<53 – 25 µm	2.425	0.147	2.058	0.773
<25 – 10 µm	2.465	0.096	1.720	0.837
< 10 µm	1.484	0.286	0.544	0.828

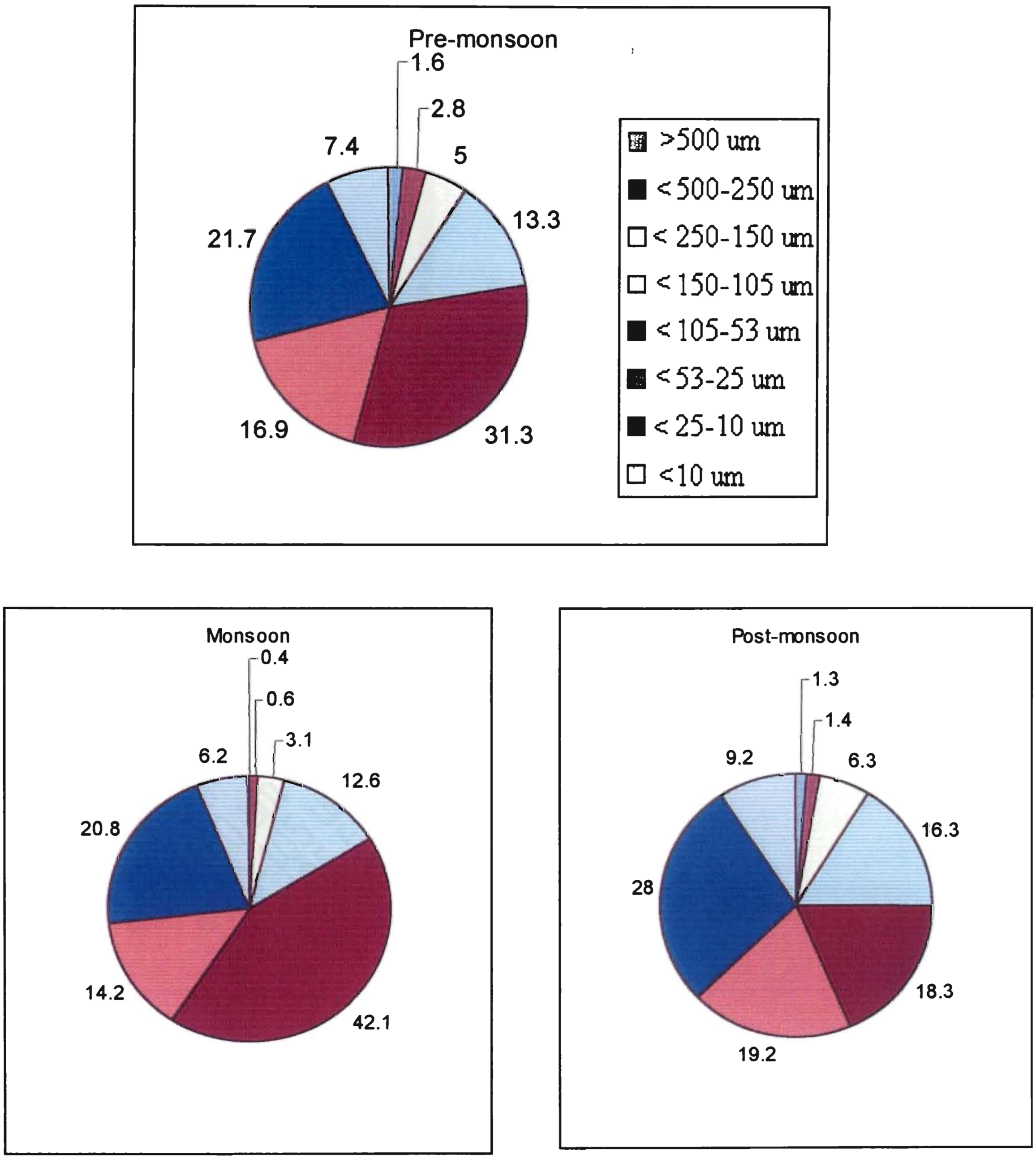
- Table 4.14- Diversity indices for station 2 during the post- monsoon season.

Size groups ▼	Shannon index	Simpson index	Richness index	Evenness index
> 500 µm	0.000	1.000	0.000	0.000
<500 – 250 µm	1.652	0.213	0.643	0.922
<250 – 150 µm	2.046	0.171	1.179	0.823
<150 – 105 µm	1.872	0.242	1.459	0.675
<105 – 53 µm	2.282	0.189	1.934	0.750
<53 – 25 µm	2.559	0.157	2.289	0.805
<25 – 10 µm	1.301	0.507	1.461	0.459
< 10 µm	1.326	0.309	0.517	0.740


Abundance of size fractions of planktonic algae (No. /l) during the different seasons at station 1
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Pre-monsoon
Monsoon
Post-monsoon
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um

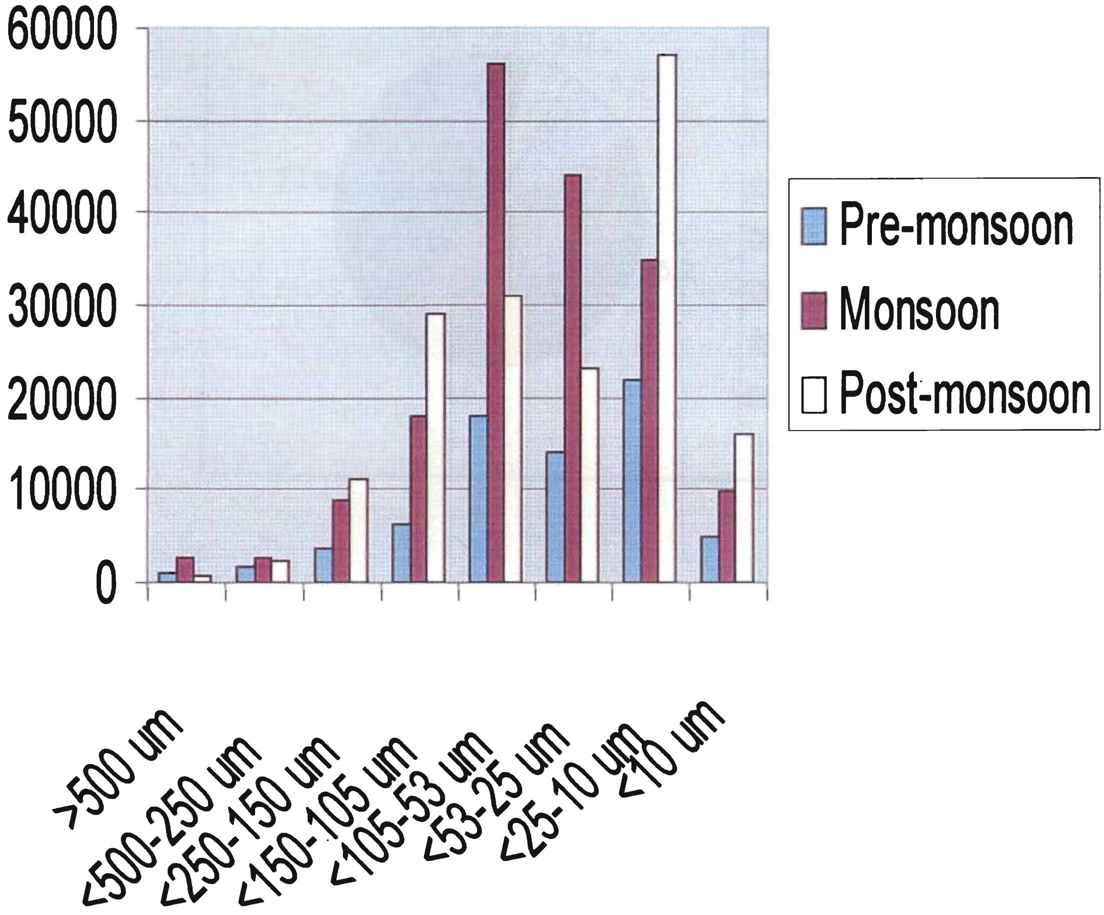
79 A

Abundance of various size fractions of planktonic algae as percentage during the different seasons at station 1

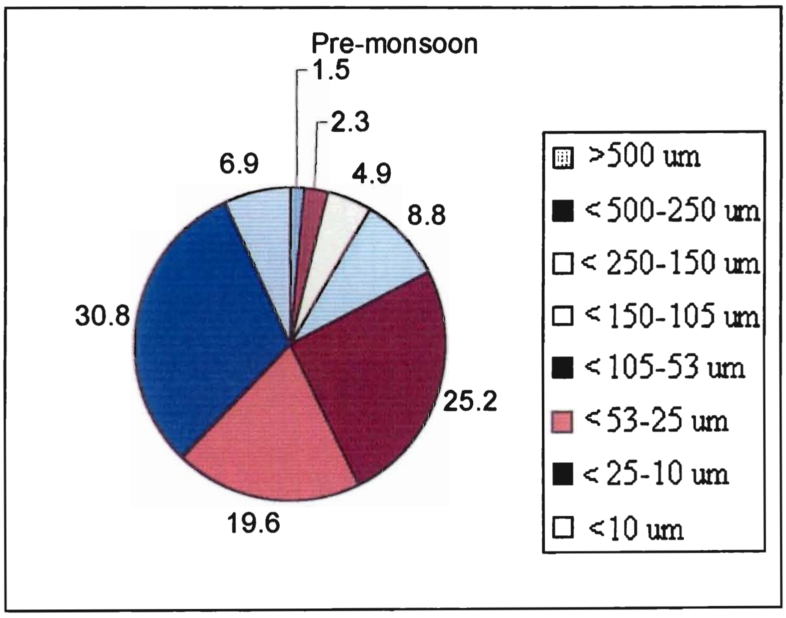


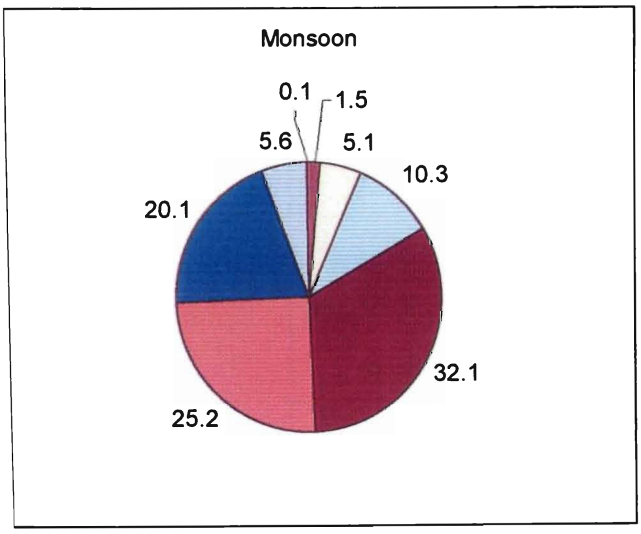
79 B

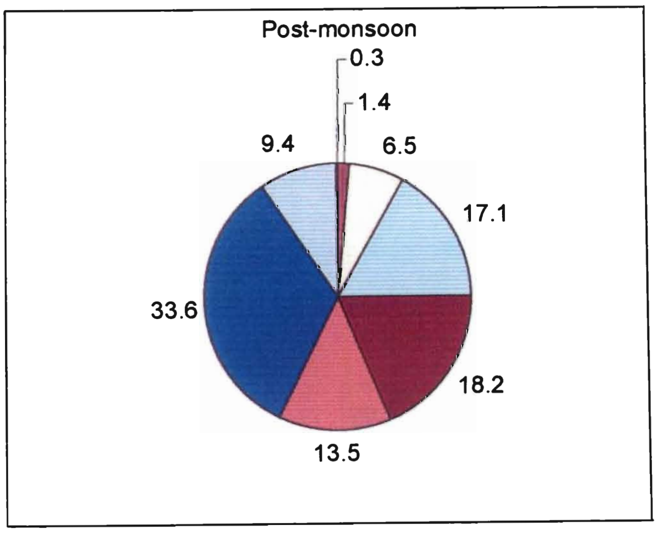
Abundance of size fractions of planktonic algae (No. /l) during the different seasons at station 2



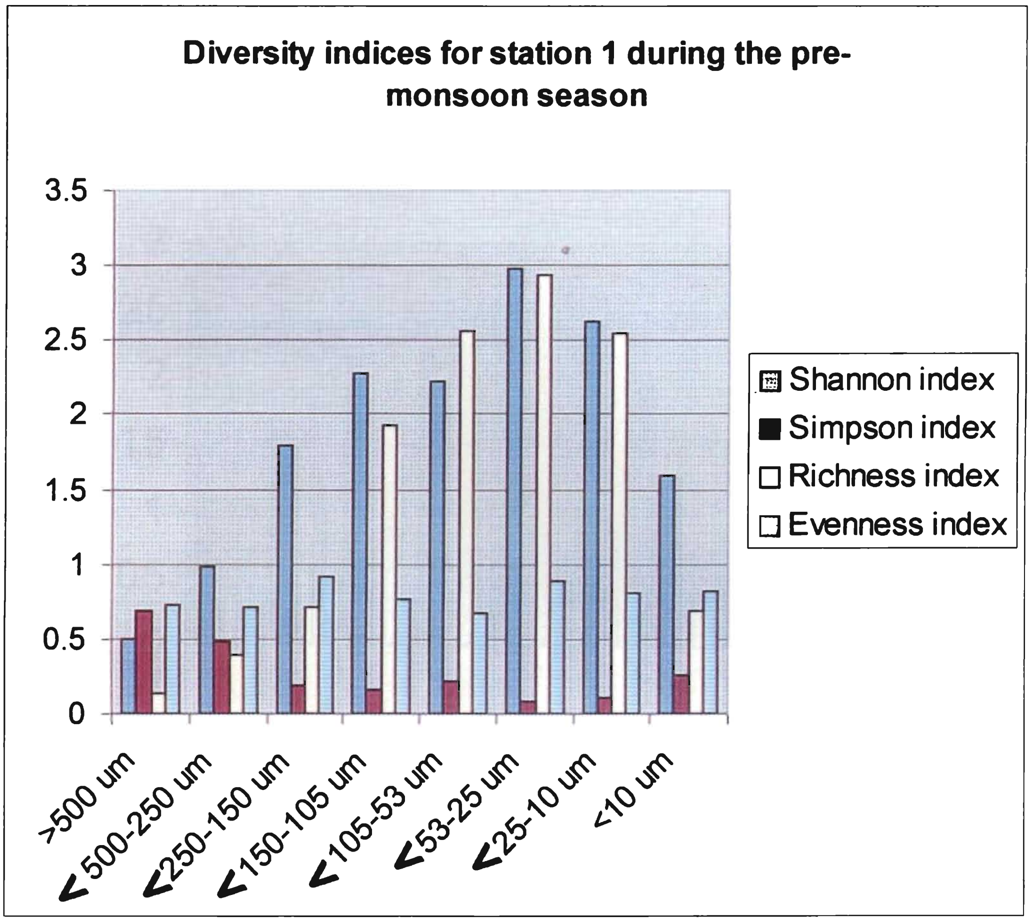
Abundance of various size fractions of planktonic algae as percentage during the different seasons at station 2



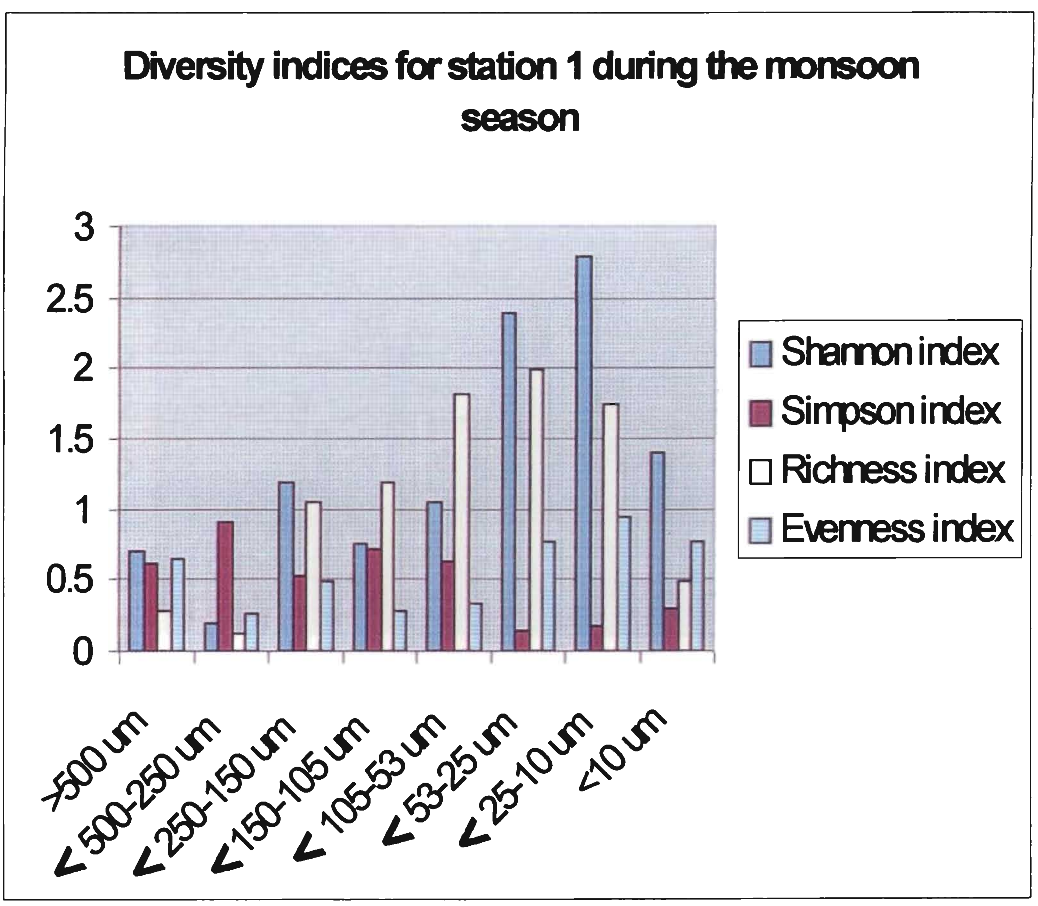




79D

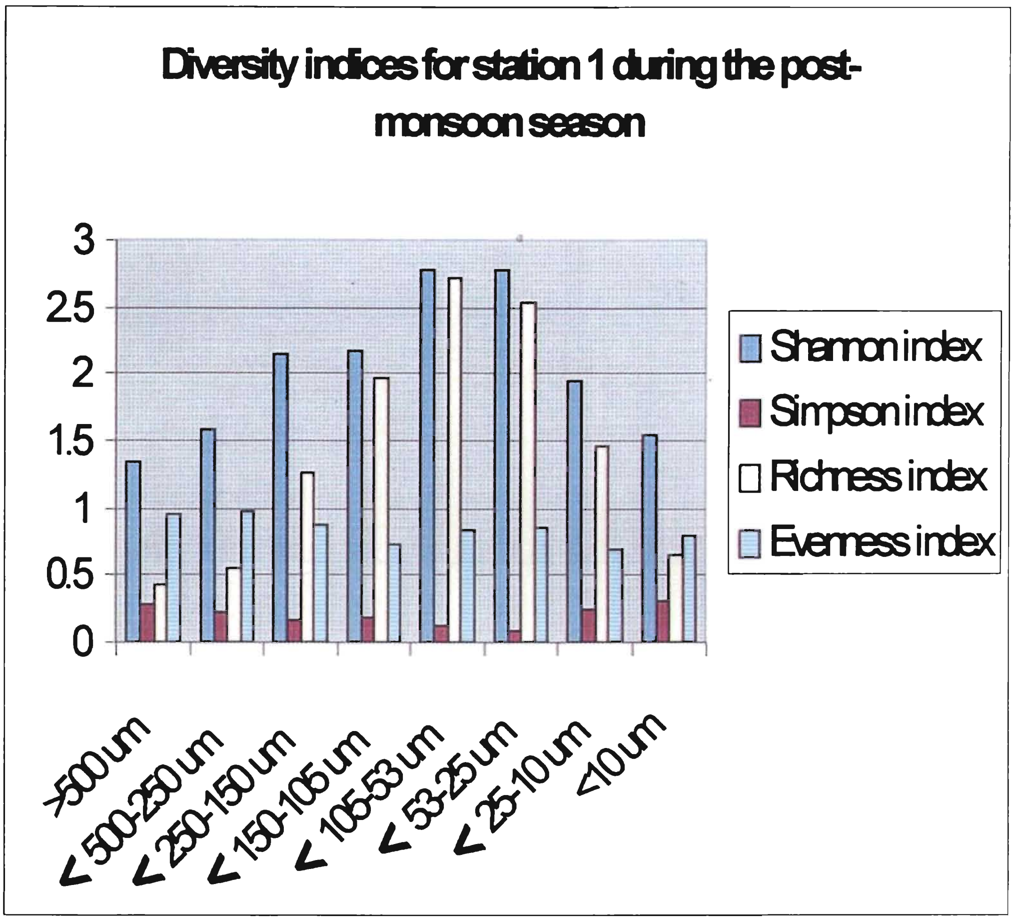


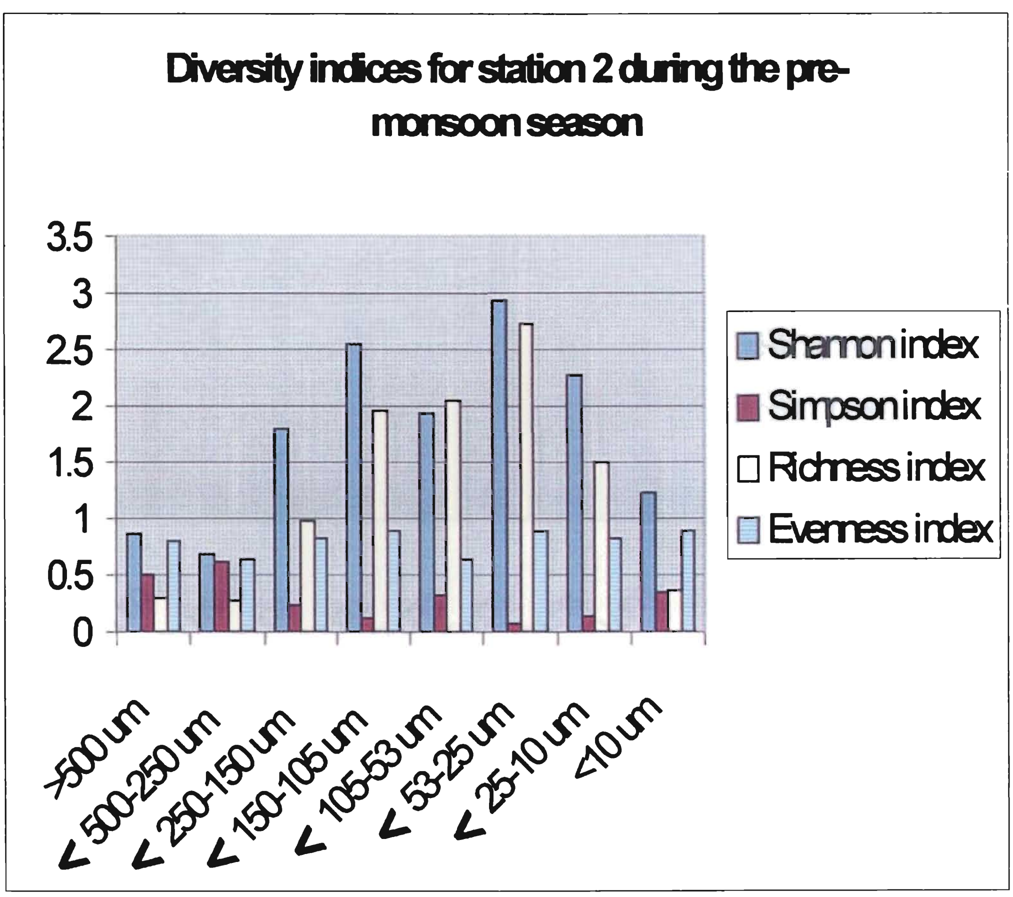
Diversity indices for station 1 during the pre-monsoon season
3.5
3
2.5
2
1.5
1
0.5
0
Shannon index
Simpson index
Richness index
Evenness index
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um



Diversity indices for station 1 during the monsoon season
3
2.5
2
1.5
1
0.5
0
Shannon index
Simpson index
Richness index
Evenness index
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um

79E


Diversity indices for station 1 during the post-monsoon season
3
2.5
2
1.5
1
0.5
0
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
<10 um
Shannon index
Simpson index
Richness index
Evenness index


Diversity indices for station 2 during the pre-monsoon season
3.5
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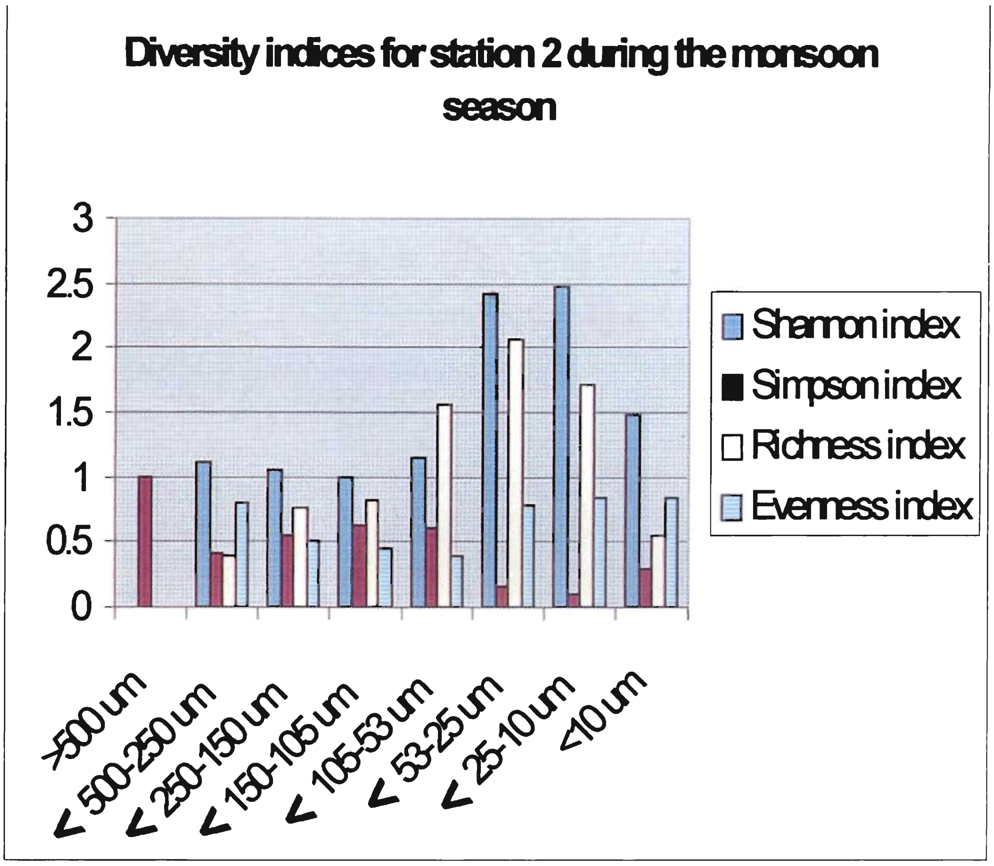
2.5
2
1.5
1
0.5
0
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
<10 um
Shannon index
Simpson index
Richness index
Evenness index


Diversity indices for station 2 during the monsoon season
3
2.5
2
1.5
1
0.5
0
Shannon index
Simpson index
Richness index
Evenness index
>500 um
< 500-250 um
< 250-150 um
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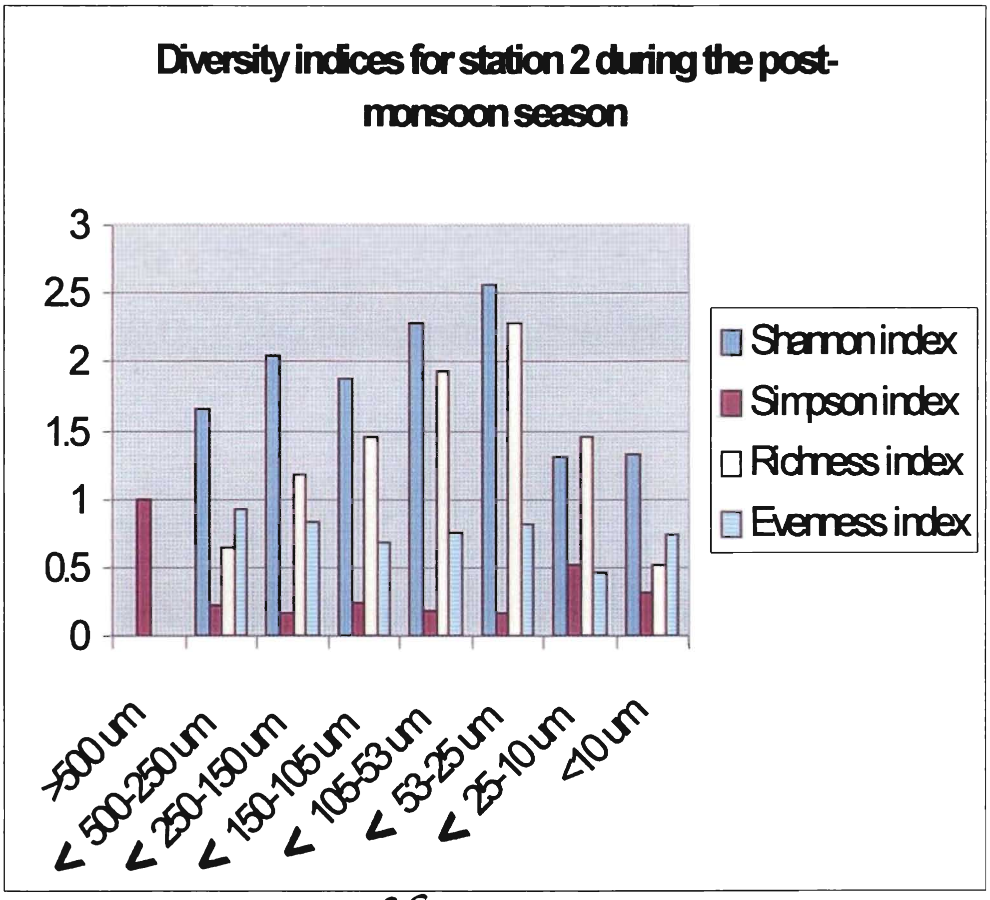
< 25-10 um
<10 um


Diversity indices for station 2 during the post-monsoon season
3
2.5
2
1.5
1
0.5
0
Shannon index
Simpson index
Richness index
Evenness index
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
<10 um

CHAPTER 5

CHLOROPHYLL *a* CONCENTRATION OF SIZE FRACTIONS OF PLANKTONIC ALGAE

INTRODUCTION:

All living organisms depend on the conversion of radiant solar energy to chemical energy that occurs in the process of photosynthesis. In the photosynthesis the conversion of light to chemical energy is greatly dependent upon chlorophyll. Among the various pigments (chlorophylls, carotenes, xanthophylls and biliproteins) which have been found to be involved in photosynthesis, only chlorophyll *a* is common to all photosynthetic organisms. Chlorophyll *a* is recognized therefore to be the main pigment, and all other pigments are considered to be accessory pigments.

Measurement of chlorophyll *a* is one of the most frequently used techniques in assessing standing crop of planktonic algae, since it is universally present in them.

Generally, oceanic regions in temperate and moderately high latitudes have a fairly high standing crop whereas low latitudes, and the central areas of oceanic gyres, are characterized by low standing crop. Long shore winds along the coastal zone can cause up welling, such regions have very large algal crop. In most regions of the world, whatever the latitude, the planktonic algae near the coast is normally richer than that of the offshore and oceanic waters. In the lower latitudes the standing crop over the year shows relatively small variations, whereas at high latitudes there are very clear seasonal fluctuations with high standing crop in the spring, contrasting sharply with low standing crop in the winter. Significant differences may be seen between the standing crops of planktonic algae in coastal and offshore areas.

In contrast to the warm open oceans, many coastal areas in the tropics show large fluctuations in the standing crop of the planktonic algae, due partly to local climatic conditions, partly to a different grazing intensity. Subramanyan (1959) suggested maximum amplitude of algal standing crop of 150 times for some Indian waters. In the eastern tropical pacific the average grazing pressure in oceanic areas is about three times that of inshore waters, so that the crop of inshore waters is more variable than that of the open ocean (Malone, 1971).

Planktonic algae irrespective of their size variations contribute to the total amount of chlorophyll *a*, but the relative contribution of each size group varies, depending on the prevailing environmental conditions. Jochem (1989) found that, in western Baltic, picoplankton attained its greatest importance in mid-summer, contributing 8 – 33 % of the total chlorophyll. Kawabata et al (1993) observed that, in the Vellar estuary, south-east coast of India, the largest quantity of chlorophyll *a* was found in the sizes fraction of 5 – 10 µm. Liu et al (1993) found that, net phytoplankton with cell size > 20 µm in the southern Atlantic Ocean having abundant nutrients accounted for the highest proportion (65 %) of the total chlorophyll *a*, while in infertile southern Indian Ocean, picoplankton accounted for the highest proportion, for example, (47 %) of the total chlorophyll *a*. In the south-west Pacific Ocean, subtropical convergence and in oceanic New Zealand waters, picoplankton (< 2 µm) formed more than 30 % of chlorophyll *a* and primary production in most water types and seasons, except when the 20 – 200 µm size fraction dominated in western coastal waters in spring and in the subtropical convergence in winter and spring (Bradford, 1997). Li et al (1998) found that, in the East China Sea, picoplankton, nanoplankton and net plankton accounted on average for 47, 33 and 20 % of the total chlorophyll.

Subramanyan and Sarma (1965) in the area off Calicut, south-west coast of India, estimated the standing crop of microalgae by fractional filtration followed by pigment measurement and confirmed the very large size of the standing crop, especially during the south-west monsoon season. Although in some occasions (June 1959, August 1960) nanoplankton comprised more than 80 % of the standing crop, on average it constituted only about 40 %. Shah (1969) found that, in the Laccadive Sea off Cochin, chlorophyll *a* values ranged between almost nil and about 8 mg / m^3 at the surface and between zero and 6 mg / m^3 at 15 m depth. If total column (0 – 16 m) pigments were considered, values ranged between approximately 5 and 210 mg / m^2 Taking total pigment content, June to October were the rich months and November to March the poor months, average values being about 150 and 20 mg / m^2, respectively. January was the poorest month with 5 – 10 mg / m^2

Land run-off, in addition to the coastal up welling off the south-west coast of India, during the south-west monsoon period, leads to a general richness of the microalgal standing crop.

RESULTS:

All planktonic algae irrespective of their size range contribute to the entire photosynthetic potential. An understanding of the distribution of chlorophyll *a* among the various size fractions of planktonic algae at different seasons, in the coastal waters of the south-west coast of India is quite useful for a more reliable interpretation of the seasonal fluctuation of fishery resources.

At station 1, during the pre-monsoon season, the larger size group of > 500 µm in size which included the diatoms *Chaetoceros curvisetus* and *Thalassiothrix longissima* contributed 0.10 mg / m^3, 3.2 % of the total chlorophyll *a*. The planktonic algae of the size fraction of < 500 – 250 µm, consisting of the diatoms *Chaetoceros curvisetus*, *Chaetoceros affinis*, *Thalassiothrix longissima* and *Asterionella japonica* contributed 0.11 mg / m^3, i.e. 3.6 % of the total pigment. The size group of < 250 – 150 µm, which was dominated by the diatoms *Thalassiothrix longissima* and *Chaetoceros curvisetus* along with other diatoms such as *Chaetoceros spp. Rhizosolenia setigera* and *Asterionella japonica* gave 0.12 mg / m^3, i.e. 3.9 % to the total chlorophyll *a* content. The contribution of the size group of < 150 – 105 µm to the total amount of chlorophyll *a* was found to be 0.16 mg / m^3, i.e. 5.2 %. *Chaetoceros curvisetus* was the dominant species in this size group, the other planktonic algae were *Chaetoceros spp. Rhizosolenia spp. Nitzschia spp. Thalassiosira coramandeliana, Pleurosigma directum. Bacteriastrum varians. Biddulphia mobiliensis. Asterionella japonica. Schroderella delicatula. Guinardia flaccida. Ditylum sol* and *Streptotheca thamensis*. The planktonic algae of the size group of < 105 – 53 µm in size contributed 0.47 mg / m^3. i.e. 15.2 % of the total chlorophyll *a*, *Chaetoceros curvisetus* was the dominant species, and the other species were *Chaetoceros spp. Thalassiosira coramandeliana. Nitzschia spp. Pleurosigma directum. Bacteriastrum varians. Thalassiothrix longissima, Asterionella japonica, Schroderella delicatula. Biddulphia mobiliensis. Corethron inerme. Hemiaulus sp. Ditylum sol, Planktoniella sol. Rhizosolenia spp, Ceratium furca, Peridinium spp, Dinophysis caudata* and *Pyrophacus horologicum*. The size fraction of < 53 – 25 µm contributed 0.33 mg / m^3. i.e.10.6 % of the total chlorophyll *a*. the planktonic algae of this size group were *Thalassiosira coramandeliana* and *Rhizosolenia setigera* as the dominant species, the other microalgae were, *Rhizosolenia stolterfothii. Chaetoceros spp. Pleurosigma directum. Coscinodiscus radiatus. Hemiaulus sp. Schroderella delicatula. Amphiprora gigantae. Asterionella japonica. Biddulphia mobiliensis, Nitzschia delicatissima. Stephanopyxis palmeriana. Thalassionema nitzschioides. Peridinium spp. Ceratium furca. Prorocentrum gracile. Dinophysis caudata, Dictyocha fibula* and *Johannesbaptistia pellucida*. The contribution of the planktonic algae in the size range of < 25 – 10 µm was 0.46 mg / m^3, i.e. 14.8 % of the total chlorophyll *a*. The dominant species of this size group was *Skeletonema costatum*, the other species being *Nitzschia spp. Rhizosolenia spp, Thalassiosira spp, Pleurosigma directum. Schroderella delicatula. Leptocylindrus danicus. Thalassionema* *nitzschioides*, *Ceratium furca*, *Prorocentrum micans*, *Gonyaulax sp* and *Johannesbaptistia pellucida*. The major contribution was found to be that of the smallest size group of < 10 µm in size, with 1.35 mg / m^3, i.e. 43.5 % of the total chlorophyll *a*. The planktonic algae included in this size fraction were *Fragilaria oceanica*, *Navicula hennedyii* and *Thalassiosira coramandeliana* (as the dominant species), the other forms were *Thalassiothrix franenfeldii*, *Leptocylindrus danicus*, *Nitzschia spp* and *Johannesbaptistia pellucida*.

The total amount of chlorophyll *a* during the pre-monsoon season at station 1 was relatively low, with average value of 3.10 mg / m^3 (Table 5.1).

- Table 5.1-Average values of chlorophyll *a* during the pre-monsoon season at station 1.

Size groups ▼	Chlorophyll *a* (mg / m^3)	%
> 500 µm	0.10	3.2
< 500 – 250 µm	0.11	3.6
< 250 – 150 µm	0.12	3.9
< 150 – 105 µm	0.16	5.2
< 105 – 53 µm	0.47	15.2
< 53 – 25 µm	0.33	10.6
< 25 – 10 µm	0.46	14.8
< 10 µm	1.35	43.5
Total	3.10	100

In the monsoon season, *Asterionella japonica*, *Eucampia zoodiacus* and *Oscillatoria nigroviridis* of the largest size group of > 500 µm were contributing with 0.24 mg / m^3, i.e. 1.6 % of the total chlorophyll *a*. The size group of < 500 – 250 µm which was formed of *Asterionella japonica* and *Fragilaria oceanica* contributed 0.27 mg / m^3, i.e. 1.8 % of the total chlorophyll *a*. The size fraction of < 250 – 150 µm was contributed 0.33 mg / m^3, i.e. 2.2 %. *Asterionella japonica* was the dominant species of this size group, the other microflora were *Nitzschia spp. Thalassiosira coramandeliana. Thalassiothrix spp. Bacteriastrum varians. Hemiaulus sp. Rhizosolenia styliformis. Chaetoceros curvisetus* and *Fragilaria oceanica.* The contribution of the planktonic algae in the size range of < 150 – 105 µm has been found to be 1.18 mg / m^3, i.e. 7.9 % of the total chlorophyll *a*, *Asterionella japonica* was dominating in this size group, the other species were *Chaetoceros spp. Rhizosolenia spp. Nitzschia spp. Pleurosigma directum. Ditylum sol. Eucampia zoodiacus. Fragilaria oceanica. Thalassiothrix longissima* and *Oscillatoria nigroviridis.* The size group of < 105 – 53 µm contributed significantly during this season, yielding 4.59 mg / m^3, i.e. 30.8 % of the total chlorophyll *a*, this group was also dominated by the diatom *Asterionella japonica*, the other members were *Rhizosolenia spp. Nitzschia spp. Thalassiosira spp. Thalassiothrix spp. Coscinodiscus spp. Pleurosigma spp. Chaetoceros curvisetus. Eucampia zoodiacus. Thalassionema nitzschioides. Ditylum sol. Skeletonema costatum. Biddulphia mobiliensis. Guinardia flaccida. Planktoniella sol. Bacteriastrum varians. Fragilaria oceanica* and *Oscillatoria nigroviridis.* The microalgae of the size group of < 53 – 25 µm were contributing 2.57 mg / m^3, i.e. 17.2 % of the total amount of chlorophyll *a*, *Asterionella japonica* was the dominant species, the other microalgae were *Thalassiosira coramandeliana. Nitzschia spp. Rhizosolenia spp. Thalassiothrix spp. Pleurosigma directum. Coscinodiscus radiatus. Thalassionema nitzschioides. Fragilaria oceanica. Skeletonema costatum. Eucampia zoodiacus. Corethron inerme, Biddulphia mobiliensis. Peridinium depressum. Dinophysis caudata. Dictyocha fibula* and *Johannesbaptistia pellucida.* The planktonic algae within the size range of < 25 – 10 µm have been found to contribute by 1.28 mg / m^3, i.e. 8.6 % of the total chlorophyll *a*, *Nitzschia longissima* was the dominant microalgae in this size group, the others were *Asterionella japonica, Thalassiosira coramandeliana, Navicula hennedyii, Pleurosigma directum, Rhizosolenia spp.*

Coscinodiscus radiatus, Thalassiothrix frauenfeldii, Thalassionema nitzschioides, Nitzschia delicatissima, Skeletonema costatum, Fragilaria oceanica, Eucampia zoodiacus, Licmophora sp. Biddulphia mobiliensis and *Prorocentrum micans.* The smallest size group of < 10 µm was contributing 4.46 mg / m^3, i.e. 29.9 % of the total chlorophyll *a*. The planktonic algae belonged to this size group were *Thalassiosira coramandeliana, Nitzschia longissima, Fragilaria oceanica, Navicula hennedyii, Thalassiothrix frauenfeldii* and *Johannesbaptistia pellucida*.

The total chlorophyll *a* was relatively the highest during the monsoon season with average value of 14.92 mg / m^3 (Table 5.2).

- Table 5.2- Average values of chlorophyll *a* during the monsoon season at station 1.

Size groups ▼	Chlorophyll *a* (mg / m^3)	%
> 500 µm	0.24	1.6
< 500 – 250 µm	0.27	1.8
< 250 – 150 µm	0.33	2.2
< 150 – 105 µm	1.18	7.9
< 105 – 53 µm	4.59	30.8
< 53 – 25 µm	2.57	17.2
< 25 – 10 µm	1.28	8.6
< 10 µm	4.46	29.9
Total	14.92	100

During the post-monsoon season, *Thalassiothrix longissima, Chaetoceros curvisetus, Nitzschia delicatissima* and *Asterionella japonica* were recorded in the largest size group of > 500 µm; their contribution to the total chlorophyll *a* has been found to be 0.10 mg / m^3, 1.1 %. The size group of < 500 – 250 µm which included the diatoms *Thalassiothrix longissima, Nitzschia* *delicatissima, Chaetoceros atlanticus, Asterionella japonica* and *Bacteriastrum varians* recorded 0.12 mg / m^3, contributing 1.3 % of the total chlorophyll *a*. The contribution of the planktonic algae within the size range of < 250 – 150 µm was 0.15 mg / m^3, i.e. 1.7 %. The species included in this size fraction were *Chaetoceros curvisetus, Chaetoceros spp. Nitzschia spp. Rhizosolenia stolterfothii. Thalassiothrix longissima. Asterionella japonica. Biddulphia mobiliensis. Bacteriastrum varians. Skeletonema costatum* and *Oscillatoria nigroviridis.* The planktonic algae of the size fraction of < 150 – 105 µm contributed with 0.21 mg / m^3, 2.3 % of the total pigment, the observed species were *Chaetoceros curvisetus* (dominant), *Chaetoceros spp. Nitzschia spp. Rhizosolenia spp. Asterionella japonica. Streptotheca thamensis. Thalassiothrix longissima. Bacteriastrum varians. Biddulphia mobiliensis. Skeletonema costatum. Ceratium fusus* and *Oscillatoria nigroviridis.* The size group of < 105 – 53 µm, has been found to contribute 0.64 mg / m^3, i.e. 7.1 % of the total chlorophyll *a*, *Chaetoceros curvisetus* was the dominant species, the other microflora being *Chaetoceros spp. Asterionella japonica. Nitzschia spp. Rhizosolenia stolterfothii. Navicula hennedyii, Ditylum sol. Eucampia zoodiacus. Thalassiosira subtilis. Skeletonema costatum. Thalassionema nitzschioides. Amphiprora gigantae. Diplonies sp. Thalassiothrix longissima. Bacteriastrum varians. Biddulphia mobiliensis. Leptocylindrus danicus. Ceratium spp. Peridinium depressum. Gonyaulax sp. Pyrocystis fusiformis* and *Oscillatoria nigroviridis.* The contribution of the size fraction of < 53 – 25 µm was 0.73 mg / m^3, 8.1 %, the microalgae found in this size group were *Skeletonema costatum* (dominant). *Asterionella japonica. Chaetoceros curvisetus, Guinardia flaccida. Rhizosolenia spp. Thalassiothrix frauenfeldii. Nitzschia spp. Thalassionema nitzschioides. Thalassiosira spp. Biddulphia mobiliensis, Navicula hennedyii. Coscinodiscus radiatus. Leptocylindrus danicus, Schroderella delicatula. Amphiprora gigantae. Ceratium furca. Gymnodinium veneficum* and *Dictyocha fibula.* The micro flora within the size fraction of < 25 – 10 µm contributed by 0.80 mg / m^3, 8.8 % of the total pigment, the members of this size group were *Skeletonema costatum* (dominant species). *Nitzschia spp*, *Leptocylindrus danicus*, *Hemiaulus sp*, *Thalassionema nitzschioides*, *Rhizosolenia spp*, *Pleurosigma directum*, *Navicula hennedyii*, *Thalassiothrix frauenfeldii*, *Thalassiosira coramandeliana*, *Prorocentrum micans* and *Oscillatoria nigroviridis*. The highest contribution was that of smallest size group of < 10 µm in size. They yielded 6.30 mg / m^3, i.e. 69.6 % of the total amount of chlorophyll *a*, *the* microalgae belonged to this size group were *Skeletonema costatum*, *Nitzschia longissima*, *Thalassionema nitzschioides* and *Navicula hennedyii* (dominant species), *Rhizosolenia spp*, *Thalassiosira coramandeliana* and *Gymnodinium veneficum*.

The average total chlorophyll *a* recorded during the post-monsoon season at station 1, was 9.05 mg / m^3 (Table 5.3).

- Table 5.3-Average values of chlorophyll *a* during the post-monsoon season at station 1.

Size groups ▼	Chlorophyll *a* (mg / m^3)	%
> 500 µm	0.10	1.1
< 500 – 250 µm	0.12	1.3
< 250 – 150 µm	0.15	1.7
< 150 – 105 µm	0.21	2.3
< 105 – 53 µm	0.64	7.1
< 53 – 25 µm	0.73	8.1
< 25 – 10 µm	0.80	8.8
< 10 µm	6.30	69.6
Total	9.05	100

At station 2, in the pre-monsoon season, the largest size group of > 500 µm contributed 0.11 mg / m^3, which is 2.4 % of the total chlorophyll *a*. *Thalassiothrix longissima* (dominant), *Chaetoceros curvisetus* and *Bacteriastrum varians* were found in this size group. The size group of < 500 – 250 µm contributed 0.13 mg / m^3, consisting 3.0 % of the total chlorophyll *a*. Two diatom species *Thalassiothrix longissima* (dominant), *Asterionella japonica* and a single species of blue green algae *Oscillatoria nigroviridis* were present in this size group. The planktonic algae within the size range of < 250 – 150 µm contributed 0.17 mg / m^3, which is 3.8 % of the total pigment, the microalgae included diatoms such as *Chaetoceros curvisetus*, *Thalassiothrix longissima* (as the dominant species), *Asterionella japonica*, *Thalassiothrix frauenfeldii*, *Chaetoceros spp.* *Hemiaulus sp.* *Bacteriastrum varians*, and *Thalassiosira spp.* The size fraction of < 150 – 105 µm recorded 0.19 mg / m^3, contributing 4.2 % of the total chlorophyll *a*, *Chaetoceros curvisetus* and *Thalassiothrix longissima* were the dominant species, the other species were *Chaetoceros spp.* *Nitzschia spp.* *Rhizosolenia spp.* *Thalassiothrix frauenfeldii*. *Thalassionema nitzschioides*. *Asterionella japonica*. *Schroderella delicatula*. *Hemiaulus sp.* *Bacteriastrum varians*, *Fragilaria oceanica*, *Thalassiosira coramandeliana*, *Pleurosigma directum*, and *Oscillatoria nigroviridis*. The size group of < 105 – 53 µm contributed 0.52 mg / m^3, which is 11.5 %. This size fraction included *Chaetoceros curvisetus*, as the dominant species, the other microflora were *Chaetoceros spp.* *Rhizosolenia spp*, *Nitzschia delicatissima*, *Thalassiosira coramandeliana*.. *Biddulphia mobiliensis*, *Asterionella japonica*, *Bacteriastrum varians*, *Schroderella delicatula*. *Planktoniella sol*. *Coscinodiscus radiatus*. *Thalassiothrix frauenfeldii*, *Thalassionema nitzschioides*. *Ceratium furca*. *Ceratium tripos*. *Pyrophacus horologicum* and *Oscillatoria nigroviridis*. The contribution of the size fraction of < 53 – 25 µm gave 0.47 mg / m^3, which is 10.4 % of the total chlorophyll *a*. *Thalassiosira subtilis*, *Thalassiosira coramandeliana* and *Rhizosolenia setigera* were the dominant species, the others being *Skeletonema costatum*, *Nitzschia spp*, *Rhizosolenia spp*, *Pleurosigma directum*, *Corethron inerme*, *Schroderella delicatula*, *Chaetoceros curvisetus*, *Biddulphia mobiliensis*, *Asterionella japonica*, *Hemiaulus sp*, *Bacteriastrum varians*, *Coscinodiscus radiatus*, *Thalassionema nitzschioides*, *Thalassiothrix frauenfeldii*, *Ceratium furca*, *Dinophysis caudata*, *Pyrophacus horologicum*, *Gonyaulax sp* and *Dictyocha fibula*. The planktonic algae of the size group of < 25 – 10 µm were *Nitzschia delicatissima*, *Skeletonema costatum* and *Thalassiosira coramandeliana*, *Nitzschia longissima*, *Leptocylindrus danicus*, *Asterionella japonica*, *Schroderella delicatula*, *Thalassionema nitzschioides*, *Rhizosolenia spp*, *Corethron inerme*, *Pleurosigma directum* and *Johannesbaptistia pellucida*. They contributed 0.80 mg / m^3, which is 17.7 % of the total chlorophyll *a*. The highest contribution in terms of chlorophyll *a* was by the smallest size group of < 10 µm in size, which recorded 2.12 mg / m^3, which is 47.0 % of the total pigment. the members of this size group which could be observed were *Thalassiosira coramandeliana*, *Nitzschia longissima*, *Navicula hennedyii* , *Rhizosolenia stolterfothii* and the blue-green alga *Johannesbaptistia pellucida*.

The total chlorophyll *a* content recorded was the lowest at station 2, during the pre-monsoon season, with an average value of 4.51 mg / m^3 (Table 5.4).

- Table 5.4-Average values of chlorophyll *a* during the pre-monsoon season at station 2.

Size groups ▼	Chlorophyll *a* (mg / m^3)	%
> 500 µm	0.11	2.4
< 500 – 250 µm	0.13	3.0
< 250 – 150 µm	0.17	3.8
< 150 – 105 µm	0.19	4.2
< 105 – 53 µm	0.52	11.5
< 53 – 25 µm	0.47	10.4
< 25 – 10 µm	0.80	17.7
< 10 µm	2.12	47.0
Total	4.51	100

During the monsoon season, the planktonic algae > 500 µm recorded 0.10 mg / m^3, which is 1.9 % of the total chlorophyll *a*, *Asterionella japonica* was the only species recorded in this size group. The size group of < 500 – 250 µm recorded 0.12 mg / m^3, which is 2.3 %. The planktonic algae of this size fraction included *Asterionella japonica*, *Thalassiothrix longissima*, *Chaetoceros curvisetus* and *Oscillatoria nigroviridis*. The planktonic algae of the size group < 250 – 150 µm were *Asterionella japonica*, *Nitzschia spp*, *Thalassiothrix longissima*, *Chaetoceros curvisetus*, *Coscinodiscus radiatus*, *Fragilaria oceanica* and *Oscillatoria nigroviridis*. They contributed 0.14 mg / m^3, 2.7 % of the total pigment. The microalgae within the size range of < 150 – 105 µm contributed 0.26 mg / m^3, which is estimated to be 4.9 % of the total chlorophyll *a*. *Asterionella japonica*, *Nitzschia spp*, *Chaetoceros spp*, *Pleurosigma directum*, *Thalassiothrix longissima* and *Oscillatoria nigroviridis* formed this size group. The size group of < 105 – 53 µm in size contributed 1.15 mg / m^3, which is 21.8 % of the total chlorophyll *a*, *Asterionella japonica* was the dominant species here, the other species being *Nitzschia spp, Rhizosolenia spp, Thalassiosira coramandeliana, Pleurosigma directum, Coscinodiscus radiatus, Chaetoceros curvisetus, Biddulphia mobiliensis, Skeletonema costatum, Thalassionema nitzschioides, Planktoniella sol, Thalassiothrix longissima, Eucampia zoodiacus, Fragilaria oceanica* and *Oscillatoria nigroviridis*. The microalgae within the size fraction of < 53 – 25 μm contributed 1.10 mg / m^3, which form 20.8 % of the total chlorophyll *a*, *Thalassiosira subtilis, Thalassiosira coramandeliana* and *Asterionella japonica* were the dominant microalgae, and the other forms were *Thalassiothrix spp, Thalassionema nitzschioides, Pleurosigma directum, Skeletonema costatum, Rhizosolenia spp, Hemiaulus sp, Fragilaria oceanica, Biddulphia mobiliensis, Nitzschia spp, Eucampia zoodiacus, Chaetoceros curvisetus, Leptocylindrus danicus, Coscinodiscus radiatus, Dinophysis caudata, Oscillatoria nigroviridis* and *Dictyocha fibula*. The size group of < 25 – 10 μm contributed 0.53 mg / m^3, 10.0 % of the total chlorophyll *a*, the microalgae found here were *Asterionella japonica, Skeletonema costatum, Thalassiosira coramandeliana* and *Nitzschia delicatissima* as the dominant species, the other species were *Rhizosolenia spp, Nitzschia longissima, Guinardia flaccida, Pleurosigma directum, Thalassiothrix spp, Hemiaulus sp, Thalassionema nitzschioides, Fragilaria oceanica, Navicula hennedyii* and *Coscinodiscus radiatus*. The highest amount of chlorophyll *a* was recorded for the smallest size group of < 10 μm in size, its contribution was 1.88 mg / m^3, i.e. 35.6 % of the total chlorophyll *a* content. The species dominated in this group were *Nitzschia longissima, Skeletonema costatum* and *Navicula hennedyii*; the other forms are *Thalassiosira coramandeliana, Rhizosolenia setigera* and *Fragilaria oceanica*.

The total amount of chlorophyll *a* was the highest during the monsoon season, average value being 5.28 mg / m^3 (Table 5.5).

- Table 5.5- Average values of chlorophyll *a* during the monsoon season at station 2.

Size groups ▼	Chlorophyll *a* (mg / m^3)	%
> 500 µm	0.10	1.9
< 500 – 250 µm	0.12	2.3
< 250 – 150 µm	0.14	2.7
< 150 – 105 µm	0.26	4.9
< 105 – 53 µm	1.15	21.8
< 53 – 25 µm	1.10	20.8
< 25 – 10 µm	0.53	10.0
< 10 µm	1.88	35.6
Total	5.28	100

During the post-monsoon season, the contribution of the largest size group of > 500 µm was 0.06 mg / m^3, i.e. 1.3 % of the total chlorophyll *a*. The diatom *Thalassiothrix longissima* was the only planktonic algal species in this size fraction. The size group of < 500 – 250 µm in size contributed 0.10 mg / m^3, which form 2.2 % of the total chlorophyll *a*. The planktonic algae found were *Nitzschia delicatissima*, *Thalassiothrix longissima*, *Asterionella japonica*, *Nitzschia spp*, *Chaetoceros spp* and *Pyrocystis fusiformis*. The microalgae within the size range of < 250 – 150 µm contributed 0.25 mg / m^3, i.e. 5.4 % of the total chlorophyll *a*. *Chaetoceros curvisetus*, *Asterionella japonica*, *Skeletonema costatum*, Chaetoceros *spp*, *Bacteriastrum varians*, *Thalassiothrix longissima*, *Biddulphia mobiliensis*, *Nitzschia delicatissima* and *Ditylum sol* were found in this size group. The size fraction of < 150 – 105 µm was contributed 0.40 mg / m^3, i.e. 8.6 % of the total chlorophyll *a*, *Chaetoceros curvisetus* and *Asterionella japonica*, *Chaetoceros spp*, *Bacteriastrum varians*, *Streptotheca thamensis*, *Nitzschia delicatissima*, *Thalassiothrix longissima*, *Rhizosolenia alata*, *Biddulphia mobiliensis*, *Guinardia flaccida*, *Leptocylindrus danicus*, *Skeletonema costatum* and *Oscillatoria nigroviridis* were the microflora present. The microflora within the size range of < 105 – 53 µm contributed 0.43 mg / m^3, i.e. 9.2 % of the total. *Chaetoceros curvisetus*, Asterionella *japonica*, *Chaetoceros spp*. *Nitzschia spp*. *Coscinodiscus radiatus*. *Rhizosolenia stolterfothii*. *Skeletonema costatum*. *Thalassiothrix longissima*. *Thalassiosira coramandeliana*, *Ditylum sol*, *Eucampia zoodiacus*. *Biddulphia mobiliensis*, *Streptotheca thamensis*. *Bacteriastrum varians*. *Guinardia flaccida*. *Ceratium furca* and *Ceratium fusus* were present in this size fraction. The size group of < 53 – 25 µm contributed 0.39 mg / m^3, i.e. 8.4 % of the total chlorophyll *a*. *Skeletonema costatum*. *Asterionella japonica*. *Nitzschia spp*. *Thalassiosira subtilis*. *Pleurosigma directum*, *Coscinodiscus radiatus*. *Rhizosolenia stolterfothii*, *Thalassiothrix frauenfeldii*, *Navicula hennedyii*. *Thalassionema nitzschioides*, *Biddulphia mobiliensis*. *Leptocylindrus danicus*. *Corethron inerme*. *Chaetoceros curvisetus*, *Guinardia flaccida*. *Ceratium furca*. *Peridinium tuba*. *Dinophysis caudata* and *Gonyaulax sp* were the microflora present. The contribution of the microalgae of the size group of < 25 – 10 µm was 0.63 mg / m^3, i.e. 13.5 % of the total chlorophyll *a*. *Skeletonema costatum*, *Nitzschia spp*. *Navicula spp*, *Coscinodiscus radiatus*, *Pleurosigma directum*. *Rhizosolenia stolterfothii*. *Leptocylindrus danicus*. *Thalassiosira coramandeliana*. *Thalassiothrix frauenfeldii*. *Thalassionema nitzschioides* and *Dinophysis caudata* were present at varying concentration. The most significant contribution was that of the smallest size group of < 10 µm in size, its contribution was 2.39 mg / m^3, 51.4 % of the total chlorophyll *a*. The species present were *Skeletonema costatum*, *Nitzschia longissima*, *Navicula hennedyii*. *Fragilaria oceanica*. *Rhizosolenia stolterfothii* and *Thalassiosira coramandeliana*.

The total amount of chlorophyll *a*, at station 2, during the post-monsoon season has been found to be 4.65 mg / m^3 (Table 5.6).

- Table 5.6- Average values of chlorophyll *a* during the post-monsoon season at station 2.

Size groups ▼	Chlorophyll *a* (mg / m^3)	%
> 500 µm	0.06	1.3
< 500 – 250 µm	0.10	2.2
< 250 – 150 µm	0.25	5.4
< 150 – 105 µm	0.40	8.6
< 105 – 53 µm	0.43	9.2
< 53 – 25 µm	0.39	8.4
< 25 – 10 µm	0.63	13.5
< 10 µm	2.39	51.4
Total	4.65	100

DISCUSSION:

The quantum of primary photosynthetic pigment i.e. chlorophyll *a* in the water sample is considered as a measure of the standing crop of primary producers and potential productivity. Planktonic algae of the all size fractions contribute to the total amount of the pigment. but the relative contribution of each size group varies depending on the hydrographic parameters predominating in the area as well as the selective grazing of herbivorous zooplankton.

In the coastal waters of Cochin, south-west coast of India at station 1, during the pre-monsoon season, the amount of chlorophyll *a* was increasing with the decrease in the size of planktonic algae. It has been found to increase from 0.10 mg / m^3 in the size group of > 500 µm to 0.47 mg / m^3 for the size group of < 105 – 53 µm. In the next smaller size group of < 53 – 25 µm chlorophyll *a* concentration was decreased to 0.33 mg / m^3. The highest chlorophyll *a* concentration was recorded by the size group of < 10 µm for which the value was 1.35 mg / m^3. The relatively low concentration of chlorophyll *a* within the size groups of < 53 – 25 µm and < 25 – 10 µm might have been due to the grazing effect by herbivorous zooplankton. Heinrich (1962) emphasized that spatial and temporal variations in the standing crop must include consideration of the timing and intensity of grazing. The total amount of chlorophyll *a* was relatively low during this season with an average value of 3.10 mg / m^3; this may be due to the low concentration of nutrients in the coastal waters and/or intensive grazing during the pre-monsoon season. Jayaraman and Sheshappa (1957) assumed that the seasonal variations in the phytoplankton pigments are controlled by phosphate concentration in the sea off Cochin.

During the monsoon season, the lowest value of 0.24 mg / m^3 was observed for the largest size group of > 500 µm, while the higher values were found in the size groups < 105 – 53 µm and < 10 µm, with averages of 4.59 mg / m^3; and 4.46 mg / m^3, respectively. It was increasing from 0.24 mg / m^3 at > 500 µm size group to 4.59 mg / m^3 at the size group of < 105 – 53 µm, then decreases to reach the value of 1.28 mg / m^3 at < 25 – 10 µm size fraction, then increases to 4.46 mg / m^3 at the smallest size group of < 10 µm. The high values of chlorophyll *a* concentration at relatively larger size fractions of < 105 – 53 µm and < 53 – 25 µm can be attributed to the high concentration of nutrients in the coastal waters during the monsoon season which enhance the growth of larger planktonic algae. The low concentration of chlorophyll *a* in the size group of < 25 – 10 µm might have been the result of the selective grazing by zooplankton. The total content of chlorophyll *a* is relatively high during the monsoon period; this may be due to the high concentration of nutrients in the coastal water during this time of the year. The average value of total chlorophyll *a* concentration was 14.92 mg / m^3.

In the post-monsoon season, chlorophyll *a* concentration was generally increasing gradually with the decrease in the size of planktonic algae. The lowest value of 0.10 mg / m^3 was recorded in the larger size group of > 500 µm, whereas the highest value of 6.30 mg / m^3 recorded in the smallest size group of < 10 µm. Li et al (1998), found the same trend in the East China Sea, in which chlorophyll *a* content increases gradually with the decreasing size of microalgae. The total amount of chlorophyll *a* during the post-monsoon season was found to be intermediate, higher than the amount observed during the pre-monsoon and lower than that was reported during the monsoon season. The average value recorded was 9.05 mg / m^3

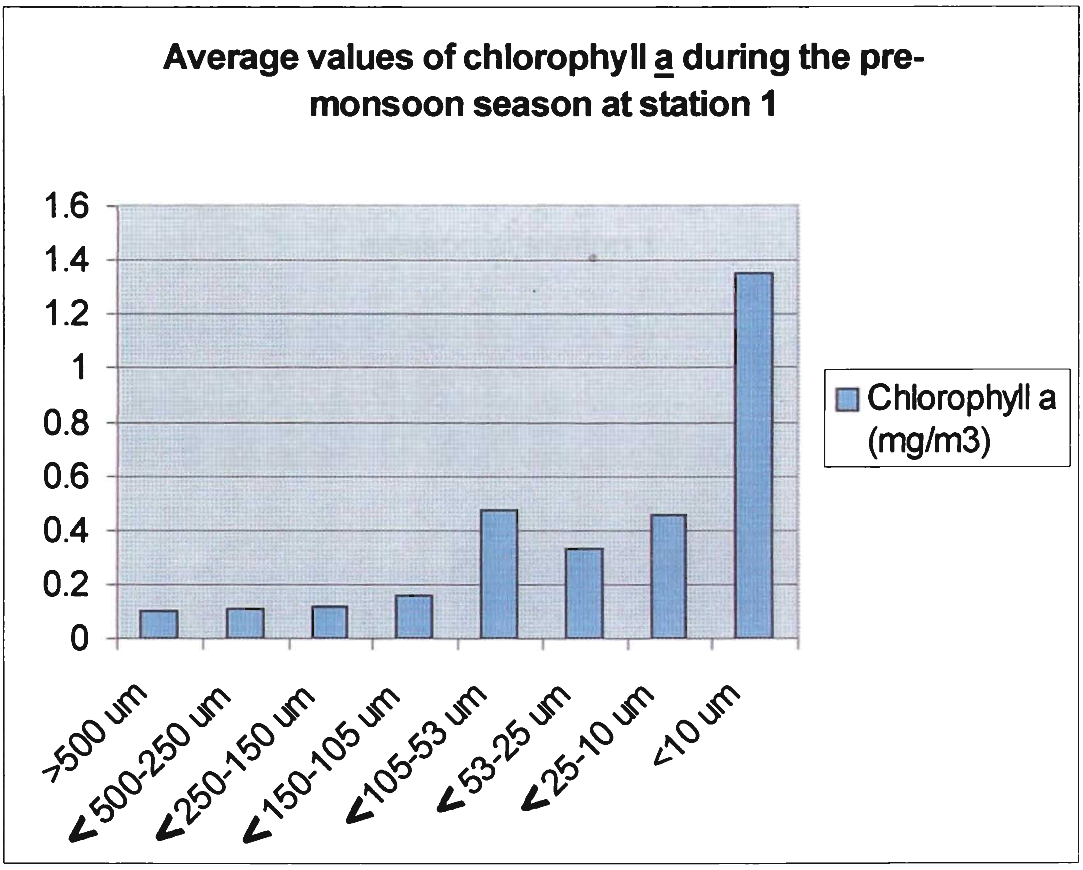
At station 2, during the pre-monsoon season, chlorophyll *a* concentration increases from 0.11 mg / m^3 for the size fraction of > 500 µm to 0.52 mg / m^3 for the size group of < 105 – 53 µm, then decreased to 0.47 mg / m^3 for the size group of < 53 – 25 µm, then increases again to reach its highest value of 2.12 mg / m^3 at the smallest size group of < 10 µm. The low concentration at the size group of < 53 – 25 µm may be due to the selective grazing effect of zooplankton. The total chlorophyll *a* concentration was found to be low in the pre-monsoon months, that is may be due to the low concentration of nutrients and/or intensive grazing. The average value recorded during this season was 4.51 mg / m^3.

In the monsoon season, the amount of chlorophyll *a* was fluctuating between 0.10 mg / m^3 at the largest size group of > 500 µm and 1.88 mg / m^3 at the smallest size group of < 10 µm. It has been found to increase from 0.10 mg / m^3 at the largest size fraction to 1.15 mg / m^3 at the size group of < 105 – 53 µm, then decreases to reach 0.53 mg / m^3 at < 25 – 10 µm size group; the smallest size fraction of < 10 µm was having the highest chlorophyll *a* value, 1.88 mg / m^3. The high concentration of chlorophyll *a* at the relatively larger size groups of < 105 – 53 µm and < 53 – 25 µm may be attributed to the higher concentration of nutrients in the coastal water during this season which enhances the growth of relatively larger planktonic algae. The low concentration of chlorophyll *a* for the size group of < 25 – 10 µm might be due to the selective grazing of plankton feeders. The total amount of chlorophyll *a* during the monsoon season was relatively high, with average value of 5.28 mg / m^3; this is due to the higher concentration of nutrients in the coastal waters during the monsoon period.

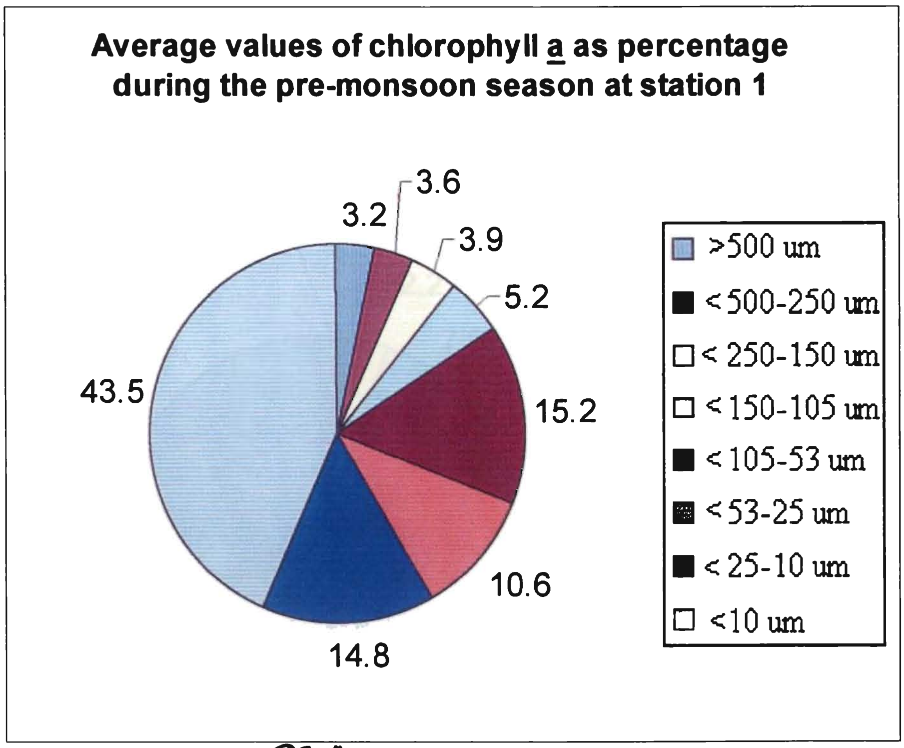
During the post-monsoon season, the distribution of the total chlorophyll *a* among the various size fractions had shown the same trend, with the lower concentration of 0.06 mg / m^3 existing in the larger size group of > 500 µm and the highest of 2.39 mg / m^3 in the smallest size fraction of < 10 µm. With the same trend, it was increasing from 0.06 mg / m^3 at the larger size group of > 500 µm to 0.43 mg / m^3 at the size group of < 105 – 53 µm, then decreases at the size group of < 53 – 25 µm, with only 0.39 mg / m^3, then increases to reach its highest value of 2.39 mg / m^3 at the smallest size fraction of < 10 µm. The low chlorophyll *a* content in the size group of < 53 – 25 µm can be recalled again as a result of selective grazing of the herbivorous zooplankton. The total amount was slightly higher than that of the pre-monsoon value. The average total chlorophyll *a* value was 4.65 mg / m^3. The lower chlorophyll *a* values at station 2, during the monsoon and the post-monsoon seasons may be occurred due to the environmental stress as well as the grazing effect at this station.

Generally, in the coastal waters of Cochin, south-west coast of India, the contribution of various size fractions of planktonic algae to the total chlorophyll *a* has been found to increase with the decrease in the size of microalgae. Li et al (1998) found the same trend in the East China Sea, he reported that, picoplankton, nanoplankton and net plankton accounted on average for 47, 33 and 20 % of the total chlorophyll. The relatively low concentration of chlorophyll *a* which may be observed in the size fractions of < 53 – 25 µm and < 25 – 10 µm can be attributed to the selective grazing of zooplankton.

During the pre-monsoon and post-monsoon seasons, the contribution of the planktonic algae < 25 µm in size to the total chlorophyll *a* is significantly higher than that of the larger planktonic algae, whereas during the monsoon season, the contribution of the microflora > 25 µm is more important.

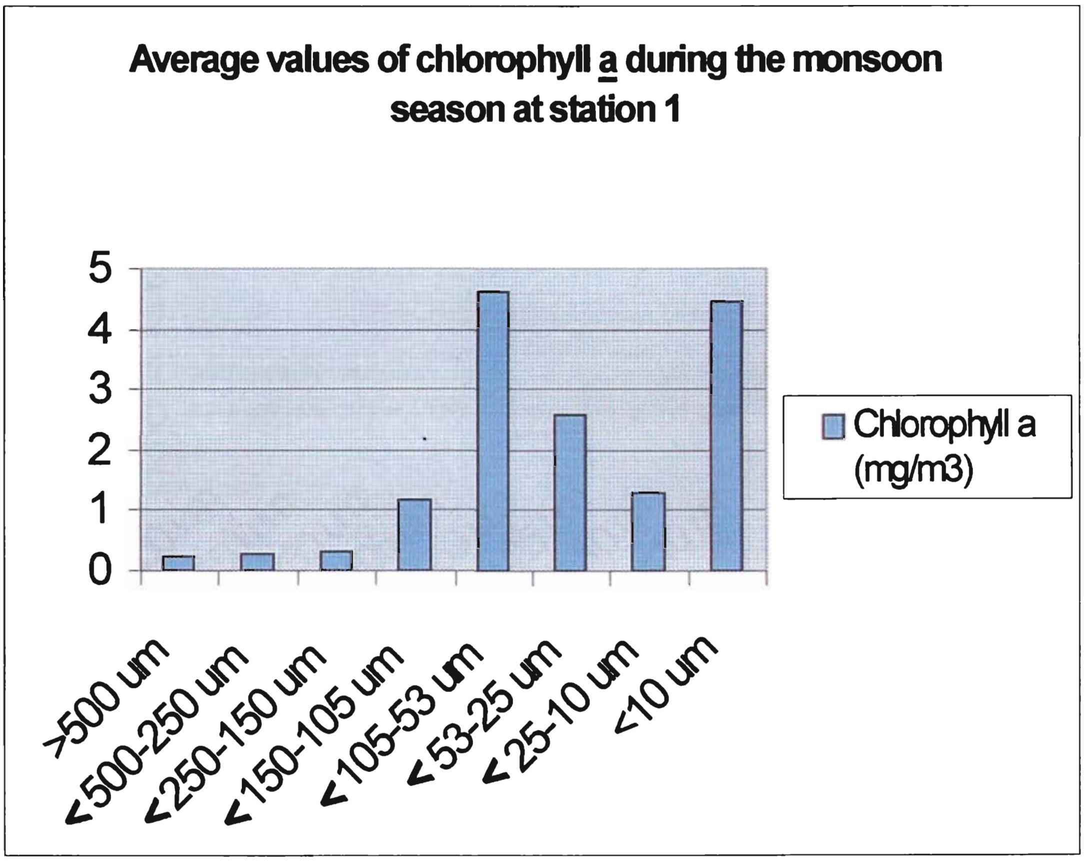


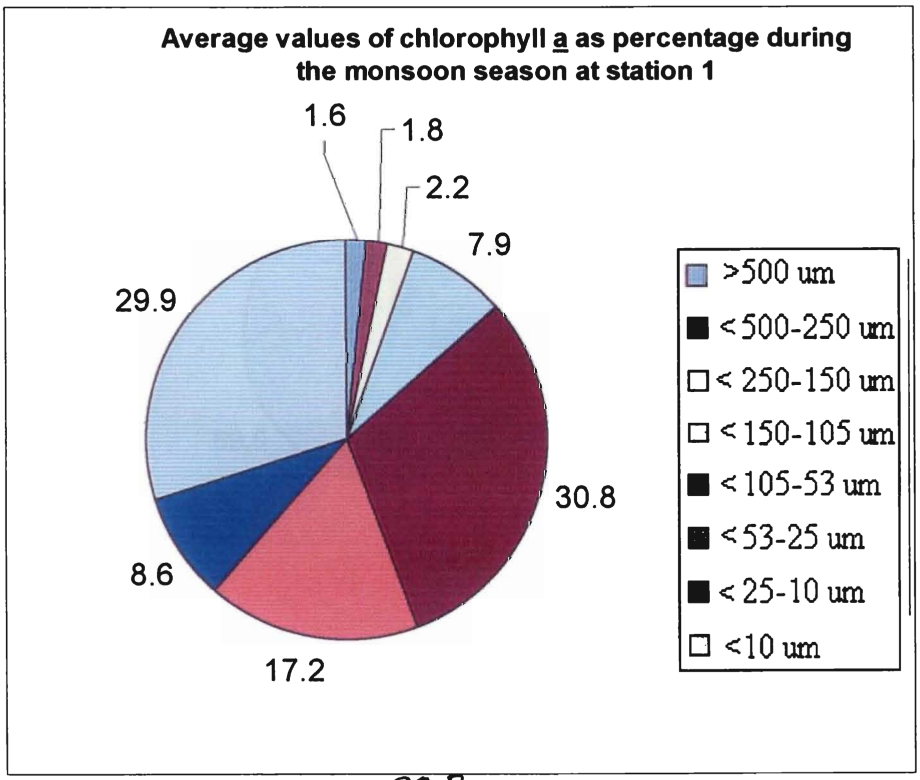
Average values of chlorophyll a during the pre-monsoon season at station 1
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um
Chlorophyll a (mg/m3)

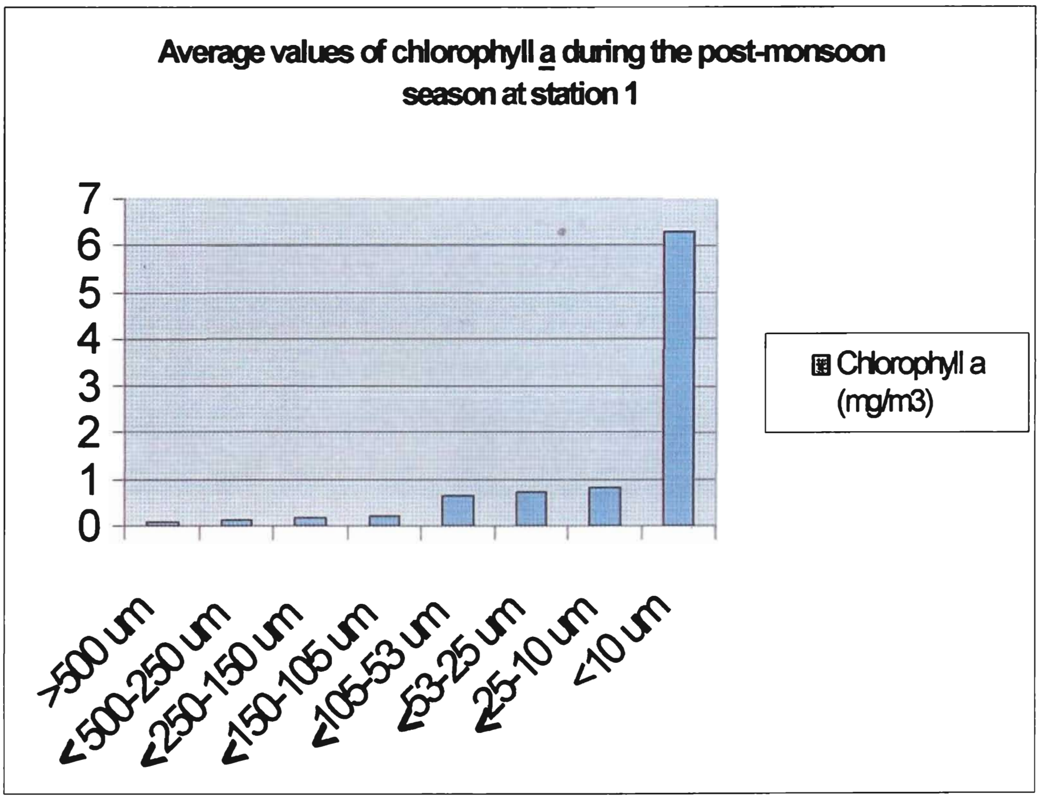


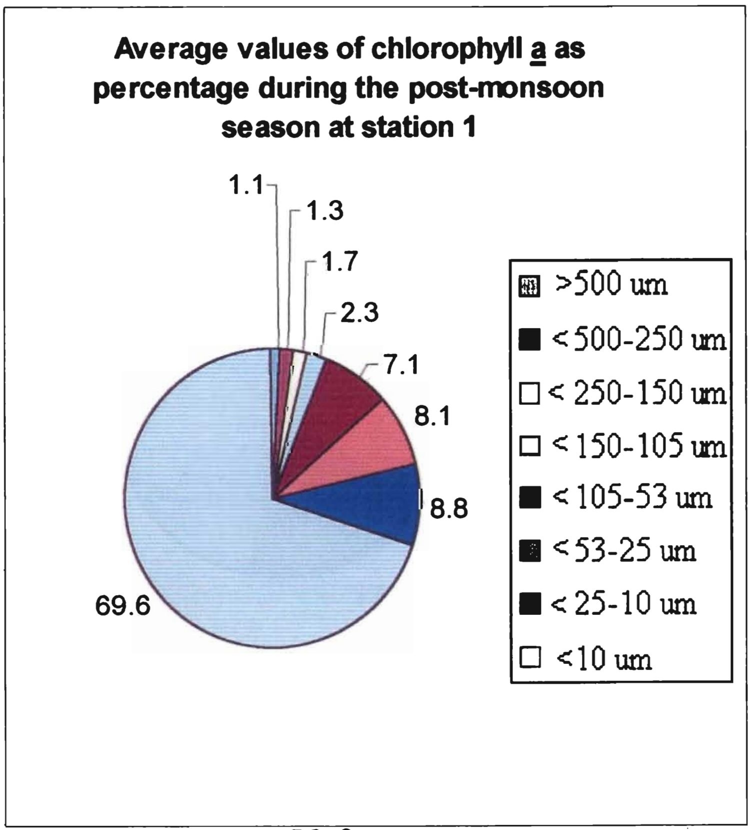
Average values of chlorophyll a as percentage during the pre-monsoon season at station 1
3.2
3.6
3.9
5.2
15.2
10.6
14.8
43.5
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
<10 um

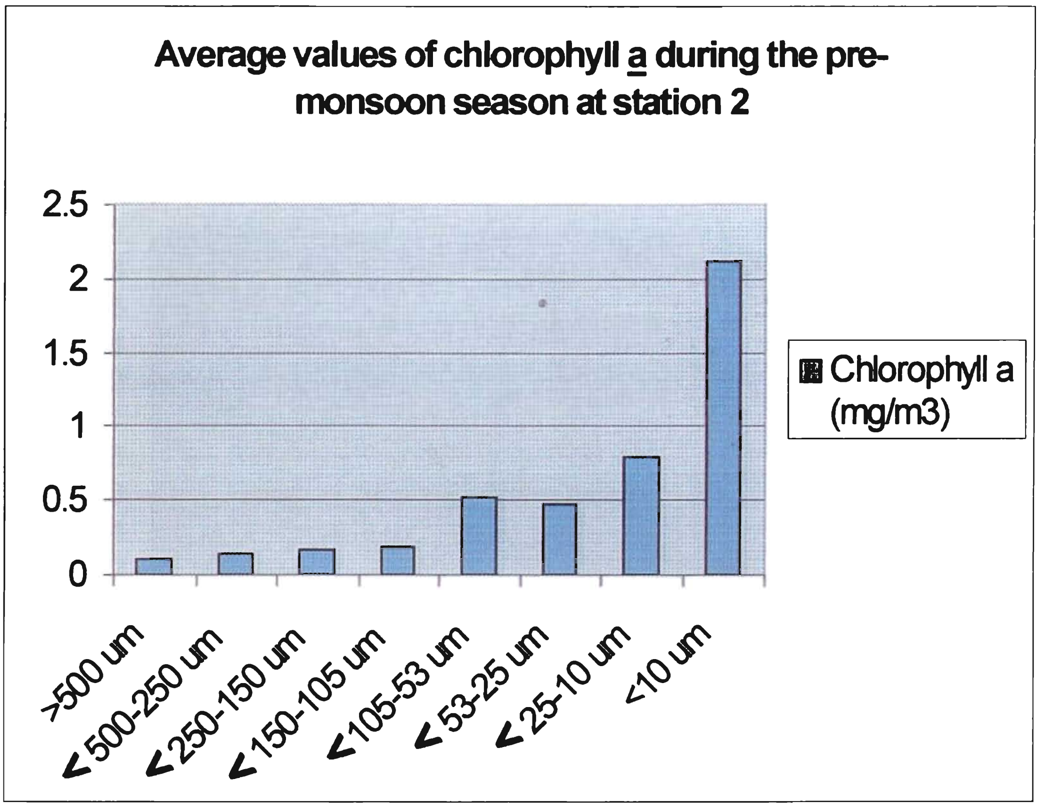
99 A

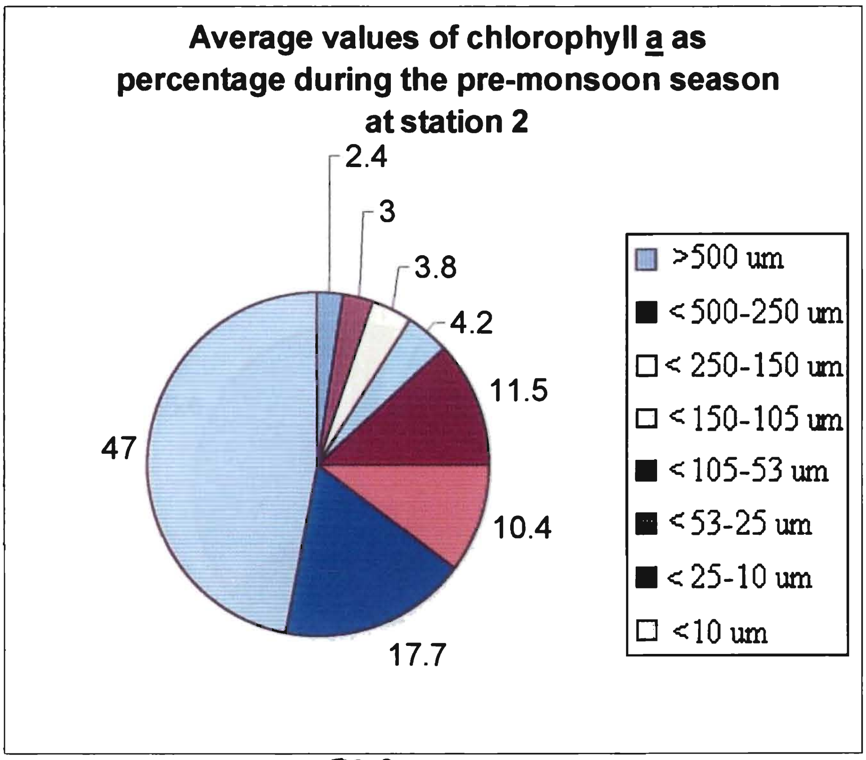

Average values of chlorophyll a during the monsoon season at station 1
5
4
3
2
1
0
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um
Chlorophyll a (mg/m3)


Average values of chlorophyll a as percentage during the monsoon season at station 1
1.6
1.8
2.2
7.9
29.9
30.8
8.6
17.2
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
<10 um

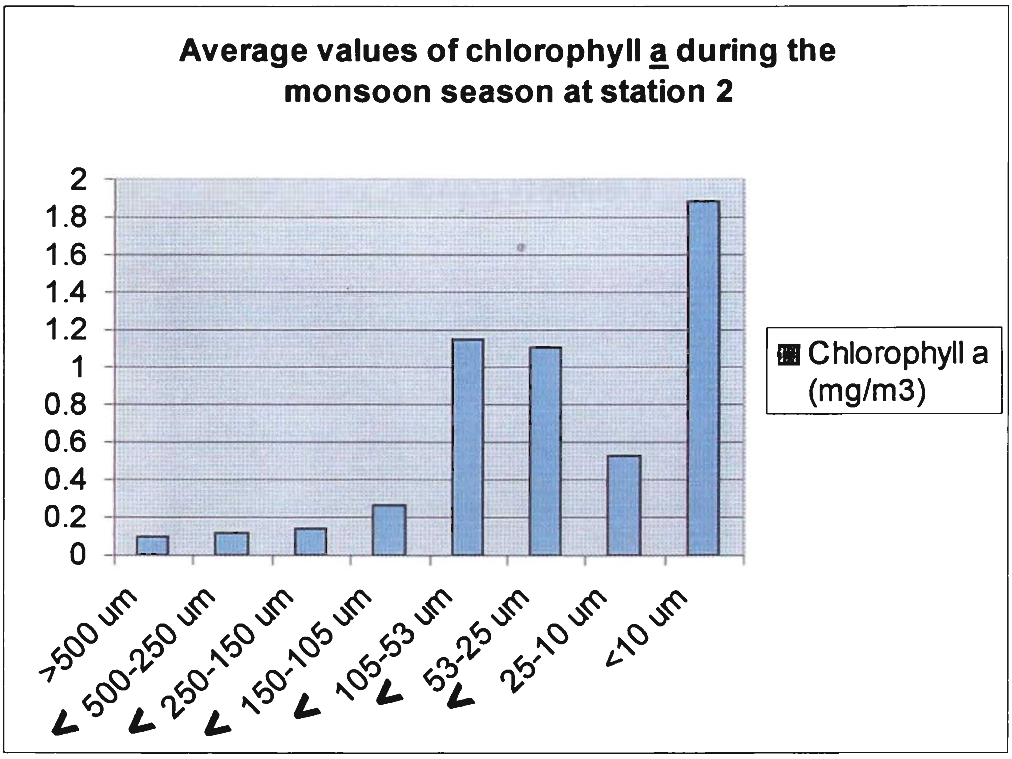

Average values of chlorophyll a during the post-monsoon season at station 1
7
6
5
4
3
2
1
0
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um
Chlorophyll a (mg/m3)


Average values of chlorophyll a as percentage during the post-monsoon season at station 1
1.1
1.3
1.7
2.3
7.1
8.1
8.8
69.6
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
<10 um

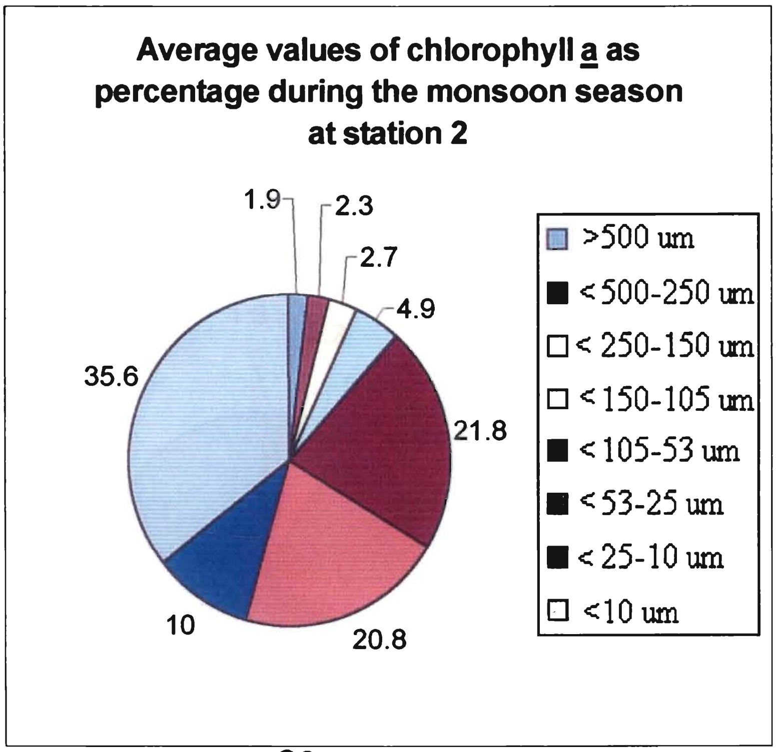

Average values of chlorophyll a during the pre-monsoon season at station 2
2.5
2
1.5
1
0.5
0
Chlorophyll a (mg/m3)
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um


Average values of chlorophyll a as percentage during the pre-monsoon season at station 2
2.4
3
3.8
4.2
11.5
10.4
17.7
47
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
<10 um

99 D

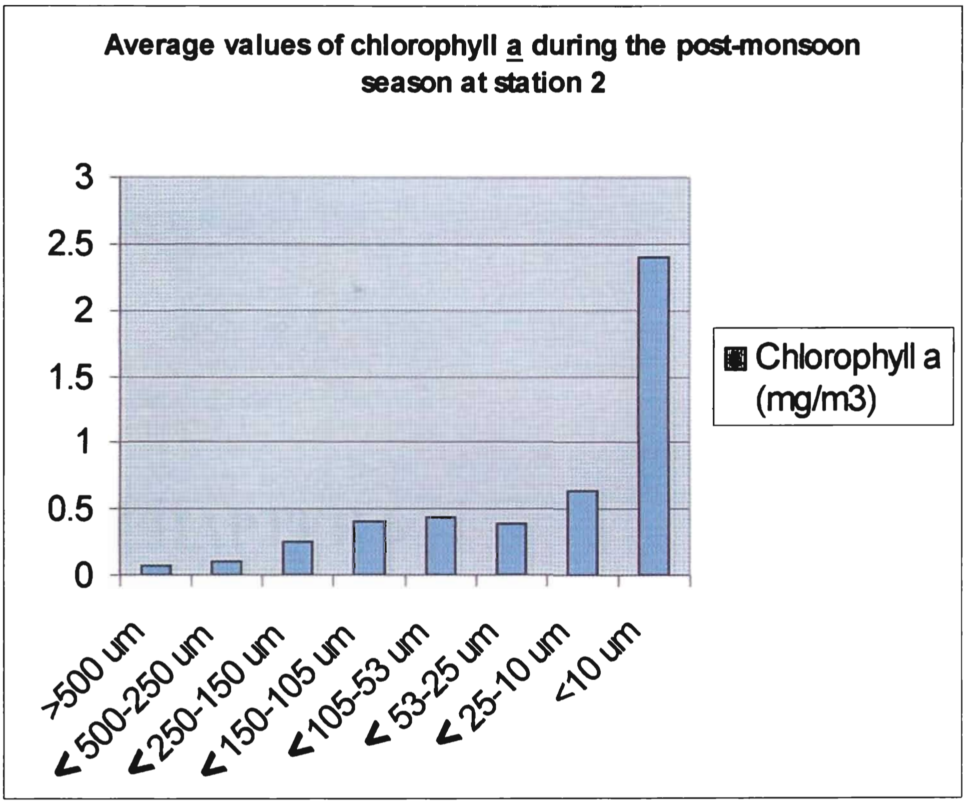


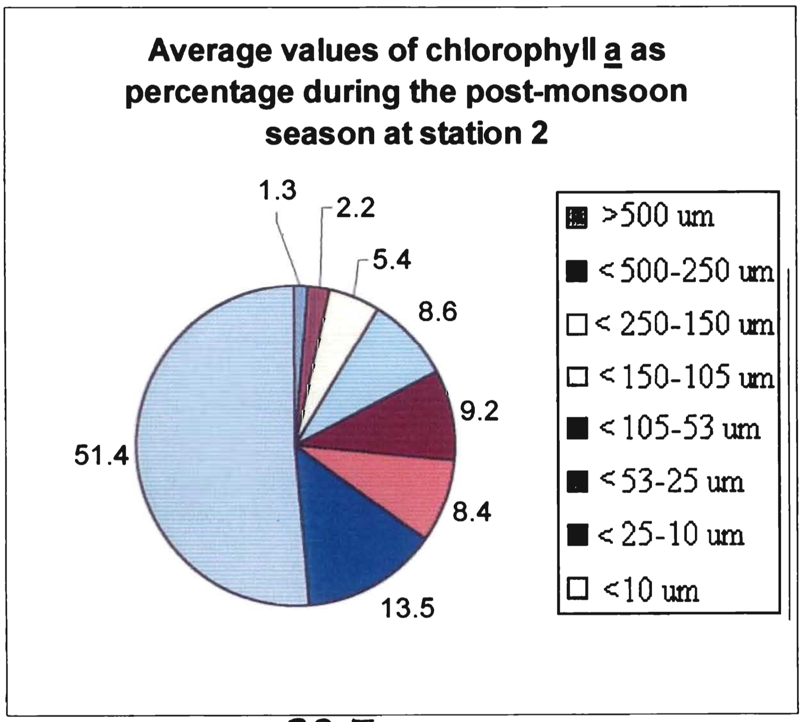
Average values of chlorophyll a during the monsoon season at station 2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
<10 um
Chlorophyll a (mg/m3)



Average values of chlorophyll a as percentage during the monsoon season at station 2
1.9
2.3
2.7
4.9
21.8
20.8
10
35.6
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
<10 um

99E


Average values of chlorophyll a during the post-monsoon season at station 2
3
2.5
2
1.5
1
0.5
0
Chlorophyll a (mg/m3)
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um


Average values of chlorophyll a as percentage during the post-monsoon season at station 2
1.3
2.2
5.4
8.6
9.2
8.4
13.5
51.4
>500 um
<500-250 um
< 250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um

99 F

CHAPTER 6

FRACTIONATED PRIMARY ORGANIC PRODUCTIVITY

- INTRODUCTION:

Production of organic matter by planktonic algae is of utmost importance as the entire fishery resources are dependent on this phenomenon. Productivity of planktonic algae depends on the hydrographic parameters of the particular environment such as light intensity, temperature, salinity, nutrients, grazing etc. which vary spatially and seasonally.

Seasonal variations in primary production in oceanic regions are generally correlated with latitudes. In general, productivity in warm oceans, especially in the centre of major gyres, is low, apart from areas of up welling and divergences, and is subjected to relatively small and often irregular fluctuations throughout the year. By contrast, seas at moderately high latitudes may show a much higher level of primary production though this is strongly influenced by pronounced seasonal fluctuations. In most regions of the world, whatever the latitude, primary production in the coastal regions is normally higher than that of the oceanic areas.

Various size groups of planktonic algae synthesize food at the primary trophic level, and have a significant role in the bio productivity of the marine ecosystem. The relevance of the contribution of various size fractions is more in the diet of consumers. The larvae of pelagic fishes and shellfishes need very small size of planktonic algae; their requirements increase with the increasing size of larvae. Since the various size fractions of planktonic algae form the food of the different varieties of consumers, many of them being selective feeders, the study of different size fractions of microalgae and their relative contribution to the primary organic production is a useful tool for the estimation of the quantities and qualities of fisheries.

Several attempts have been done for studying the contribution of various size fractions of planktonic algae to the primary production in different parts of the world ocean. Broeckel (1985) found that, in the south-eastern Weddell Sea. 70 % of the total primary production (670 mg C / m^2 / day) was contributed by the < 20 µm size fraction (usually pennate and / or centric diatoms). In the temperate neritic water of Funka Bay. Japan. 66 % of the annual primary production occurred during the spring phytoplankton bloom with 95 % being accounted for by the > 10 µm size fraction. which was dominated by diatoms (Maita. 1988). Under low nutrient concentrations during summer, small phytoplankters (< 2 µm) accounted for 40 to 75 % of the total primary production at the central station. and from 25 to 59 % at the coastal station. A sudden nutrient enrichment at the coastal station during the summer triggered the growth of the large size fraction. Hopcroft (1990) showed that, in the shelf waters south of Kingston. Jamaica. the contribution of net plankton (> 20 µm), nanoplankton (2 – 20 µm) and picoplankton (0.2 – 2 µm) to the total primary production was 27, 30 and 43 %, respectively. Gradinger et al. (1992) reported that, in the central Red Sea and Gulf of Aden. 76 – 77 % of the total chlorophyll *a* and primary production was contributed by picoplankton (0.2 – 2 µm). Ning et al. (1993) found that, in the Indian sector of the southern Ocean, the contribution of nanoplankton with picoplankton to the total productivity was 69 %, which prove their importance in phytoplankton community of the Antarctic waters. Wang et al. (1996) found that, nanoplankton (3 – 20 µm) contributed 58.32 % and 41.14 % of primary productivity of Ziamen western waters and the northern Taiwan strait, respectively. Picoplankton (0.2 – 3 µm) dominated the productivity (66.09 %) in the southern Taiwan Strait. Bradford (1997) showed that, off the west and east coasts of south Island, New Zealand, in austral winter and spring, picoplankton (< 2 µm) formed > 30 % of the integrated chlorophyll *a* and daily potential primary production in most water types and seasons, except when the 20 – 200 μm size fraction dominated in west coast waters in spring and in subtropical convergence in winter and spring.

In the Indian waters, Joseph (1988) found that, in the coastal waters of the south-west coast of India, 62.6 % of the total primary production is contributed by microalgae of < 60 μm in size. Gomes et al. (1992) reported that, in the Andaman Sea, of the total mean euphotic column production, 37 % was attributed to picoplankton, whereas nano and net phytoplankton contributed 40 and 23 %, respectively. Kawabata (1993) showed that, in Vellar estuary (south-east coast of India); the highest gross production is attributed to the microalgae of the size fraction of 5 – 10 μm.

The present chapter aims at the elucidation of the contribution of >500, < 500-250, < 250-150, < 150-105, <105-53, < 53-25, < 25-10 and <10 μm size groups of planktonic algae to the primary organic productivity of the south west coast of India.

- RESULTS:

The contribution of various size fractions of planktonic algae to the total primary productivity is not uniform which again shows seasonal and spatial fluctuations.

In the coastal waters of Cochin, south-west coast of India, at station 1, during the pre-monsoon season, the rate of primary production of the largest size group of > 500 μm has been found to be 5.8 mg C / m^3 / day, which was 1.9 % of the total production. Productivity of the planktonic algae within the size range of < 500 – 250 μm increased to 6.9 mg C / m^3 / day, i.e. 2.2 % of the total primary production. The contribution of the size group of < 250 – 150 μm increased to 7.6 mg C / m^3 / day, i.e. 2.5 %. The planktonic algae of the size fraction of < 150 – 105 μm contributed 12.1 mg C / m^3 / day, i.e. 3.9 % of the total primary production. Planktonic algae of the size group of < 105 – 53 μm gave 19.9 mg C / m^3 / day, contributing 6.5 % of the total productivity. The size group of < 53 – 25 µµm gave only 11.8 mg C / m^3 /day, recording 3.8 % of the total production. The size fraction of < 25 – 10 µµm recorded 21.4 mg C / m^3 day, i.e. 7.0 %. The highest contribution to the total primary production was that of the planktonic algae of the smallest size group of < 10 µm, in which the productivity was 222.4 mg C / m^3 / day, composing 72.2 % of the total primary productivity. The total primary production during the pre-monsoon season was relatively low, 307.9 mg C / m^3 / day. (Table 6.1).

In the monsoon season, the largest size fraction of > 500 µm contributed 9.6 mg C / m^3 / day, which is only 1.1 %. The planktonic algae within the size range of < 500 – 250 µm were found to contribute by 15.0 mg C m^3 / day, which is 1.7 % of the total primary production. Primary production of the planktonic algae in the size group of < 250 – 150 µm has been found to be 23.1 mg C / m^3 / day, 2.7 % of the total productivity. The increase in primary production continues also in the size group of < 150 – 105 µm, in which the productivity was 31.7 mg C / m^3 / day, 3.8 %. A significant increase in the primary production has been noticed in the size fraction of < 105 – 53 µm, in which the recorded productivity was 221.4 mg C / m^3 /day, i.e. 25.8 %. A decrease in productivity has been recorded in the size group of < 53 – 25 µm, in which the microalgae were contributing by 101.2 mg C / m^3 / day, which is 11.8 % of the total primary production. A sharp decrease in primary production has been found in the size fraction of < 25 – 10 µm, where the recorded productivity was only 34.4 mg C / m^3 / day, i.e. 4.0 % of the total production. The highest contribution was that of the planktonic algae within the smallest size group of < 10 µm, which was contributing by 421.3 mg C / m^3 / day, 49.1 % of the total primary production. Generally, the total primary production during the monsoon season is relatively high, 857.7 mg C / m^3 / day. (Table 6.2).

During the post-monsoon season, the contribution of the largest size group of > 500 µm to the total productivity was found to be 4.0 mg C / m^3 / day, composing 0.9 % of the total primary production. The planktonic algae of the size fraction of < 500 – 250 µm contributed by 7.6 mg C / m^3 / day, which was 1.6 %. The rate of primary production of the planktonic algae within the size range of < 250 – 150 µm was found to be 14.3 mg C / m^3 / day, contributing 3.0 % of the total productivity. The planktonic algae of the size fraction of < 150 – 105 µm were found to contribute by 16.1 mg C / m^3 / day, 3.4 % of the total production. Productivity of the microalgae of the size group of < 105 – 53 µm recorded 18.8 mg C / m^3 / day, 4.0 %. The increase in productivity was also observed in the size group of < 53 – 25 µm, in which the primary production was 21.8 mg C / m^3 / day, 4.7 % of the total productivity. In the size group of < 25 – 10 µm, productivity also increased recording 24.9 mg C / m^3 / day, which was 5.3 %. The highest contribution to the total primary production was that of the planktonic algae within the smallest size group of < 10 µm, which contributed by 361.6 mg C / m^3 / day, 77.1 % of the total productivity. The total productivity during the post-monsoon season was higher than that of the pre-monsoon season but lower than that of the monsoon season recording 469.1 mg C / m^3 / day (Table 6.3).

At station 2, during the pre-monsoon season, primary production of the largest size group of > 500 µm has been found to be 7.8 mg C / m^3 / day, contributing 1.8 % of the total productivity. The planktonic algae within the size group of < 500 – 250 µm contributed by 16.9 mg C / m^3 / day, i.e. 3.9 % of the total production. The increase in productivity continues in the size group of < 250 – 150 µm, in which productivity was recorded to be 23.5 mg C / m^3 / day, 5.5 %. The increase in productivity has been seen in the size fraction of < 150 – 105 µm, where primary productivity was 25.7 mg C / m^3 / day, 6.0 % of the total production. The increase in production has been also recorded in the size group of < 105 – 53 µm, in which productivity was 42.2 mg C / m^3 / day, 9.8 %. A remarkable decrease in primary production has been recorded in the size group of < 53 – 25 µm, where productivity was only 28.3 mg C / m^3 / day, 6.6 %. Productivity increases again in the size group of < 25 – 10 µm, recording 52.6 mg

C / m^3 / day, 12.2 % of the total carbon fixed. The highest contribution to the total primary production was that of the planktonic algae within the smallest size group of < 10 µm, which was contributing by 233.3 mg C / m^3 / day, 54.2 %. The total primary production was relatively low during the pre-monsoon season, 430.3 mg C / m^3 / day (Table 6.4).

In the monsoon season, the contribution of the largest size group of > 500 µm to the total productivity was found to be 11.3 mg C / m^3 / day, 2.2 %. The size group of < 500 – 250 µm contributed by 16.2 mg C / m^3 / day, 3.1 % of the total primary production. The increase in primary production continues in the size group of < 250 – 150 µm, in which productivity was found to be 35.8 mg C / m^3 / day, 6.8 %. The planktonic algae within the size range of < 150 – 105 µm have been found to contribute with 79.7 mg C / m^3 / day, 15.2 % of the total productivity. The climax of the gradual increase in productivity was reached in the size group of < 105 – 53 µm, which was contributing by 88.6 mg C / m^3 / day, 16.9 % to the total primary production. A decrease was noticed in the size group of < 53 – 25 µm, in which primary productivity has been found to be 86.5 mg C m^3 / day, 16.5 %. A sharp decrease in productivity was found in the size group of < 25 – 10 µm, where the recorded primary production was only 27.1 mg C / m^3 day, 5.2 % of the total carbon fixed. The major contribution was that of the planktonic algae of the smallest size group of < 10 µm, which was contributed by 178.8 mg C / m^3 / day, 34.1 % of the total productivity. The total primary production was relatively high during the monsoon season, 524.0 mg C / m^3 / day (Table 6.5).

During the post-monsoon season, productivity of the largest two size groups (> 250 µm) was practically nil. The planktonic algae within the size range of < 250 – 150 µm contributed by 28.0 mg C / m^3 / day, 5.6 % of the total primary production. Productivity of the size group of < 150 – 105 µm has been found to be 37.5 mg C / m^3 / day, which is 7.5 % of the total carbon fixed. Primary production continues to increase in the size group of < 105 – 53 µm, in which the recorded productivity was 39.2 mg C / m^3 / day, 7.8 %. A decrease in productivity was noticed in the size group of < 53 – 25 µm, where the recorded productivity was 37.4 mg C / m^3 / day, 7.5 % of the total production. Primary production increased again in the size group of < 25 – 10 µm, contributing by 80.7 mg C / m^3 / day, 16.1 % to the total productivity. Here also, the highest contribution to the total primary organic productivity was attributed to the planktonic algae < 10 µm in size, which have been found to contribute by 277.5 mg C / m^3 / day, 55.5 % of the total production. The total primary production during the post-monsoon season has been found to be higher than that of the pre-monsoon season, but lower than that of the monsoon season, recording 500.3 mg C / m^3 / day (Table 6.6).

- DISCUSSION:

Primary organic productivity in the coastal waters of Cochin, south-west coast of India is controlled by the hydrographic parameters, especially nutrients which determine also the contribution of various size fractions of planktonic algae to the total primary production.

At station 1, during the pre-monsoon season, productivity was found to increase gradually from 5.8 mg C / m^3 / day for the largest size group of > 500 µm to 19.9 mg C / m^3 / day for the size group of < 105 – 53 µm, then decreases to 11.8 mg C / m^3 / day for the size group of < 53 – 25 µm, then increases again to reach the highest value for the smallest size group of < 10 µm, in which the recorded productivity was 222.4 mg C / m^3 / day. The low productivity at the size group of < 53 – 25 µm could be attributed to the selective grazing of zooplankton which reduce the standing crop of planktonic algae of this size group and hence lower their primary production. During this season, the contribution of the planktonic algae < 25 µm in size, to the total productivity was highly significant, this may be due to the low concentration of nutrients in the coastal waters, in such conditions the smallest planktonic algae grow well and better than the larger microalgae, that is, due to their higher efficiency to absorb nutrients as compared with the larger micro flora. The total primary production has been found to be low, 307.9 mg C / m^3 / day; this may be attributed to the low concentration of nutrients, especially phosphate, in the coastal waters, during the pre-monsoon period.

In the monsoon season, primary production was gradually increasing from 9.6 mg C / m^3 / day for the largest size group of > 500 µm to 221.4 mg C / m^3 / day for the size group of < 105 – 53 µm, then decreases to reach 34.4 mg C / m^3 / day for the size group of < 25 – 10 µm. The major contribution was that of the smallest size group of < 10 µm, where the recorded productivity was 421.3 mg C / m^3 / day. The low productivity in the size groups of < 53 – 25 µm and < 25 – 10 µm can be attributed to the selective grazing by zooplankton. During the monsoon season, the microalgae > 10 µm contribute significantly to the total primary production, this is due to the availability of high concentration of nutrients in the coastal waters, which enhance growth and productivity of the larger microalgae. The total primary production, has been found to be high, 857.7 mg C / m^3 / day, during the monsoon months, this may be due to the availability of high concentration of nutrients, brought to the coastal waters by the seasonal up welling and land-run off associated with rains.

During the post-monsoon season, primary productivity has been found to increase from 4.0 mg C / m^3 / day for the largest size group of > 500 µm to 361.6 mg C / m^3 / day for the smallest size group of < 10 µm, this may indicate a decreased grazing intensity or shifted grazing towards the smallest size group of microalgae or both. The total productivity was higher than that of the pre-monsoon season, but lower than that of the monsoon season, recording 469.1 mg C / m^3 / day (Table 6.3), and this is showing a positive correlation between productivity and phosphate concentration in the south-west coast of India. During this season, the major contribution to the total productivity was that of the planktonic algae < 25 μm in size.

At station 2, during the pre-monsoon season, productivity of the various size groups has shown the same trend as that at station 1. Productivity increases from 7.8 mg C / m^3 / day for the largest size group of > 500 μm to 42.2 mg C /m^3 day for the size group of < 105 – 53 μm, then decreases for the size group of < 53 – 25 μm, recording only 28.3 mg C / m^3 / day, then increases again to reach the highest value, 233.3 mg C / m^3 / day at the smallest size group of < 10 μm. The low productivity at the size group of < 53 – 25 μm could be attributed to the intensive and selective grazing by zooplankton during this season of the year. Here also, the microalgae < 25 μm in size contributed significantly to the total primary production. The total primary production was found to be low, 430.3 mg C / m^3 / day, during the pre-monsoon season, this may be occurred due to the intensive grazing by zooplankton associated with the relatively low concentration of nutrients in the coastal waters during the pre-monsoon period.

In the monsoon season, the contribution of various size fractions of planktonic algae to the total productivity increases from 11.3 mg C / m^3 / day for the largest size group of > 500 μm to 88.6 mg C / m^3 / day for the size group of < 105 – 53 μm, then decreases at the size groups of < 53 – 25 μm and < 25 – 10 μm recording 86.5 mg C / m^3 / day, and 27.1 mg C / m^3 / day, respectively. The major contribution was that of the microalgae within the smallest size group of < 10 μm, in which primary production was found to be 178.8 mg C / m^3 / day. Low productivity at size groups of < 53 – 25 μm and < 25 – 10 μm may be attributed to the selective grazing by zooplankton. During the monsoon period, the major contribution of planktonic algae to the total primary production was that of the microalgae > 10 μm in size. The total productivity was relatively high, 524.0 mg C / m^3 / day; this may be due to the availability of high concentration of nutrients in the coastal waters during the monsoon season.

During the post-monsoon season, productivity of the planktonic algae > 250 µm was practically nil. A gradual increase in the contribution of various size groups of planktonic algae to the total productivity was noticed. It was increasing from 28.0 mg C / m^3 / day at the size group of < 250 – 150 µm to 39.2 mg C / m^3 / day for the size group of < 105 – 53 µm. The size group of < 53 – 25 µm recorded 37.4 mg C / m^3 / day. Highest production value of 277.5 mg C / m^3 / day was recorded at the smallest size group of < 10 µm. Low productivity for the size group of < 53 – 25 µm can be attributed to the selective grazing by zooplankton. Here also, the major contribution to the total primary production was that of the planktonic algae < 25 µm in size. The total productivity has been found to be greater than that of the pre-monsoon season and less than that of the monsoon season recording. 500.3 mg C m^3 / day, indicating low grazing intensity during the post-monsoon season.

Generally, high primary production was observed in the coastal waters of Cochin, south-west coast of India during the SW monsoon season, when high concentration of nutrients is available in the coastal waters. Kabanova (1968), summarizing the results of primary production measurements in the Indian Ocean by the expeditions of various countries, indicated that the period of summer SW monsoon was more productive than the period of winter NE monsoon. Maximova (1971) summarized the distribution of nutrients in relation to primary production. The distribution of primary production in the areas north of 40 ° S followed the same general pattern as that of nutrients. There was positive correlation between the average values in 5° latitudinal zones of the primary production and of the nutrients in the surface 100 m layer.

During the pre-monsoon season, productivity was low at both stations, due to the low concentration of nutrients in the coastal waters associated with intensive grazing by zooplankton.

In the post-monsoon period, productivity values have been found to be intermediate between that of the pre-monsoon and the monsoon seasons, due to the presence of relatively low concentration of nutrients accompanied with mild grazing activity by zooplankton.

Regarding the contribution of various size groups of planktonic algae to the total productivity in the south-west coast of India, it has been noticed that productivity increases with the decrease in size of planktonic algae except in the case of the size groups of < 53 – 25 µm and < 25 – 10 µm. This is may be due to the selective grazing by zooplankton, which in turn reduce the standing crop of planktonic algae at these size groups and hence lower the rate of their primary production.

Generally, in the coastal waters of Cochin, south-west coast of India, during the pre and the post-monsoon seasons, the major contribution to the total primary production was that of the planktonic algae < 25 µm in size. This may be due to the relatively low concentration of nutrients in the coastal waters. In such conditions, smaller microalgae, due to their higher efficiency to absorb nutrients, grow well and reproduce better than the larger microalgae. During the monsoon season, the microalgae > 10 µm in size contribute significantly to the total primary production, as there is high concentration of nutrients in the coastal waters, which enhance growth and reproduction of the larger microalgae. Maita (1988) found that, in the temperate neritic water of Funka Bay, Japan, 66 % of the annual primary production occurred during the spring phytoplankton bloom with 95 % being accounted for by the size fraction of > 10 µm, which was dominated by diatoms. Under low nutrient concentrations during summer, small microalgae (< 2 µm) accounted for 40 to 75 % of the total primary production at the central station, and from 25 to 59 % at the coastal station. A sudden nutrient enrichment at the coastal station during the summer triggered the growth of the larger microalgae.

- Table 6.1- Contribution of size fractions of planktonic algae to productivity during the pre-monsoon season at station 1.

Size groups ▼	mg C / m^3 / day	%
> 500 µm	5.8	1.9
< 500 – 250 µm	6.9	2.2
< 250 – 150 µm	7.6	2.5
< 150 – 105 µm	12.1	3.9
< 105 – 53 µm	19.9	6.5
< 53 – 25 µm	11.8	3.8
< 25 – 10 µm	21.4	7.0
< 10 µm	222.4	72.2
Total	307.9	100

- Table 6.2- Contribution of size fractions of planktonic algae to productivity during the monsoon season at station 1.

Size groups ▼	mg C / m^3 / day	%
> 500 µm	9.6	1.1
< 500 – 250 µm	15.0	1.7
< 250 – 150 µm	23.1	2.7
< 150 – 105 µm	31.7	3.8
< 105 – 53 µm	221.4	25.8
< 53 – 25 µm	101.2	11.8
< 25 – 10 µm	34.4	4.0
< 10 µm	421.3	49.1
Total	857.7	100

- Table 6.3- Contribution of size fractions of planktonic algae to productivity during the post-monsoon season at station 1.

Size groups ▼	mg C / m^3 / day	%
> 500 µm	4.0	0.9
< 500 – 250 µm	7.6	1.6
<250 – 150 µm	14.3	3.0
< 150 – 105 µm	16.1	3.4
< 105 – 53 µm	18.8	4.0
< 53 – 25 µm	21.8	4.7
< 25 – 10 µm	24.9	5.3
< 10 µm	361.6	77.1
Total	469.1	100

- Table 6.4- Contribution of size fractions of planktonic algae to productivity during the pre-monsoon season at station 2.

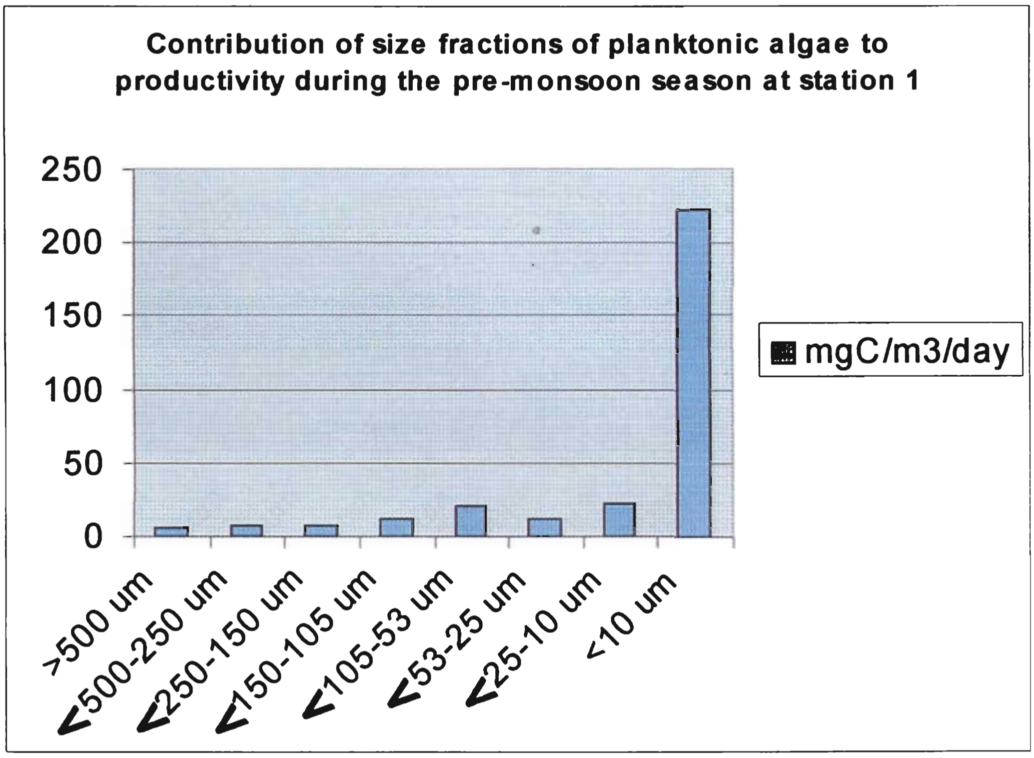
Size groups ▼	mg C / m^3 / day	%
> 500 µm	7.8	1.8
< 500 – 250 µm	16.9	3.9
< 250 – 150 µm	23.5	5.5
< 150 – 105 µm	25.7	6.0
< 105 – 53 µm	42.2	9.8
< 53 – 25 µm	28.3	6.6
< 25 – 10 µm	52.6	12.2
< 10 µm	233.3	54.2
Total	430.3	100

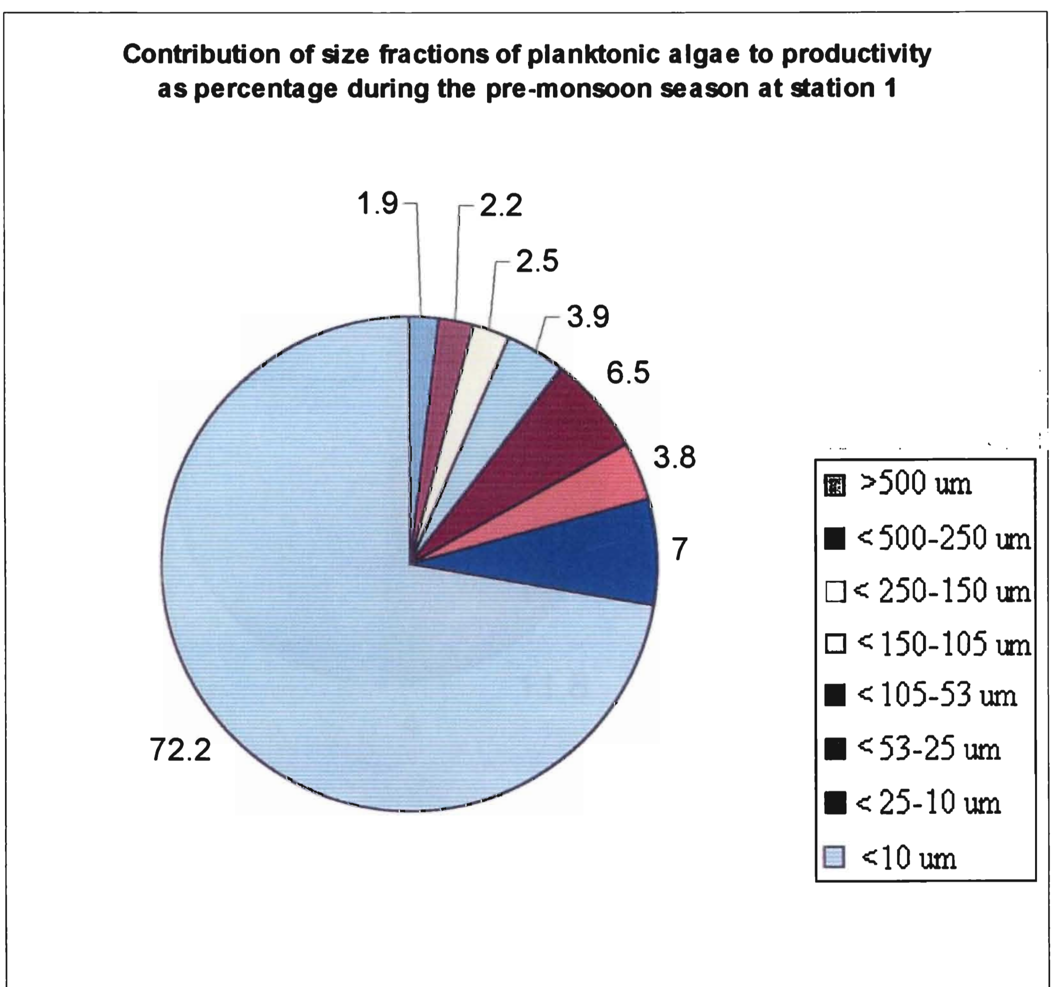
- Table 6.5- Contribution of size fractions of planktonic algae to productivity during the monsoon season at station 2.

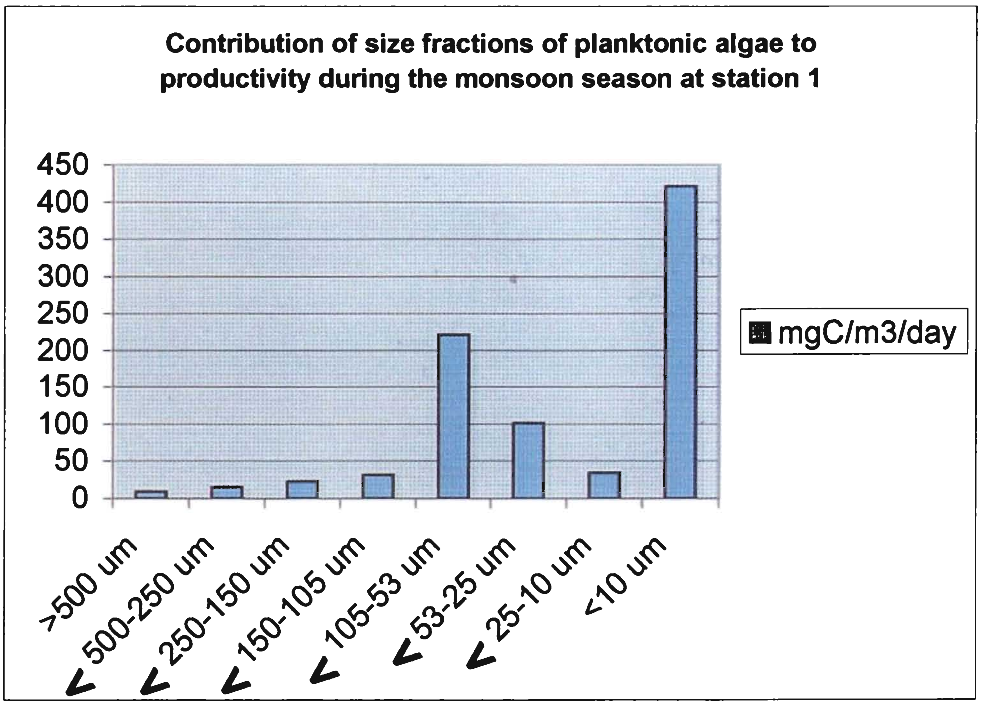
Size groups ▼	mg C / m^3 / day	%
> 500 µm	11.3	2.2
< 500 – 250 µm	16.2	3.1
< 250 – 150 µm	35.8	6.8
< 150 – 105 µm	79.7	15.2
< 105 – 53 µm	88.6	16.9
< 53 – 25 µm	86.5	16.5
< 25 – 10 µm	27.1	5.2
< 10 µm	178.8	34.1
Total	524.0	100

- Table 6.6- Contribution of size fractions of planktonic algae to productivity during the post-monsoon season at station 2.

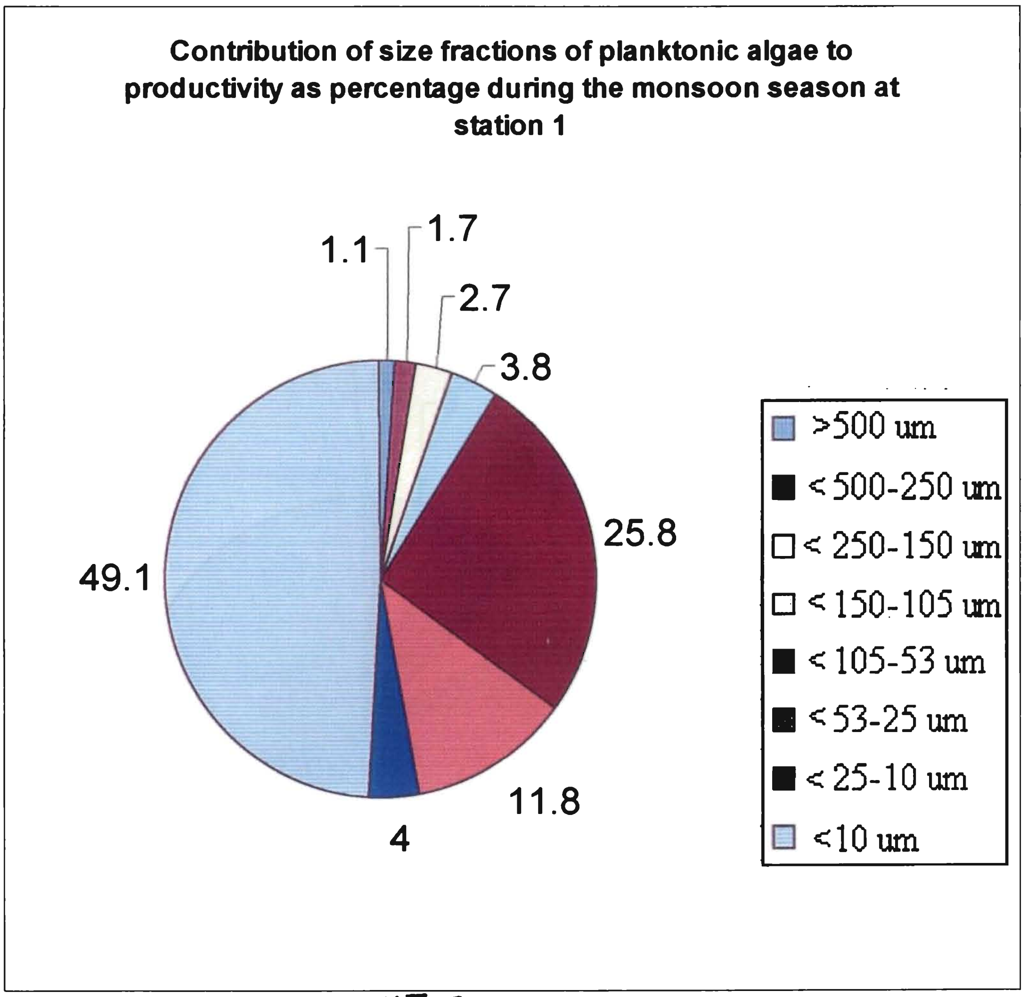
Size groups ▼	mg C / m^3 / day	%
> 500 µm	–	–
< 500 – 250 µm	–	–
< 250 – 150 µm	28.0	5.6
< 150 – 105 µm	37.5	7.5
< 105 – 53 µm	39.2	7.8
< 53 – 25 µm	37.4	7.5
< 25 – 10 µm	80.7	16.1
< 10 µm	277.5	55.5
Total	500.3	100


Contribution of size fractions of planktonic algae to productivity during the pre-monsoon season at station 1
250
200
150
100
50
0
mgC/m3/day
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um


Contribution of size fractions of planktonic algae to productivity as percentage during the pre-monsoon season at station 1
1.9
2.2
2.5
3.9
6.5
3.8
7
72.2
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
<10 um

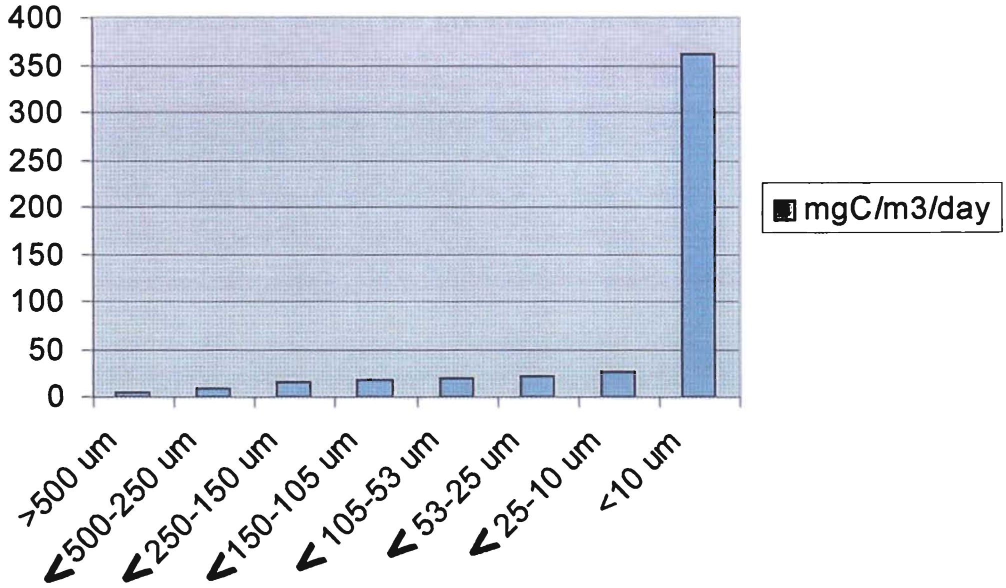


Contribution of size fractions of planktonic algae to productivity during the monsoon season at station 1

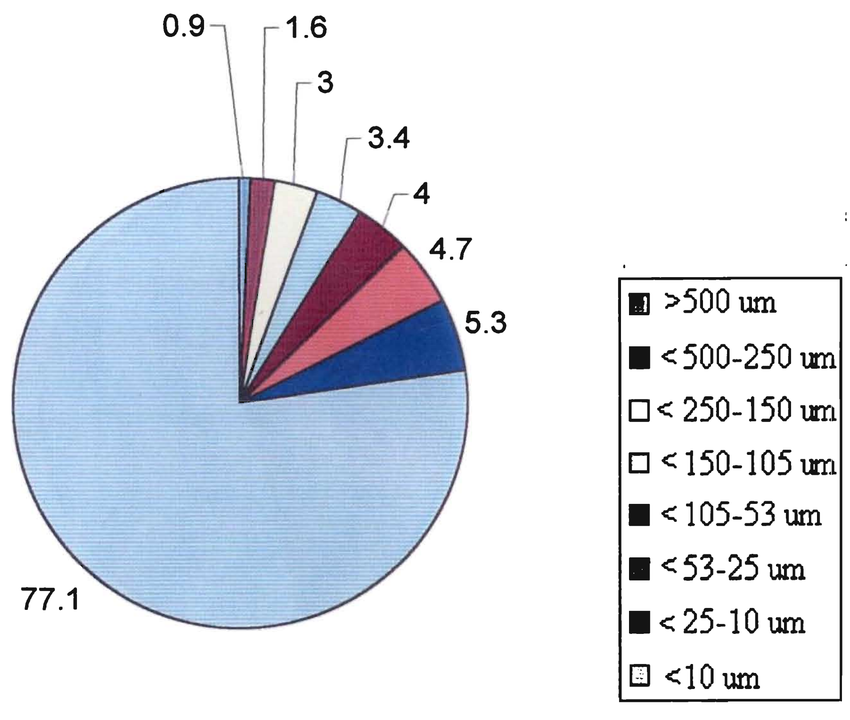


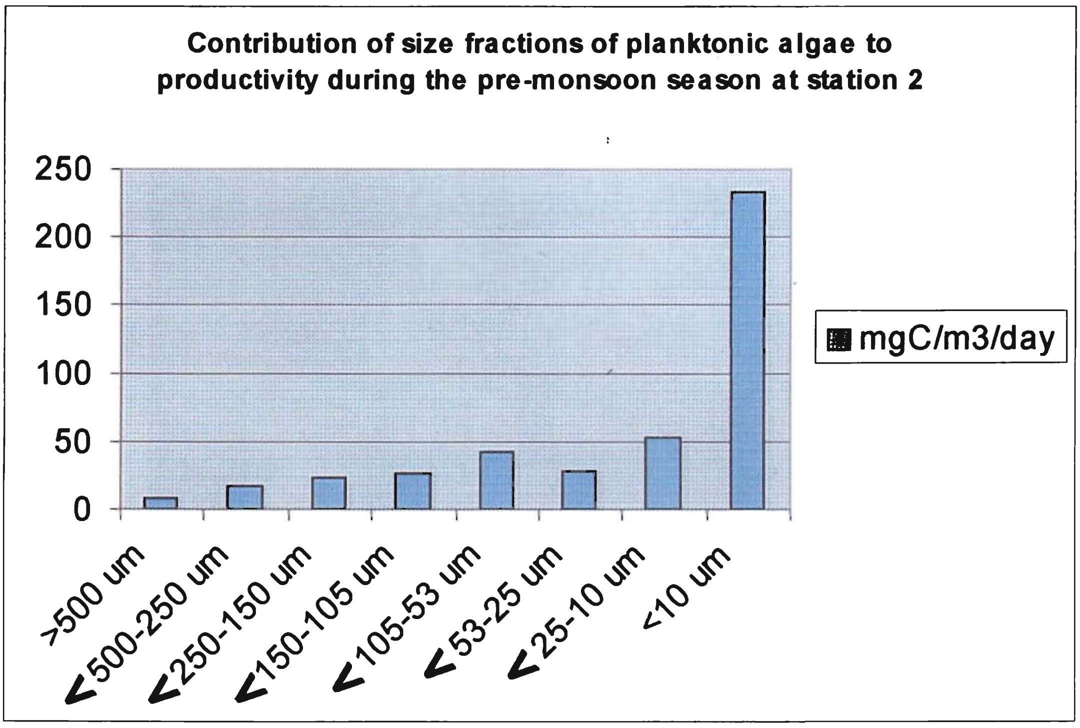
Contribution of size fractions of planktonic algae to productivity as percentage during the monsoon season at station 1

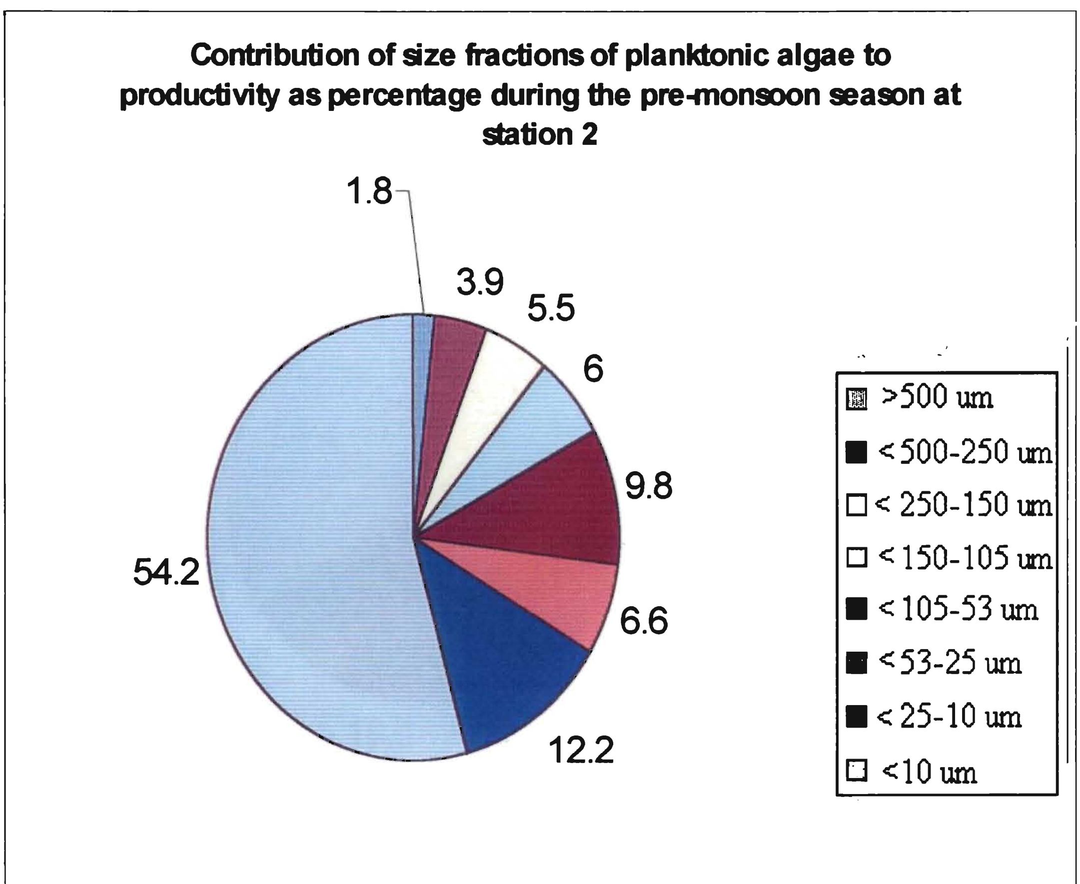
Contribution of size fractions of planktonic algae to productivity during the post-monsoon season at station 1

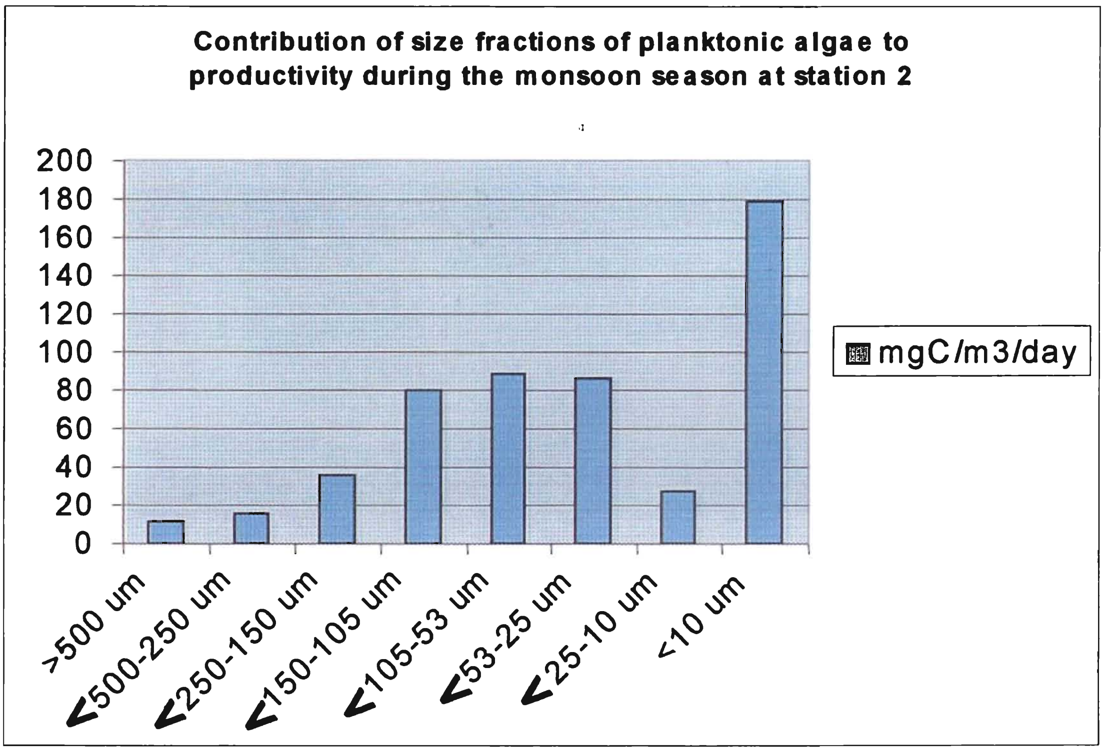


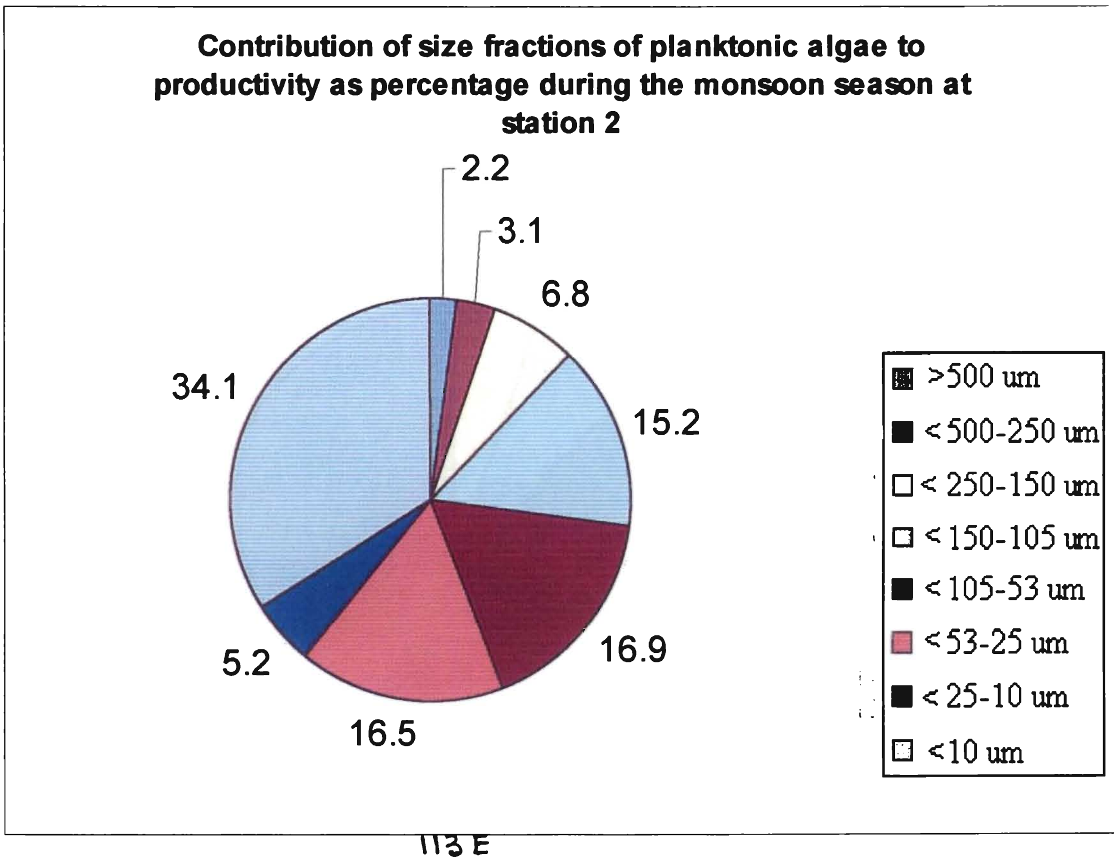
Contribution of size fractions of planktonic algae to productivity as percentage during the post-monsoon season at station 1

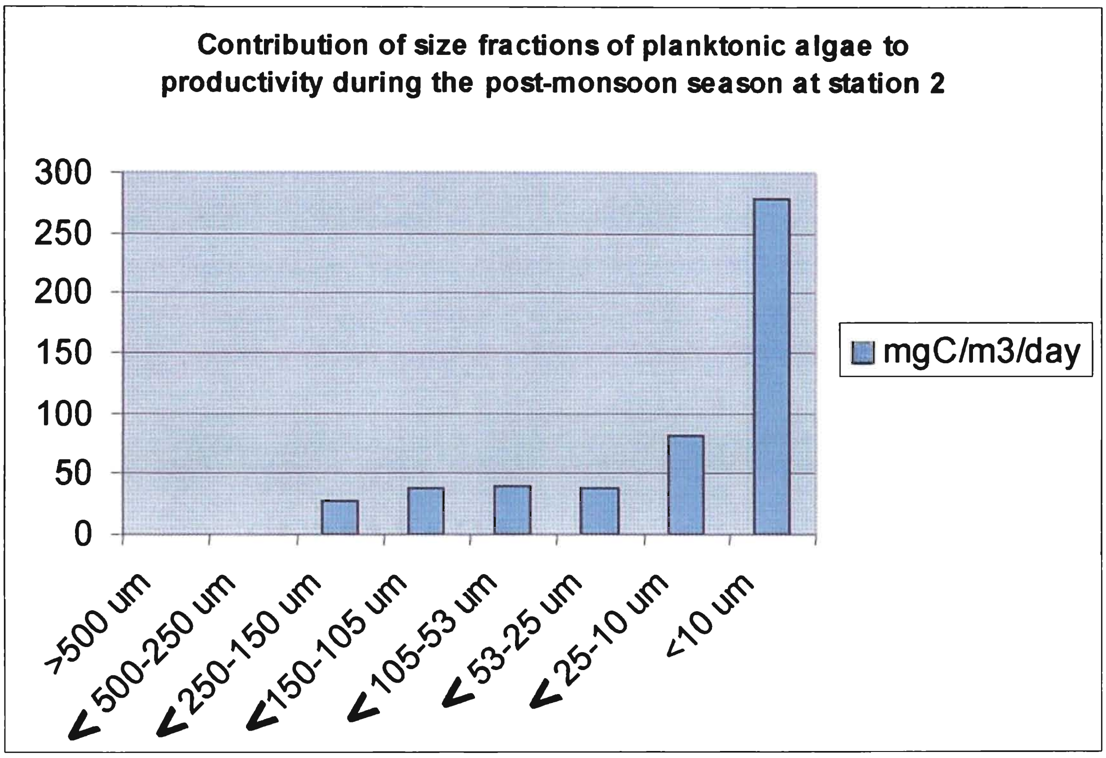



Contribution of size fractions of planktonic algae to productivity during the pre-monsoon season at station 2
250
200
150
100
50
0
mgC/m3/day
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um


Contribution of size fractions of planktonic algae to productivity as percentage during the pre-monsoon season at station 2
1.8
3.9
5.5
6
9.8
6.6
12.2
54.2
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
<10 um


Contribution of size fractions of planktonic algae to productivity during the monsoon season at station 2
200
180
160
140
120
100
80
60
40
20
0
mgC/m3/day
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um


Contribution of size fractions of planktonic algae to productivity as percentage during the monsoon season at station 2
2.2
3.1
6.8
15.2
16.9
16.5
5.2
34.1
>500 um
< 500-250 um
< 250-150 um
< 150-105 um
< 105-53 um
< 53-25 um
< 25-10 um
< 10 um


Contribution of size fractions of planktonic algae to productivity during the post-monsoon season at station 2
300
250
200
150
100
50
0
mgC/m3/day
>500 um
<500-250 um
<250-150 um
<150-105 um
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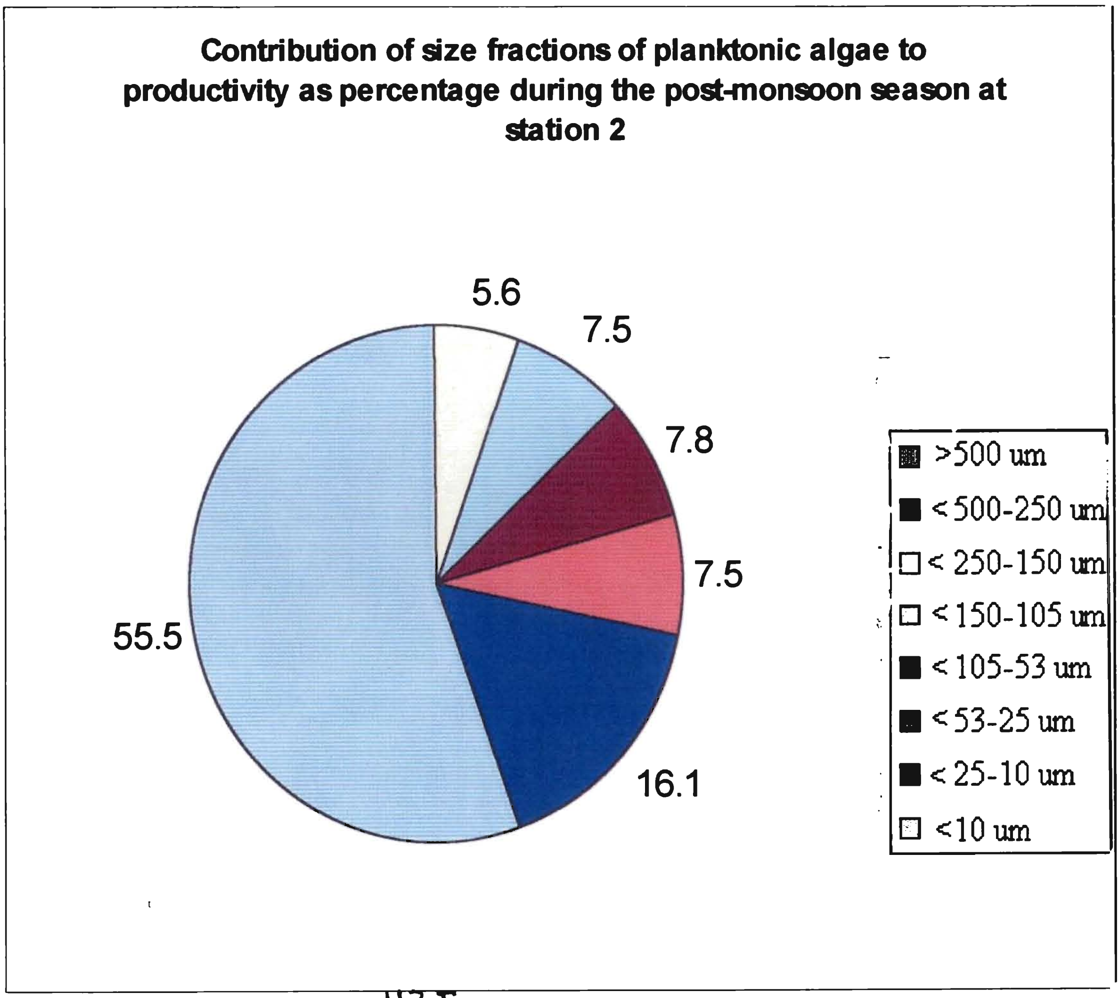
Contribution of size fractions of planktonic algae to productivity as percentage during the post-monsoon season at station 2
5.6
7.5
7.8
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>500 um
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< 25-10 um
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SUMMARY

SUMMARY

The bioproductivity of the marine environment is dependent on various primary producers, ranging in size from picoplankton to larger macro phytoplankton. The quantity and quality of various size fractions of planktonic algae at any locality depend mainly on the hydrographic conditions of the area under study.

India is characterized by a steady annually occurring phenomenon, viz., the "monsoon" or the rainy season. Accordingly, the climatic seasons in India are divided into: 1) the pre-monsoon season (February – May), 2) the monsoon season (June – September) and the post-monsoon season (October – January). In the south west coast of India, temperature has been found to be within the limits of tolerance throughout the year, and does not have a significant effect on growth and productivity of planktonic algae. The sea surface has been found to receive sufficient light throughout the year. Salinity appears to have little or no significant role on the growth and productivity of planktonic algae. Nutrients have been found to be the most important ecological factor controlling growth and productivity of planktonic algae. Higher concentrations of nutrient salts during the monsoon season in the coastal waters occur due to the up welling of subsurface cold-nutrient rich waters, and also as a result of land-run off associated with heavy rains during this season.

In the coastal waters of Cochin, south west coast of India, planktonic algal community is composed mainly of the diatoms, the dinoflagellates, the blue-green algae and the silicoflagellates, the former two contributing the major flora and found distributed in the all size fractions. The maximum number of species of diatoms at station 1 and station 2 was found in the pre-monsoon season, 33 species and 32 species, respectively, comprising 73.4 % and 76.2 % of total number of species of planktonic algae. The minimum number of species of

diatoms was observed during the monsoon season. 28 species at station 1; and 22 species at station 2, 82.4 % and 88.0 % of the total flora, respectively (tables 3.1 & 3.2). Dinoflagellates have been found to be more abundant during the pre-monsoon season with 9 species at station 1; and 7 species at station 2. The lowest number of species of dinoflagellates was recorded during the monsoon season with 3 species at station1: and only 1 species at station 2 (tables 3.1 & 3.2). The maximum number of species of planktonic algae was recorded in the pre-monsoon season, with 45 species at station 1; and 42 species at station 2. The minimum number of species has been found at both stations during the monsoon season, with 34 species at station 1; and 25 species at station 2 (table 3.3).

Generally, the size groups of planktonic algae greater than 53 µm are dominated by filamentous, chain forming and colonial diatoms, while the size groups smaller than 53 µm usually formed of small and unicellular pennate and centric diatoms, dinoflagellates and some other flagellates and blue-green algae. In the coastal waters of the south-west coast of India, during the pre-monsoon season, the chain forming diatom *Chaetoceros curvisetus* was found to be the dominant microalgae, whereas in the monsoon season, the colonial diatom *Asterionella japonica* was the dominant species.

At both stations, on average, the abundance of microalgae < 53 µm in size, tends to be higher than that of planktonic algae > 53 µm during the pre and the post-monsoon seasons, while the density of microalgae > 53 µm becomes significant during the monsoon season, this may be related to the concentration of nutrients. During the pre and the post-monsoon seasons the concentration of nutrients in the coastal waters is normally low, and in such conditions, the smaller planktonic algae with their higher efficiency of nutrients utilization grow and reproduce well and outnumber the larger microalgae; while during the monsoon season, when the concentration of nutrients is high, the chance is more favorable for the larger planktonic algae to grow and reproduce with higher efficiency and outnumber the smaller size fractions.

At station 1, during the pre and post-monsoon seasons, the lowest species diversity was found for the largest size group of > 500 µm, while the highest species diversity and the lowest species dominance have been reported for the size group of < 53 – 25 µm. So, during the pre and the post-monsoon seasons the microalgae within the size fraction of < 53 – 25 µm become the most important among all other size groups in providing food for a large number of species of consumers in the coastal waters of the south-west coast of India.

In the monsoon season, the lowest species diversity was observed for the size group of < 500 – 250 µm, in which the highest species dominance was recorded. High diversity was seen for the size groups of < 53 – 25 µm and < 25 – 10 µm, so they might be a significant source of food for a large number of species of marine organisms.

Station 2, showed the same trend, with the highest species diversity in the size fraction of < 53 – 25 µm during the pre and the post-monsoon seasons, and within the size groups of < 53 – 25 µm and < 25 – 10 µm in the monsoon season. The size groups of < 53 – 25 µm, during the pre and the post-monsoon seasons, and with the size fraction of < 25 – 10 µm during the monsoon season, serve as a very important source of food for a large number of marine organisms inhabiting the coastal waters of the south-west coast of India.

Planktonic algae irrespective of their size variations contribute to the total amount of chlorophyll *a*, but the relative contribution of each size group varies, depending on the prevailing environmental conditions. The amount of chlorophyll *a* has been found to increase with the decrease in the size of planktonic algae. The relatively low concentration of chlorophyll *a* within the size groups of < 53 – 25 µm and < 25 – 10 µm might have been due to the grazing effect by herbivorous zooplankton. During the pre-monsoon and post-monsoon seasons, the contribution of the planktonic algae < 25 µm in size to the total chlorophyll *a* is significantly higher than that of the larger microalgae, whereas during the monsoon season, the contribution of the micro flora > 25 µm is more important.

Production of organic matter by planktonic algae is of utmost importance as the entire fishery resources are dependent on this phenomenon. Since the various size fractions of planktonic algae form the food of the different varieties of consumers, many of them being selective feeders, the study of different size fractions of microalgae and their relative contribution to the primary organic production is a useful tool for the estimation of the quantities and qualities of fisheries. Generally, high primary production was observed in the coastal waters of Cochin, south-west coast of India during the SW monsoon season, when high concentration of nutrients is available in the coastal waters. During the pre-monsoon season, productivity was low at both stations, due to the low concentration of nutrients in the coastal waters associated with intensive grazing by zooplankton. In the post-monsoon period, productivity values have been found to be intermediate between that of the pre-monsoon and the monsoon seasons, due to the presence of relatively low concentration of nutrients accompanied with mild grazing activity by zooplankton.

Regarding the contribution of various size groups of planktonic algae to the total productivity in the south-west coast of India, it has been noticed that productivity increases with the decrease in size of planktonic algae except in the case of the size groups of < 53 – 25 µm and < 25 – 10 µm. This is may be due to the selective grazing by zooplankton, which in turn reduce the standing crop of microalgae at these size groups and hence lower the rate of their primary production.

Generally, in the coastal waters of Cochin, south-west coast of India, during the pre and the post-monsoon seasons, the major contribution to the total primary production was that of the planktonic algae < 25 µm in size This may be due to the relatively low concentration of nutrients in the coastal waters. In such conditions, smaller microalgae, due to their higher efficiency to absorb nutrients, grow well and reproduce better than the larger microalgae. During the monsoon season, the microalgae > 10 µm in size contribute significantly to the total primary production, as there is high concentration of nutrients in the coastal waters, which enhance growth and reproduction of the larger microalgae, i.e. above 10 µm in size.

- Table 7.1-Average values of primary production, chlorophyll *a* and cell numbers during the pre-monsoon season (February – May 2000) at station 1.

Size group	P. P mg C/m^3/d	%	Chl. *a* mg/m^3	%	No. /L	%
> 500 µm	5.8	1.9	0.10	3.2	1.3 x 10^3	1.6
500 - 250µm	6.9	2.2	0.11	3.6	2.3 x 10^3	2.8
250 - 150 µm	7.6	2.5	0.12	3.9	4.2 x 10^3	5.0
150 - 105 µm	12.1	3.9	0.16	5.2	1.1 x 10^4	13.3
105 - 53 µm	19.9	6.5	0.47	15.2	2.6 x 10^4	31.3
53 - 25 µm	11.8	3.8	0.33	10.6	1.4 x 10^4	16.9
25 - 10 µm	21.4	7.0	0.46	14.8	1.8 x 10^4	21.7
< 10 µm	222.4	72.2	1.35	43.5	6.1 x 10^3	7.4
Total	307.9	100	3.10	100	8.3 x 10^4	100

- Table 7.2- Average values of primary production, chlorophyll *a* and cell numbers during the monsoon season (June – September 2000) at station 1.

Size group	P. P mgC/m^3/d	%	Chl. *a* mg/m^3	%	No./L	%
> 500 µm	9.6	1.1	0.24	1.6	1.6 x 10^3	0.4
500 - 250 µm	15.0	1.7	0.27	1.8	2.8 x 10^3	0.6
250 - 150 µm	23.1	2.7	0.33	2.2	1.4 x 10^4	3.1
150 - 105 µm	31.7	3.8	1.18	7.9	5.7 x 10^4	12.6
105 - 53 µm	221.4	25.8	4.59	30.8	1.9 x 10^5	42.1
53 - 25 µm	101.2	11.8	2.57	17.2	6.4 x 10^4	14.2
25 - 10 µm	34.4	4.0	1.28	8.6	9.4 x 10^4	20.8
< 10 µm	421.3	49.1	4.46	29.9	2.8 x 10^4	6.2
Total	857.7	100	14.92	100	4.5 x 10^5	100

-Table 7.3- Average values of primary production, chlorophyll *a* and cell numbers during the post-monsoon season (October 2000 – January 2001) at station 1.

Size group	P. P $mgC/m^3/d$	%	Chl. *a* mg/m^3	%	No. /L	%
> 500 µm	4.0	0.9	0.10	1.1	1.3×10^3	1.3
500 – 250 µm	7.6	1.6	0.12	1.3	1.5×10^3	1.4
250 – 150 µm	14.3	3.0	0.15	1.7	6.6×10^3	6.3
150 – 105 µm	16.1	3.4	0.21	2.3	1.7×10^4	16.3
105 – 53 µm	18.8	4.0	0.64	7.1	1.9×10^4	18.3
53 – 25 µm	21.8	4.7	0.73	8.1	2.0×10^4	19.2
25 – 10 µm	24.9	5.3	0.80	8.8	2.9×10^4	28.0
< 10 µm	361.6	77.1	6.30	69.6	9.6×10^3	9.2
Total	469.1	100	9.05	100	1.0×10^5	100

- Table 7.4-The hydrographic parameters during the pre-monsoon, the monsoon and the post-monsoon at station 1.

Season	Temperature ^0C	Salinity ‰	Nitrate µg. at/l	Nitrite µg. at /l	Phosphate µg. at/l	Silicate µg. at/l
Pre- monsoon	31	34.4	3.21	0.32	0.27	9.71
Monsoon	26	36.0	4.14	1.28	2.71	25.40
Post- monsoon	29	33.0	1.08	0.83	1.13	8.58

- Table 7.5-Average values of primary production, chlorophyll *a* and cell numbers during the pre-monsoon season (February – May 2000) at station 2.

Size group	P. P mgC/m^3/d	%	Chl. *a* mg / m^3	%	No. /L	%
> 500 µm	7.8	1.8	0.11	2.4	1.1 x 10^3	1.5
500 – 250 µm	16.9	3.9	0.13	3.0	1.7 x 10^3	2.3
250 – 150 µm	23.5	5.5	0.17	3.8	3.5 x 10^3	4.9
150 – 105 µm	25.7	6.0	0.19	4.2	6.3 x 10^3	8.8
105 – 53 µm	42.2	9.8	0.52	11.5	1.8 x 10^4	25.2
53 – 25 µm	28.3	6.6	0.47	10.4	1.4 x 10^4	19.6
25 – 10 µm	52.6	12.2	0.80	17.7	2.2 x 10^4	30.8
< 10 µm	233.3	54.2	2.12	47.0	4.9 x 10^3	6.9
Total	430.3	100	4.51	100	7.2 x 10^4	100

- Table 7.6-Average values of primary production, chlorophyll *a* and cell numbers during the monsoon season (June – September 2000) at station 2.

Size group	P. P mgC/m^3/d	%	Chl. a mg/m^3	%	No. /L	%
> 500 µm	11.3	2.2	0.10	1.9	2.5 x 10^2	0.1
500 – 250 µm	16.2	3.1	0.12	2.3	2.6 x 10^3	1.5
250 – 150 µm	35.8	6.8	0.14	2.7	8.9 x 10^3	5.1
150 – 105 µm	79.7	15.2	0.26	4.9	1.8 x 10^4	10.3
105 – 53 µm	88.6	16.9	1.15	21.8	5.6 x 10^4	32.1
53 – 25 µm	86.5	16.5	1.10	20.8	4.4 x 10^4	25.2
25 – 10 µm	27.1	5.2	0.53	10.0	3.5 x 10^4	20.1
< 10 µm	178.8	34.1	1.88	35.6	9.8 x 10^3	5.6
Total	524.0	100	5.28	100	1.7 x 10^5	100

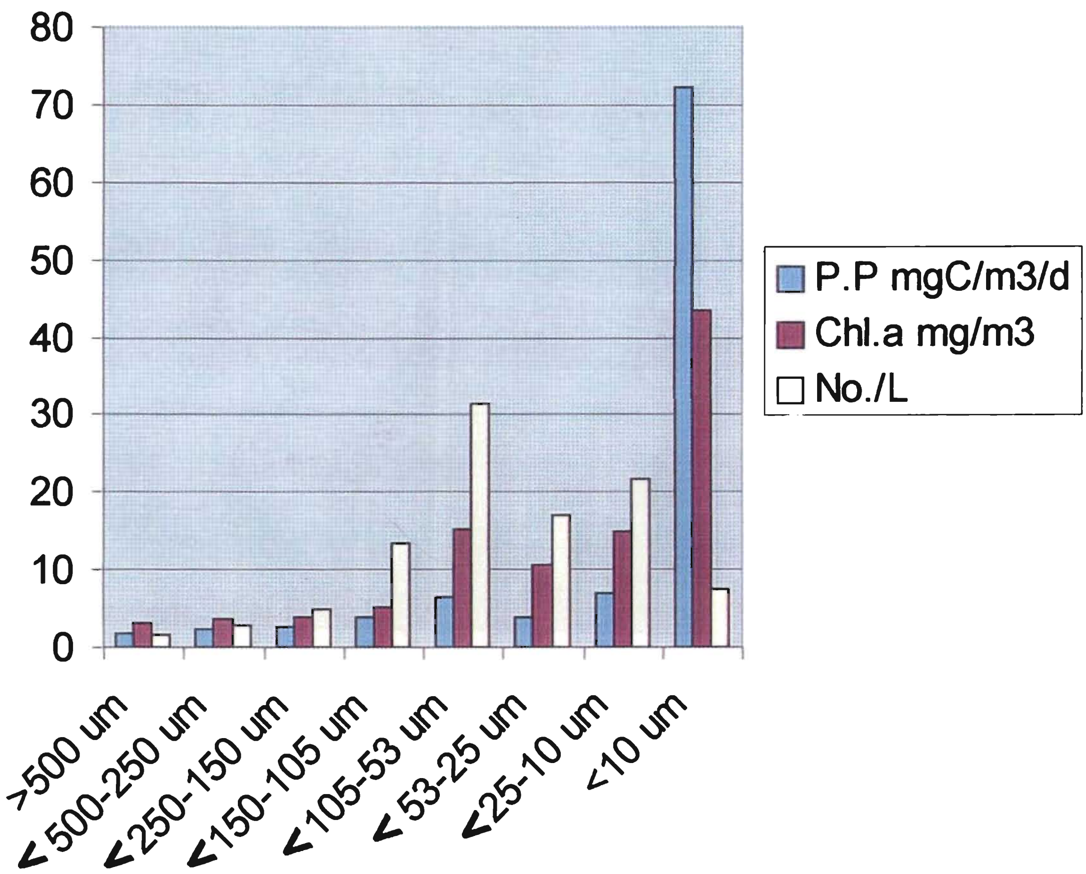
- able 7.7- Average values of primary production, chlorophyll *a* and cell numbers during the post monsoon season (October 2000 – January 2001) at station 2.

Size group	P. P mgC/m^3/d	%	Chl. a mg/m^3	%	No. /L	%
> 500 µm	-	-	0.06	1.3	5.0x10^2	0.3
500 – 250 µm	-	-	0.10	2.2	2.4 x 10^3	1.4
250 – 150 µm	28.0	5.6	0.25	5.4	1.1 x 10^4	6.5
150 – 105 µm	37.5	7.5	0.40	8.6	2.9 x 10^4	17.1
105 – 53 µm	39.2	7.8	0.43	9.2	3.1 x 10^4	18.2
53 – 25 µm	37.4	7.5	0.39	8.4	2.3 x 10^4	13.5
25 – 10 µm	80.7	16.1	0.63	13.5	5.7 x 10^4	33.6
< 10 µm	277.5	55.5	2.39	51.4	1.6 x 10^4	9.4
Total	500.3	100	4.65	100	1.6 x 10^5	100

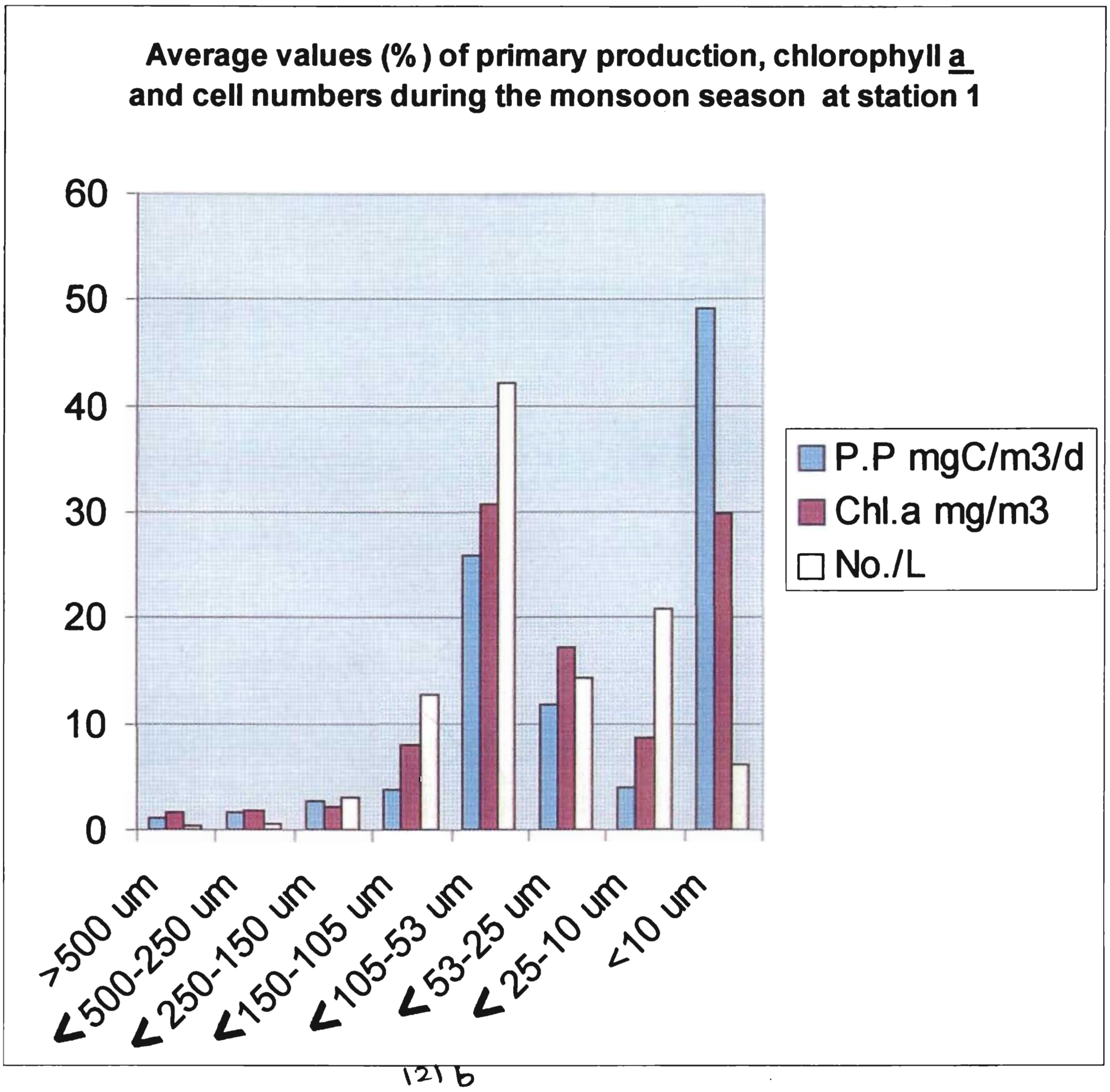
- Table 7.8-The hydrographic parameters during the pre-monsoon, the monsoon and the post-monsoon at station 2.

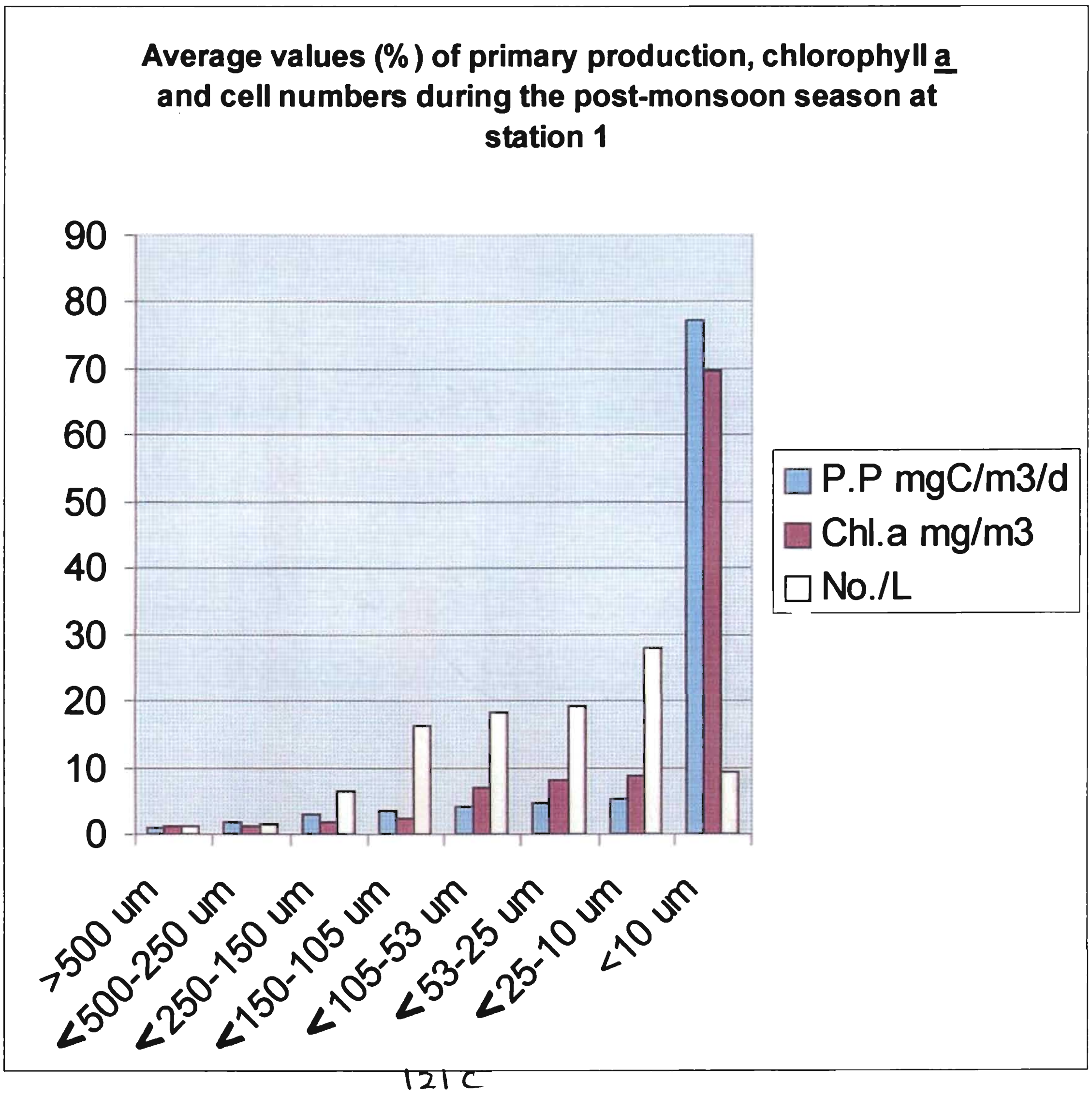
Season	Temperature ^{0}C	Salinity ^{0}/$_{00}$	Nitrate µg. at/l	Nitrite µg. at/l	Phosphate µg. at/l	Silicate µg. at/l
Pre- monsoon	31	33	2.92	0.56	1.05	11.08
Monsoon	26	34	5.89	1.77	2.68	31.95
Post- monsoon	30	31	1.44	0.52	0.98	9.76

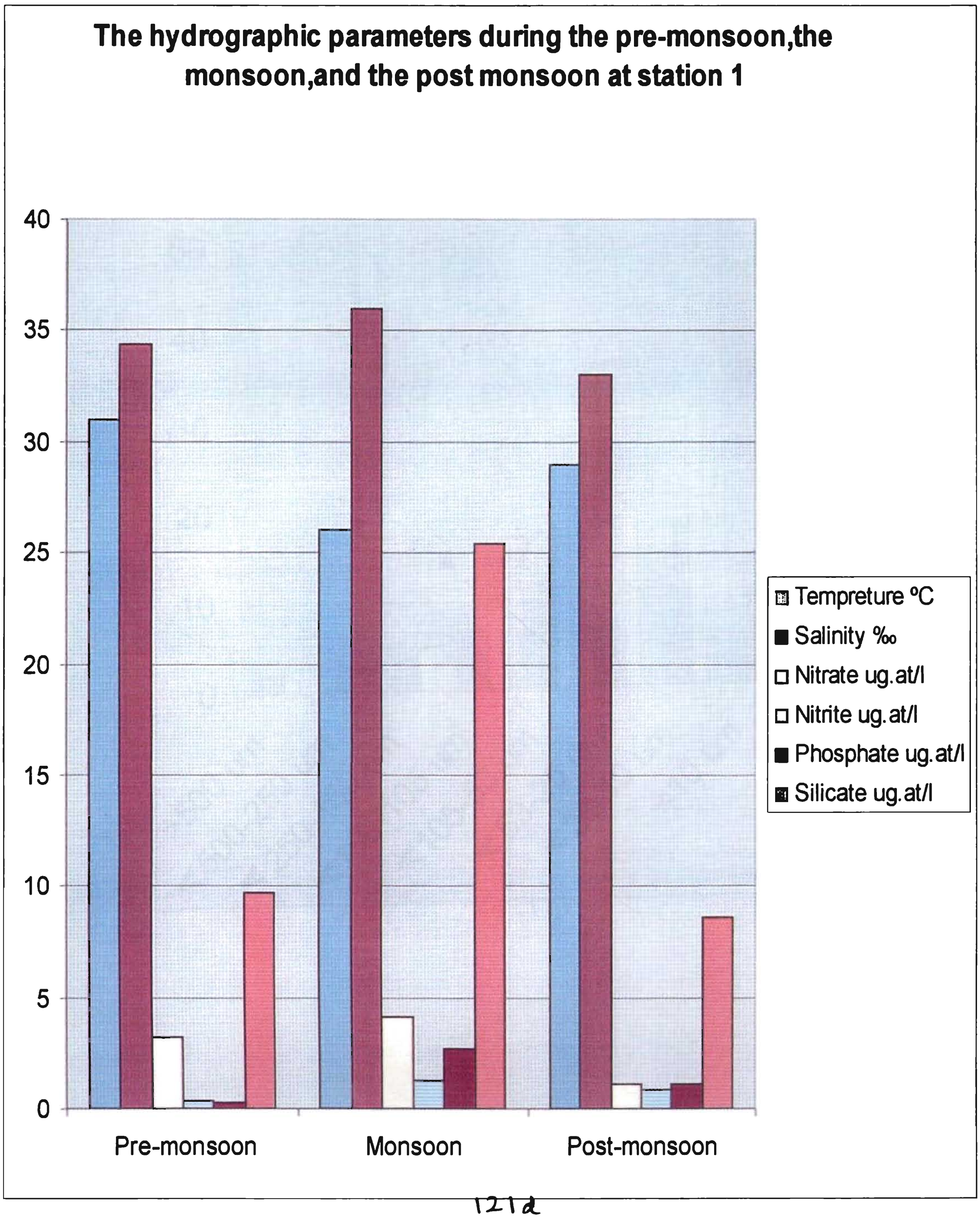
Average values (%) of primary production, chlorophyll a and cell numbers during the pre-monsoon season at station 1

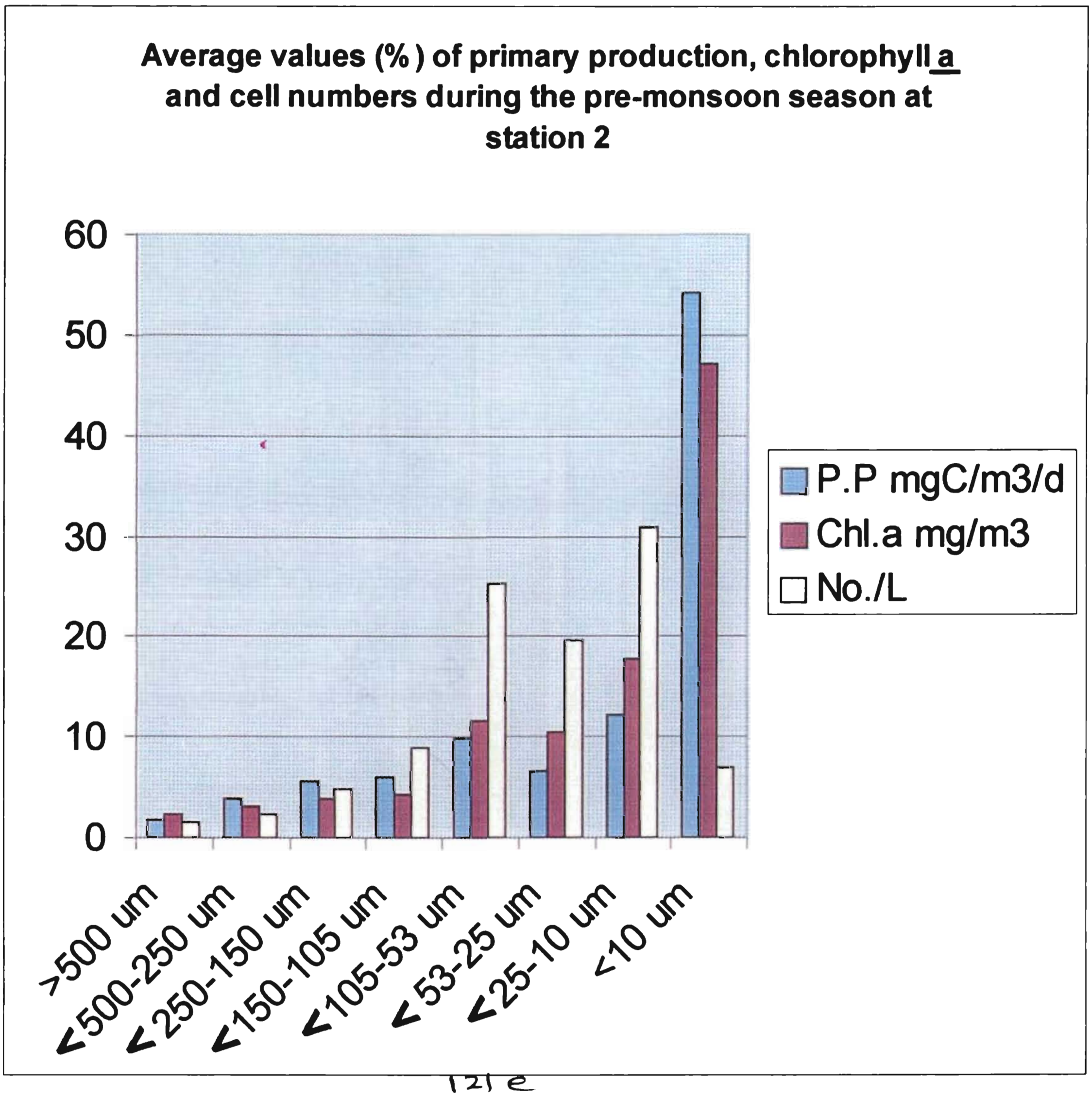


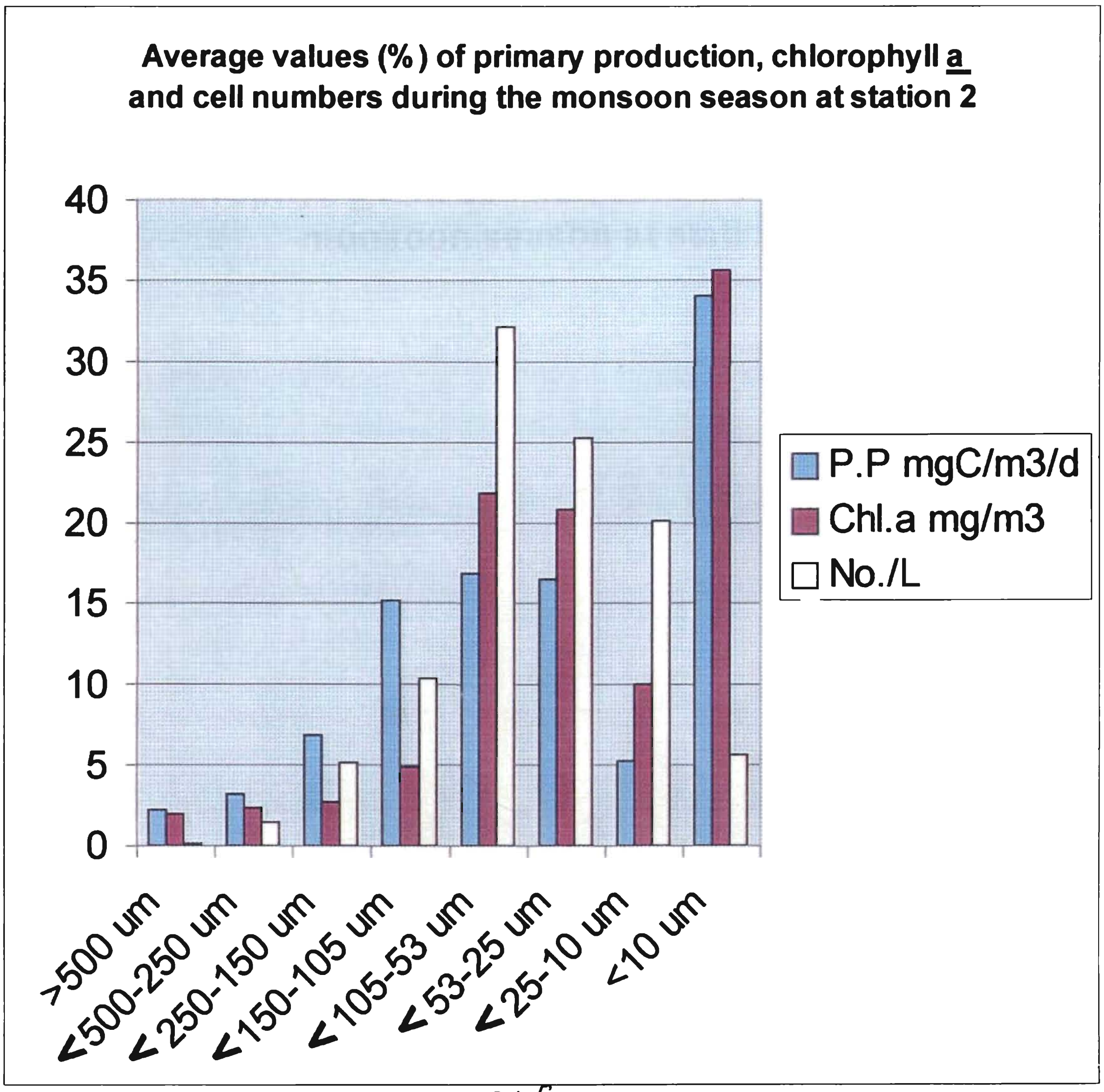
(2) a


Average values (%) of primary production, chlorophyll a and cell numbers during the monsoon season at station 1
60
50
40
30
20
10
0
P.P mgC/m3/d
Chl.a mg/m3
No./L
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um


Average values (%) of primary production, chlorophyll a and cell numbers during the post-monsoon season at station 1
90
80
70
60
50
40
30
20
10
0
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um
P.P mgC/m3/d
Chl.a mg/m3
No./L

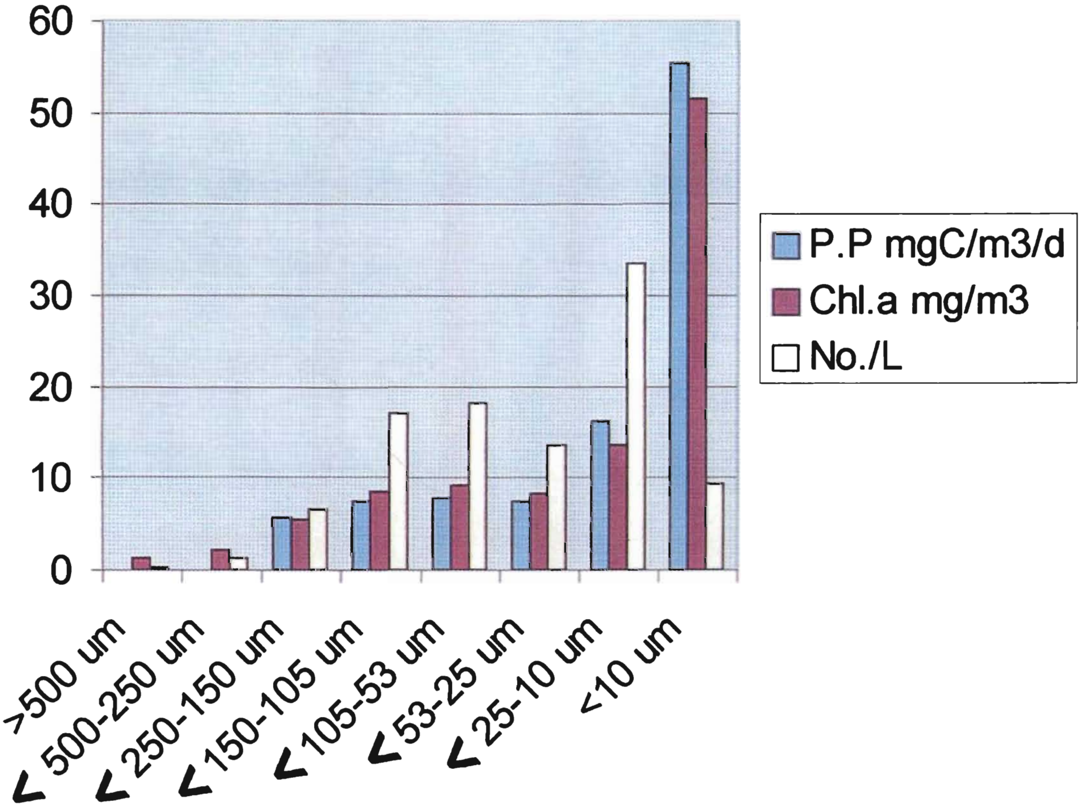

The hydrographic parameters during the pre-monsoon,the monsoon,and the post monsoon at station 1
40
35
30
25
20
15
10
5
0
Pre-monsoon
Monsoon
Post-monsoon
Tempreture °C
Salinity ‰
Nitrate ug.at/l
Nitrite ug.at/l
Phosphate ug.at/l
Silicate ug.at/l

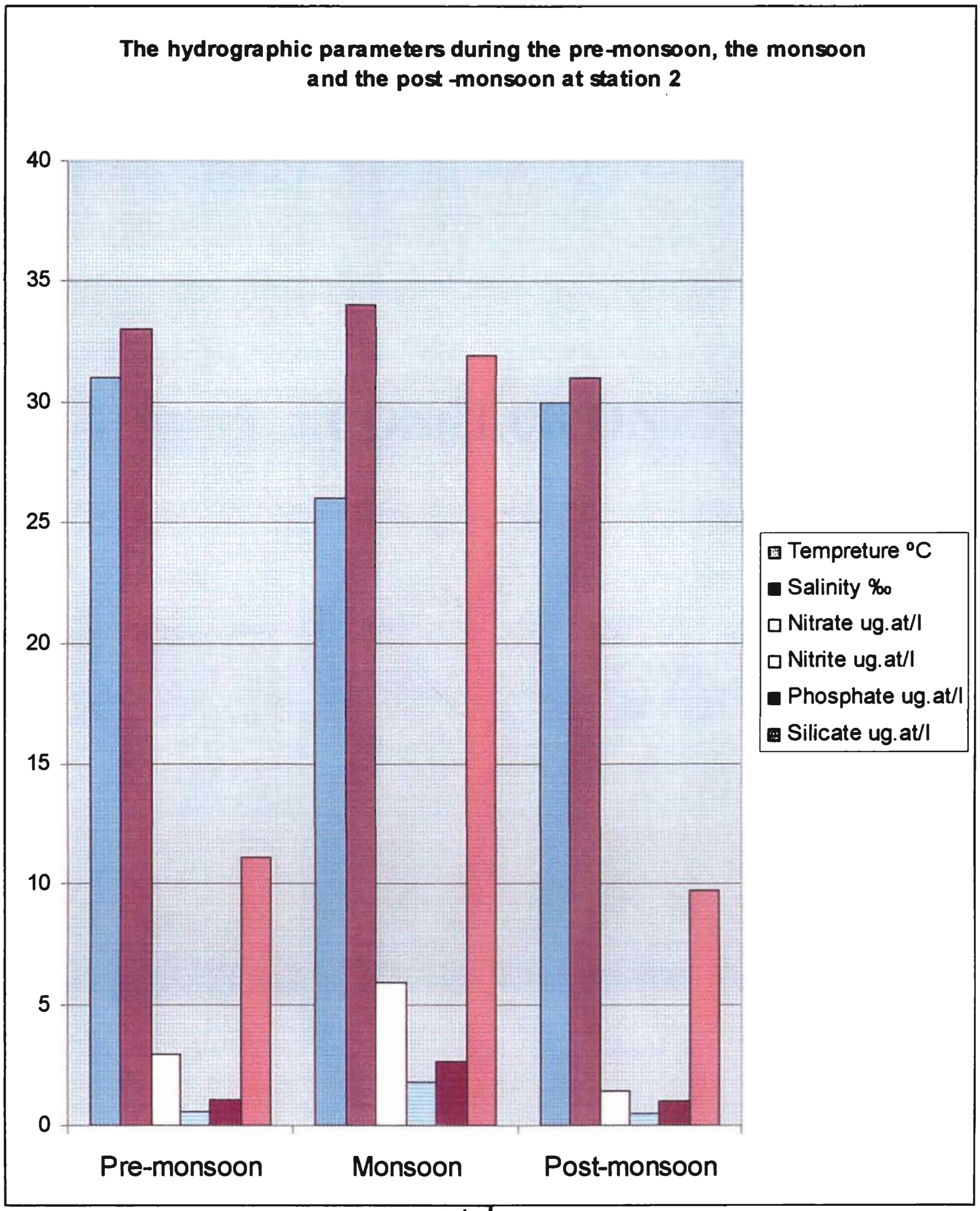

Average values (%) of primary production, chlorophyll a and cell numbers during the pre-monsoon season at station 2
60
50
40
30
20
10
0
P.P mgC/m3/d
Chl.a mg/m3
No./L
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um
121 e



Average values (%) of primary production, chlorophyll a and cell numbers during the monsoon season at station 2
40
35
30
25
20
15
10
5
0
P.P mgC/m3/d
Chl.a mg/m3
No./L
>500 um
<500-250 um
<250-150 um
<150-105 um
<105-53 um
<53-25 um
<25-10 um
<10 um

Average values (%) of primary production, chlorophyll a and cell numbers during the post-monsoon season at station 2




The hydrographic parameters during the pre-monsoon, the monsoon and the post-monsoon at station 2
40
35
30
25
20
15
10
5
0
Pre-monsoon
Monsoon
Post-monsoon
Tempreture °C
Salinity ‰
Nitrate ug.at/l
Nitrite ug.at/l
Phosphate ug.at/l
Silicate ug.at/l

121 h

CONCLUSION

Conclusion

Planktonic algae form the first link in the marine food chain and their rate of synthesis of organic matters being influenced by various environmental parameters. The bioproductivity at higher trophic levels is dependent on the productivity at the first trophic level.

In the coastal waters of Cochin, south west coast of India, the environmental parameters such as light, temperature and salinity exhibit small variations throughout the year. Nutrients exhibit significant seasonal variations, and there is a positive correlation among the standing crop and productivity of planktonic algae and nutrients. Nutrients, especially phosphate, seems to be the most important limiting factor, controlling growth and productivity of planktonic algae. Jayaraman and Sheshappa (1957) assumed that the seasonal variations in the phytoplankton pigments are controlled by phosphate concentration in the sea off Cochin. Grazing also an important factor, zooplankton and the other herbivorous organisms may reduce the quantity of planktonic algae and hence reduce the rate of their primary productivity.

The study of different size fractions of planktonic algae and their relative contribution to the primary organic production is a useful tool for the estimation of the quantity and quality of fisheries. As the primary consumers, small zooplankton including the early larval stages of fishes and shellfishes are very small in size, they require very small size fractions of planktonic algae to be used as food. The availability of smaller size fractions of planktonic algae in divers and enough quantities can be used as an indicator for the presence of rich fishery resources. Concurrent information on planktonic algae, zooplankton, fishes and of the contribution of various size fractions of the microalgae to primary production would be useful for the assessment of the magnitude of fisheries. To be precise, an understanding of the phenomenon of the selective grazing of certain fishes and shellfishes especially their larval stages which feed exclusively on certain species of planktonic algae, would be useful for the prediction of the possible occurrence of specific type of fishes or a particular fishery.

In the coastal waters of Cochin, planktonic algae less than 53 µm in size contribute significantly to primary productivity and the biodiversity of the microflora, indicating the presence of rich fishery resources in the south west coast of India.

On analysis of the contribution of various size fractions of planktonic algae it is found that the predominant flora in the sea belong to the size group of < 10 µm in size, contributing on average, 46.2 % of the total chlorophyll ***a*** and 57.0 % of the total primary production. The contribution of planktonic algae having < 10 µm has so far been underestimated as they would not be traced by ordinary light microscope. As a considerable percentage of chlorophyll and productivity is the contribution of picoplankton and the predominant species among the picoplankton being cyanobacteria it may be concluded that cyanobacteria are one among the dominant taxonomic classes of planktonic algae. The assessment of potential fisheries excluding the contribution of picoplankton would be far from near approximation. The area of investigation would also be extended from the euphotic zone to deeper zone where the picoplankton may be distributed.

Any assessment of the magnitude of primary productivity based on the observed standing crop of algal plankton larger than 10 µm in size alone would lead to substantial underestimation. Lack of information on these small microflora would result in illogical conclusion. A deeper investigation on the occurrence of these microalgae and proper identification of their species would be of immense help for the assessment of the specificity and magnitude of fishery resources.

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