CHAPTER 3

PHYTOPLANKTON

Introduction

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3.1 INTRODUCTION

Phytoplankton can define as free floating unicellular, filamentous and colonial organism that grows autotrophically in aquatic environments (Khuantrairong & Trichaiyaporn, 2008). All phytoplankton are single-celled organisms and, other than the bacterioplankton, are protista and very essential component in the marine ecosystem as primary producers at the very beginning of food web (Reynolds, 1984). It is aptly called 'grasses of sea' in view of their importance in sustaining higher life forms in any aquatic systems. Phytoplankton as a group is largely made up of diatoms, dinoflagellates, cocolithophores, cryptomonads, chrysomonads, green algae and cynobacteria (blue-green algae). Diatoms and dinoflagellates are the most important members of the marine phytoplankton. It is also called the capsules of nutrients. The coccoid cyanobacteria (blue-green algae) are so small (0.2-2.0 μm) that their relative contribution and importance was overlooked until just recently. In fact, the photosynthesizing bacterioplankton are the most abundant photosynthetic organisms on Earth and are estimated to compose half of all the photosynthetic biomass in the ocean! These bacterioplankton are difficult to culture in the lab, difficult to preserve, and difficult to observe with the common light microscope.

Primary production, defined as a change in community biomass over time is a function of new organic material formed and of losses due to respiration, sinking, grazing, diffusion and advection during the specified time period (Niebauer, 1989; Walsh, 1975). The continental shelves are the 4 times as productive as open sea (Chavez, 1987)

The diatoms are also equally important primary producers in the ocean, it estimated to contribute up to 45% of the total oceanic primary production. Diatoms are members of the algae (plant-like) protists. Diatoms produce a silica (SiO_2) mineralized cell wall (called a frustules or test), typically 20-200 µm in size, with some species reaching up to 2 mm in length. Some diatoms live as solitary single cells and some live in interconnected chains with others. Diatoms lack flagella (small whip-like or tail-like filaments) that other groups commonly utilize to control suspension, so some diatoms regulate buoyancy with intracellular low-density fats to counter sinking due to the dense silica frustules. Diatoms also rely on turbulent mixing of surface waters through wind to keep them suspended in the euphotic zone. Diatoms mostly contain green chlorophyll, and in the case of very highly concentrated populations of diatoms, they may color the water green.

Biodiversity patterns in phytoplankton, similar to other organisms, are largely governed by physical, chemical and other hydrological conditions of their habitat. Light is the most limiting factor for primary production. Succession of phytoplankton is controlled by various environmental factors such as salinity, level of nutrients, etc. (Bhattathiri, 1992). Phytoplankton production contributes about 95% of total production in the marine environment.

As the most sensitive organisms they serve as indicators of water quality with their ability to detect even subtle changes taking place in the marine environment (Sivasamy, 1990). Plankton reflects the effect of water quality and works as our aquatic 'canaries in the cage' and serves as indicators of water quality. Phytoplankton can be used as environmental indicators since they reflect even the slight changes taking place in their immediate environment by changing their species composition, biomass, community structure, Chlorophyll pigment and productivity. (Tilman, 1982; Huisman and Weissing, 1995; Diehl *et al.*, 2002; Hessen *et al.*, 2002)

For example, Raman and Prakash (1989) reported that species of *Thalassiosira* are known to bloom in the areas affected by sewage pollution. In the Arabian Sea winter bloom were observed by Banse and Mcclain (1986).

Information on the phytoplankton community structure and diversity in the waters of west coast of India is well documented (Achuthankutty *et al.*, 1981; Davassy, 1983; Jayalakshmy *et al.*, 1986; Davassy and Goes, 1989; Ramaiah *et al.*, 1995; Sawant and Madhupratap, 1996; Vareethiah and Haniffa, 1997; Nair, 2002; Kumari and John, 2003; Madondkar *et al.*, 2007; Ramaiah *et al.*, 2007). In east coast notable works have been carried out by Madhav and Kondalarao (2004), Jyothibabu *et al.*, (2003) and Mohamed *et al.*, (2009). Planktonic biota of Gulf waters has been the subject of study since early 1960s. Planktonic diversity and seasonal abundance in Kandla waters was first reported by Ramamurthy and Dhawan (1963) and Dhawan (1970). Gopalakrishnan (1972) and Mahyavanshi (1975) reported occurrence of 57 and 63 diatom species in Gulf waters. A maximum of 28 phytoplankton genera and 21 zooplankton groups in different coastal stretches of Kachchh were reported by Nair (2002). Contribution on phytoplankton species inventory along with other coastal marine fauna and flora has been made recently in the Gulf of Kachchh waters by Nair (2002) and Singh *et al.*, (2006). Recently Saravanakumar *et al.*, (2008) came out with the community structure and temporal variation of phytoplankton in mangrove lined creeks of Northwest Kachchh coast. Knowledge on the phytoplankton in the coastal waters of Gulf of Kachchh, especially in the northern coast of Gulf of Kachchh is poor. In order to explore phytoplanktonic population in Kachchh coastal waters, the present study was carried out. This chapter consolidates the finding of the two year study (2007-09) on phytoplanktonic diversity carried out in the coastal water of Mundra, Mandvi and Sanghi on Kachchh coast. The study aims to understand species composition, relative abundance distribution and diversity of phytoplankton community and to see that how composition varies over time and space echoing the stability of the system.

3.2 Methodology:

The phytoplankton were collected from all three sampling stations i.e Mundra (22^{0}46′ 03.82″ N, 69^{0}37′ 03.56″ E), Mandvi (22^{0}50′13.31″ N, 69^{0}12′ 54.45″E) and Sanghi (23^0 23′ 17.68 N, 68^0 33′ 27.29″ E) at monthly interval during high tide and low tide both. Data on *in situ* water quality parameters were also analyzed for comparison from each sample during plankton sampling. Monthly samples were pooled into three seasons i.e. Monsoon (July to October), Winter (November to February) and Summer (March to June) as there is no much difference in composition and diversity of plankton at monthly interval.

Surface sampling were carried out with a 40 cm diameter and 135 cm length net of 51μM mesh size net by towing it with motorized boat at a speed of 2 nautical miles (Fig. 3.1). The net fitted with a flow meter (Hydrobios) to measure the amount of water passes through net. Plankton adhering to the net were concentrated in the net bucket by splashing seawater. The phytoplankton soup collected in the net were transferred to a pre-cleaned rinsed and labeled container and preserved with 5% neutralized formaldehyde. The containers were appropriately labeled indicating the details of collection and were transferred to laboratory for further analysis. The initial and final flow meter reading was noted down for calculating the amount of water filtered.

Fig: 3.1 Sample collection by Plankton net

Quantitative analysis of phytoplankton (cell count) was carried out using Sedgewick-Rafter counting chamber. 1 ml of sample added to a Sedgwick counting chamber was observed under an inverted compound microscope. Number of cells present in individual units of the counting chambers (1/1000) were noted and identified up to species level. Number of observations was fixed so as to represent the entire quantity of the soup (generally more than 30 times) and the recorded data were used for further calculations with which density and diversity of the phytoplankton in 1 liter of the seawater was calculated. Density (no/L) was calculated using the formula

$N = n \times v / V$ (where N is the total no/L;

n is average no of cells in 1 ml;

v is volume of concentrate;

V is total volume of water filtered).

In order to counter check the accuracy of the density and diversity of phytoplankton the same were estimated through settlement methods as well.

One liter of seawater sample was taken in a clean high density polythene container and was added with preservative solution. In the laboratory the samples were allowed to settle and the overlying water column was decanted. The concentrated soup was observed under microscope in a Sedgewick Rafter and final density was calculated and compared with the earlier values obtained in the net method.

Different diversity and dominance indices (Shannon H, Evenness e^H/S, Margalef, Pielou evenness) for species diversity, evenness and richness were computed following Magurran (1988) for all the samples. Agglomerative hierarchical cluster analysis and MDS was used to assess level of similarity among different stations in all the 3 seasons in both the years.

3.3 Results:

3.3.1 Phytoplankton composition and distribution:

The phytoplankton composition, distribution and diversity were studied for the duration of June 2007 to May 2009. The distribution and composition of phytoplankton is almost equal during both years during year 2007-08. Total 88 species of the phytoplankton were recorded from three study stations i.e. Mundra, Mandvi and Sanghi, while during 2008-09, total 82 species were recorded which shows marginal decline of 6 species from year 2007-08.

Phytoplanktons are classified into 4 major groups (Pennate diatom, Centric Diatoms, Dinoflagellates and Cyanobacteria). Contribution of all groups were almost similar in the both the years during different seasons. Centric diatoms predominated phytoplanktonic composition during study, 50% during 2007-08 and 51.21% during 2008-09 followed by pinnate diatom, dinoflagellates and cyanobacteria (Table. 3.1, 3.2). Cyanobacteria as a major group were represented by two species Anabaenaa sp. and Oscillatoria sp. (Table 3.3). Anabaenaa sp. is recorded only once during summer at Mundra.

Throughout the study period a total of 42 genera have been recorded under these four major groups. Season wise total 38, 25 and 34 genera were recorded during summer, monsoon and winter during 2007-08, while during 2008-09 these numbers were 31, 32 and 34.

These show that there is no seasonal consistency in the generic composition as number of genera was more during summer and winter in 2007-08 whereas in 2008-09 Monsoon and winter seasons records higher number of genera.

During study total 34, 41 and 38 genera were recorded at Mandvi, Mundra and Sanghi respectively while year wise these stations represent 34, 36 and 36 genera during 2007-08 and 31, 37 and 32 during 2008-09. Species composition was higher during winter (80 species) followed by summer (78 species) and monsoon ((74 species). Number of species was higher during first year which recorded 68, 73 and 46 species during winter, summer and monsoon whereas in the same seasons during the second year it records 73, 69 and 73 species. Species richness was higher during monsoon of second year with 73 species than the first year which recorded only 46 species. Station-wise, generic and species composition was much higher at Mundra than Mandvi and Sanghi in the overall analysis. Station-wise, generic and species composition was much higher at Mundra than Mandvi and Sanghi in the overall analysis

Station-wise, generic and species composition was much higher at Mundra than Mandvi and Sanghi in the overall analysis. However, seasonal inconsistency between first and second year could be seen in stations also. During 2007-08 generic representation were equal at Mundra and Sanghi while during 2008-09 at Mundra generic representation was higher than other two stations.

Season-wise, species composition was richer during summer during first year, but during second year, monsoon and winter recorded higher species composition of 73. Group wise composition showed diatoms (both centric and pennate) were more dominant and dinoflagellates were comparatively less dominant during all the seasons in both the years

Phytoplankton composition during first year showed that 82.41% of total species were diatoms (both pennate and centric) in all the season while dinoflagellates and Cyanobacteria constituted 12% and 2.19%, respectively. Phytoplankton composition during first year showed that 85.23% of total species were diatoms (both pennate and centric) in all the season while dinoflagellates and Cyanobacteria constituted 12.5% and 2.27%, respectively. During second year, constitution of diatoms was 85.37% while dinoflagellates and cyanobacteria constituted 1.22% and 13.41%, respectively.

Contribution of Cyanophycea was less during second year (1.22%) than the first year (2.27%). During the entire study, phytoplankton population was composed of 50% centric diatoms, 35.23% pennate diatoms, 12.50% dinoflagellates and 2.27% cyanophyceae. Genus and species distribution pattern in different study stations revealed that the numbers of genera and species were higher during summer of first year with 38 genera and 73 species and during winter of second year with 34 genera with 73 species. Lowest genera of 23 and species of 32 were recorded at Mundra during monsoon of first year and 23 genera and 41 species at Mandvi during second year. Generally number of species was less during monsoon in all the stations while during second year summer recorded lesser number of species (Table 3.4).

Overall species distribution during first year showed that 39 species (44.32%- out of 88 species) had wider temporal distribution and they were recorded in all the three seasons twenty eight species like *Anabaenaa, Bacteriastrum varians, Ceratium breve, Ceratium declinatum, Ceratium falcatum, Ceratium macrocerus,* *Chaetoceros affinis, Chaetoceros curvicetus, Chaetoceros debilis, Chaetoceros diversus, Chaetoceros peruvianus, Chaetoceros simplex, Climacosphenia, Coconeis littoralis, Coscinodiscus eccentricus, Coscinodiscus jonesianus, Dinophysis caudate, Eucampia zoodiacus, Manguinea fusiformis, Melosira, Nitzschia braarudi, Nitzschia closterium, Nitzschia sigma Pleurosigma angulatum Rhizosolenia castracanei, Rhizosolenia cohlea, Schroederella setigera* and *Thalassiosira coramandalina* showed highly restricted distribution (Table 3.3). They were recorded during any one season. During second year, 14 species (*Asterionella japonica, Bacillaria paradoxa, Biddulphia sinensis, B. mobiliensis, Coscinodiscus gigas, C. granii, Ditylum brightwelli, D. sol, Fragilaria oceanic, Gyrosigma balticum, Nitzschia sp, Planktoniella sol, Pleurosigma sp, Triceratium fuvas*) had 100% occurrence in all the stations and seasons. Least occurrence was recorded for species like *Cymbella sp, Hemiaulus sinensis, Manguinea fusiformis, Rhizosolenia castracanei* and *Schroederella* sp. which were recorded in any one season or station during second year. During first year species like *Anabaenaa, Ceratium breve, Ceratium declinatum, Ceratium falcatum, Ceratium macrocerus, Chaetoceros diversus, Chaetoceros symplex, Climacosphenia, Coconeis littoralis, Dinophysis caudata, Eucampia zoodiacus, Manguinea fusiformis, Nitzschia braarudi, Nitzschia closterium, Nitzschia sigma, Pleurosigma angulatum, Rhizosolenia cohlea and Schroederella setigera* were recorded only once in any one season or station.

The overall relative frequency of occurrence during the year 2007-08 showed that out of 88 species, 40 species (45.45%) had more than 50% relative frequency of occurrence (Table 3.7)

While during 2008-09 out of 82 species, 51 species (62.19%) has more than 50% relative frequency of occurrence.

3.3.2. Graphical or distributional techniques:

3.3.2.1. K- Dominance curve:

K-dominance curves, developed by Lambshead *et al.,* (1983), result from plotting percentage cumulative abundance against species rank *k* on a logarithmic scale, where species assemblage x is more diverse than y if the curve for y is everywhere below or touching that of x. The lower line had the higher diversity and that if the lines for two samples crossed then they will tend to rank differently for different diversity indices.

During the present study, multiple k-dominance plots were constructed for all the samples, seasons and stations as implemented in PRIMER. Fig 3.2 shows the observed findings for all samples collected during entire collection period. It can be seen that the maximum faunal population was 58 species in Sanghi during monsoon 2009 and it's contributing 66% of the total faunal numbers. The minimum species count (32) was recorded at Mundra during monsoon, 2008.

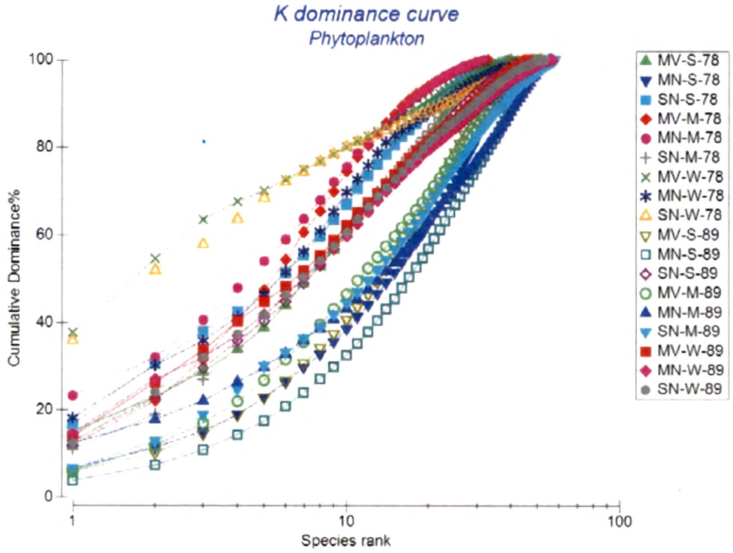


Fig: 3.2 K dominance curve for phytoplankton

3.3.3. Multivariate methods:

3.3.3.1. Cluster analysis (Bray-Curtis similarity)

Cluster analysis is a technique in which entities are sequentially linked together according to their similarity (or dissimilarity) producing a two dimensional hierarchical structure (dendrogram). Similarity of cases is either specified directly in a distance matrix, or defined in terms of some distance function. In the present case, hierarchical cluster analysis technique was used to see how similar different phytoplanktonic communities in the three stations studied were. Figs 3.3 display the results of the hierarchical clustering, using the group average linking on the phytoplankton species abundance data for the 3 stations during six seasonal collections. Bray-Curtis similarities were calculated on the Biodiversity profession 4th root transformed data (as implemented in PRIMER 6).

From the cluster analysis of the first year, it was observed that the maximum similarity (61.98%) was observed between Mandvi Monsoon and Mundra Monsoon while during second year maximum similarity (76.12%)were observed between Mundra winter and Sanghi winter.

From the overall cluster analysis (Winter 2008 to Monsoon 2009), it was observed that maximum similarity (77.47%) was between Sanghi Summer 2007-08 and 2008-09. Next similarity (76.12%) was between Sanghi Winter and Mundra Winter during 2008-09. Mandvi showed 66.72% similarity between winter 2007-08 and 2008-09. Sanghi Monsoon 2007-08 and Monsoon 2008-09 joined with 64.84% and Mundra Monsoon 2008-09 and Mandvi Monsoon 2007-08 joined with 62.2%. This same trend was confirmed in MDS ordination.

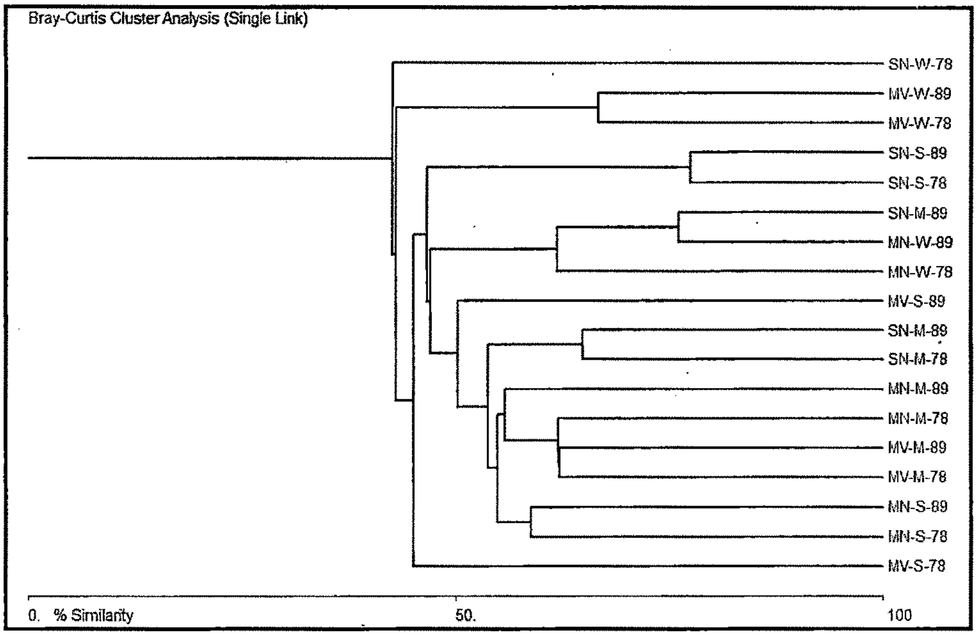


Fig: 3.3 Hierarchical clustering of phytoplankton.

3.3.3.2. Multi dimensional scaling (MDS):

The purpose of MDS is to construct a " map" or *configuration* of the samples, in a specified number of dimensions, which attempts to satisfy all the conditions imposed by the rank (dis) similarity matrix. To confirm this pattern of grouping, ordination (MDS) was done for all the seasons. The trend observed in cluster analysis was quiet evident here. The stress values found in MDS configurations were low (<0.1) suggesting good representation of interrelationship between the fauna of stations sampled.

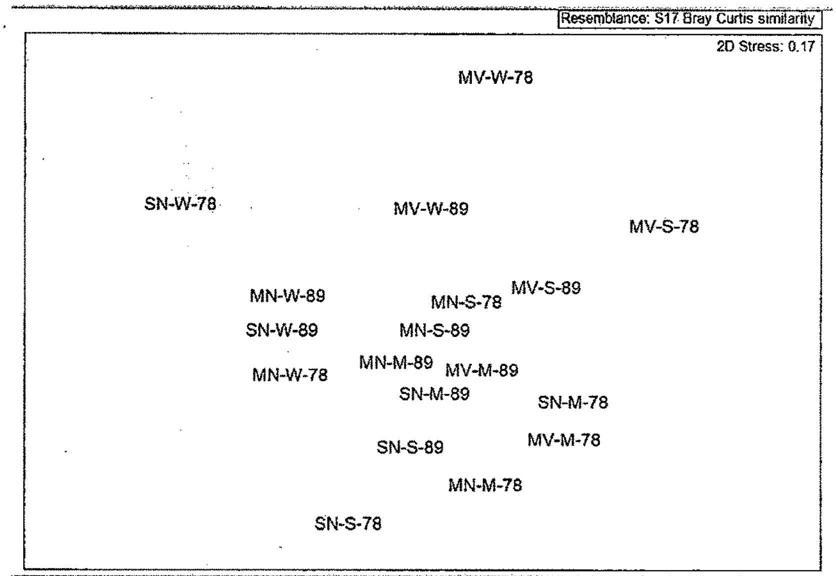


Fig: 3.4 MDS of the seasons and stations showing phytoplankton assemblages at various similarity levels during entire collection period.

3.3.4 Density:

Phytoplankton density values across seasons and stations for the whole study period ranged were between 334 cells/L to 1351 cells/L (Table 3.5).

In first year Sanghi recorded higher density than Mandvi and Sanghi during summer and monsoon, while in second year Mundra records higher density than Mandvi and Sanghi during summer and winter. Density values were higher during winter in both the years while summer recorded lower values. During first year maximum density recorded at Mundra was 1245 cells/L during winter while the minimum density of 334 cell/L was at Mandvi during monsoon. Similar to first year, maximum (1351 cells/L) and minimum (529 cells/L) was again recorded at Mundra and Mandvi during winter and summer in second year. Average density during first year across season was highest at Sanghi (734 cells/L) followed by Mundra (723 cells/L) and Mandvi (419cells/L) similarly during second year plankton density was higher at

Mundra (1081 cells/L) followed by Sanghi (987 cells/L) and Mandvi (616 cells/L).

During present study plankton density values generally decreased in the order of Mundra>Sanghi>Mandvi.

Across the stations phytoplankton density was highest during winter (885 cells/L) followed by summer (584 cells/L) and monsoon (407 cells/L) during first year. In case of second year density were highest during winter (1080 cells/L) followed by monsoon (914 cell/L) and summer (690 cells/L).

During overall study period phytoplankton density values found greater during winter (982 cells/L) followed by monsoon (661 cells/L) and summer (632 cells/L).

Among all study stations through seasons and stations the number of species varied from 32 to 54. Similarly, species-specific relative abundance could be observed with few species numerically more dominant than the others. (Table 3.5)

Species like *Chaetoceros sp, Thalassiothrix nitzschioides, Synedra sp, Thalassionema nitzschioides, Biddulphia mobiliensis, B. sinensis,* showed high relative dominance during previous year. During second year *Chaetoceros sp, Thalassiothrix nitzschioides, Thalassiothrix sp, Biddulphia mobiliensis, Biddulphia sinensis, Ditylum brightwellii, Biddulphia heterocerus, Synedra sp. and Thalassionema nitzschioides* shows high relative dominance. *Eucampia, Anabaenaa, Nitzachia braarudi, Melosira, Manguinea fusiformis,* and *Schroederella* sp recorded very low dominancy and occurred only in either in one or two stations or seasons.

Species like *Asterionella japonica, Bidulphia mobilensis, Bidulphia sinensis, Ditylum sol, Fragillaria oceanica,*and *Pleurosigma sp* shows very wide spatial and temporal distribution. They were found in all stations during all seasons.

Species like *Bacillaria paradoxa, Bidulphia heterocerus, Coscinodiscus centralis, Coscinodiscus granii, Coscinodiscus sp, Ditylum brightwelli, Gyrosigma, Planktonella sol, Rhizosolenia sp, Thalassiothrix nitzschioides* and *Triceratium fuvas* found in more than 90% samples.

During the entire study, out of 88 species recorded, 54 species (61.36%) showed relatively low density constituting less than 1% in the total abundance

This observed dominance of few species might be due to their ability to take advantage of the prevailing conditions and available nutrients. Nutrient requirement of the individual species vary depending on species specific nutrient uptake kinetics, assimilation and storage capacities which determines species dominance in a given area (Tilman *et al.*, 1982).

3.3.5. Species diversity, Evenness and Richness:

Information on species diversity, richness and evenness of biological components of the ecosystem is essential to understand detrimental changes in environs or deterioration of water quality (Krishnamoorthy and Subramanian, 1999). Species diversity is a basic measure of community structure and organization and the most important parameter to understand the health status of the ecosystem. The index gives a measure of how individuals in a community are distributed (Prasad, 2003).

Shannon diversity indices (H') values for phytoplankton for entire study period of two years ranged from 2.36 to 3.85 (Table 3.6). Diversity values during the second year were generally higher than the first year values. Station-wise, average diversity values were higher at Mundra (3.35) whereas at Mandvi and Sanghi diversity values for both the years were 3.12 and 3.18 respectively. Season wise, summer average was higher (3.21) during first year while during second year average diversity was higher (3.69) during monsoon (Table 3.6). Recorded diversity values indicate even distribution of phytoplankton species in the study stations.

Pielou's Evenness values ranged from 0.25 to 0.90 (Table 3.6). Evenness values were generally higher in all the stations during summer and lower during winter in all the stations. Similarly, second year recorded higher evenness values than the first year. Station-wise, Mundra recorded comparatively higher evenness values than Mandvi and Sanghi. Similar to diversity values, higher evenness values at Mundra showed that species distribution was more uniform and evenly distributed in these stations.

Mergalef's richness values ranged for the entire study period from 5.26 to 8.37 (Table 3.6). Average Mergalef's richness values were higher (7.40) during second year than the first year (6.65). Season-wise Mergalef values where higher (7.25) during summer of first year, while during second year it was higher during monsoon (7.78). Similar to Pielou's evenness value, station-wise average Mergalef's richness was higher at Mundra both during first and second year (6.98, 7.75) than the other two stations.

3.4 Discussion:

Phytoplankton abundance and species composition in an marine ecosystem are closely linked to various physical (advection, light, temperature salinity, etc), chemical (pH, nutrients) and biological (grazing) factors as well as interactions among them. This leads to temporal reduction in number of species, associated with an increase in the abundances of those few species which are well adapted to changing environmental parameters (Odum and Odum, 1959). Coastal waters of arid zones like Kachchh are likely to respond to environmental changes in different ways than the other coastal systems receiving normal rainfall. In Kachchh coast, low precipitation, high salinity and flash floods during short spell of terrestrial run-off expose them to sudden shift in governing parameters and render them highly vulnerable. Low density values presently recorded ranging from 334 cells/L to 1351 cells/L for the entire study period may be due to these factors. Density of phytoplankton in the study area seems to be comparatively very less considering the phytoplankton densities observed during several studies along west coast waters. Phytoplankton densities varied from 12,000 to 322000 cells/L in the surf zone and 7000 to 2,35000cell/L in the back waters of Cochin (Selvaraj *et al*, 2003). Maximum cell count of 2641×10^3/L was recorded at Thane creek of Bombay (Ramiah *et al*, 1998). Tiwari and Nair (1998), in their studies observed very high variations in cell count ($17\text{-}5980 \times 10^3$/L) and the average cell count for the entire study was 266×10^3/L. significantly less phytoplankton density values recorded presently might be due to the harsh environment including high salinity, temperature and aridity of the hinter land.

Phytoplankton of all the three study stations are characterized by species capable of tolerating higher salinity ranges since salinity in the three study stations in both the year recorded higher values apparently due to the aridity of the region. Comparatively lesser diversity and abundance values recorded at Mandvi might be related with its open coastal nature with high turbulent waters. Contrarily, Mundra and Sanghi stations are mangrove lined creek systems with less water turbulence. In Sanghi and Mundra stations, nutrient influx from mangrove environment apparently influences the phytoplanktonic communities in their waterways explaining the higher diversity values recorded in these coasts. In turn, Phytoplanktonic communities make important contributions to the functioning of mangrove ecosystems (Kathiresan and Bingham, 2001). Selvam (1992) reported that phytoplankton productivity in mangrove lined creeks were four times higher than the adjacent open ocean in south India. The low water speed in these creek environment and high stability of the water column probably play a role in the higher diversity and abundance recorded in these two stations. The present study also revealed that there was no much spatial variability in abundance and diversity in the three study stations. Similar physio-chemical characteristics of the three sites though they have varying environmental settling could be the reason for this close similarity in abundance. In all the three stations phytoplanktonic communities are characterized by the dominance of diatoms and dinoflagellates. Dominance of these two groups in Kachchh coastal waters was earlier reported by several workers (Nair, 2002; Singh, 2002). Similarly, density values recorded in the present study were comparable with those recorded in other coastal stretches of Kachchh (Nair *et al.*, 2002).

Vast difference in phytoplankton density values were observed among different studies carried out at in Gulf of Kachchh region earlier. NIO (1998) during their studies recorded an average population count of 38.2×10^3 cells/L at Kandla creek by settlement method. In the same waters COMAPS (1998) study by the same settlement method observed a minimum phytoplankton density of 172 cells/L and maximum density of 684 cells/L with an average value of 355 cells/L which is comparable with the results obtained in the present study. In the same study at Vadinar, a minimum of 104 cells/L, and a maximum of 2148 cells/L with an average of 685 cells/L was recorded.

Fluctuations in phytoplankton population densities were due to various factors such as salinity, light, turbidity temperature and nutrients. (Chandran, 1987; Roden *et al.*, 1987). Considering the given climatic conditions at the study site, it is reasonable to have lesser phytoplankton density. Low density observed during monsoon in the present study could be due to increased total suspended solids (TSS) brought in by terrestrial run-off. This increased TSS level at Sanghi could also be due to the combination of high wave actions during winter and the dredging activities of the nearby port. Usually phytoplanktonic communities with higher diversities are dominated by diatoms, exhibit higher photosynthetic rates and efficiencies related with high water temperature, salinity, species richness and diversity (Duarte *et al.*, 2006).

Table 3.1. Major Groups of Phytoplankton and their Species numbers in three seasons and Stations during 2007-08

Group	Winter				Summer				Monsoon				3 seasons
	MN	MV	SN	ES	MN	MV	SN	ES	MN	MV	SN	ES	
Cyanophycea	0	1	1	1	1	0	0	1	1	1	1	1	2 (2.27%)
Pennate Diatom	21	16	15	25	19	19	15	27	10	11	14	16	31 (35.23%)
Centric Diatom	28	23	26	33	30	20	25	37	20	20	23	27	44 (50%)
Dinoflagellates	4	1	9	9	4	1	7	8	1	1	2	2	11 (12.5%)
Total	**53**	**41**	**51**	**68**	**54**	**40**	**47**	**73**	**32**	**33**	**40**	**46**	**88**

Table 3.2. Major Groups of Phytoplankton and their Species numbers in three seasons and Stations during 2008-09

Group	Winter				Summer				Monsoon				3 seasons
	MN	MV	SN	ES	MN	MV	SN	ES	MN	MV	SN	ES	
Cyanophycea		1		1				1	1	1	1	1	1(1.22%)
Pennate Diatom	20	17	18	20	16	20	17	25	18	16	18	21	28 (34.15%)
Centric Diatom	31	26	29	28	31	19	26	35	31	28	33	33	42 (51.22%)
Dinoflagellates	6	2	6	6	5	2	6	9	6	3	6	8	11 (13.41%)
Total	57	46	53	69	52	41	49	73	56	48	58	73	82

MN- Mundra, MV- Mandvi, SN- Sanghi, ES- Entire study

Table 3.3. Phytoplankton Density in Different Stations and Seasons during 2007-08

Sr No.	Type of group	Species	Summer			Monsoon			Winter		
			MV	MN	SN	MV	MN	SN	MV	MN	SN
1	P D	*Amphora*			15				1		
2	C	*Anabaenaa*		1							
3	P D	*Asterionella japonica*	7	11	29	5	5	25	3	7	5
4	P D	*Bacillaria paradoxa*	7	13	1	2		1	6	56	6
5	C D	*Bacteriastrum varians*		11	17						
6	C D	*Bidulphia aurita*	7	10		2		1	22	1	4
7	C D	*Bidulphia heterocerus*	8	16	1	1	4	1	9	13	2
8	C D	*Bidulphia longicrusis*						6			1
9	C D	*Bidulphia mobilensis*	11	1	28	30	32	15	14	64	9
10	C D	*Bidulphia sinensis*	10	16	36	7	15	58	5	55	3
11	C D	*Campylodiscus*	1	1	4		1	5	2	3	144
12	D	*Ceratium breve*			7						
13	D	*Ceratium declinatum*									1
14	D	*Ceratium falcatum*									2
15	D	*Ceratium furca*		9	1	3	2	1		6	3
16	D	*Ceratium inflatum*		1	1						2
17	D	*Ceratium kofoidii*		1	1					1	2
18	D	*Ceratium macrocerus*									1
19	D	*Ceratium tripos*			3			2		1	5
20	C D	*Chaetoceros affinis*	9	11							
21	C D	*Chaetoceros curvicetus*								15	33
22	C D	*Chaetoceros debilis*								58	43
23	C D	*Chaetoceros diversus*		10							
24	C D	*Chaetoceros dydymus*			8	1		6		12	21
25	C D	*Chaetoceros peruvianus*		10	7						
26	C D	*Chaetoceros sp*		33	57		2	4		219	321
27	C D	*Chaetoceros simplex*			23						

28	P D	*Climacosphenia*	1								
29	P D	*Coconeis littoralis*			7						
30	C D	*Coscinodiscus centralis*	1	15	2	21	6	22	6	12	8
31	C D	*Coscinodiscus eccentricus*		11	28						
32	C D	*Coscinodiscus gigas*	28	10		6	7	52	4	5	
33	C D	*Coscinodiscus granii*	47	16		16	11	51	3	11	14
34	C D	*Coscinodiscus jonesianus*		12	11						
35	C D	*Coscinodiscus linetus*	15	14		1		2	3	1	
36	C D	*Coscinodiscus oculus iridis*		19	1	11	4	24	2	14	4
37	C D	*Coscinodiscus radiatus*	7	12			1		4	1	8
38	C D	*Coscinodiscus sp*	1	16	1	23	22	18	13	18	66
39	C D	*Cyclostella*		1	1	1	1	12	5		7
40	P D	*Cymbella*						1		1	
41	D	*Dinophysis caudate*			1						
42	D	*Dinophysis miles*			1				1		3
43	P D	*Diploneis robustus*	1		1					1	
44	C D	*Ditylum brightwelli*		18	17	15	18	58	2	38	5
45	C D	*Ditylum sol*	7	16	1	1	2	52	1	34	6
46	C D	*Eucampia*	1	46		4	31	2	9	38	9
47	C D	*Eucampia zoodiacus*		21							
48	P D	*Fragillaria oceanica*	1	4	33	3	6	8	12	68	3
49	P D	*Grammatophora undulate*	21	1					90	1	16
50	P D	*Gyrosigma*	1	1	1	9	15	4	6	10	4
51	P D	*Gyrosigma balticum*	1	1	33			2	1	4	
52	C D	*Hemialus sinensis*	15							5	
53	C D	*Lauderia*					1		6	18	53
54	C D	*Leptocylindricus*	22	23	9		1				
55	P D	*Manguinea fusiformis*	1								
56	C D	*Melosira*		10	12						
57	P D	*Navicula*	80			2	1	3	2	11	2
58	P D	*Nitzschia braarudi*									1
59	P D	*Nitzschia distans*	18	15						2	
60	P D	*Nitzschia closterium*						2			

61	P D	*Nitzschia longisimma*	21	12		1	2	3		1	
62	P D	*Nitzschia sp*		11	20	3	3			1	
63	P D	*Nitzschia sigma*		11							
64	P D	*Nitzschia striata*	8	1		2		5	3	11	25
65	C	*Oscillatoria*				40	13	20	1		2
66	C D	*Planktonella sol*		1	34	8	6	16	1	1	4
67	C D	*Planktoniella blanda*		3		1			5	4	6
68	P D	*Pleurosigma angulatum*			10						
69	P D	*Pleurosigma elongatum*	1	1	7					1	
70	P D	*Pleurosigma galapgense*	1						1	2	
71	P D	*Pleurosigma setifera*	1	1					1	1	1
72	P D	*Pleurosigma sp*	1	1	2	46	17	10	4	14	4
73	D	*Protoperidium depressum*	23	1						3	5
74	P D	*Pseudo nitzschia*		1						4	5
75	C D	*Rhizosolenia castracanei*							1		7
76	C D	*Rhizosolenia cohlea*									1
77	C D	*Rhizosolenia setifera*			12			1		1	
78	C D	*Rhizosolenia sp*	12	37	34	23	4	5	2	8	3
79	C D	*Schroederella setigera*			12						
80	C D	*Skeletonema*	10							1	
81	P D	*Surirella sp*		1			1		1		
82	P D	*Synedra*		10	1				202	57	2
83	P D	*Thalassionema nitzschioides*	1	1	108	9	8	9	48	63	2
84	C D	*Thalassiosira coramandalina*								1	1
85	P D	*Thalassiothrix nitzschioides*	1	21	130	34	118	8	5	236	7
86	P D	*Thalassiothrix sp*						1			5
87	C D	*Triceratium fuvas*	1	10	1	2	3	7	4	31	
88	C D	*Triceratium reticulatum*	1		10	1		1	2		
		Density	411	561	780	334	363	524	513	1245	897
		No. of species	40	54	47	33	32	40	41	53	51

Table:3.4 Species richness and genus present at station

	2007-08			2008-09			During Entire study		
	MV	MN	SN	MV	MN	SN	MV	MN	SN
Genus	34	36	36	31	37	32	34	41	38
species	55	68	76	64	78	73	67	84	83

Table 3.5. Phytoplankton Density, Diversity and Species and Genera in Study Stations 2007-09

		Density-N0/L		No of Genera		No of Species	
Seasons	**Stations**	**2007-08**	**2008-09**	**2007-08**	**2008-09**	**2007-08**	**2008-09**
Winter	Mandvi	513	653	**25**	**26**	41	**41**
	Mundra	1245	1351	28	**26**	53	**52**
	Sanghi	897	1237	27	**26**	51	**49**
Summer	Mandvi	411	529	25	**23**	40	**48**
	Mundra	561	866	29	**25**	54	**56**
	Sanghi	780	676	27	**24**	47	**58**
Monsoon	Mandvi	334	666	20	**23**	33	**46**
	Mundra	363	1027	23	**30**	32	**57**
	Sanghi	524	1049	22	**27**	40	**53**
Annual	Mandvi	419	**616**	34	**31**	55	**64**
	Mundra	723	**1081**	36	**37**	68	**78**
	Sanghi	734	**987**	36	**32**	76	**73**

Table 3.6 : Shannon diversity index H, Evenness e and Margalef index.

Year	Season	Station	Shannon H log e	Evenness e^H/S	Margalef
2007-08	Summer	Mandvi	**2.978**	0.4915	6.48
		Mundra	**3.578**	0.6628	8.373
		Sanghi	**3.087**	0.4664	6.908
	Monsoon	Mandvi	**2.889**	0.5445	5.507
		Mundra	**2.62**	0.429	5.259
		Sanghi	**3.029**	0.5168	6.229
	winter	Mandvi	**2.362**	0.2588	6.41
		Mundra	**2.954**	0.362	7.296
		Sanghi	**2.554**	0.2522	7.354
2008-09	Summer	Mandvi	**3.602**	0.8948	6.379
		Mundra	**3.851**	0.9046	7.54
		Sanghi	**3.343**	0.5775	7.366
	Monsoon	Mandvi	**3.626**	0.7823	7.229
		Mundra	**3.732**	0.7456	7.931
		Sanghi	**3.725**	0.7153	8.195
	winter	Mandvi	**3.296**	0.5871	6.943
		Mundra	**3.385**	0.518	7.768
		Sanghi	**3.356**	0.5409	7.303

Table 3.7: species specific relative abundance of phytoplankton

Sr no	Species	2007-08			2008-09			Over all study		
		S	M	W	S	M	W	S	M	W
1	*Amphora*	15(0.86)	(0)	1(0.04)	15(0.72)	(0)	3(0.09)	30(0.78)	(0)	4(0.07)
2	*Anabaena*	1(0.06)	(0)	(0)	(0)	(0)	(0)	1(0.03)	(0)	(0)
3	*Asterionella japonica*	47(2.68)	35(2.87)	15(0.56)	55(2.66)	56(2.04)	20(0.62)	102(2.67)	91(2.3)	35(0.59)
4	*Bacillaria paradoxa*	21(1.2)	3(0.25)	68(2.56)	31(1.5)	24(0.88)	140(4.32)	52(1.36)	27(0.68)	208(3.53)
5	*Bacteriastrum varians*	28(1.6)	(0)	(0)	15(0.72)	13(0.47)	(0)	43(1.12)	13(0.33)	(0)
6	*Bidulphia aurita*	17(0.97)	3(0.25)	27(1.02)	35(1.69)	23(0.84)	30(0.93)	52(1.36)	26(0.66)	57(0.97)
7	*Bidulphia heterocerus*	25(1.43)	6(0.49)	24(0.9)	24(1.16)	37(1.35)	180(5.55)	49(1.28)	43(1.09)	204(3.46)
8	*Bidulphia longicrusis*	(0)	6(0.49)	1(0.04)	14(0.68)	16(0.58)	(0)	14(0.37)	22(0.56)	1(0.02)
9	*Bidulphia mobilensis*	40(2.28)	77(6.31)	87(3.28)	51(2.46)	112(4.08)	138(4.26)	91(2.38)	189(4.77)	225(3.82)
10	*Bidulphia sinensis*	62(3.54)	80(6.55)	63(2.37)	80(3.86)	95(3.46)	108(3.33)	142(3.71)	175(4.42)	171(2.9)
11	*Campylodiscus*	6(0.34)	6(0.49)	149(5.61)	22(1.06)	15(0.55)	3(0.09)	28(0.73)	21(0.53)	152(2.58)
12	*Ceratium breve*	7(0.4)	(0)	(0)	7(0.34)	33(1.2)	13(0.4)	14(0.37)	33(0.83)	13(0.22)
13	*Ceratium declinatum*	(0)	(0)	1(0.04)	8(0.39)	9(0.33)	17(0.52)	8(0.21)	9(0.23)	18(0.31)
14	*Ceratium falcatum*	(0)	(0)	2(0.08)	(0)	13(0.47)	21(0.65)	(0)	13(0.33)	23(0.39)
15	*Ceratium furca*	10(0.57)	6(0.49)	9(0.34)	17(0.82)	27(0.98)	23(0.71)	27(0.71)	33(0.83)	32(0.54)
16	*Ceratium inflatum*	2(0.11)	(0)	2(0.08)	23(1.11)	7(0.26)	(0)	25(0.65)	7(0.18)	2(0.03)
17	*Ceratium kofoidii*	2(0.11)	(0)	3(0.11)	2(0.1)	7(0.26)	7(0.22)	4(0.1)	7(0.18)	10(0.17)
18	*Ceratium macrocerus*	(0)	(0)	1(0.04)	8(0.39)	3(0.11)	(0)	8(0.21)	3(0.08)	1(0.02)
19	*Ceratium tripos*	3(0.17)	2(0.16)	6(0.23)	4(0.19)	29(1.06)	23(0.71)	7(0.18)	31(0.78)	29(0.49)
20	*Chaetoceros affinis*	20(1.14)	(0)	(0)	35(1.69)	24(0.88)	27(0.83)	55(1.44)	24(0.61)	27(0.46)
21	*Chaetoceros curvicetus*	(0)	(0)	48(1.81)	32(1.55)	54(1.97)	42(1.3)	32(0.84)	54(1.36)	90(1.53)
22	*Chaetoceros debilis*	(0)	(0)	101(3.8)	(0)	9(0.33)	39(1.2)	(0)	9(0.23)	140(2.37)
23	*Chaetoceros diversus*	10(0.57)	(0)	(0)	8(0.39)	88(3.21)	66(2.04)	18(0.47)	88(2.22)	66(1.12)

Sr no	Species	2007-08			2008-09			Over all study		
		S	M	W	S	M	W	S	M	W
24	*Chaetoceros dydymus*	8(0.46)	7(0.57)	33(1.24)	37(1.79)	47(1.71)	18(0.56)	45(1.18)	54(1.36)	51(0.86)
25	*Chaetoceros peruvianus*	17(0.97)	(0)	(0)	15(0.72)	(0)	36(1.11)	32(0.84)	(0)	36(0.61)
26	*Chaetoceros sp*	90(5.14)	6(0.49)	540(20.34)	73(3.52)	63(2.3)	332(10.24)	163(4.26)	69(1.74)	872(14.79)
27	*Chaetoceros symplex*	23(1.31)	(0)	(0)	37(1.79)	21(0.77)	21(0.65)	60(1.57)	21(0.53)	21(0.36)
28	*Climacosphenia*	1(0.06)	(0)	(0)	6(0.29)	17(0.62)	21(0.65)	7(0.18)	17(0.43)	21(0.36)
29	*Coconeis littoralis*	7(0.4)	(0)	(0)	2(0.1)	(0)	17(0.52)	9(0.24)	(0)	17(0.29)
30	*Coscinodiscus centralis*	18(1.03)	49(4.01)	26(0.98)	27(1.3)	75(2.74)	31(0.96)	45(1.18)	124(3.13)	57(0.97)
31	*Coscinodiscus eccentricus*	39(2.23)	(0)	(0)	54(2.61)	33(1.2)	(0)	93(2.43)	33(0.83)	(0)
32	*Coscinodiscus gigas*	38(2.17)	65(5.32)	9(0.34)	27(1.3)	97(3.54)	24(0.74)	65(1.7)	162(4.09)	33(0.56)
33	*Coscinodiscus granii*	63(3.6)	78(6.39)	28(1.05)	37(1.79)	92(3.36)	31(0.96)	100(2.62)	170(4.29)	59(1)
34	*Coscinodiscus jonesianus*	23(1.31)	(0)	(0)	31(1.5)	57(2.08)	24(0.74)	54(1.41)	57(1.44)	24(0.41)
35	*Coscinodiscus linetus*	29(1.66)	3(0.25)	4(0.15)	35(1.69)	28(1.02)	10(0.31)	64(1.67)	31(0.78)	14(0.24)
36	*Coscinodiscus oculus iridis*	20(1.14)	39(3.19)	20(0.75)	(0)	21(0.77)	9(0.28)	20(0.52)	60(1.51)	29(0.49)
37	*Coscinodiscus radiatus*	19(1.08)	1(0.08)	13(0.49)	36(1.74)	9(0.33)	15(0.46)	55(1.44)	10(0.25)	28(0.47)
38	*Coscinodiscus sp*	18(1.03)	63(5.16)	97(3.65)	28(1.35)	98(3.57)	48(1.48)	46(1.2)	161(4.06)	145(2.46)
39	*Cyclostella*	2(0.11)	14(1.15)	12(0.45)	(0)	17(0.62)	7(0.22)	2(0.05)	31(0.78)	19(0.32)
40	*Cymbella*	(0)	1(0.08)	1(0.04)	(0)	13(0.47)	(0)	(0)	14(0.35)	1(0.02)
41	*Dinophysis caudata*	1(0.06)	(0)	(0)	23(1.11)	8(0.29)	12(0.37)	24(0.63)	8(0.2)	12(0.2)
42	*Dinophysis miles*	1(0.06)	(0)	4(0.15)	(0)	11(0.4)	3(0.09)	1(0.03)	11(0.28)	7(0.12)
43	*Diploneis robustus*	2(0.11)	(0)	1(0.04)	11(0.53)	21(0.77)	5(0.15)	13(0.34)	21(0.53)	6(0.1)
44	*Ditylum brightwelli*	35(2)	91(7.45)	45(1.69)	47(2.27)	114(4.16)	87(2.68)	82(2.14)	205(5.17)	132(2.24)
45	*Ditylum sol*	24(1.37)	55(4.5)	41(1.54)	32(1.55)	77(2.81)	67(2.07)	56(1.46)	132(3.33)	108(1.83)
46	*Eucampia*	47(2.68)	37(3.03)	56(2.11)	33(1.59)	30(1.09)	135(4.17)	80(2.09)	67(1.69)	191(3.24)
47	*Eucampia zoodiacus*	21(1.2)	(0)	(0)	(0)	(0)	(0)	21(0.55)	(0)	(0)

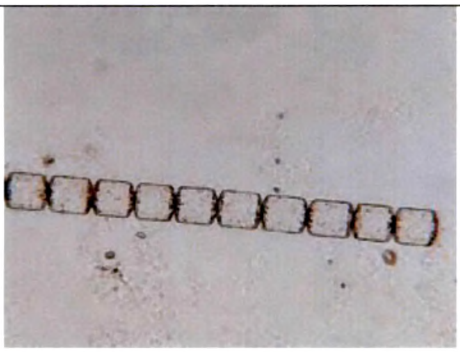
Sr no	Species	2007-08			2008-09			Over all study		
		S	M	W	S	M	W	S	M	W
48	*Fragillaria oceanica*	38(2.17)	17(1.39)	83(3.13)	29(1.4)	29(1.06)	119(3.67)	67(1.75)	46(1.16)	202(3.43)
49	*Grammatophora undulata*	22(1.26)	(0)	107(4.03)	8(0.39)	(0)	110(3.39)	30(0.78)	(0)	217(3.68)
50	*Gyrosigma*	3(0.17)	28(2.29)	20(0.75)	35(1.69)	38(1.39)	20(0.62)	38(0.99)	66(1.67)	40(0.68)
51	*Gyrosigma balticum*	35(2)	2(0.16)	5(0.19)	36(1.74)	22(0.8)	15(0.46)	71(1.86)	24(0.61)	20(0.34)
52	*Hemialus sinensis*	15(0.86)	(0)	5(0.19)	(0)	(0)	7(0.22)	15(0.39)	(0)	12(0.2)
53	*Lauderia*	(0)	1(0.08)	77(2.9)	(0)	19(0.69)	48(1.48)	(0)	20(0.5)	125(2.12)
54	*Leptocylindricus*	54(3.08)	1(0.08)	(0)	68(3.28)	43(1.57)	15(0.46)	122(3.19	44(1.11)	15(0.25)
55	*Manguinea fusiformis*	1(0.06)	(0)	(0)	(0)	11(0.4)	(0)	1(0.03)	11(0.28)	(0)
56	*Melosira*	22(1.26)	(0)	(0)	(0)	(0)	(0)	22(0.58)	(0)	(0)
57	*Navicula*	80(4.57)	6(0.49)	15(0.56)	38(1.83)	55(2.01)	54(1.67)	118(3.09	61(1.54)	69(1.17)
58	*Nitzschia braarudi*	(0)	(0)	1(0.04)	(0)	(0)	(0)	(0)	(0)	1(0.02)
59	*Nitzschia distans*	33(1.88)	(0)	2(0.08)	54(2.61)	7(0.26)	8(0.25)	87(2.28)	7(0.18)	10(0.17)
60	*Nitzschia closterium*	(0)	2(0.16)	(0)	23(1.11)	16(0.58)	21(0.65)	23(0.6)	18(0.45)	21(0.36)
61	*Nitzschia longisimma*	33(1.88)	6(0.49)	1(0.04)	13(0.63)	38(1.39)	2(0.06)	46(1.2)	44(1.11)	3(0.05)
62	*Nitzschia sp*	31(1.77)	6(0.49)	1(0.04)	39(1.88)	42(1.53)	71(2.19)	70(1.83)	48(1.21)	72(1.22)
63	*Nitzschia sigma*	11(0.63)	(0)	(0)	25(1.21)	21(0.77)	25(0.77)	36(0.94)	21(0.53)	25(0.42)
64	*Nitzschia striata*	9(0.51)	7(0.57)	39(1.47)	7(0.34)	21(0.77)	5(0.15)	16(0.42)	28(0.71)	44(0.75)
65	*Oscillatoria*	(0)	73(5.98)	3(0.11)	(0)	79(2.88)	5(0.15)	(0)	152(3.84)	8(0.14)
66	*Planktonella sol*	35(2)	30(2.46)	6(0.23)	43(2.08)	57(2.08)	13(0.4)	78(2.04)	87(2.2)	19(0.32)
67	*Planktoniella blanda*	3(0.17)	1(0.08)	15(0.56)	11(0.53)	8(0.29)	9(0.28)	14(0.37)	9(0.23)	24(0.41)
68	*Pleurosigma angulatum*	10(0.57)	(0)	(0)	27(1.3)	(0)	(0)	37(0.97)	(0)	(0)
69	*Pleurosigma elongatum*	9(0.51)	(0)	1(0.04)	14(0.68)	53(1.93)	1(0.03)	23(0.6)	53(1.34)	2(0.03)
70	*Pleurosigma galapgense*	1(0.06)	(0)	3(0.11)	17(0.82)	12(0.44)	9(0.28)	18(0.47)	12(0.3)	12(0.2)
71	*Pleurosigma setifera*	2(0.11)	(0)	3(0.11)	5(0.24)	42(1.53)	10(0.31)	7(0.18)	42(1.06)	13(0.22)

Sr no	Species	2007-08			2008-09			Over all study		
		S	M	W	S	M	W	S	M	W
72	*Pleurosigma sp*	4(0.23)	73(5.98)	22(0.83)	49(2.37)	89(3.25)	48(1.48)	53(1.39)	162(4.09)	70(1.19)
73	*Protoperidium depressum*	24(1.37)	(0)	8(0.3)	23(1.11)	(0)	4(0.12)	47(1.23)	(0)	12(0.2)
74	*Pseudo nitzschia*	1(0.06)	(0)	9(0.34)	(0)	(0)	(0)	1(0.03)	(0)	9(0.15)
75	*Rhizosolenia castracanei*	(0)	(0)	8(0.3)	(0)	(0)	4(0.12)	(0)	(0)	12(0.2)
76	*Rhizosolenia cohlea*	(0)	(0)	1(0.04)	12(0.58)	27(0.98)	5(0.15)	12(0.31)	27(0.68)	6(0.1)
77	*Rhizosolenia setifera*	12(0.68)	1(0.08)	1(0.04)	52(2.51)	3(0.11)	11(0.34)	64(1.67)	4(0.1)	12(0.2)
78	*Rhizosolenia sp*	83(4.74)	32(2.62)	13(0.49)	48(2.32)	39(1.42)	25(0.77)	131(3.43	71(1.79)	38(0.64)
79	*Schroederella setigera*	12(0.68)	(0)	(0)	11(0.53)	(0)	(0)	23(0.6)	(0)	(0)
80	*Skeletonema*	10(0.57)	(0)	1(0.04)	34(1.64)	38(1.39)	4(0.12)	44(1.15)	38(0.96)	5(0.08)
81	*Surirella sp*	1(0.06)	1(0.08)	1(0.04)	(0)	(0)	(0)	1(0.03)	1(0.03)	1(0.02)
82	*Synedra*	11(0.63)	(0)	261(9.83)	12(0.58)	34(1.24)	162(5)	23(0.6)	34(0.86)	423(7.17)
83	*Thalassionema nitzschioides*	110(6.28	26(2.13)	113(4.26)	123(5.94	36(1.31)	49(1.51)	233(6.09	62(1.56)	162(2.75)
84	*Thalassiosira coramandalina*	(0)	(0)	2(0.08)	(0)	15(0.55)	81(2.5)	(0)	15(0.38)	83(1.41)
85	*Thalassiothrix nitzschioides*	152(8.68	160(13.1)	248(9.34)	89(4.3)	179(6.53)	43(1.33)	241(6.3)	339(8.55)	291(4.94)
86	*Thalassiothrix sp*	(0)	1(0.08)	5(0.19)	(0)	3(0.11)	296(9.13)	(0)	4(0.1)	301(5.11)
87	*Triceratium fuvas*	12(0.68)	12(0.98)	35(1.32)	35(1.69)	17(0.62)	66(2.04)	47(1.23)	29(0.73)	101(1.71)
88	*Triceratium reticulatum*	11(0.63)	2(0.16)	2(0.08)	14(0.68)	6(0.22)	23(0.71)	25(0.65)	8(0.2)	25(0.42)
		1752 (100)	1221 (100)	2655 (100)	2071 (100)	2742 (100)	3241 (100)	3823 (100)	3963 (100)	5896 (100)

Plate 3.1 Phytoplankton recorded during study

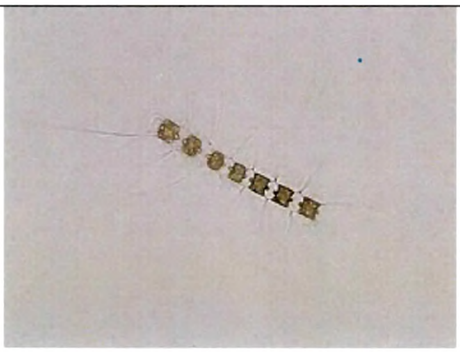
Asterionella japonica

Ceratium furca



Lauderia sp.

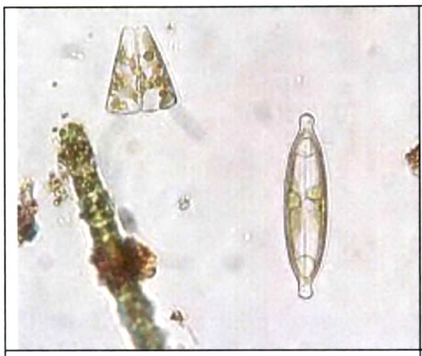
Ceratium tripos



Chaetoceros didamus

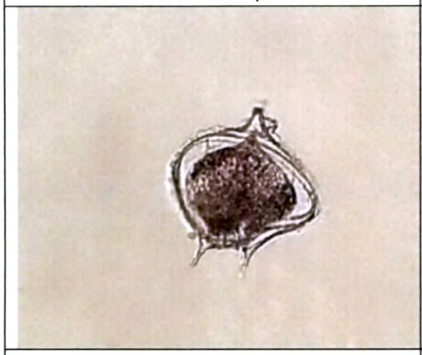
Ditylum brightwelli

Plate 3.2 Phytoplankton recorded during study



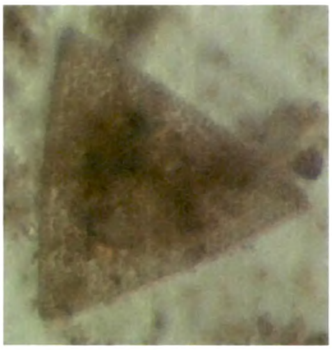
Navicula sp.

Nitzschia closterium

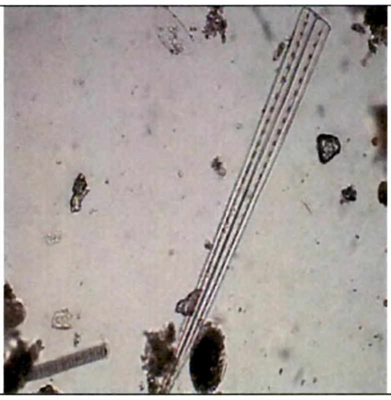


Protoperidium sp.

Skeletonema sp.

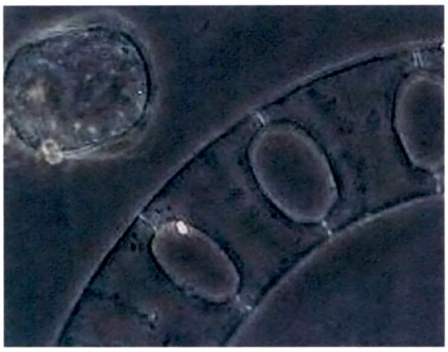


Triceratium sp.



Climacosphenia sp.

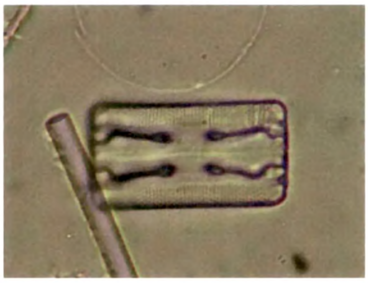
Plate 3.3 Phytoplankton recorded during study



Eucampia sp.

Thalasiosera sp.

Thalassiothrix sp.



Gramatophora sp.

Climacosphenia sp.

Pleurosigma sp.