CHAPTER 4

PHYTOPLANKTON
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STUDY OF PHYTOPLANKTON

4.1 Introduction

The word plankton comes from an ancient Greek word which means “floating,” or “drifting” and the literature is described by Hensen (1887) and Thurman(1997). Plankton are the microscopic and aquatic forms of animals and plants that freely float in aquatic environment and these are the community which is made up of tiny plates, These organisms float through water bodies both fresh and salty around the globe. Primarily, plankton live in the sunny zone of the aquatic environment, even though some species are found in much deeper water. Some plankton play an important role to maintain food chain (nutrient) in the aquatic balance. Their absence in the water body indicates an aquatic disproportion.

According to Emiliani(1991), the study of plankton is called planktology a planktonic individual is referred to as a plankter .Generally there are three types of plankton. Phytoplankton are plant like and they obtained their energy in the form of carbohydrates by photosynthesis. Several are unicellular found in large groups called blooms that change the color of water body. Zooplankton possess animal-like characteristics, and can sometimes get very large. There are various types of zooplankton that are the eggs and larvae of other sea creatures, these species of zooplankton grow and develop into much larger organisms. For many of these creatures, their main source of food is the phytoplankton. Some of the larger species of zooplankton are true predators and feed on other zooplankton. According to Chandrashekhar and Kodarkar (1997), the concept of biological indication of water quality and important aspect of aquatic assessment. Therefore many workers have used zooplankton as an indicators for monitoring the quality of water and status of pollution. Zooplanktons play an important role in the aquatic productivity, trophodynamics in water. However, zooplankton become the main food of fishes and thus can also be used as indicators of the trophic status of a water body (Verma and Munshi,1987). Thus, zooplankton play an essential role in transforming energy from producers to the consumers; from one trophic level to the next trophic level, finally leading to the fish production, which is mainly considered as the final product of aquatic environment (Singh, 2000).
4.2 Material and Methods

The study area BMIT was visited at monthly intervals for two years during January, 2009 to December, 2010. The water samples containing phytoplankton were collected at the periphery of study site from three stations namely BMIT A, BMIT B and BMIT C, in between 8 to 10 AM. According to Edmonson (1963) ten liters of water were filtered through the plankton net No. 25 of bolting silk with mesh size 40 micron. Net was washed with the water by inverting it to collect the plankton attached to the net and the volume of sample was made to 100 ml. The collected samples were taken in separate vials and preserved by 1 ml of 4 % formalin and 1 ml of Lugol’s Iodine at the BMIT site. 10 ml of sample from each station was further concentrated by centrifuging (Remi, R-24) at 2000 RPM for 10 minutes. For quantitative estimation of plankton, 1 ml well mixed sample was taken on ‘Sedgewick Rafter Cell’. To calculate density of plankton the averages of seven counts were made for each sample and the result were expressed as number of organisms per liter of collected sample of water. Qualitative study of phytoplankton was carried out up to the genus/species level using the standard keys given by Sarode and Kamat (1984); Philipose (1967) and Edmondson (1963). The two year study data (January, 2009 to December, 2010) were pooled for four months and three seasons and analyzed for seasonal changes, with respect to summer (January, February, March and April), Monsoon (May, June, July and August), Winter (September, October, November and December). Further, the Mean, Standard Error of Mean (SEM) were calculated for each season and One Way ANOVA with no post test for various parameters for four seasons were performed using Graph Pad Prism version 3.00 for Windows (Graph Pad Software, San Diego California, USA). The correlation between the physico-chemical parameters and the plankton density were calculated. The Pearson Correlation was calculated by keeping plankton as dependent variable and other abiotic and biotic factors as independent variables with the help of SPSS 7.5 for Windows. The P value for ANOVA is non significant if P > 0.05 (ns), Significant if P < 0.05 (*), Significantly significant (**) if P < 0.001 and highly significant if P < 0.0001.

According to Hurlbert (1971) the number of species present in an area may be considered as its ‘species richness’ a frequently used measure. Species richness can be correlated positively with some measures of ecological diversity. Phytoplankton
are studied. The phytoplankton study includes four major groups they are Cyanophyceae, Chlorophyceae, Bacillariophyceae and Euglenophyceae,

The phytoplankton name come from the Greek world phyton means ‘plant’ and plankton means ‘wanderer’ (Thurman, 2007). Phytoplankton are microscopic unicellular colonial algae, they are autotrophic and heterotrophic component of plankton society present in all natural water bodies. They are distributed by various parameters such as ecological, geological and climatic. Phytoplankton are sensitive to the water pollution or supplementary changes in water bodies, serve as biological indicator of water quality and pollution status (Saladia, 1997) and that is why are generally used for monitoring environmental contamination (Wu, 1999). The pollution of water was not only in physical and chemical parameters but also in algal species composition (Mercado, 2003). According to Sedamkar and Angadi (2003) especially in tropical inland waters leading to deterioration of potable potential of water. Thus the study of phytoplankton is also significant to evaluate the quality of freshwater. The effects of human activities alarming on the global population of phytoplankton are an area of dynamic research. Changes in the water column, the rate of temperature dependent biological reactions and the atmospheric supply of nutrients are not expected to have important effects on future phytoplankton productivity (Steinacher et al., 2010).

The density, diversity and species richness of plankton are controlled by several physicochemical parameters of water bodies Nair et al (1983). Therefore, phytoplankton have been used rather frequently as indicators to observe and understand changes in the hydrobiology under climatic or seasonal variations (Fevre-Lehoerff et al., 1995; Beaugarand and Reid, 2000 and Li et al., 2000.

While studying water quality of the BMIT is important to assess status of primary producers the phytoplankton. The present chapter deals with density and diversity of phytoplankton at BMIT, North Maharashtra, India. In the present study at BMIT that receives the monsoon and an attempt is made to find out the effect of season on phytoplankton community. The phytoplankton families represented at BMIT were.
4.2.1 Cyanophyceae

Blue green algae is considered as very small ancient group comprising of about 2500 species placed under 150 genera distributed all over the world. They exist either as a unicellular individual or filaments called trichome. They are generally found on rocks or soil forming a blackish crust when dried out. The Cyanophyceae (Blue green algae) has been among the most studied of all the planktonic groups. Previously classified as algae in the division Cyanophyta (Cyano = blue green), these organisms are now considered as true bacteria called cyanobacteria with simple prokaryotic cell structure. They occur in unicellular, filamentous or colonial forms and most of them are ensheathed with mucilaginous sheaths either individually or in colonies. The cyanobacteria are further classified as coccoid family Chroococcaceae e.g. *Microcystis* and filamentous families Oscillatoriceae e.g. *Oscillatoria*, Nostocaceae e.g. *Anabaena* and Rivulariaceae e.g. *Gloeotrichia*. Bold (1973) named this group as Cyanochloronata which is considered to be more appropriate than Cyanobacteria or Cyanophyta. However, biochemical relationships of some selected organisms from various groups by Schwartz and Dayhoff (1978), have shown that from biochemical point of view ‘blue greens’ are quite distant from bacteria when their ferredoxin sequences, c-type cytochromes and 5s ribosomal RNA sequences are taken into consideration.

Members of family Cyanophyceae form calcareous concentrations in the form of carbon crystals on the stones e.g. *Chaetophora* colony. These concentrations can form grayish-white sandy deposits along the lake shores and even extend out as calcareous ooze into deeper water (Round, 1985). Heterocysts, unique to Cyanophyceae (except Oscillatoriaeae), are differentiated cells that are major sites of nitrogen fixation. They show circadian rhythms and their capacity for photosynthesis and nitrogen fixation is regulated by biological clock, reset by light/ dark cues, at the level of gene expression Golden et. al.(1997).

4.2.2 Chlorophyceae

The second family that was observed at BMIT was Chlorophyceae. Chlorophyceae or Green algae are characterized by organized cellular components such as nucleus and chloroplast with chlorophyll A as well as B. There are about 6500
species of green algae worldwide. Green algae form greenish scum on the surface of stagnant water or grow firmly attached to the submerged rock, pieces of wood and other objects in water. It belongs to the division Chlorophyta or the ‘green algae’, which are highly developed photosynthetic living plants with simple morphology. Chlorophyta includes majority of algae particularly of fresh water bodies. According to Krishnamurthy (2000), three classes of green algae are now recognized, such as Chlorophyceae, Prasinophyceae and Charophyceae. These algal classes are usually illustrous on the basis of their pigmentation, nature of food reserves, fine structure of plastids, chemical nature of the cell wall and the number, position and fine structural details of flagella in the motile stages. The chlorophyceae are an extremely large and morphologically diverse group of algae that are more or less distributed in fresh water environment. Most of these planktonic green algae belong to the orders Volvocales e.g. *Eudorina, Volvox* and Chlorococcales e.g. *Pediastrum, Selenastrum*. Many members are flagellated or amoeboid, at least in the gamete stages in order Zygmematales and the desmids (Conjugales, Desmidiales). Eutrophic lakes, especially in temperate region often have large summer growths of Chlorococcales e.g. *Pediastrum, Chlorella* and these become especially abundant in the small lakes and ponds. According to Round (1985) a few desmids e.g. *Closterium, Cosmerium* are characteristics of eutrophic lakes and these are important indicator organisms especially when the absence of the bulk of desmid species is taken into account.

### 4.2.3 Bacillariophyceae (Diatoms)

The diatoms comprise about 1600 species grouped under about 200 genera. Bacillariophyceae constitute an important part of the fresh and marine water plankton, which form the basic food of the aquatic animals and possess Chlorophyll A and C. The third group of phytoplankton found at BMIT was the most important group of algae the Bacillariophyceae (Diatoms). Most species of Diatoms are sessile and associated with littoral substrata. Their primary characteristics are presence of silicified cell walls. Both unicellular and colonial forms are common among the diatoms. The group is commonly divided into the centric diatoms (Centrals), which have radial symmetry and the pennate diatoms (Pennales) that exhibit essentially bilateral symmetry. The Pennate diatoms are differentiated in four major groups: that are

1) the Araphidineae which posses a pseudoraphe e.g. *Asterionella* and *Fragillaria*
2) Raphidioidineae, in which a rudimentary raphe occurs at the cell ends e.g. *Actinella* and *Eunotia*  
3) The Monoraphidineae, which have a raphe on one valve and a pseudoraphe on the other e.g. *Achnanthes* and *Cocconeis* and  
4) Biraphidineae in which the raphe occurs on both the valves e.g. *Amphora, Cymbella, Gomphonema, Nevicula, Nitzschia and Surirella*. These divisions are of more than taxonomic interest since distinct nutritional requirements favour the growth of one group over another (Wetzel, 2001). The diatoms in littoral zone are important contributors of the primary production in shallow aquatic ecosystems (Wetzel, 1990). Some of the genera of diatoms are pollution tolerant. Palmer (1980) stated that *Synedraacus, Gomphonema sp.*, *Cyclotella sp.* and *Melosira sp.* are found in organically rich water and play an important role in water quality assessment and trophic structure. Diatoms are important inPaleolimnological studies to reconstruct the past eutrophication of lakes on the basis of paleolimnological evidences (Taylor et. al., 2006).

### 4.2.4 Euglenophyceae

Euglenophyceae are commonly found in small fresh water bodies, they are mostly unicellular aquatic algae and are comprised of more than 800 species and 40 genera. The Euglenophyceae is the forth and relatively smaller group found in the BMIT. When conditions are favorable, the euglenoids develop in large amount. Munawar (1972), reported that the high values of carbon dioxide, phosphates and low dissolved Oxygen favor the growth of Euglenophyceae. Almost all of them are unicellular, lack a distinct cell wall and possess one, two or three flagella that arise from an invagination in the cell membrane. Most of euglenoids are pigmented. The unpigmented euglenoids are able to ingest solid particles (phagotrophic) and are treated as Protozoa. The pigmented ones are photosynthetic and facultatively heterotrophic (Wetzel, 2001). This free swimming microalgal group of wide geographical distribution is found worldwide, occurring predominantly in small freshwater bodies, with high organic content (Round, 1985; Wetzel 2001 and Sandra et.al; 2007). Several species are known as indicator of organically polluted environments (Kaur, et.al;2001; Tiwari and Chauhan 2006; Hafsa and Gupta 2009; Nandan and Mahajan 2003). Due to the significance of the Euglenophyceae as organic pollution indicator, it is essential to document the information about them with their environmental preferences.
4.3 Result and Discussion

4.3.1 Total Phytoplankton

In the investigation of BMIT during the study period of two years (January, 2009 to December, 2010) total 38 genera and 59 species of phytoplankton were identified at BMIT belonging to four taxonomic assemblages Cyanophyceae (Blue green algae), Chlorophyceae (Green algae), Bacillariophyceae (Diatoms) and Euglenophyceae.

The percentage density of these four groups of phytoplankton recorded as two years % average (Table 4.1, Fig.4.1), in decreasing order, was Bacillariophyceae (42.65 %), Chlorophyceae (32.62 %), Cyanophyceae (22.19 %) and Euglenophyceae (2.53 %). The maximum density was recorded in summer (3219 ± 61.6 No/L) and minimum in monsoon (1656± 130 No/L) while it was slightly decreased in winter season (2932 ± 104 No/L) in monsoon as compared to summer(Table 4.1, Fig.4.3 ).

At BMIT two years percentage of species richness of total phytoplankton (Table 4.2, Fig. 4.2) also occurred in the similar decreasing order as density with Bacillariophyceae (48 %), Chlorophyceae (24 %), Cyanophyceae (21 %) and Euglenophyceae (7%). Total phytoplankton density showed highly significant seasonal variations (P < 0.0001) (F \textsubscript{21} 67.2). Maximum species of total phytoplankton were recorded in summer (23.25 ± 0.45) and minimum in winter (18.88 ± 0.44) and medium in (21.50 ± 0.56) monsoon (Table 4.2, Fig. 4.4).

Maximum density of phytoplankton noted at BMIT in summer may be attributed to maximum sunlight and higher temperature as is reported to stimulate growth of the aquatic autotrophs Vyas and Kumar (1968); Murugavel and Pandian (2000); Hujare (2005); Patil (2011) 21.67°C. The role of photoperiod and temperature in determining density of phytoplankton has been reported by Bhardwaja (1940); Nazneen (1980). Additional, the water level decreases in summer under Indian climatic conditions, the phytoplankton aggregate resulting in their increased density. Robert et.al. (1974) suggested that pH 5 to 8.5 is ideal for phytoplankton growth and this was found to be in the present investigation. According to Murulidhar and Murthy (2014) the higher pH (8.0) is favorable for the growth of phytoplankton same observation were recorded by Ekhande et.al. (2013) of Yashwant Lake (pH, 8.6), Toranmal. The pH of water changed with the changes in the climatological and vegetational factor as reported by Tahir Atıcı and Cem Tokatli (2014) pH (8.8), Kant and Kachroo (1971) ; George (1961) pH (9.6) found the high pH value increased the growth of algae.
At study site BMIT the Transparency, TDS, TH and Mg we positively correlated with total density of phytoplankton while negatively correlated with WC, TSS, NO$_3$, PO$_4$, and SO$_4$. (Table 4.3). Available literature indicates that temperature is one of the important determining factors for phytoplankton density and shows positive correlation Unni and Pawar (2000). However, various classes as well as individual species of algae have minimum, optimum and maximum temperatures for growth Palmer (1980). An opposite position occurs during monsoon when the water
cover are highest, plankton get more distributed resulting in decline in their density. The abundance of phytoplankton was recorded lowest during monsoon season, when the water column was remarkably stratified to a large extent because of heavy rainfall, high turbidity caused by run-off, reduced salinity, decreased temperature and pH, overcast sky and cool conditions. However, during this season, freshwater algal forms like *Anabaena sp, Chlorella sp, Nostoc sp, Lymnya sp, Spirogyra sp, Volvox sp*, were noticed. In addition the short photoperiod and lower temperature might not be much favorable to phytoplankton density. However, once the lake is stabilized the productivity increases resulting in higher density compared to monsoon. Similar trends were observed by Jyotsna (2014) of Satyavaram Pond, Srikakulam (Chlorophyceae 61% > Cyanophyceae 21% > Bacillariophyceae 15% > Euglenophyceae 3%). While density of Phytoplankton was lower reported by Mathivanan et.al. (2007) in Cauvery river (Cyanophyceae16 % > Chlorophyceae 13% > Euglenophyceae13% > Bacillariophyceae 12 %). When compared with phytoplankton density of other water bodies like reservoirs in plains of Maharashtra More and Nandan (2000); tropical reservoirs in Brazil Cleber and Giani( 2001) and Jawale and Patil (2009), the density of phytoplankton at BMIT was fluctuate.

Calcium is an important element of plant tissue, as it increases the availability of other ions and reduces the toxic effects of NO$_3^-$ (Manna and Das, 2004). As per the present study Calcium in the form of total hardness may be playing a vital role in the growth of phytoplankton resulting in significant positive correlations in total phytoplankton density with total hardness. While the influence of difference in the substratum and surrounding area is noted for those chemical parameters on which biota depends.

**Species richness**

In the present study the sequence of percentage density and species richness in decreasing order were Bacillariophyceae > Chlorophyceae > Cyanophyceae > Euglenophyta (Table 4.1 and 4.2) indicating no traces of eutrophication. This is supported by the representation of various species belonging to the four families studied. At study site BMIT, a in tropics, 59 species of phytoplankton that include 9 Cyanophyceae (Blue green algae),30 Bacillariophyceae (Diatoms), 14 Chlorophyceae (Green algae) and 6 Euglenophyceae did showed oscillations. Among these,
Bacillariophyceae appeared to be the dominant group. The nutrients increase due to human activities in the catchments; lead to change of Lake Flora from Diatom assemblage to those of greens and blue greens (Hutchinson, 1967).

According to Sharma and Durve (1985) was declare that the most undesirable feature of eutrophication is the change in the lake flora from diatoms (Bacillariophyceae) and greens (Chlorophyceae) to the blue greens (Cyanophyceae) that are favoured by increased nutrients. The nutrient enrichment at BMIT is reflected as increase and decrease in these three groups quantitatively as well as qualititatively over major part of the year in accordance to nutritional changes. Species richness of total phytoplankton in the BMIT also showed significant oscillations (P < 0.0001, F_{2.21} 20.18.) with decreasing trend from summer to monsoon to minimum in winter.
The maximum species richness of total phytoplankton (Fig. 4.2) recorded in summer was mainly due to the dominance of diatoms (48%) followed by members of Cyanophyceae and Chlorophyceae. As far as microhabitats was concerned the diatoms completely dominated the epipelic community throughout the year. During summer the increase in thermal stability of water column coincided with moderate nutrient depletion. However, there are species that favoured by mixing in water and higher nutrient concentration. The species richness of total phytoplankton decrease with the onset of monsoon that when plankton got distributed, reaching minimum species richness in winter when temperature and sunlight are minimum. In short the exogenous factors such as addition of rain water and silt may tend to disrupt equilibrium dynamics in monsoon while stable conditions of water in summer with change in temperature and photoperiod influence phytoplankton positively.

4.3.2 Cyanophyceae (Blue Green Algae)

At the study site BMIT Cyanophyceae were third dominant quantitative group of total phytoplankton with an average of two years percentage great quantity of 22.19 % (Table 4.1, Fig.4.1). Density of the Blue green algae (Table 4.1, Fig. 4.5) was maximum in winter season (866 ± 30.5 No /L) and minimum during monsoon period (357 ± 27.9 No/L) and median with (521±37.1No/L) in summer. (P < 0001 F 2 21 65.65). Total nine species with eight genera of Cyanophyceae (Annexure I) were reported during the study period. The average two years mean percentage of species richness of blue green algae was 21. The Maximum richness of species for Cyanophyceae was also recorded in winter (5.5 ± 0.26) and minimum recorded in summer (3.5±0.32). While in the monsoon the species richness was (4.50± 0.50),(Table 4.2, Fig.4.6) (P < 0.01 F 2217).

Pulle and Khan (1995) studied seasonal variation in primary production in Isapur dam, Maharashtra. Water temperature plays an important role in the periodicity of blue green algae (Hutchinson, 1967) as moderately high temperatures support their growth (Tucker and Loyd, 1984) and Naik et.al. 2005). The density of Cyanophyceae (Table-4.1) at BMIT was maximum in winter and minimum in monsoon. Similar result was reported by Mazher Sultana and Dawood Sharief (2004).
However, a negative correlation with AT at 0.01 level and non-significant with WT at BMIT. The same observation were noted by Bhatt et.al., (1999); Ekhande (2010) and Patil (2011). There are significant differences of opinion regarding the effect of pH on abundance of algal flora. However, the pH of BMIT was alkaline throughout the study period with maximum in summer (7.90 ± 0.13) and minimum in monsoon (7.2 ± 0.04). The individual cyanobacterial species have considerable specializations and are intolerant to a high degree of environmental variability (Padisak and Reynolds, 1998). Though the abundance was low in summer in present study maximum nine species of blue green algae were recorded from study site. These species we Microcystis viridis, Aphanocapsa montana, Spirulina subtillissma, Oscillatoria limosa, Oscillatoria brevis, Phormidium ambiguum, Lyngbyabergei, Nostoc spongiaeformae and Anabaena amphique species.

In the investigation at BMIT the water was showing pH around 7.90 , the seasonal density of Cyanophyceae was low. Among other physicochemical parameters (chapter 3) significant positive correlations were observed with AT, Trans, DO and density of Cyanophyceae as was also observed by (Krishnan, 2008) and significant negative correlations with CO₂ (Johnston and Jacoby, 2003) are of the judgment that low dissolved CO₂ is suitable for growth of Cyanophyceae. The nutrients NO₃⁻ and PO₄³⁻ were significantly negatively correlated with Cyanophyceae density. Hence the utilization of the nutrients for the growth results into higher density. The positive significant correlation between Cyanophyceae density and DO. has been observed at BMIT, the similar result recorded by Tiwari and Chauhan (2006) in seasonal phytoplanktonic diversity of Kitham lake, Agra.Izaguirre et.al; (2004), noted algal assemblages across a wetland, from a shallow lake to relictual oxbow lakes (Lower Parana River, South America).

According to Brunberg and Blomqvist (2002) Microcystis is a widely distributed organism which dominate the phytoplankton community in nutrient rich lakes. *Microcystis aeruginosa* is one of the main pollution producers of lakes (Kearns and Hunter, 2001); Lindholmet.al; (2003). Its presence poses a threat to the aquatic ecosystem. The degree to which water may be affected by these algae must therefore be well monitored. Further, other two pollution indicator genera *Anabaena* and
Oscillatoria that produce neurotoxins characterized as contact irritants were also recorded at BMIT but in low density. According to Mischke and Nixdorf (2003), the presence of Anabaena and Oscillatoria indicate beginning of biological pollution. Members of Oscillatoriaceae family are known to tolerate the combination of intermittent nutrient deficiency and low light conditions. Such conditions are produced by the frequent but irregular mixing of water in summer and they built up very dense population that increases turbidity. However, in summer the nutrient deficiency and high light conditions due to increase in transparency prevail. At higher temperature with high CO₂ and low Oxygen levels in summer Oscillatoria sp., Microcystis sp., Nostoc sp. and Anabaena species flourish (Tiwari and Chauhan, 2006). According to Seenayya (1972) and More (1997) the occurrence of Microcystis sp, the toxin producing blue green algae in the blooms of Cyanophyceae is a significant feature of tropical freshwater ecosystems are attributed to nutrients, particularly to Phosphorus enrichment. Zafar (1994), observed that the presence of diatoms was due to concentration of phosphates as it was in present investigation. Increased detection of 'cyano-toxins' in water bodies has generated a complex change for water resource managers all over the world (Johnston and Jacoby, 2003). Other factors that regulate Cyanophyceae are high water temperature, stable water column, low light availability, high pH, low dissolved CO₂ and low total N to P ratio TN: P ratio (Welch, 1992) and Paerl, 1988).

![Fig. 4.5: Density of Cyanophyceae No./L](image-url)
However, in the present study the Cyanophyceae and Chlorophyceae have been negatively significantly correlated (Table 4.3) indicating that the members of Cyanophyceae are not dominating the system. Natural systems are characterized by a variety of biotic and abiotic factors coupled with multiple species interactions. Although nutrient concentrations are considered fundamental for the development of cyanobacterial blooms, many other variables are involved in their ecological success (Dokulil and Teubner, 2002). Cyanobacteria are expected to be moderate in natural and unpolluted water bodies. However, in nutrient rich water bodies, they grow abundantly and their density increases to millions of cells per liter leading to a cyanobacterial blooms (Sangolkar et. al., 1999). No such condition is noted at BMIT over the study period of two years.

4.3.3 Chlorophyceae (Green Algae)

During the investigation period the chlorophyceae was second dominant quantitative component of algal composition of BMIT. The average two years percentage was calculated 32.62 %. (Table. 4.1, Fig.4.1). The density of green algae was maximum in winter (1358 ± 52.60 No/L) and minimum (483.5 ± 42.95 No/L) in monsoon period, while it was (721.0 ± 62.77 No/L) in summer. (Table.4.1, Fig.4.7) (P < 0.0001, F2 21 71.8). In the investigation total 14 species belonging to 9 genera of green algae (Annexure I) were identified during the present study. It showed average mean biannual percentage of species richness as 24. (Table 4.2, Fig. 4.2). The Maximum species richness was observed in winter (6.62 ± 0.18) and minimum in
summer (3.37 ± 0.18) and moderate in monsoon (5.5 ± 0.18). Green algae varied non-significantly across the season (Table 4.2, Fig.4.8) \( (F_{2,17} 79.59) \).

Green alga, the second dominant group in relation to density as well as diversity was identified. Chlorophyceae the free living phytoplankton, is mostly limited to shallow waters and attached to the submerged plants or found in moist soil. Maximum density of green algae was recorded in winter when temperature and photoperiod were minimum at BMIT (Table 4.1). Many workers reported the distribution and abundance of Chlorophyceae. The abundance of Chlorophyceae was highest during the pre-monsoon period, which could be attributed to more stable hydrographical conditions and was lowered during the monsoon months when the water column was remarkably stratified to a large extent because of heavy rainfall, high turbidity caused by run-off, and decreased temperature and pH Kumar et. al.(2012); Huddar (1995); Islam et.al. (2001). In the present study as noted for other groups, the minimum density of Chlorophyceae in monsoon may be attributed to the dilution effect due to the rains as well as drifting of algae along with the water. Like Cyanophyceae the maximum density of Chlorophyceae was recorded in winter and low during summer indicate that their contribution is low in increase in the total plankton density of summer. The Chlorophyceae is the second dominant group recorded at BMIT which coincides with the predominance of the diatoms over the green algae noted by Baruah et.al., (1993) and Krishnan et.al. (1999).

In cold climatic conditions, an increase in organic load commonly leads to a shift in the ecosystem from Diatom dominated flora to green and blue green in the form of nutrient input due to human activities in catchment. In the present study of BMIT though the Diatom dominated over green algae quantitatively. Chlorophyceae was second dominant group with average density of 32.62%. same record was noted by Giriayappanavar and Patil (2010) found 24.99 %, at belgaum and Wadral lake, wadral karnataka. Further, significant seasonal variations recorded in the density of Chlorophyceae indicated their dependence on physico-chemical as well as biological components of the system (Table 4.3) Among biological components of BMIT, Chlorophyceae is positively correlated to Bacillariophyceae and Cyanophyceae at the level of 0.01, adding to the total density while non significantly with the minor group Euglenophyceae. However, among physical parameters AT and WT have negative effect whereas WC has no significant effect on Chlorophyceae. Water temperature of study site, being located at higher altitude, fluctuated in comparatively narrow range
and hence probably produced non signified effect on Chlorophyceae, while Total solids and suspended particles prevented growth of Chlorophyceae and its dissolved components might have no significant effect indicating that chemical components have less influence on Chlorophyceae. Further, CO$_2$ showed negative influence (P < 0.01) while dissolved Oxygen positive influence on Chlorophyceae. Rather, the nutrients have significant negative relations as they were trapped by growing Chlorophyceae population. The alkaline nature of water body has been reported to promote the dense growth of Chlorophyceae (Gulati and Wurtz, 1980). The BMIT was found to be alkaline throughout the year. Chlorophyceae phytoplankton order of Chlorococcalean is known to prefer inorganic nutrients providing alkaline pH (Rao, 1995 and Krishnan, 2008) and thrive well in water rich in NO$_3$ than phosphates. Total hardness and transparency also influence Chlorophyceae density positively (Bhatt et al., 1999).

Species richness of Chlorophyceae with total 14 species of 9 genera of BMIT. These genera are Ulothrix, Oedogonium, Bulbochaetae, Pediastrum, Eudorina, Spirogyra, Closterium, Staurastrum, Cosmarium, Volvax and Microspora of these Closterium, Staurastrum and Cosmerium are considered as desmids which indicate good quality of water and absence of desmids is an indication of heavy pollution of water (Hosmani et al., 2002). Detailed study of desmid flora would be useful in managing the pristine quality of BMIT. According to Hutchinson (1967) desmids e.g. Cosmarium are associated with oligotrophic freshwater and in these, they may form an important food source for herbivore fish. The food chain relations of endemic and endangered species of fishes may include specific phytoplankton species. Moreover, the dominance of Desmids over Chlorococcales (Pediastrum) a group indicative of eutrophication (Rott, 1984) in the lake may be considered as a positive biological sign to suggest that the trophic characteristics of the system are still within control. Further, the different species of Chlorophyceae have differential preference for Magnesium and Phosphate for their growth and high Calcium content and low pH values favour their growth (Munawar, 1974). Typical species of nutrient rich waters we Mougeotia, Oocystis, Ulothrix, Spirogyra, Micractinium (Sreenivasan et al., 1997). Among these genera Ulothrix and Spirogyra were recorded in BMIT in low density. Annexure I, the species of Coelastrum, Oocystis, Scendesmus, Zygnema, Chlamydomonas, Chlorella, Spirogyra, Tribonema and Closterium are found in polluted waters. Of these only Spirogyra and Closterium were found in study area of BMIT in low density. The algal community structures thus suggest that the system is
still under natural control as is evidenced by the dominance of sensitive species and rare occurrence of tolerant species, this indicates that the water is not much polluted.

4.3.4 Bacillariophyceae (Diatoms)

In the present study Bacillariophyceae (Diatoms) was the most dominant family in the total phytoplankton abundance with an average biannual percentage 42.65%. (Fig. 4.1) Maximum density of diatoms was recorded in summer with (1926± 116.4 No/L), and the minimum density was recorded in monsoon with (703.5 ± 76.29 No/L) while moderate in winter season (721.0±55.70 No/L) at BMIT study site. (Table 4.1, Fig. 4.9). Total thirty species of diatoms (Annexure I) were recorded in the BMIT, which showed significant seasonal variations (P < 0.0001, F2 21 172.8)
with 48% of average (Table 4.2, Fig. 4.2). Maximum species of diatoms were also recorded in summer (15.38 ± 0.26) but minimum in monsoon (8.37 ± 0.37), while it was (6.12 ± 0.44) in winter (Table 4.2, Fig. 4.10).

The diatoms constitute an important component of the fresh water or marine plankton, the environmental factor such as physico-chemical and biological factors influence the abundance and species richness of diatoms, which is reflected in their seasonal variations. According to Pearsall (1923); Schorder (1940); and Mahajan (2001), the temperature is the most important factor affecting the growth of diatoms. Maximum diatom density was recorded in summer at BMIT. The observation reported by Shinde et.al. (2012), maximum Bacillariophyceae were recorded during summer at north site (41.89 and 1173 org l-1) and minimum during monsoon at south site (6.96 and 195 org l-1) from Harsool, Savangi dam, Aurangabad, and also reported by Sabata and Nayar (1987); Hujare (2005); Hafsa and Gupta (2009); Jawale and Patil (2009) and Ekhande (2010). According to Sing and Swarup (1979) the phosphate, nitrate and Calcium are the favorable parameters for the diatom population in Suraha lake. The population of diatoms was considerably increased with increased concentration of phosphates by Sing (1960); Zafar (1964); Hergenrader (1980) and Pendse et.al. (2000).The highest number of Bacillariophyceae recorded during the period of highest temperature reported by Mishra and Panigraphy (1995) in Bahuda estuary. In addition the water quality in terms of concentration of organic matter, DO, pH, and other physical factors play an important role in the distribution of diatoms. Diatoms are reported to absorb phosphates in large quantities than their requirements (Rutner, 1963) and Munawar (1970). Philipose (1960) has reported direct relation of phosphates with diatoms. In present study, minimum to moderate phosphates were recorded in winter and summer respectively when the diatom populations were moderate to maximum. In additions Nitrates have also been given the prime importance in diatom ecology, Rao(1995). Nitrate is also considered as the main controlling parameter in the periodicity of diatoms, this was tallied with the observation of Ganpati(1943); Zafar(1964) and Nandan and Patel(1986). However, in the present study the diatom density is found to be positively correlated with the AT, WT, TDS, CO₂, CL, TH and CA at 0.01 level at the BMIT.
Maximum species composition of diatoms were recorded in summer season and post-monsoon by Mishra and panigraphy (1995), maximum peak during winter and least in monsoon season (Nautiyal et al., 1996). According to Nandan and Magar (2007) and Sharma (2009), the greater diatoms observed at summer and winter in their annual studies. However, in present seasonal study a steady increase from winter to summer has been recorded at BMIT. The effect of rains in distributing the plankton in general and resulting decline in their density stands true for diatoms too in monsoon.
In the investigation at BMIT the total 30 Bacillariophyceae species were recorded belonging to 17 genera (Annexure I), this indicates availability of their distinct nutritional requirements at BMIT. Patrick (1973) concluded that many species of diatoms can tolerate at various temperature range. The study at BMIT indicated that this group of species were found abundantly when water temperature fluctuated between winter 21.5 °C and summer 26.5 °C.

Palmer (1969) has listed the taxa emphasis with reference to pollution index. In the present study some of these pollution tolerant species were also observed in BMIT these are: *Navicula, Melosira, Gomphonema, Fragilaria, Surirella, Cymbella*, Similar taxa were also recorded by Nandan and Mahajan (2007) at Suki Dam, Maharashtra. It is general observation that *Cymbella, Fragilaria species, Gomphonema* are commonly found in organically rich waters. The clean water diatom species *Amphora ovalis, Cymbella sp., Pinnularia sp.* were also found in the waters of BMIT. This indicates that though not yet polluted, if the care is not taken may get polluted in future as it is having potential for deterioration and eutrophication under the influence of pollution and anthropogenic activities.

### 4.3.5 Euglenophyceae

The biannual average density of Euglenophyceae appeared to be a very small group quantitatively that comprised only 2.53 %. and it also showed significant seasonal variations ($P<0.0001$, $F_{2, 21} 5.43$) (Table 4.1). Maximum density of Euglenophyceae was recorded in monsoon ($115.5\pm14.05$ No/L) and minimum in summer ($50.88\pm4.32$ No/L), while it was moderate in winter ($74.38\pm17.31$ No/L) (Table 4.1, Fig.4.11). Biannual average percentage species richness of Euglenophyceae was 7%. The Maximum species richness was observed in monsoon with ($3.12 \pm 0.44$), while minimum in winter ($0.6 \pm 0.18$). and medium in summer season (Table 4.2, Fig. 4.12). Total six species of Euglenophyceae were recorded at BMIT. It showed significant seasonal variation ($P < 0.0001$, $F_{2, 21} 23.95$).

In the present investigation of BMIT the abundance of Euglenophyceae showed seasonal variation attributed to sequential variation in physico-chemical parameters. Maximum density of euglenophyta was recorded in monsoon, the similar
observation also reported by Hafsa and Gupta (2009). Euglenophyceae are found commonly in small water bodies which is rich in organic matter. According to Palmer (1969) the Euglenophyceae are the biological indicators of organic pollution. Several species are known as indicators of organically polluted environment (Hafsa and Gupta 2009). Kumar, et al. (1974) observed the blue green and euglenoid flagellates were mostly associated with organically rich effluents low in DO. Munwar (1972); Tripathi and pandey (1995) and Hegde and Sujata (1997) have reported that high water temperature, phosphates, nitrates, and low Carbon dioxide support the growth of euglenoids.

Euglenophyceae was the group represented in the lowest percentage density in the research area of BMIT water with annual average percentage density of only 2.53%. When its seasonal variations we considered higher density of Euglenophyceae was recorded in the monsoon and lowest in the summer. Maximum euglenoids in monsoon could be attributed to influx of rainwater which carried high amount of organic matter from the drainage. Pendse et. al. (2000) reported the higher Euglenophyceae population during monsoon period when the water showed good amount of nutrients which is similar to present study at BMIT.

According to Duttagupta et. al. (2004); Bhuiyan and Gupta (2007) Iron, Calcium and Magnesium play a great role in stimulating and maintaining Euglena blooms. Drastic decrease in the population of Euglenophyceae in winter has been attributed to the used up of essential nutrients during their bloom period in monsoon. Venkateshwarlu et. al. (1981) reported that euglenoid bloom occured in sewage infested polluted water where organic matter and Iron concentration we high.
In present investigation in BMIT, the density of Euglenophyceae showed positive correlations with TSS, PO₄, SO₄ and NO₃ while negative correlations with Trans., TH, pH. (Table 4.3). The similar result were reported by Ekhande (2010) and Patil (2011). In the BMIT water only six species of Euglenophyceae belonging to two genera representing in a minute 7% of the total diversity of phytoplankton were observed. Minimum number of species were noted such as *Euglena spirogyra* and *Euglena gaumei* most common in monsoon. According to Alam and Khan (1996) the occurrence of *Euglena sp* and *Phacus sp*, are a direct indication of beginning of pollution load because both these species in generally considered to be dominant and
tolerant of polluted ponds. However, Tiwari and Srivastava (2004) found *Euglena sp.* and *Phacus sp.* in industrially polluted as well as non-polluted waters in North India and also observed that these are the species with greater ecological amplitude to their occurrence in aquatic systems exhibiting varying levels of pollution load. Though the pollution indicator species were found in BMIT their density and species richness were very poor, so for the proper management of this water body continuous monitoring will be necessary.

In conclusion, BMIT water supports good diversity and density of phytoplankton with Bacillariophyceae as the most common group while Euglenophyceae the least. The Study area is not yet polluted, but BMIT water is utilized for human activities and domestic purposes. If care is not taken it can soon undergo deterioration and develop into a deteriorated habitat.
Table 4.1 Seasonal Variations in density of different groups of phytoplankton (No/L) with two years mean percentage density at BMIT during January, 2009 to December, 2010.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>F value</th>
<th>Summer</th>
<th>Monsoon</th>
<th>Winter</th>
<th>Two years %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tot. Phy.</td>
<td>F₂ 2167.2</td>
<td>3219 ± 61.6</td>
<td>1656 ± 130</td>
<td>2932 ± 104</td>
<td>-</td>
</tr>
<tr>
<td>Cyano.</td>
<td>F₂ 2165.65</td>
<td>521 ± 37.1</td>
<td>357 ± 27.9</td>
<td>866 ± 30.5</td>
<td>22.19</td>
</tr>
<tr>
<td>Chloro.</td>
<td>F₂ 2171.8</td>
<td>721.0 ± 62.77</td>
<td>483.5 ± 42.95</td>
<td>1358 ± 52.60</td>
<td>32.62</td>
</tr>
<tr>
<td>Bacill.</td>
<td>F₂ 2165.56</td>
<td>1926 ± 116.4</td>
<td>703.5 ± 76.29</td>
<td>721.0 ± 55.70</td>
<td>42.65</td>
</tr>
<tr>
<td>Eugle.</td>
<td>F₂ 215.43</td>
<td>50.88 ± 4.320</td>
<td>115.5 ± 14.05</td>
<td>74.38 ± 17.31</td>
<td>2.53</td>
</tr>
</tbody>
</table>


Table 4.2 Seasonal Variations in Species richness of different groups of Phytoplankton (No. of Species) with two years mean % density at BMIT during January, 2009 to December, 2010.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>F value</th>
<th>Summer</th>
<th>Monsoon</th>
<th>Winter</th>
<th>Two years %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tot. Phy.</td>
<td>F₂ 2120.18</td>
<td>23.25 ± 0.45</td>
<td>21.50 ± 0.56</td>
<td>18.88 ± 0.44</td>
<td>-</td>
</tr>
<tr>
<td>Cyano.</td>
<td>F₂ 217.00</td>
<td>3.5 ± 0.32</td>
<td>4.50 ± 0.50</td>
<td>5.5 ± 0.26</td>
<td>21</td>
</tr>
<tr>
<td>Chloro.</td>
<td>F₂ 2179.59</td>
<td>3.37 ± 0.18</td>
<td>5.5 ± 0.18</td>
<td>6.62 ± 0.18</td>
<td>24</td>
</tr>
<tr>
<td>Bacill.</td>
<td>F₂ 21172.8</td>
<td>15.38 ± 0.26</td>
<td>8.37 ± 0.37</td>
<td>6.12 ± 0.44</td>
<td>48</td>
</tr>
<tr>
<td>Eugle.</td>
<td>F₂ 2123.95</td>
<td>1.00 ± 0.0</td>
<td>3.12 ± 0.44</td>
<td>0.62 ± 0.18</td>
<td>7</td>
</tr>
</tbody>
</table>

Table No. 4.3 Pearson correlation of total Phytoplankton density along with individual group with Abiotic parameters of BMIT during January, 2009 to December, 2010.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Atmospheric Temperature (AT) °C</td>
<td>.032</td>
<td>.584**</td>
<td>-.653**</td>
<td>.588**</td>
<td>.155</td>
</tr>
<tr>
<td>2</td>
<td>Water Temperature (WT) °C</td>
<td>-.049</td>
<td>-.551**</td>
<td>-.614**</td>
<td>.528**</td>
<td>.174</td>
</tr>
<tr>
<td>3</td>
<td>Water Cover (WC) %</td>
<td>-.420*</td>
<td>.156</td>
<td>.268</td>
<td>-.889**</td>
<td>-.303</td>
</tr>
<tr>
<td>4</td>
<td>Total Solids (TS) mg/L</td>
<td>-.397</td>
<td>-.841**</td>
<td>-.886**</td>
<td>.371</td>
<td>.512</td>
</tr>
<tr>
<td>5</td>
<td>Total Suspended Solids (TSS) mg/L</td>
<td>-.826**</td>
<td>-.850**</td>
<td>-.857**</td>
<td>-.183</td>
<td>.865**</td>
</tr>
<tr>
<td>6</td>
<td>Total Dissolved Solids (TDS) mg/L</td>
<td>.000</td>
<td>-.626**</td>
<td>-.686**</td>
<td>.664**</td>
<td>.140</td>
</tr>
<tr>
<td>7</td>
<td>Transparency (Trans) Cm</td>
<td>.680**</td>
<td>.830**</td>
<td>.848**</td>
<td>.013</td>
<td>-.759**</td>
</tr>
<tr>
<td>8</td>
<td>Carbon Dioxide (CO₂) mg/L</td>
<td>.162</td>
<td>-.61**</td>
<td>-.693**</td>
<td>.609**</td>
<td>.160</td>
</tr>
<tr>
<td>9</td>
<td>Dissolved Oxygen (DO) mg/L</td>
<td>-.027</td>
<td>.605**</td>
<td>.648**</td>
<td>-.665**</td>
<td>-.110</td>
</tr>
<tr>
<td>10</td>
<td>Chloride (CL) mg/L</td>
<td>-.056</td>
<td>-.635**</td>
<td>-.705**</td>
<td>.603**</td>
<td>.262</td>
</tr>
<tr>
<td>11</td>
<td>Total Hardness (TH) mg/L</td>
<td>.563**</td>
<td>.063</td>
<td>-.056</td>
<td>.710**</td>
<td>-.329**</td>
</tr>
<tr>
<td>12</td>
<td>Potentia hydrogenii (Ph)</td>
<td>.678*</td>
<td>.310</td>
<td>.298</td>
<td>.542**</td>
<td>-.544**</td>
</tr>
<tr>
<td>13</td>
<td>Nitrate (NO₃) mg/L</td>
<td>-.567**</td>
<td>-.713**</td>
<td>-.716**</td>
<td>.013</td>
<td>.472**</td>
</tr>
<tr>
<td>14</td>
<td>Phosphate (PO₄) mg/L</td>
<td>-.657**</td>
<td>-.817**</td>
<td>-.860**</td>
<td>.022</td>
<td>.688**</td>
</tr>
<tr>
<td>15</td>
<td>Sulphate (SO₄) mg/L</td>
<td>-.869**</td>
<td>-.825**</td>
<td>-.819**</td>
<td>-.272</td>
<td>.915**</td>
</tr>
<tr>
<td>16</td>
<td>Calcium (Ca) mg/L</td>
<td>.608**</td>
<td>.088</td>
<td>.060</td>
<td>.685**</td>
<td>-.401</td>
</tr>
<tr>
<td>17</td>
<td>Magnesium (Mg) mg/L</td>
<td>.642**</td>
<td>.258</td>
<td>.196</td>
<td>.583**</td>
<td>-.512**</td>
</tr>
</tbody>
</table>

** The pearson correlation is significant at the 0.01 level (two tailed)
*The pearson correlation is significant at the 0.05 level (two tailed)
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<tr>
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<td><em>Chloro-Pediastrum simplex</em></td>
</tr>
<tr>
<td><img src="image4.png" alt="Image" /></td>
<td><em>Chloro-Spirogyra hyalina</em></td>
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<td><img src="image5.png" alt="Image" /></td>
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<td><img src="image6.png" alt="Image" /></td>
<td><em>Diatom-Fragilaria construens</em></td>
</tr>
<tr>
<td><img src="image7.png" alt="Image" /></td>
<td><em>Euglino-Phacus logicauda</em></td>
</tr>
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<td><img src="image8.png" alt="Image" /></td>
<td><em>Diatom-Rhopalodia gibba</em></td>
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