Chapter:4
Phytoplankton

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Introduction

Phytoplanktons are microscopic algae that occur in unicellular, colonial or filamentous forms. Most of them have photosynthetic ability and are eaten by zooplankton (APHA, 2012). These communities dominate the pelagic ecosystems that cover 70 % of the world's surface area. Phytoplanktons adapted to live partially or continuously in open water. According to Reynolds, (2006) phytoplankton are photoautotrophic elements of plankton community and major primary producers of organic carbon. Phytoplankton grow photoautotrophically in aquatic environments (Wassie and Melese, 2017) and colonize the upper part of the water column, down to limit of penetration of light. Phytoplankton form good indicators of water quality as they have rapid turn-over time and are sensitive indicator of environmental stresses. They constitute the basis of nutrient cycle of an ecosystem hence play an important role in maintaining equilibrium between living organisms and abiotic factors (Wetzel, 2001).

Biodiversity is crucial prerequisite for the upholding of ecosystem services providing manifold benefits to human wellbeing (Millenium Ecosystem Accessment 2005). Phytoplankton biodiversity, support primary productivity and provide food (via the trophic cascade), regulate water quality and climate (e.g. via nutrient and carbon fixation, oxygen production) as well as support aesthetic aspects (e.g. preventing cyanobacteria dominance and blooms in water bodies). Phytoplankton growth and diversity are controlled by seasonal temperature changes as well as increasing water temperatures (Schabhu¨ttl, *et al*., 2013). Temperature is among major determinants that influence phytoplankton growth rates, nutrient stoicheochemistery and spatial and temporal distribution in fresh water systems.

According to Giripunje *et al*., (2013) and Gulecal and Temel, (2014) phytoplankton ecology is an indicator of the increase of impacts of influencing factors and provides a ground for maintaining and assessing strategies of the freshwater lake management. Factors like climatic conditions, water-shed features, land use, geochemical factors, soil or sediment, are important for management of phytoplankton. Study and monitoring of Phytoplankton are useful for control of physic-chemical and biological conditions of the water in any irrigation project (Naselli–Flores, 2000).

These most ubiquitous aquatic forms collectively account for about half the earth's primary producers. However, light penetration, temperature, nutrient enrichment, toxic substances, mixing of water, parasites, behaviour and heterotrophic microorganism activities influence phytoplankton growth (Reynolds, 1987). They are the key component of the aquatic food web in oceanic and inland waters reflecting the trophic status of the water body (Silva *et al*., 2013).

Phytoplankton occupy lowest trophic level in aquatic ecosystem food chain (Murluidhar and Murthy, 2015 Joseph, 2017; Hajong and Ramanujam, 2018 Joseph, 2017; Hajong and Ramanujam, 2018) and interactions between phytoplankton and zooplankton form an essential basis of the food chain in natural and man-made water bodies (Jacqueline *et al*., 1994). These interactions may administer aquatic productivity that is realized in terms of the amount of fish harvested from aquatic ecosystems. Studies of Phytoplankton density and diversity in water quality assessment have been emphasized (Chaturvedi *et al*., 2001; Jarousha, 2002; Agale, *et al*., 2013; Silva *et al*., 2013). Such surveys thus help to find out the trophic status and the organic pollution in the ecosystem (Mani *et al*., 2017). Human activities like washing cloth, washing cattle and agricultural activities create favorable condition for growth of phytoplankton (Barve and Sonawane, 2017). Sharma *et al*., (2016) also reported that increased concentration in turbidity, total dissolved solids, nitrates and phosphates have an adverse effect on the density of phytoplankton. Further, they also depicted that as sediment load increases, the growth of phytoplankton decreases. Phytoplankton are also affected by physical, chemical and biological factors, making them valuable tool in monitoring programmes. The phytoplankton and zooplankton are always inversely proportional in an aquatic environment because the zooplankton feed on the phytoplankton thus density of phytoplankton is directly correlated with potentiality of an aquatic ecosystem (Quasim, 1973).

Phytoplankton a key tool for understanding the maintenance of species diversity (Stomp *et al*., 2011) and species richness is considered a simple measure to qualify and express the complexity of an ecosystem (Nabout *et al*., 2007). Phytoplankton richness is an important criterion in assessing water body and for its preservation and conservation, as well as an important element to be considered when proposing strategies for maintenance of biodiversity (Bortolini *et al*., 2014).

They respond quickly to environmental changes (Patil *et al*., 2013) and are used as indicator to access the ecological status of the water bodies. Eutrophication a global phenomenon is associated with nutrient enrichment of aquatic ecosystem and the increase in production of certain plankton. This causes unfavorable organic matter pollution resulting in a series of unfavorable changes in water ecosystems making it impossible to properly exploit the reservoir (Bhateria and Abdullah, 2015). The main elements causing eutrophication are nitrogen, phosphorus and carbon body.

Unplanned urbanization, rapid industrialization, indiscriminate use of artificial chemicals in agriculture, cause aquatic pollution and deteriorate quality of aquatic biota (Yeole and Patil, 2005). In this context, phytoplankton are important biological parameters to assess the pollution level (Singh *et al*., 2016). They play an important role in synthesis of organic material and influence the ecosystem, aquatic food chain and water characteristics.

These bio-indicator reflect the quality of water and controls the dynamics of productivity (Priya *et al*., 2016). Hence, assessment of phytoplankton from any freshwater body is felt essential. In the present study plankton density of three water bodies of rain deficient North Maharashtra are considerd over two years. The group studied are Bacillariophyceae, Chlorophyceae, Cyanopyceae and Euglenophyta over three seasons summer, monsoon and winter.

Total Phytoplankton - Results

During the two year study period total 42 genera and 78 (36+22+14+6) species of phytoplankton belonging to four taxonomic groups i.e. Bacillariophyceae, Chlorophyceae, (Diatoms), Cyanophyceae and Euglenophyta were recorded at all the three water bodies, Malpur dam, Baldane reservoir and Krishna park reservoir (Annexture-1).

Density of Total Phytoplankton: Density

The density of various groups of phytoplankton recorded in biannual percentage (Table- 4) in decreasing order at Malpur dam was Bacillariophyceae 42.16 % > Chlorophyceae 32.82 % > Cyanophyceae 22.5 % > Euglenophyta 2.52 %, at Baldane reservoir, it was 3.9 % > 31 % > 23.31 % 2.8 % and at Krishna park 42.8 % > 31.86 % > 21.5% and 3.91 % respectively .

Maximum densities of total phytoplankton (Table 4) were recorded in summer at Malpur dam 3363 ± 66 no/l, Baldane reservoir 3913 ± 79.92 no/l and at Krishna park 2971 ± 81.04 no/l, while minimum phytoplankton density was recorded in monsoon

1740 ± 131 no/l, 2046 ± 131.6 no/l and 1634 ± 106.2 no/l respectively. The density was moderate in winter with 3149 ± 102 no/l, 3240 ± 181.9 no/l and 2721 ± 130 no/l respectively. The total phytoplankton administered significant seasonal variation with $P < 0.0001$ at all three water bodies $F_{2\ 21}$ 26.9, $F_{2\ 21}$ 47.21 and $F_{2\ 21}$ 43.67 at Malpur dam, Baldane reservoir and Krishna park respectively.

Pearson correlation of total phytoplankton density with physicochemical parameters administered significant positive correlation with Cl, MgH, pH, SO_4, TDS, TH, Trans. and with other phytoplankton parameters., densities of Chlorophyceae, Cyanophyceae, Bacillariophyceae, species richness of Bacillariophyceae, Chlophyceae, Cyanophyceae and species richness of total phytoplankton at all three water bodies. At KP positive correlation are noted with CaH whereas no correlation was noted with chlorides. Total phytoplankton density is negatively correlated with PO_4, TSS, WC and Density of euglenophyta and species richness of euglenophyta.

Species richness of total phytoplankton

Biannual percentage of the species richness of total phytoplankton was as Bacillariophyceae 51.01 % > Chloropyceae 23.98 % > Cyanophyceae 18.1 % > euglenophyta 6.91 % at Malpur dam, 50.0 % > 23 % > 21.3 % > 6.2 % respectively at Baldane reservoir while 48.8 %> 22.97 % > 20.3 % > 7.91 % at Krishna park

Maximum species richness of total phytoplankton was recorded in summer at Malpur dam 23.30 ± 0.26 species, at Baldane reservoir 25.5 ± 0.5 species and at Krishna park 23.41 ± 0.41 species and was minimum in winter (17.4 ± 0.18, 21.13 ± 0.35 and 19.01 ± 0.32 no. respectively). Total phytoplankton species richness started increasing in monsoon with 20.8 ± 0.41, 22.13 ± 0.52 and 21.75 ± 0.45 at Malpur dam, Baldane reservoir and Krishna park respectively. The total phytoplankton administered significant seasonal variation at Malpur dam $P < 0.0001$ $F_{2\ 21}$ 63.10, Baldane reservoir $P < 0.0001$ $F_{2\ 21}$ 24.7 and at Krishna park $P < 0.0001$ $F_{2\ 21}$ 19.01.

Pearson correlation of species richness of total phytoplankton showed positive significant correlation with MgH, TDS, density of bacillariophyceae, species richness of bacillariophyceae and negative significant correlation with PO_4 and WC at all three water bodies. The total species richness of phytoplankton of individual water body showed significant positive and negative correlation with different abiotic and biotic factors

Bacillariophyceae (Diatoms): Density

Diatoms were first dominant quantitative component of the total phytoplankton with biannual percentage density of 42.16 % (Malpur dam), 43.9 % (Baldane reservoir) and 42.8 % (Krishna park). Maximum density of diatoms was recorded in summer when it was 1970 ± 128 no/l, 2163 ±109 no./l and 1729 ± 127.5 no/l at Malpur dam, Baldane reservoir and Krishna park respectively while minimum density were recorded in monsoon with 738 ± 74.1 no./l, 871.5 ± 83.37 no./l and 692.6 ± 61.48 no./l, In winter its density was 774 ± 75.5 no./l, 1006 ± 96.73 and 712.4 ± 53.83 no./l at Malpur dam, Baldane reservoir and Krishna park respectively. The density of bacillariophyceae showed significant seasonal variations $P < 0.0001$ $F_{2\ 21}$ 14.21 (Malpur dam), $P < 0.0001$ $F_{2\ 21}$ 53.56 (Baldane reservoir) and $P < 0.0001$ $F_{2\ 21}$ 45.95 (Krishna park).

Correlation of bacillariophyceae density showed significant positive correlation with abiotic parameters (Cl, CO_2, MgH, pH, SO_4, TDS, TH) and biotic parameters (Density of total phytoplankton, species richness of total phytoplankton and species richness of bacillariophyceae) and negative significant correlation with DO, PO_4 and WC at all three wetlands. Density of diatoms of individual wetland showed significant and nonsignificant positive and or negative correlation with other abiotic and biotic parameters studied.

Species richness

Total eighteen genera and thirty six species of bacillariophyceae were recorded (Annexture-I) during study period. Bacillariophyceae formed the first qualitative component in the total phytoplankton assemblage of thr total phytoplankton recorded during study period at all three wetlands.

Mean biannual percentage of bacillariophyceae species was 51.01 %, 50.00 % and 48.8 % at Malpur dam, Baldane reservoir and Krishna park respectively. Maximum mean species richness was recorded in summer 16.3 ± 0.25 no, Malpur dam, 16.75 ± 0.37. at Baldane reservoir and 15 ± 0.63 at Krishna park. Its minimum mean species richness was recorded in winter at 5.50 ± 0.18 no. 7.38 ± 0.42 no. and 6.75 ± 0.31 no. of species, while moderate in monsoon 9.63 ± 0.50 no., 10.25 ± 0.36 no. and 9.88 ± 0.39 no. at Malpur dam, Baldane reservoir and Krishna park respectively. The bacillariophyceae species richness administered (Table 4) significant seasonal variation at Malpur dam with $P < 0.0001$ $F_{2\ 21}$ 7.54, at Baldane reservoir with ($P < 0.0001$ $F_{2\ 21}$ 155.8 and at Krishna park with $P < 0.0001$ $F_{2\ 21}$ 30.13.

Pearson correlation of bacillariophyceae species richness (Table 4) showed positive significant correlation with abiotic parameters (AT, Cl, CO_2, MgH, pH, SO_4, TDS, TH, WT) and biotic parameters (Species richness of total phytoplankton and density of bacillariophyceae) and showed negative significant correlation with DO, PO_4 and WC, at all three wetlands, while species richness of bacillariophyceae of individual wetlands showed positive and negative significant and nonsignificant correlation with other abiotic and biotic factors.

Chlorophyceae (Green algae): Density

Chlorophyceae was second dominant quantitative component of the total phytoplankton. Its biannual percentage density was 32.82%, 31% and 31.86% at respectively at the three reservoirs (Table 4).

The density of chlorophyceae was maximum in winter (Table 4) with 1420 ± 56.37 no/l, 1266 ± 53.18 no/l and 1199 ±45.18 no./l respectively, it started decreasing in summer with 782.9 ± 60.47 no./l, 994.6 ± 57.61 no./l and 685 ± 48.4 no./l and further declined to reach minimum in monsoon to 506.1 ± 41.18 no./l, 587.5 ± 47.91 no./l and 450 ± 40.63 no./l at respectively. The density of chlorophyceae (Table 4) showed significant seasonal variations at $P < 0.0001$ $F_{2\ 21}$ 25.88 (Malpur dam), $P < 0.0001$ $F_{2\ 21}$ 41.47 (Baldane reservoir) and $P < 0.0001$ $F_{2\ 21}$ 72.89 (Krishna park).

Pearson correlation of chlorophyceae density showed significant positive correlation with biotic parameters (DO and transparency), biotic factors (Density of cyanophyceae, species richness of cyanophyceae, species richness of chlorophyceae and total density of phytoplankton and negatively significantly correlated with AT, CO_2, density of euglenophyta, species richness and density of cyanophyta, species richness of total phytoplankton, TS, TSS and WT. at all three water bodies. The density of chlorophyceae of individual water body showed significant and non significant positive and or negative correlations with other abiotic and biotic parameter (Table 4).

Species richness

Total fourteen genera and twenty two species of chlorophyceae were recorded during study period (Annexture-I) with second dominant qualitative component (27.27 to 28.78 %) of total phytoplankton species recorded during study period at three wetlands. Mean biannual percentage of chlorophyceae species was 28.78 %, 27.86 % and 27.27 % at Malpur dam, Baldane reservoir and Krishna park respectively.

Maximum species richness of chlorophyceae (Table 4) was recorded in winter 6.5 ± 0.20 species (at Malpur dam), 6.75 ± 0.25 species (at Baldane reservoir) and 6.38 ± 0.18 species (at Krishna park). Minimum species richness was recorded in summer 3.50 ± 0.20 species, 3.75 ± 0.37 species and 3.63 ± 0.26 species which started increasing in the next season and recorded moderate in monsoon with 4.75 ± 1.16 species, 5.0 ± 0.27 species and 4.87 ± 0.29 species respectively. It recorded significant seasonal variation at Malpur dam ($P < 0.0001$ $F_{2\ 21}$ 11.82), Baldane reservoir ($P < 0.0001$ $F_{2\ 21}$ 25.43) and Krishna park ($P < 0.0001$ $F_{2\ 21}$ 29.98) (Table 4).

Correlation of chlorophyceae species richness (Table4) showed positive significant correlation with abiotic factors (DO and transparency) and biotic factors (density of chlorophyceae, density of cyanophyceae, species richness of cyanophyceae) and negative significant correlation with AT, Cl, CO_2, TS and WT at all three wetlands. While species richness of chlorophyceae of individual wetland showed significant and nonsignificant positive and negative correlation with different abiotic and abiotic parameters.

Cyanophyceae (Blue green algae) Density

During the two year study period total 8 genera and fourteen species of cyanophyceae were recorded at the three water bodies (Annexture-I). Blue green algae were third dominant quantitative component of the total phytoplankton density with percentage density 22.5, 23.31 and 21.5 at Malpur dam, Baldane reservoir and Krishna Park respectively (Table 4).

The density of cyanophyceae was maximum in winter (Table 4) with 917 ± 26.1 no./l, 936 ± 45.59 no./l and 762.9 ± 51.5 no./l, at Malpur dam, Baldane reservoir and Krishna park it decreased in summer to 564 ± 34.3 no./l, 697.1 ± 40 no./l and 493.8 ± 13.94 no./l further declined in monsoon to 376 ± 33.4 no./l, 418.6 ± 25.25 no./l and 314.9 ± 37.36 no./l at the three water bodies. The densities of cyanophyceae (Table 4) showed significant seasonal variation ANOVA $P < 0.0001$ $F_{2\ 21}$ 24.1 (Malpur dam), $P < 0.0001$ $F_{2\ 21}$ 46.63 (Baldane reservoir) and $P < 0.0001$ $F_{2\ 21}$ 26.92 (Krishna park reservoir).

Pearson correlation of cyanophyceae density (Table 4) showed significant positive relation with abiotic parameters (DO, transparency) and biotic factors (Density of Chlorophyceae, density of total phytoplankton, and species richness of chlorophyceae) and significant negative correlation with abiotic factors (AT, CO_2, TS,

TSS and WT) and biotic factors (density and species richness of euglenophyceae) at all three water bodies.

Species richness

Total eight genera and 14 species of cyanophyceae were recorded during study period (Annexture-I). Cynophyceae formed third dominant qualitative component (around 18- 20 %) of total species recorded. Mean biannual percentage of cyanophyceae was 18.1 %, 21.3 % and 20.3 % at Malpur dam, Baldane reservoir and Krishna park respectively.

Maximum mean species richness of Cyanophyceae (Table 4) were recorded in winter were 4.75 ± 0.16 species (Malpur dam), 6.25 ± 0.25 species (Baldane reservoir) and 5.63 ± 0.26 species (Krishna park) while minimum were recorded in summer at 2.63 ±0.18, 3.75 ± 0.25 and 3.25 ± 0.16. It increased in monsoon reaching 3.75 ± 0.16, 4.63 ± 0.18 and 4.25 ± 0.25 no. of species at Malpur dam, Baldane reservoir and Krishna Park respectively. It administered significant seasonal variation at Malpur dam ($P < 0.0001$ $F_{2\ 21}$ 19.20), Baldane reservoir ($P < 0.0001$ $F_{2\ 21}$ 30.46) and Krishna park ($P < 0.0001$ $F_{2\ 21}$ 26.92).

Pearson correlation of cyanophyceae species richness (Table 4) showed positive Correlation with abiotic factor (DO and transparency) and biotic factors (density of chlorophyceae, species richness of chlorophyceae, density of cyanophyceae) and negative significant correlation with abiotic factors (AT, CO_2, TS and WT) at all three water bodies. The species richness of cyanophyceae of individual water body showed significant positive and negative correlation with other abiotic and biotic factors (Table 4).

Euglenophyta: Density

Euglenophyta was fourth quantitative component of the total phytoplankton (Table 4) Biannual percentage density of euglenophyta was 6.91 % (Malpur dam), 6.2 % (Baldane reservoir) and 7.91 % (Krishna park). Maximum density of euglenophyta was recorded in monsoon with 120 ± 13.7 no/l, 168.3 ± 17.41 no./l and 176.3 ± 27.69 no./l at Malpur dam, Baldane reservoir and Krishna park respectively. Their minimum density was recorded in winter at 37.8 ± 3.94 no./l, 31.63 ± 2.14 no./l and 47.25 ± 5.21 no./l, while in summer it was 49.9 ± 3.48 no./l, 58.13 ± 5.75 no./l and 63.5 ± 5.76 no./l at Malpur dam, Baldane reservoir and Krishna park respectively. It showed significant seasonal variations with $P < 0.0001$ $F_{2\ 21}$ 25.71 (Malpur dam), $P < 0.0001$ $F_{2\ 21}$ 46.22 (Baldane reservoir) and $P < 0.0001$ $F_{2\ 21}$ 17.9 (Krishna park) .

Pearson correlation of euglenophyta density (Table 4) showed significant positive correlation with PO_4, TSS, TS, and WC, while significant negative correlations with abiotic parameters (pH, TH and transparency) and biotic parameters (Density of chlorophyceae, cyanophyceae and total phytoplankton, species richness of chlorophyceae and cyanophyceae). At all three wetlands density of euglenophyta of individual wetland showed significant and nonsignificant positive and negative correlation with other abiotic and biotic parameters.

Species richness

Total two genera and six species of euglenophyta were recorded (Annexture-I) during two year study period. Euglenophyta formed fourth qualitative component in the total phytoplankton assemblage (3 to 4 %).

Maximum mean species richness of euglenophyta were recorded in monsoon 4.75 ±0.16 no. (Malpur dam), 2.25 ± 0.16 no. (Baldane reservoir) and 2.75 ± 0.16 no. Krishna park). Minimum mean species richness was recorded in winter 0.63 ± 0.18 no., 0.75 ± 0.16 no and 0.88 ± 0.13 no. of species, it increased in summer to 1.00 ± 00 no., 1.25 ± 0.16 no. and 1.50 ± 0.19 no. at Malpur dam, Baldane reservoir and Krishna park respectively. It administered significant seasonal variation at Malpur dam ($P < 0.0001$ F 2 21 19.13), Baldane reservoir ($P < 0.0001$ F 2 21 21.7) and Krishna park ($P < 0.0001$ F 2 21 35).

Correlation of euglenophyta species richness (Table 4) showed positive significant correlation with density euglenophyta, TS, TSS and negative and significant correlation with abiotic factors (pH, TH and transparency) and biotic factors (density of total phytoplankton, chlorophyceae and cyanophyceae) at all three wetlands. The species richness of euglenophyta of individual wetland showed significant nonsignificant positive and negative correlation with different abiotic and biotic parameters.

Discussion

Total phytoplankton Density

Phytoplankton, the primary and the initial biological components from which the solar energy is transferred to higher organisms through food chain (Reynolds, 1984; Khan 2003; Tiwari and Chauhan, 2006; Saifullah *et al*., 2014) are also necessary to sustain a healthy aquatic ecosystem (Xu, 1997; Yu, 2014). Virtually phytoplankton regulate all the dynamic features of water body such as colour, clarity, trophic state, zooplankton and fish production (Goldman and Horne, 1983). The physicochemical parameters are the major factors that control the dynamics and structure of the phytoplankton of aquatic ecosystem (Hulyal and Kaliwal, 2009) especially in the Indian freshwater systems which are influenced by physical, chemical and biological conditions (Sugunan, 2000; Gopal and Zutshi, 1998). This results in three distinct plankton pulses coinciding with Indian climate (Sugunan, 2000). Though wave action of currents and influx of rain water with high turbidity act as limiting factors during monsoon influencing plankton, remarkably stratified water column of postmonsoon merging into winter, with decreased wind velocity, suspended and dissolved particles settle down lowering the turbidity and favour the phytoplankton community. (Chaudhari and Pillai, 2009). Saravanakumar *et al*. (2008) have reported that the phytoplankton population is reduced in monsoon because of heavy rainfall, high turbidity, reduced salinity, pH, temperature, cloudy skies and low nutrient concentration and parasitism etc. In present study it is reflected as Peak of Cyanophyceae and chlorophyceae in winter. Further, phytoplankton density and the turbidity due to total suspended solids were negatively correlated supporting the observations. Seasonality in phytoplankton population has been reported (Dakshini and Gupta, 1979).

Permanent bloom of phytoplankton in lakes of Indian peninsula are usually recorded during summer due to shallow depth, nutrients enrichment and adequate sunlight (Sugunan, 2000) as is also observed in the present study. Moderate density of total phytoplankton recorded in winter is due to reduced turbulence resulting in clean lake water at all three water bodies. Temperature which drops in winter plays significant role in phytoplankton ecology. However, in southern parts of India, where temperature never drops below 16ºC such fluctuation does not occur. Here, the rainfall is the major factor influencing phytoplankton annual cycle (Giripunje *et al*., 2013). Against to this Jain *et al*. (2007) reported lower phytoplankton in winter in the

north Indian waterbodies due to low rate of sunshine and effect of strong continental winds leading to lowering temperature of the water.

Chaturvedi *et al*. (1999) reported that in summer long duration of sunshine, increases salinity, pH and trophotropic activities which result in the growth of freshwater phytoplankton. Studies reported that maximum photoperiod and higher temperature invigorate growth of the phytoplankton (Murugavel and Pandian, 2000; Sunkad, 2002; Hajong and Ramanujan, 2018). In addition in the Indian climatic conditions water level decreases in summer resulting in aggregation of plankton in smaller area. In the present study total phytoplankton density administered negative significant correlation with water cover, which agrees with the above observations i.e. increased the density. Apart from higher temperature in summer the higher pH (alkaline pH) may also support the higher density of phytoplankton (Hujare, 2005). The alkaline pH is favorable for the growth of phytoplankton. In summer, the high density of algal assemblages impart dark green colour to the lake, these events result from high temperature, high pH, light intensity and low depth of the lake (Chattopadhyay and Banerjee, 2007). The high nutrient concentrations with shallow depth of lake indirectly add to the concentration of phosphate and nitrates, inducing phytoplankton growth.

In the present study of three water bodies the phosphate and nitrates were negatively correlated with the density of total phytoplankton which may be interpreted as their utilization for the growth of the phytoplankton. However, the SO_4, Mg hardness and Cl are positively correlated with the density of total phytoplankton. Magnesium is the main constituent of chlorophyll and its concentration remains lower than calcium (Zutshi and Khan, 1988) is true in the present study too. Further, the high concentration of dissolved oxygen recorded in the winter due to active photosynthesis by algae and lower water temperature resulting in the association of oxygen with water may be supported by the fact that even at higher densities of phytoplankton low oxygen were recorded in summer. Phosphate the nutrient in primary productivity of fresh water generally accounts for 1 – 1.2 % of the ash free dry mass of healthy, active cells (Reynold, 2006), however in the present study the phosphate concentration varied between 0.074 ± 0.01 to 0.34 ± 0.04. Many species can take up freely available phosphorus at very rapid rates, sufficient to sustain a doubling of cell mass in matter of few minutes. In pelagic ecosystem the phosphorus is often considered to be the biomass limiting constraint (Reynolds, 2006). Considering above

discussion the available phosphate level may be favourable for normal multiplication of the phytoplankton.

Among the nutrients, nitrogen is the second element whose relative scarcity impinges upon the ecology of phytoplankton. Nitrogen is the constituent of amino acids, and hence of all the synthesized proteins too. Nitrogen accounts for not less than 3 % of the ash free dry mass of living cells (Reynolds, 2006). The principal forms of combined nitrogen available to photoautotrophs are the ions nitrate, nitrite and ammonium (NO_2-,NO_3-,and NH_4^+) although this may not be true for all phytoplankton. The biogeochemical cycling of nitrogen is mediated mainly by organisms. The algal species that eventually proliferate in the waterbodies must not only be able to tolerate conditions of nutrient limitation but should be able to withstand and utilize other sources of nitrogen to their advantage. In the present study the seasonal fluctuation in nitrate levels is noted to be negatively significantly correlated with total phytoplankton density at Malpur dam, while non-significantly at Baldane reservoir and Krishna park reservoir.

The nitrate is reduced to nitrite due to sedimentation and low pH. Lowest nitrate concentration recorded in summer may be attributed to maximum phytoplankton density in the same season. Both nutrients (nitrate and phosphate) are beneficial for algal productivity (Ayoade, 2000). Nutrients may have been derived from the decomposed organic matter remains of plants, animal and sewage; although it is also argued that algal proliferation during this period (summer) depletes nutrient concentrations (Olele and Ekelemu, 2008). Ovie *et al*. (2000) reported that low concentration of phosphorus and nitrate occurs due to over 90 % of the element buried at the bottom sediment, which has significant implication for nutrient dynamics and phytoplankton composition (Kadiri, 2000).

Species richness of total phytoplankton: Density

Many freshwater bodies in India are polluted so enumeration of phytoplankton biodiversity in such wetlands is essential to know the wealth of the ecosystem and to plan its conservation measures. Diatoms are good indicators of pollution and occur in unpolluted habitats of the lake (Trivedi, 1993; Sharma and Durve, 1985). Some species in polluted waters have increased enormously making water unfit for drinking and recreation (Divya *et al*., 2013). The increased nutrients shift diatom flora to green and blue green flora leading to eutrophication. Sequence of percentage density and species richness of 4 groups of phytoplankton occurring in decreasing order as

Bacillariophyceae > Chlorophyceae > Cyanophyceae > Euglenophyta in the present study indicate no eutrophication in the three water bodies. This is also supported by the species composition at three water bodies as bacillariophyceae is dominant group, followed by Chlorophyceae, Cyanophyceae and least euglenophyta (Annexture-I).

The biotic community of any water body is outcome and geo-morphological characteristics of any wetland (Stevenson and Pan, 1990; Karr *et al*., 2000). On the basis of seasonal variations of phytoplankton of Sulur lake it has been reported that the difference in temperature and photic conditions influence the density favorably (Manickam 2017). Higher species richness of phytoplankton is noted in present study too. Temperature was high in summer with longer days this may be responsible for higher reproduction which regulate the biogeochemical activities in aquatic environment increasing the higher species richness. Water temperature is known to influence the aquatic weed growth and algal blooms (Gupta and Sharma, 1993). Highest sun intensity and long days occuring in the areas of fresh water lakes in summer favor more species, while less sunshine hours of winter may support only few species. Hence, moderate species richness was recorded in winter. During monsoon minimum species richness of phytoplankton recorded may be attributed to non uniform intensity of sunlight and moderate temperatures. Further, monsoon brings in turbidity, higher nutrient levels and lower transparency, unfavourable for development of certain species (Sharma and Tiwari, 2018).

Bacillariophyceae: Diatoms

Diatoms are potential indicators of water quality due to their sensitivity and strong response to physical, chemical and biological changes (Palmer, 1980; Kalyoncu and Serbetchi, 2013; Sawaiker and Rodrigues, 2017). According to Suphan *et al*. (2012) studying diatom assemblages, relationship between diatoms and the physico chemical parameters of water can predict environmental changes, and give an early warning towards freshwater ecological problems. Diatoms, the silicified algae in the range of 2 to 200 µm in diameter or length, are a single cell functionally. It appears in different form in nature such as associated into filaments, forming chain of cells or arranged within mucilage tube. They can exist as solitary cell in open water or in colonies on wet submerged surface (Round *et al*. 1990). The siliceous cell wall encloses the cell and has ornamental structures. The remarkable property of this siliceous wall is its transparency that allows light to enter.

In the present study of three wetlands, diatoms were the first dominant quantitative component of the total phytoplankton community. Diatoms community distribution in a lake is dominated by the combination of physical, chemical and biological factors which is reflected as their seasonal variations (Murugavel and Pandian, 2000; Fabricus *et al*., 2003; Reynolds, 2006; Jadhav *et al*., 2016)as is noted in present study. Summer peak of diatoms have been recorded by many Indian researchers (Hujare, 2005; Hulyal and Kaliwal, 2009; Ekhande *et al.*, 2013; Patil *et al*., 2013). Temperature influences the production of diatoms, as they seem to grow and colonise during the warmer period (Kuldipkumar, 1990; Mahadev *et al*., 2016). The Bacillariophyceae density is increased when the temperature fluctuates between 25.3^{o}C to 31.4 ^{o}C (Hazarika *et al*., 1998). In the present study morning temperature fluctuation varied around 26.0±0.63 ^{o}C in summer which may be favorable for diatoms. In addition high pH value also promotes the growth of algae (Kamat, 1965; Hujare, 2005; Patil *et al.*, 2013). In three reservoirs maximum pH value were recorded in summer (between 8.1±0.05 BR to 8.19±0.025). Suitable water temperature and alkaline nature of water may be the reason for high density of diatoms in the three lakes. Temperature and pH were significantly positively correlated with density of diatoms, except at Baldane reservoir, where it showed nonsignificant positively correlation.

The phosphate was significantly negatively correlated with density and species richness of diatoms in the present study. Munawar, (1970) has stated that bacillariophyceae absorb quantities of phosphates more than requirement. Diatom growth is dependent on supplies of available silica, which tends to decrease with phosphate enrichment of diatoms (Joseph and Ouseph, 2010). Silica is prerequisite for the growth and development (Escavarage and Prins, 2002). Temperature, light and nutrients regulate rates of silica deposition (Blank *et al*., 1986). Apart from these variables salinity also seem to influence silica deposition (Blank *et al*., 1986) and mineralization in the frustules (Gensemer, 1990., Vrieling *et al*., 1999). Though the silica in the present investigation was not assessed high density of diatoms in the wetlands indicate that sufficient silica is present in the water which may due to demineralization as well as supplied by drainage (Kobbia *et al*., 1992). Further, total hardness is positively correlated with diatoms density. The positive relationship of total hardness and diatoms has also been recorded by Ekhande (2010) and Patil (2011) in the wetland waters. Transparency is one of the most important physical factors

which strongly influence the productivity and diatoms (Chattopadhay and Benarjee, 2007; Barve and Sonawane, 2017). Moderate transparency was recorded in present study supporting the diatom flora.

In present study of diatom lower density recorded in monsoon may be related to inundation of rain water as well as wave action acting as limiting factors for phytoplankton population (Sarvanakumar *et al*., 2008). However steady increase of density of diatoms from next season winter to reach peak in summer were noted at all the three wetlands under consideration.

Species richness

Bacillariophyceae that formed first qualitative component among the total phytoplankton assemblage varied between 46.96% to 49.18% of the total phytoplankton species recorded at the three wetlands throughout two years. Species richness of diatoms administered significant seasonal variations as is also recorded by Patil *et al.* ((2013); Borgohain, (2014); Jadhav *et al.* (2016) and Sawaiker and Rodrgues, (2017). Phytoplankton are influenced by temporal and spatial changes in physical properties i.e. temperature, light and nutritive levels, and biological changes i.e. grazing pressure and competition (Roy (2007). Most diatoms are adapted to wide range of water temperature and light, however, some bacillariophyceae members (e.g. *Surilella*) are adapted to dim light too. Nevertheless massive growth of diatoms (e.g. *Melosira*) occurs in full light and moderate temperature. Temperature preferences of most of the diatoms is 15-25 ^{o}C, however a few are able to resist more than 30 ^{o}C (e.g. *Nitzschia*) (Sabater, 2009).

Maximum species richness of diatoms was recorded in summer at all the three wetlands MD, BR and KP. Diatoms are ecologically diverse and colonize virtually all microhabitats in freshwater and marine systems. Availability of distinct nutritional requirements favours one group over the other. The species richness of diatoms significantly positively correlated with AT and WT, can be attributed to the summer increase in temperature and light conditions at all the three wetlands. Diatoms species richness also established significant positive correlation with pH, a summarising factor of the geochemisty of the water and as such its different values create preferences for almost all the diatom taxa. During extreme low and high pH values the diversity of the diatoms may be expected to be lower than in circumneutral waters (Sabater, 2009). In the present study, the pH values varying around the range of

8.1±0.005 was circumneutral, hence it may be concluded that the said pH is favourable for most of the diatoms species.

Some of the genera of Diatoms thrive well in sub aerial conditions, particularly in summer when sublittoral zone is drying. These include genera which can overcome the desiccation and osmotic variations by storing oils and building inner plates eg. *Pinnularia, Navicola, Melosira, Fragilaria, Melosira* (Round, 1985) also recorded in the present study. Pinnate diatoms generally found in littoral areas of the lake attached to cobbles and plants are *Melosira, Syndra, Fragilaria, Cymbella* and *Gomphonema*. Some of the diatoms common on superficial lake sediments are *Gyrasigma, Navicula, Surilrlla, Pinnularia, Stauranesis* etc.

The diatom species richness was significantly positively correlated with TDS, Cl, MgH and TH. These factors influence the salinity of water which in turn can affect the osmotic pressure within the diatom cell and nutrient uptake (Reynolds, 2006). Fresh water species require low mineral content for their normal growth. Mineral content and salinity of the studied wetlands may be favourable for the diatoms. Excess of nutrients favour certain number of tolerant diatom taxa (e.g. *Navicula, Nitzschia*), while some taxa (*Rhopalodia*) thrive well in low nitrogen level. (Round *et al*., 1990). Optima and tolerances of diatom species to nitrogen and phosphate have been known, even though these values may be conditioned by factors such as temperature and light. The knowledge of nutrient requirement forms the bases to know the condition of the lake and identifying the tolerant species well. Diatoms shows quick responses to the altered physicochemical and biological factors, hence are used as reliable environment indicators (Lange, 1979; Mc Cormic and Cairns, 1994). *Nitzschia* group of diatoms is large, diverse and ecologically versatile genus that occurs in oligotrophic water (Jadhav *et al*., 2016). However some diatoms taxa *Cymbell, Pinnularia, Amphora, Asterionella* have been recorded in the present study. This indicates that though the wetlands are not yet polluted, can get polluted if proper care is not taken.

Chlorophyceae (Green algae): Density

Chlorophyceae constitute the most heterogeneous group of photoautotrophic protists inhabiting the biosphere and show an enormously wide variety of shape, size and habitat. As primary producers, green algae are of great importance on our planet comparable to that of rainforest (Naselli-flores and Barone, 2009). In the present study of three wetlands, the chlorophyceae appeared second dominant group

quantitatively as well as qualitatively. Significant seasonal variations recorded for density of green algae at all the three wetlands, indicate their dependence on abiotic factors of the wetlands that change with season. Kulshrestha *et al*. (1991) and Tripathy and Pandey, (1990) have recorded maximum green algae in winter or postmonsoon. However, in Almatty reservoir high nutrient load with favourable light conditions in post monsoon is reported favourable for chlorophyceae (Hulyal and Kaliwal, 2009). Extrapolations of column- integrated photosynthetic production in the lakes have shown that light, especially in fully mixed water column is the main regulating factor (Talling 1957). Maximum density of chlorophyceae was, noted in winter and noted low during summer indicates that their contribution is lower in total phytoplankton density in summer. The photoperiod and temperature are low at the wetland located in the semiarid region of Maharashtra and the winter water temperature varied around 18.88±0.54^{o}C (Krishna Park) to 20.13±0.39 ^{o}C (Malpur dam). These temperatures are probably favourable for the chlorophyceae. Dominance of chlorophyceae over diatoms have been recorded by many workers (Sharma, 2009; Chaudhary and Pillai, 2009; Singh and Balsing, 2001). While in the present wetland the chlorophyceae is dominated by diatoms, this observation is supported by the studies on Ramgarh lake (Jhingran, 1989) and Kshirsagar lake (Chattopadhyay and Banerjee, 2007). Study of Kodaikanal lake by Singh and Balsing, (2001) concluded that the temperature, light, pH and seasonal variations are the main predictors to regulate the green algae.

Total suspended solids and total solids particles showed negative correlation with chlorophyceae indicating their negative effect. Dissolved carbon dioxide also has negative influence while increase in dissolved oxygen results due to increase in the growth of chlorophyceae, as O_2 is positively correlated to chlorophyceae or it may indicate that dissolved CO_2 is utilized and oxygen is liberated in the process of photosynthesis. Further, Sing and Balsing (2001) and Gulati and Wurtz (1980) have reported that alkaline nature of water body is favourable for luxuriant growth of green algae. In the present study of three wetlands water remained alkaline in the winter.

Moderately eutrophic lakes and ponds very often show amazing high density of green algae. They may represent 50-90% of the species present in the phytoplankton assemblage. Some of them may be dominating species while several are rare in an assemblage. Due to the inherent variability of the aquatic environment water bodies have specific species richness that allows some rare species to represent the ecological

memory of the ecosystem (Naselli-flores and Barone, 2009). In the present study the green algae formed second dominant quantitative component in the phytoplankton community. Due to diurnal stratification in the tropical lakes desmids (*Cosmarium, Staurastrum*) sinks in the water column which favours exploitation of nutrient and light sources (Naselli-flores and Barone, 2009). So the physical and chemical conditions of the wetlands regulate these algae. Studies of Reynolds *et al*. (2002) have shown that the genera such as *Eudori,* and *Volvox* can tolerate the shallow, nutrient rich water but are sensitive for nutrient deficiency. In shallow enriched lakes the genus *Pediastrum* may strive. They further reported that in the eutrophic equilimnia *Clostridium* and *Staurastrum* are able to tolerate medium light and carbon deficiency but are sensitive to stratification and Si depletion, while *Cosmarium* in mesotrophic epilimnia can tolerate nutrient deficiency but is sensitive to stratification and pH rise. Munawar, (1974) reported that members of green algae have differential preference for magnesium and phosphate for their growth. High calcium content and low pH favour their growth. In the present study, the species richness of green algae is significantly positively correlated with DO and transparency while negatively significantly correlated with AT, Cl, CO_2, TS and WT at all the three wetlands. Hosmani *et al*. (2002) have reported that the desmids such as *Cosmarium, Clostridium, Staurastrum* are the indicator of good quality of water and they are absent in polluted water. This flora is observed in the present study indicating that the wetlands are yet non-polluted. Rott, (1984) concluded that the dominance of chlorococales indicates eutrophication. However in present study inverse situation is observed, the species of desmids are dominated which can be suggestive that the wetlands under study are within control and not polluted. However, the monitoring of wetlands, under study is required because the pollutant tolerant species though rare, are observed during study. These species are *Spirogyra*, *Ulothrix* and *Zygrema*. Assessment of chlorophyceae is well integrates with physical, chemical and biological parameters of fresh water ecosystem studied. Green algae contain many species making data useful for statistical applications to assess water quality. It could provide powerful monitoring tool.

Cyanophyceae (Blue green algae): Density

Cyanophyceae form the mainstay of the manmade lakes, species *Microcystis aeruginosa* of cyanophyceae is dominant species causing algal bloom in Indian water

bodies (George, 1961; Nandan and Patel, 1984). However, no such algal blooms were observed in the three water bodies studies over two years.

The study recorded cyanophyceae as the third dominant group of phytoplankton, qualitatively and quantitatively. Maximum density and species richness of blue green algae was recorded in winter. The occurrence of this group has been attributed the higher temperature, slightly alkaline conditions and nutrient rich fresh water discharge due to suspended sediment which favour their growth (Harsha and Malammanavar, 2004). During heavy rainfall, flooding reduces habitat heterogeneity by inundating many aquatic habitats (Ward and Tockner, 2001). At the end of monsoon the flood recedes, the water bodies slowly recover their distinctive properties, including habitat features, biotic communities and maximizing individuality that take place in next season i.e. winter. In the present study maximum cyanophyceae density and species richness were recorded in winter. Temperature plays a significant role in the periodicity of cyanophyceae (Hutchinson, 1967). According to Naik *et al*. (2005) and Patil, (2011) moderate high temperature is favourable for growth of cyanophyceae. The atmospheric and water temperature were negatively correlated with cyanophyceae in the present study. As it is mentioned, the wetlands studied are located in the semi-arid region of Maharashtra where the temperature of water never falls below 15 ºC probably favouring the blue green algal community. Tilman and Kiesling, (1984) and Robarts and Zohary, (1987) have reported higher temperature optima required for abundance of cyanophyceae and hence maximum density in summer. In the present study the density of cyanophyceae is significantly positively correlated with transparency, however, An and Jones, (2000) reported dominance of cyanophyceae under reduced light environment. For the formation of cynobacterial bloom low light energy is required (Schreus, 1992) while to attain cyanophyceae maxima high alkalinity and high CO_2 are also necessary (Shapiro, (1997). However in present study moderate pH and minimum dissolved CO_2 were recorded that may be explainable by this fact that the cyanophyceae did not form any bloom and was third component in phytoplankton density and diversity. Johnston and Jacoby, (2003) reported that low dissolved CO_2 is favorable for growth of cyanophyceae which sustains the present observation.

In addition to light and carbon, growing phytoplankton consume nutrients. The relative abundance of cyanophyceae members may be a function of nutrients ratios (N:P) in water bodies (Cole and Sanford, 1989; Smith, 1983). Lowest N: P ratios,

closer to critical range of 16:1, occur in lakes dominated by nitrogen fixing cyanophyceae, in contrast non N-fixing species of cyanophyceae are usually the dominant contributors to summer plankton in lakes with TN:NP ratios much higher than the optimum ratio (Dokulil and Teubner, 2000).

Further, high temperature, pH, nitrate, phosphate, organic matter and low dissolved oxygen are prerequisite for the luxuriant growth of cyanophyceae (Hulyal and Kaliwal, 2009; Chellappa *et al*., 2008). Hulyal and Kaliwal (2009) also reported that the low level of calcium check the abundance of cyanophyceae. Inverse relationship between phosphates and cyanophyceae has been reported by Zafar (1967) who found that blue green algae were high when the nitrates were high and phosphate content was low.

Members of cyanophyceae usually dominate the phytoplankton community due to their capacity to grow in turbid water with low light intensity to maintain buoyancy which enhances their capacity to cultivate exponentially (Chellappa *et al*., 2008). Cyanophyceae members generally show dominance in eutrophic water (Chellappa *et al*., 2000). According to and Cyanophyceae species are found dominant in all polluted lakes as they are pollution tolerant and act as pollution indicator species (Kiran *et al*., 2006; Shekhar *et al*., 2008). In the present investigation total eight genera and fourteen species of blue green algae twelve, eleven and ten species were recorded at malpur dam, Baldane reservoir and Krishna park respectively.

In natural and unpolluted wetlands low cyanophyceae density and diversity are expected. In the present investigation pollution indicator species *Anabaena, Oscillatoria* and genus *Microcystis* were recorded but in lower numbers. The genera *Anabaena* and *Oscillatoria* produce neurotoxins, which causes irritation. However, no bloom formation was observed over two years, but their presence in wetlands is an indication of possible biological pollution if the environment changes. Mischke and Nixdorf (2003) have reported that these genera built up very dense population that increases turbidity, due to irregular mixing of water in summer. The members of cyanophyceae e.g. *Anabaena, Nostoc, Oscillatoria* and *Microcystis* flourish in summer at higher temperature and CO_2 levels and low oxygen levels (Tiwari and Chauhan 2006). *Monocystis aeurginosa* is the main bloom forming and pollution producing species of lakes (Lindholm *et al*., 2003, Nandan and Aher, 2005). However, in the present investigation *Microcystis viridis* have been recorded which on getting favourable condition can flourish. The buoyancy hypothesis is related to

forms, such as *Microcystis* that bear gas vesicles and are able to use water column stability as a resource (Reynolds *et al*., 1987). Blue green algae can rise to the surface water where light and CO_2 are available or to intermediate depth where the conditions are favourable to them. Cyanophyceae are capable of producing several extremely toxic chemicals, and have achieved notoriety for their tendency to form surface scums (generally referred as cyanobacterial bloom). Microcystin, a toxin produce by Cyanophyceae, can attack the digestive tract and cause sickness and pneumonia like symptoms while the saxitoxisn produced by genera *Nostoc* is responsible for suppressing the growth of other algae (Keating, 1989) as well as affect natural grazers (such as zooplankton), or kill potential grazers (Reynolds, 2006).

In the present investigation the density of cyaophyceae is positively significantly correlated with total density of phytoplankton, density and species richness of chlorophyceae while its species richness is positively significantly correlated to density and species richness of chlorophyceae, indicating that the members of cyanophyceae are not dominating the wetlands under study. Apart from nutrients, many other variables are also involved in the development of cyan bacterial blooms (Dokulil and Tubner, 2000) and their ecological success are probably at lower levels in three water bodies studied. The cyanobacterial dominance can be prevented or reduced and prerequisite is almost always a reduction of the nutrient load from the catchment to the lake. Artificial mixing of the water column can be particularly useful in reducing competitive advantage for cyanophyceae (Steinberg and Hartman, 1988). WHO has suggested that 1µg/l as the upper safe limit of *Microcystis*. The cyanobacterial toxin in the recreational waters may compose hazards to swimmers, sailors and anglers on ingestion of scum (bloom). Site managers are expected to give periodic warnings or banning public access to water by considering the extent of bloom.

Euglenophyta: Density

The euglenophyta a group of unicellular flagellated organisms found in freshwater and marine environments as well as on moist soil comprises a majority of 800 or so known phagotroph species or colourless heterotrophs, even some phototrophic and capable of absorbing and assimilating simple organic solutes (Reynolds, 2006). They serve as excellent bioindicators of environmental changes as well. They constitute an important group of organisms between flora and fauna. In present study an attempt has been made to study the factors governing the euglenophyta, their diversity and

distribution. Factors regulating the dynamics of euglenophyta has not been studied in detail, however certain researcher have worked on the euglenophyta (Ratha, 2006; Hosmani, 2012; Varol and Sen, 2016).

The green euglenophyta are represented poorly in the present study of three wetlands with biannual percentage density of 2.52% (Malpur dam) while 2.8% (Baldane reservoir) and 3.91% (Krishna Park). Euglenophytes showed significant seasonal variations in response to temporal variations of physical and chemical parameters. However, their density and diversity was always low compared to other three groups. Maximum density of euglenophyta was recorded in monsoon, while minimum in winter and moderate in summer at all the three wetland studied. Hafsa and Gupta (2009) also reported higher density of euglenophyta during monsoon which may be attributed to rains, which collect water from catchment area carrying rich organic matter to the wetlands which is preferred by euglenophyta (Hosmani, 2012). Among the three wetland studied (MD, BR and KP) maximum density of euglenophyta were recorded at Krishna Park which has more anthropogenic activities probably adding more organic matter to the wetland. According to Round (1985) ammonia rich environment is favourable for the euglenophyta.

Density of euglenophyta is positively significantly correlated with PO_4, TS, TSS and WC while it established significant negative correlation with Cl, pH, TH and transparency. Total phosphorus content of water has a major impact and support the growth of species of euglenophyta (Hosmani, 2012). Positive correlation between euglenophyta and phosphate were rerecorded in the present study of wetlands. Transparency was negatively correlated because their density was higher in monsoon when the wetlands were loaded with rich organic drainage; that increased turbidity too.

Species richness of euglenophyta

Taxonomic and floristic studies of euglenophyta in the north Maharashtra, India is still scarce. However, intensive research for over a period of two years for the first time reported six taxa of euglenophyta from this region. 1056 species of euglenophyta have been recorded worldwide (Guiry and Guiry, 2016). Qualitatively they formed fourth and lowest component with poor representation. Their biannual percentage variation was between 6.2% (BR) to 7.9% (KP). At Malpuer dam, 4 species *Euglena gaumei*, *Euglena acus*, *Euglena caudate* and *Phacus longicauda* were recorded. At Baldane reservoir, 3 species *Euglena spirogyra*, *Euglena gomi* and *Euglena caudate*,

while at Krishna park 4 species *Euglena spirogyra*, *Euglena acus*, *Phacus longicaud* and *Phacus triqueter* were recorded. Seasonal variations in their species richness were with maximum number recorded in monsoon and minimum in winter, while moderate in summer. Seasonal variation in physical and chemical factors attribute to seasonal variation of euglenophyta species (Hosmani, 2012). Further, he stated that euglenophyta species serve as indicator of organic pollution and the correlation of various factors can be helpful in conservation of Lake Ecosystem. Euglenophyta species richness was positively significantly correlated with TS, TSS while negatively significantly correlated with pH, TH, and transparency at all the three wetlands studied. Occurrence of *E. acus, E. spirogyra*, *Facus longicauda* are favoured by higher concentration of total phosphorus (Hosmani, 2012). However, in present study nonsignificant correlation of euglenophyta species richness and phosphate were recorded. Abundant development of euglenoids is known to occur in higher water temperature (Duangjan *et.al*., 2014).

Knowledge of the euglenophyta flora can be useful in assessment of water quality (Varol, and Sen, 2016). Though the tolerant species of euglenophytes were recorded from three wetlands studied, their density and species richness were very poor, but continuous monitoring of water can play vital role in the proper management of these wetlands.

In conclusion it can be said that the phytoplankton density and diversity of the three water bodies studied in rain deficient North Maharashtra indicate that physicochemical characteristics of these reservoir influence the diversity and density of plankton species. The pollution indicators are minimum and care should be taken so that water remains healthy for agricultural and human needs.

Table: 5.1 Seasonal Variations in density of different groups of Phytoplankton (Malpur dam.)

Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years (%)
1	**Tot. Phyto**	$F_{2\ 21}$26.9	3149 ± 102	3363 ± 66	1740 ± 131	
2	**Cyano.**	$F_{2\ 21}$ 24.1	917 ± 26.1	564 ± 34.3	376 ± 33.4	22.5 %
3	**Chloro.**	F_{221} 25.88	1420 ± 56.37	782.9 ± 60.47	506.1 ± 41.18	32.82 %
4	**Bacili.**	F_{221} 14.27	774 ± 75.5	1970 ± 128	738 ± 74.1	42.16%
5	**Eugleno**	$F_{2\ 21}$ 25.71	37.8 ± 3.94	49.9± 3.48	120 ± 13.7	2.52%

Table: 5.2 Seasonal Variations in species richness (no. of species) of different groups of Phytoplankton (Malpur dam)

Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years (%)
1	**Tot.Sp.R.Ph**	$F_{2\ 21}$ 63.10	17.4 ± 0.18	23.30 ± 0.26	20.8 ± 0.41	
2	**Cyano.**	$F_{2\ 21}$ 19.20	4.75 ± 0.16	2.63± 0.18	3.75 ± 0.16	18.1 %
3	**Chloro.**	$F_{2\ 21}$ 11.82	6.50 ± 0.20	3.50 ± 0.20	4.75 ± 0.16	23.98 %
4	**Bacili.**	$F_{2\ 21}$ 7.54	5.50 ± 0.18	16.3 ± 0.25	9.63 ± 0.50	51.01 %
5	**Eugleno**	$F_{\ 2\ 21}$19.73	0.63 ± 0.18	1.00 ± 0.00	2.63± 0.26	6.91 %

Table: 5.3 Seasonal Variations in density of different groups of Phytoplankton (Baldane reservoir)

Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years %
1	**Tot. Phyto**	$F_{2\ 21}$ 47.21	3240 ± 181.9	3913 ± 79.92	2046 ± 131.6	
2	**Cyano.**	$F_{2\ 21}$ 46.63	936.3± 45.59	697.1 ± 40	418.6 ± 25.25	23.31 %
3	**Chloro.**	F_{221} 41.47	1266 ± 53.18	994.6 ± 57.61	587.5 ± 47.91	31 %
4	**Bacili.**	F_{221} 53.56	1006 ± 96.73	2163 ± 109	871.5 ± 83.37	43.9%
5	**Eugleno**	$F_{2\ 21}$ 46.22	31.63 ± 2.14	58.13± 5.75	168.3 ± 17.41	2.8%

Table: 5.3 Seasonal Variations in density of different groups of Phytoplankton (Baldane reservoir)

Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years %
1	**Tot.Sp.R.Ph**	$F_{2\ 21}$ 24.7	21.13 ± 0.35	25.5 ± 0.5	22.13 ± 0.52	
2	**Cyano.**	$F_{2\ 21}$ 30.46	6.25 ± 0.25	3.75± 0.25	4.63 ± 0.18	21.3 %
3	**Chloro.**	$F_{2\ 21}$ 25.43	6.75 ± 0.25	3.75 ± 0.37	5.0 ± 0.27	23.00 %
4	**Bacili.**	$F_{2\ 21}$ 155.8	7.38 ± 0.42	16.75 ± 0.37	10.25 ± 0.36	50.00 %
5	**Eugleno**	$F_{2\ 21}$21.7	0.75 ± 0.16	1.25 ± 0.16	2.25 ± 0.16	6.2 %

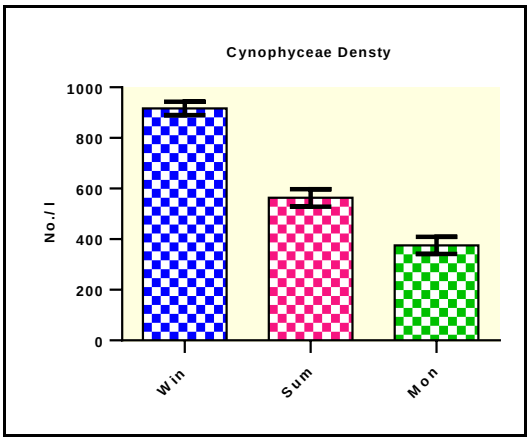
Table: 5.3 Seasonal Variations in density of different groups of Phytoplankton (Krishna Park)

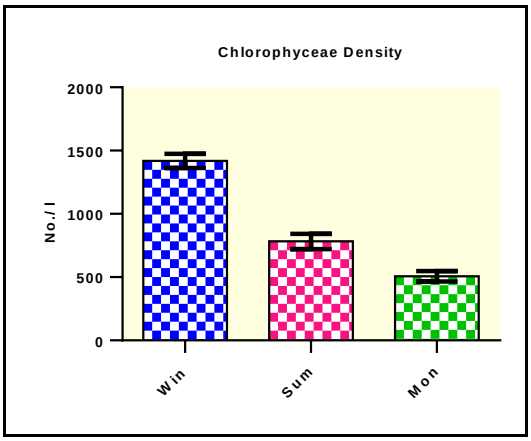
Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years %
1	**Tot. Phyto**	$F_{2\ 21}$ 43.67	2721 ± 130	2971 ± 81.04	1634 ± 106.2	
2	**Cyano.**	$F_{2\ 21}$ 35.97	762.9 ± 51.5	493.8 ± 13.94	314.9 ± 37.36	21.5 %
3	**Chloro.**	F_{221} 72.89	1199 ± 45.18	685 ± 48.4	450 ± 40.63	31.86 %
4	**Bacili.**	F_{221} 45.95	712.4± 53.83	1729 ± 127.5	692.6 ± 61.48	42.8%
5	**Eugleno**	$F_{2\ 21}$ 17.9	47.25 ± 5.21	63.5± 5.76	176.3 ± 27.69	3.91%

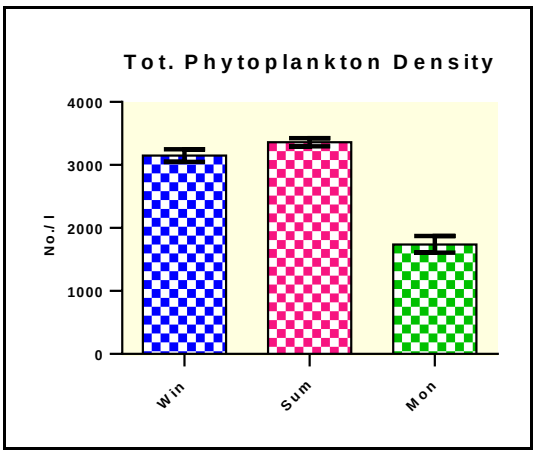
Table: 5.4 Seasonal Variations in species richness (no. of species) of different groups of Phytoplankton (Krishna Park)

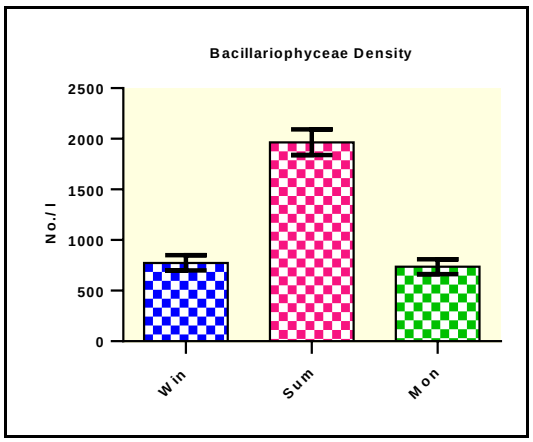
Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years %
1	**Tot.Sp.R.Ph**	$F_{2\ 21}$ 19.01	19.63 ± 0.32	23.38 ± 0.41	21.75± 0.45	
2	**Cyano.**	$F_{2\ 21}$ 26.92	5.63 ± 0.26	3.25± 0.16	4.25 ± 0.25	20.3 %
3	**Chloro.**	$F_{2\ 21}$ 29.98	6.38 ± 0.18	3.63 ± 0.26	4.87± 0.29	22.97 %
4	**Bacili.**	$F_{2\ 21}$ 80.13	6.75 ± 0.31	15 ± 0.63	9.88 ± 0.39	48.8 %
5	**Eugleno**	$F_{2\ 21}$35	0.88 ± 0.13	1.5 ± 0.19	2.75 ± 0.16	7.91 %

Figure: 4.1 Seasonal variation in density of different groups of Phytoplankton (No./ l) at Malpur Dam during October 2011 – September 2013.









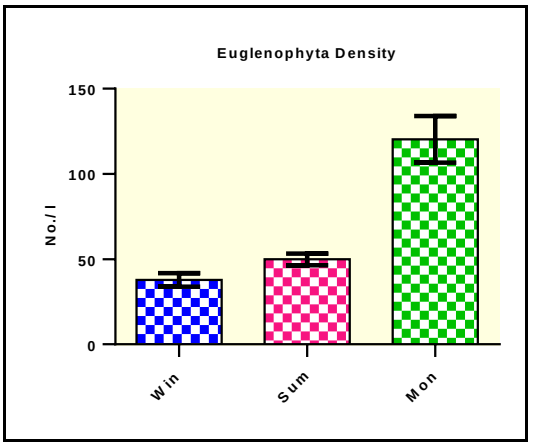
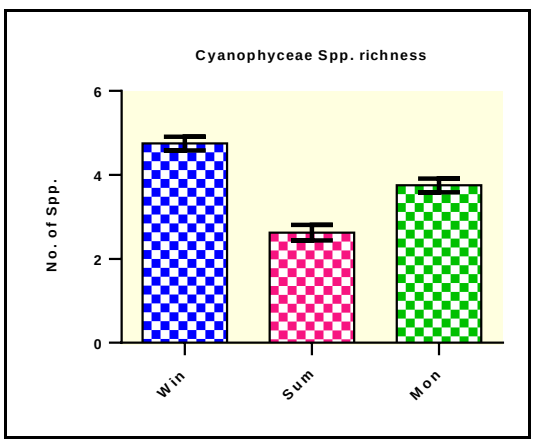
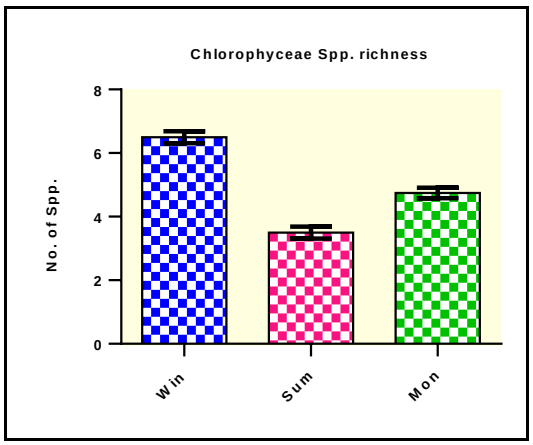
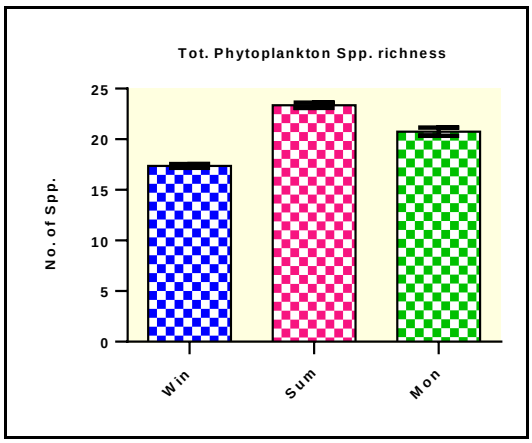
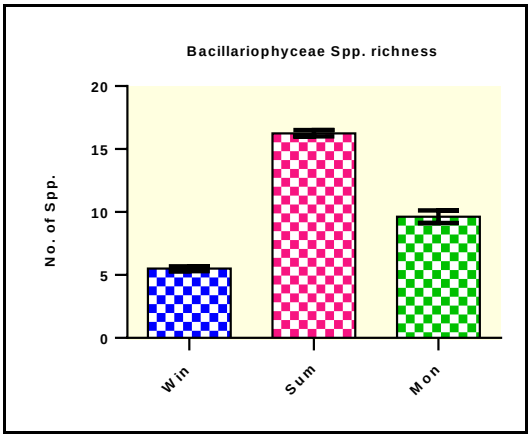


Figure: 4.1 Seasonal variation in Species richness of different groups of Phytoplankton at Malpur Dam during October 2011 – September 2013.









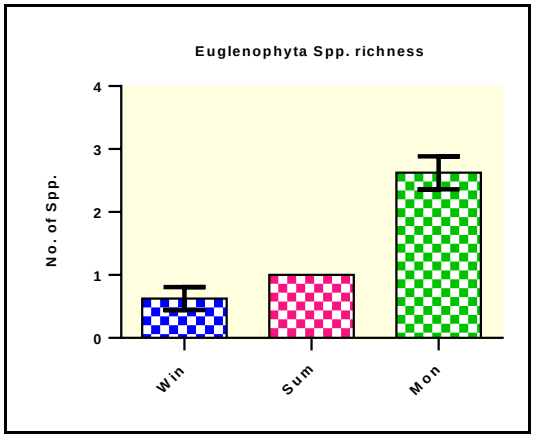


Figure: 4.1 Seasonal variations in density of different groups of Phytoplankton (No./ l) at Baldane Reservoir during October 2011 – September 2013.

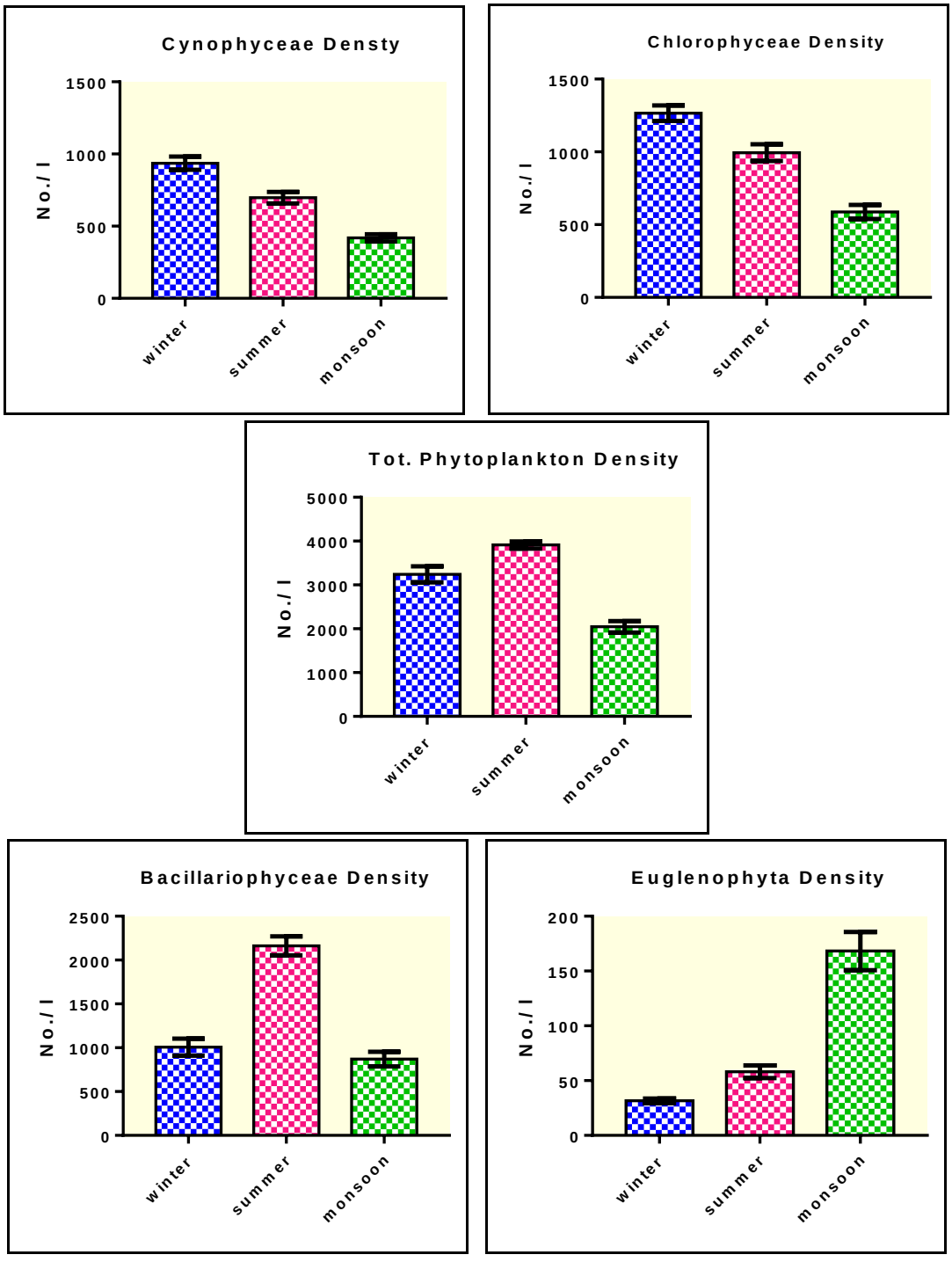


Figure: 4.1 Seasonal variations in Species richness of different groups of Phytoplankton at Baldane Reservoir during October 2011 – September 2013.

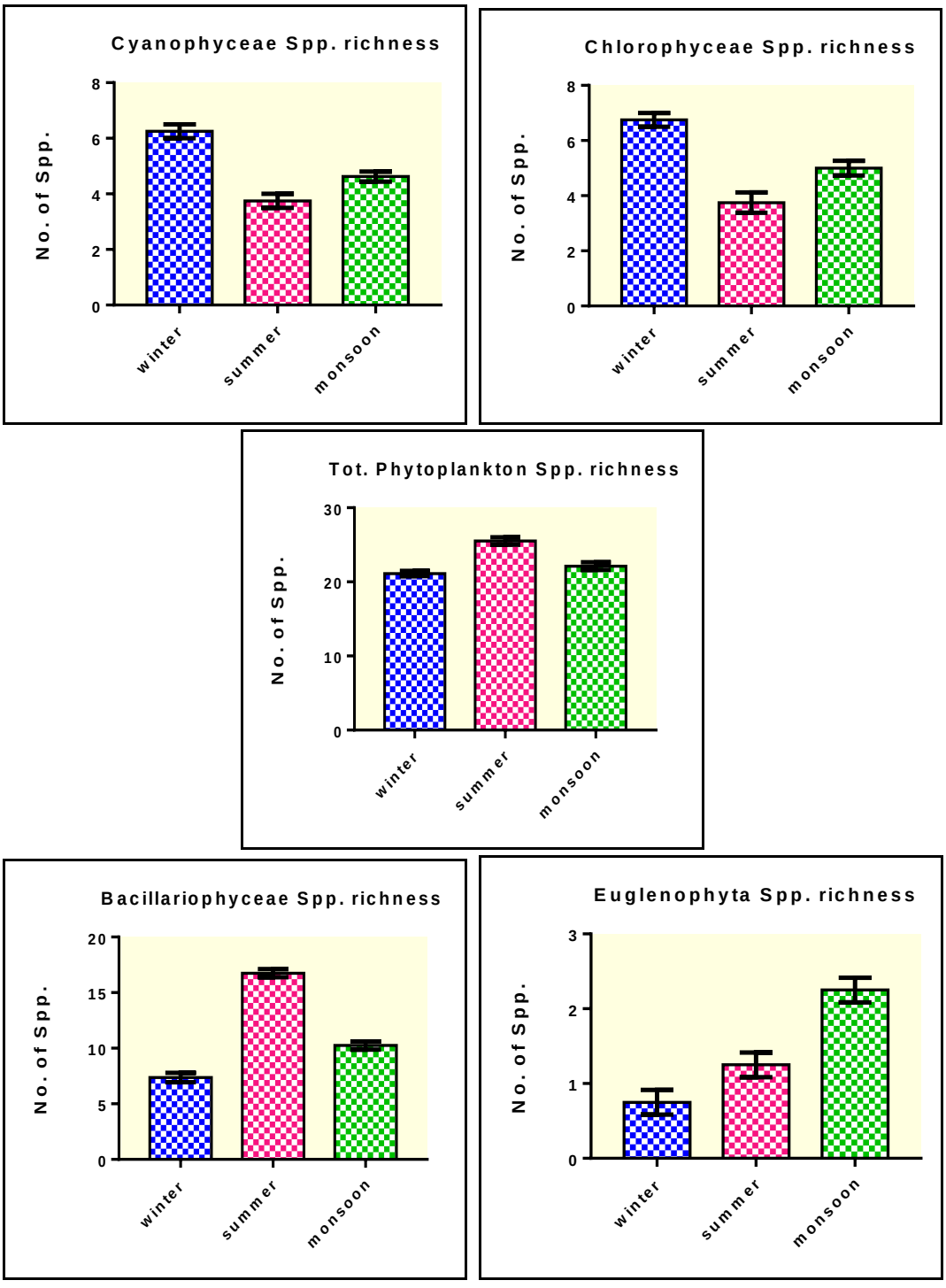


Figure: 4.1 Seasonal variations in density of different groups of Phytoplankton (No./ l) at Krishna Park during October 2011 – September 2013.

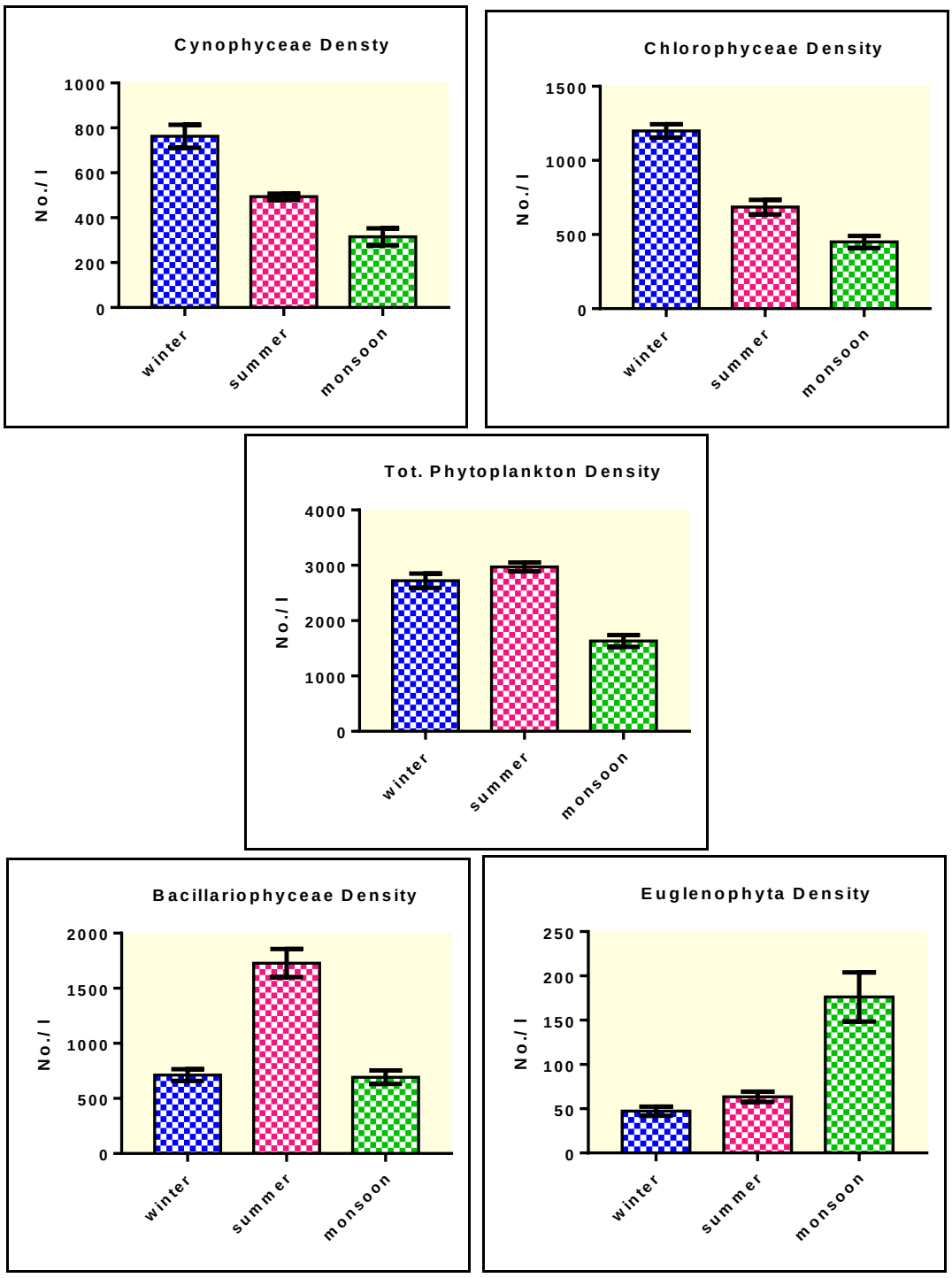
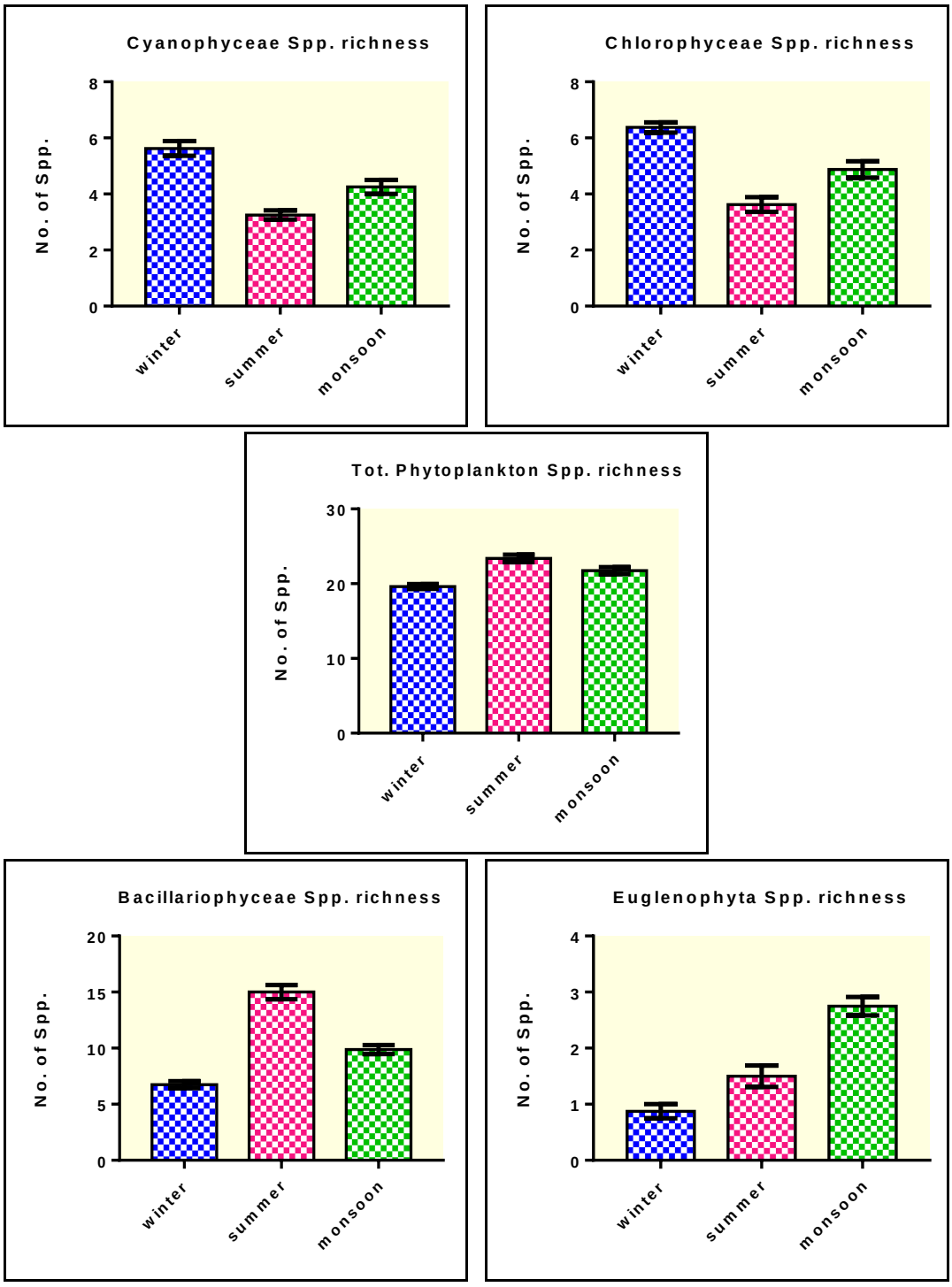


Figure: 4.1 Seasonal variations in Species richness of different groups of Phytoplankton at Krishna Park during October 2011 – September 2013.



Pearson Correlations- Phytoplankton and Physicochemical Parameter of Malpur Dam

	Den. Bacil	Den. Chlor	Den. Cyno	Den. Eugle	Sp.R. Bacil	Sp.R. Chlor	Sp.R. Cyno	SP.R. Eugle	T. Den, Phyto	T.SP. Rich
AT	.543**	-.550**	-.462*	.084	.716**	-.713**	-.766**	.080	.011	.630**
CA	.032	.309	.364	-.293	-.142	.238	.173	-.170	.287	-.126
CL	.868**	.041	.135	-.595**	.658**	-.576**	-.499*	-.403	.735**	.513*
CO2	.600**	-.686**	-.639**	.186	.825**	-.889**	-.830**	.261	-.065	.776**
Den. Bacil	1.000	-.202	-.154	-.380	.847**	-.781**	-.694**	-.285	.636**	.711**
Den. Chlor	-.202	1.000	.972**	-.764**	-.520**	.692**	.631**	-.742**	.625**	-.604**
Den. Cyno	-.154	.972**	1.000	-.798**	-.490*	.663**	.570**	-.748**	.655**	-.590**
Den. Eugle	-.380	-.764**	-.798**	1.000	-.060	-.117	-.169	.867**	-.905**	.105
DO	-.679**	.623**	.569**	-.089	-.914**	.901**	.830**	-.178	-.049	-.893**
MG	.900**	-.175	-.107	-.331	.764**	-.642**	-.685**	-.367	.586**	.607**
NO3	-.684**	-.401	-.432*	.683**	-.368	.180	.292	.654**	-.864**	-.190
PH	.745**	.368	.394	-.754**	.485*	-.316	-.367	-.753**	.881**	.258
PO4	-.776**	-.247	-.325	.749**	-.538**	.406*	.248	.589**	-.820**	-.412*
SO4	.619**	.123	.183	-.447*	.468*	-.354	-.512*	-.482*	.600**	.259
Sp.R. Bacil	.847**	-.520**	-.490*	-.060	1.000	-.930**	-.847**	-.015	.257	.948**
Sp.R. Chlor	-.781**	.692**	.663**	-.117	-.930**	1.000	.852**	-.227	-.068	-.880**
Sp.R. Cyno	-.694**	.631**	.570**	-.169	-.847**	.852**	1.000	-.175	-.061	-.734**
SP.R. Eugle	-.285	-.742**	-.748**	.867**	-.015	-.227	-.175	1.000	-.808**	.178
T. Den, Phyto	.636**	.625**	.655**	-.905**	.257	-.068	-.061	-.808**	1.000	.080
TDS	.800**	.045	.136	-.597**	.621**	-.534**	-.480*	-.473*	.682**	.450*
TH	.823**	.161	.241	-.677**	.595**	-.496*	-.515*	-.567**	.790**	.374
TRAN	.003	.904**	.891**	-.813**	-.328	.491*	.378	-.755**	.713**	-.471*
TS	.205	-.813**	-.751**	.501*	.476*	-.635**	-.443*	.616**	-.469*	.578**
T.SP.Rich	.711**	-.604**	-.590**	.105	.948**	-.880**	-.734**	.178	.080	1.000
TSS	-.366	-.750**	-.757**	.851**	-.004	-.196	-.064	.869**	-.882**	.204
WC	-.769**	-.014	-.123	.547**	-.640**	.528**	.395	.403	-.640**	-.544**
WT	.630**	-.651**	-.575**	.163	.778**	-.824**	-.811**	.203	-.003	.710**

*· Correlation is significant at the 0.05 level (2-tailed).

**· Correlation is significant at the 0.01 level (2-tailed).

Pearson Correlations- Physicochemical Parameters and Phytoplankton of Baldane Reservoir

	Den. Chlor	Den. Cyno	Den. Basil	Den. Eugle	Den. Tot	Sp.R. Basil	Sp.R. Chlor	Sp.R. Cyno	Sp.R. Eugle	Sp.R. Tot
AT	-.549**	-.551**	.385	.293	-.043	.682**	-.730**	-.834**	.215	.384
CA	.277	.400	.030	-.281	.212	-.109	.173	.126	-.463*	-.175
CL	.379	.322	.890**	-.479*	.852**	.615**	-.424*	-.299	-.338	.563**
CO2	-.425*	-.470*	.587**	.184	.165	.842**	-.852**	-.813**	.238	.612**
Den. Chlor	1.000	.947**	.199	-.869**	.707**	-.195	.522**	.545**	-.802**	.009
Den. Cyno	.947**	1.000	.156	-.825**	.673**	-.244	.555**	.606**	-.805**	-.027
Den. Basil	.199	.156	1.000	-.391	.828**	.823**	-.621**	-.543**	-.242	.712**
Den. Eugle	-.869**	-.825**	-.391	1.000	-.758**	-.054	-.246	-.286	.740**	-.161
Den. Tot	.707**	.673**	.828**	-.758**	1.000	.469*	-.136	-.060	-.637**	.512*
DO	.465*	.519**	-.603**	-.219	-.152	-.823**	.865**	.749**	-.346	-.641**
MG	.264	.256	.896**	-.381	.803**	.662**	-.467*	-.415*	-.383	.541**
NO3	-.061	-.180	-.259	.154	-.253	-.099	.111	-.034	.170	-.066
PH	.598**	.553**	.824**	-.704**	.928**	.565**	-.266	-.216	-.629**	.521**
PO4	-.495*	-.434*	-.870**	.582**	-.901**	-.593**	.360	.177	.376	-.617**
SO4	.232	.257	.737**	-.411*	.671**	.614**	-.456*	-.361	-.414*	.480*
Sp.R. Basil	-.195	-.244	.823**	-.054	.469*	1.000	-.836**	-.810**	.087	.860**
Sp.R. Chlor	.522**	.555**	-.621**	-.246	-.136	-.836**	1.000	.842**	-.363	-.531**
Sp.R. Cyno	.545**	.606**	-.543**	-.286	-.060	-.810**	.842**	1.000	-.263	-.470*
SPREUGL	-.802**	-.805**	-.242	.740**	-.637**	.087	-.363	-.263	1.000	.119
Sp.R. Tot	.009	-.027	.712**	-.161	.512*	.860**	-.531**	-.470*	.119	1.000
TDS	-.003	-.071	.780**	-.198	.543**	.684**	-.649**	-.424*	.045	.603**
TH	.373	.345	.842**	-.529**	.816**	.659**	-.418*	-.342	-.487*	.572**
TRAN	.871**	.906**	.088	-.663**	.581**	-.253	.561**	.551**	-.805**	-.068
TS	-.677**	-.719**	.218	.493*	-.245	.392	-.640**	-.517**	.636**	.230
TSS	-.858**	-.854**	-.381	.793**	-.770**	-.079	-.265	-.300	.771**	-.216
WC	-.307	-.255	-.873**	.447*	-.797**	-.652**	.486*	.329	.288	-.590**
WT	-.521**	-.534**	.400	.295	-.017	.719**	-.781**	-.766**	.260	.470*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

earson Correlations of Physicochemical Parameters and Phytoplankton of Krishna Parl

	Den. Basil	Den. Chlor	Den. Cyno	Den. Eugle	Den. Tot	Sp.R. Basil	Sp.R. Chlor	Sp.R. Cyno	Sp.R. Eugle	Sp.R. Tot
AT	.500*	-.610**	-.574**	.172	-.068	.500*	-.610**	-.574**	.172	-.068
CA	.901**	.113	.238	-.620**	.813**	.901**	.113	.238	-.620**	.813**
CL	.749**	-.652**	-.571**	.214	.123	.749**	-.652**	-.571**	.214	.123
CO2	.768**	-.668**	-.584**	.131	.117	.768**	-.668**	-.584**	.131	.117
Den. Basil	1.000	-.199	-.040	-.323	.678**	1.000**	-.199	-.040	-.323	.678**
Den. Chlor	-.199	1.000	.963**	-.741**	.581**	-.199	1.000**	.963**	-.741**	.581**
Den. Cyno	-.040	.963**	1.000	-.795**	.699**	-.040	.963**	1.000**	-.795**	.699**
Den. Eugle	-.323	-.741**	-.795**	1.000	-.797**	-.323	-.741**	-.795**	1.000**	-.797**
Den. Tot	.678**	.581**	.699**	-.797**	1.000	.678**	.581**	.699**	-.797**	1.000**
DO	-.734**	.564**	.442*	.006	-.173	-.734**	.564**	.442*	.006	-.173
MG	.952**	-.003	.151	-.498*	.782**	.952**	-.003	.151	-.498*	.782**
NO3	-.339	-.081	-.223	.212	-.371	-.339	-.081	-.223	.212	-.371
PH	.743**	.421*	.499*	-.713**	.916**	.743**	.421*	.499*	-.713**	.916**
PO4	-.830**	-.252	-.395	.692**	-.870**	-.830**	-.252	-.395	.692**	-.870**
SO4	.835**	.053	.178	-.402	.733**	.835**	.053	.178	-.402	.733**
Sp.R. Basil	1.000**	-.199	-.040	-.323	.678**	1.000	-.199	-.040	-.323	.678**
Sp.R. Chlor	-.199	1.000**	.963**	-.741**	.581**	-.199	1.000	.963**	-.741**	.581**
Sp.R. Cyno	-.040	.963**	1.000**	-.795**	.699**	-.040	.963**	1.000	-.795**	.699**
Sp.R. Eugle	-.323	-.741**	-.795**	1.000**	-.797**	-.323	-.741**	-.795**	1.000	-.797**
Sp.R. Tot	.678**	.581**	.699**	-.797**	1.000**	.678**	.581**	.699**	-.797**	1.000
TDS	.860**	-.254	-.109	-.195	.525**	.860**	-.254	-.109	-.195	.525**
TH	.852**	.178	.295	-.657**	.821**	.852**	.178	.295	-.657**	.821**
TRAN	-.024	.865**	.870**	-.833**	.616**	-.024	.865**	.870**	-.833**	.616**
TS	.326	-.843**	-.764**	.611**	-.344	.326	-.843**	-.764**	.611**	-.344
TSS	-.264	-.834**	-.850**	.897**	-.825**	-.264	-.834**	-.850**	.897**	-.825**
WC	-.823**	-.070	-.203	.455*	-.734**	-.823**	-.070	-.203	.455*	-.734**
WT	.589**	-.674**	-.595**	.181	-.033	.589**	-.674**	-.595**	.181	-.033

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).