Chapter-5

Discussion

5.1 Physico chemical Parameters

In ecological studies, physico chemical variables are extremely important in analyzing the status of an ecosystem. Hydrographic properties determine the existence of phytoplankton in an aquatic ecosystem and this knowledge is important in understanding the dynamics of the ecosystem. The biodiversity of an aquatic system shaped by the qualitative and quantitative properties of water bodies. Physico chemical variables either individually or collectively influence the system structure and distribution of microalgae. The data obtained from this study has been utilized to discuss the ecology of the freshwater algae of the study area. The rainfall pattern was found to play a significant role in the fluctuations of physicochemical characteristics of water. To assess the impact of human activities on environment by comparing the seasonal changes in physicochemical properties of an ecosystem.

5.1.1 Temperature

Temperature is basically a vital factor for its effect on chemical and biological properties of water. Temperature controls the abundance of phytoplankton in aquatic ecosystems and the determination of various parameters such as pH, alkalinity and saturation level of gases in the freshwater ecosystem (Kaushik and Saksena 1994). Fluctuations in temperature may be due to wind force, the influx of freshwater, atmospheric temperature and heavy rainfall.

Maximum water temperature observed during the month of April at station 7 and least during August at station 10 (Figure 3). The highest temperature in April could be attributed to the increased solar radiation and evaporation. Station 7 is a town area with largest population and highly crowded place. All those people, their buildings and structures create more heat than rural areas. Station 10 is a part of Bhavani river which flows through Silent valley with high rural vegetation and undisturbed area results the low temperature. Higher temperature enhances the growth of organisms, solubility of gases and reaction rate of chemicals in aquatic ecosystem. Similar findings were recorded by (Eshwarlal and Angadi 2003).

5.1.2 pH

pH of aquatic ecosystem is an important environmental factor, the variation of which along with other causes is linked with the chemical changes, species composition and life processes of living communities inhabiting them (Begum et al. 1988). In natural water bodies, pH changes due to the variation in photosynthetic activity.

During the whole study period pH value was in alkaline range. Highest value observed during the month of May at station 7 and lowest during July at station 9 (Figure 4). Least value of pH during July at station 9. Alkaline water promotes high primary productivity. Alkalinity may be due to the presence of various pollutants and chemicals like carbonate, bicarbonate, or hydroxide compounds, those materials get dissolved and portable with the water. The same findings recorded by (Chandra et al 2011; Jindal and Sharma 2011b) and stated that high photosynthetic rate of phytoplankton will reduce the free carbon dioxide resulting in enhanced pH values.

5.1.3 Electrical conductivity

Electrical conductivity depends on the concentration of the ionized substances dissolved in water and the temperature at which measurement is made. It is the power of water to conduct an electrical current. Increase in electrical conductivity may be attributed to decrease in water level due to evaporation (Bhosale et al. 2010b; Barhate and Tarar 1985b).

EC show high disparity between months and stations. Maximum value observed during the month of May at station 7 and minimum at station 9 during July (Figure 5). Extreme EC value attributed due to addition of some salts through the prevailing agricultural activities. Low due to dilution of soluble salts by rainfall during monsoon season.

5.1.4 Total dissolved solids

The term applied to the material left behind after water filtered and evaporated. It includes all the suspended cations and anions, provides a qualitative measure of the number of dissolved ions.

The high TDS value during May at station 8 (Figure 6) due to the addition of agricultural runoff from the surrounding agricultural fields (Belal et al. 2016). A comparatively high value of TDS indicates highly mineralized form of water and maximum disturbance due to human activities (Sharma and Sarang 2004).

5.1.5 Dissolved oxygen

Dissolved oxygen is an especially important parameter of water quality and forms index of physical and biological processes take place in water. Low oxygen concentration is generally associated with substantial contamination by organic matter, while high values indicate extreme plant growth. Its level depends on physico chemical and biological activities of water bodies. The dominant effect of dissolved oxygen results the succession of algae in freshwater ecosystem (Begum et al. 1988).

Highest DO values in the ecosystem during the month of August at station 10 (Figure 7) might be due to high photosynthetic activity and solubility of oxygen in river flex. The lowest oxygen values in pre monsoon during the month of April at station 7 might be due to the influence of organic waste decomposition, high water temperature and nutrient inputs (Vijayakumar 1999; Simon and Travis 2011).

5.2 Nutrients

Nutrient concentrations are crucial in phytoplankton dynamics. There is a firm positive relationship between nutrient loading and phytoplankton development in freshwater. The nutrients like nitrogen and phosphorus are essential for plant growth. Increased input of nutrients due to human activities accelerates primary production, algal bloom, excessive weed growth and eutrophication. Nutrients in freshwater bodies influence the growth, reproduction, and metabolic activities of biotic components, primarily based on seasons, freshwater inflow, tidal variations, land runoff, fertilizers in the agricultural fields, nutrients consumption and regeneration of phytoplankton (Anand and Hopper 1987).

5.2.1 Nitrate

Nitrates are the most oxidized form of nitrogen and formed from the decomposition of organic matter. Increased level of nitrogen accelerates the eutrophication process and resulting algal blooms and hypoxia.

Maximum value of nitrate recorded during the month of May at station 7 and minimum value during August at station 10 (Figure 8). High levels of nitrates in freshwater mainly due to increased domestic sewage arising from anthropogenic activities and agricultural runoffs (Yazdandoost and kaldore 2000). Station 7 characterizes excess growth of plants and phytoplankton, this results the accumulation of organic matter when they die off. The nitrate concentration trends are highly correlated with the usage of fertilizers in fields. A lower nitrate concentration might be due to the high consumption of nitrate by photosynthetic organisms.

5.2.2 Phosphate

The phosphorus is identified as a key nutrient in the biological productivity of the water. Concentration of phosphate in an ecosystem forms a good index of eutrophication in water bodies and if the concentration of phosphates exceeds its normal level along with nitrogen.

Highest value observed during pre monsoon and lowest during monsoon season (Figure 9). In the present study the phosphate content was very low. The lowest values of phosphate might be due to the high utilization by phytoplankton for their development (Perumal and Anand 2008a; Sheela et al. 2011).

5.2.3 Silicate

Silicate is an essential nutrient necessary for the growth of algae, especially diatoms (Smith 1950). The higher silicate concentration was due to increased water temperature, higher evaporation rate and the release of nutrients due to decomposition. Input of biologically available silica to the aquatic ecosystem comes largely from weathering of soils and sediment.

The occurrence of low silica was found to be related with their continuous utilization by phytoplankton especially diatoms and increased population density of phytoplankton. Maximum silicate concentration during the month of May at station 7 and least during December at station 9 (Figure 10). The silicate content relatively high during pre-monsoon due to death and decomposition of diatoms (Govindasamy et al. 2000).

The hydrographic parameters of the study area and the nutrients fluctuated with months and stations. The marked variation in nutrient status of the study area concluded that it is mainly influenced by waste discharge, agricultural runoff, application of fertilizers and intense anthropogenic activities.

5.3 Algal taxonomy

The knowledge about species diversity was essential to understand life in all its totality and to preserve and manage it for future generations (Pandey 1995). Analysis of surface water samples revealed the presence of 257 taxa from rivers in Palakkad district shown in table 2. The taxa belong to 70 genera, 26 families, 9 order and 6 classes namely chlorophyceae, xanthophyceae, bacillariophyceae, euglenophyceae, cyanophyceae and dinophyceae were identified from the 10 stations. Out of the 257 taxa, 88 (chlorophyceae 34%), 1(xanthophyceae 1%), 74 (bacillariophyceae 29%), 69 (euglenophyceae 26%), 24 cyanophyceae 9% and 1(dinophyceae 1%). The most frequent taxa found in the study area listed in table 7. They are *Synedra ulna, Aulacoseira granulata, Navicula cuspidata* and *Fragilaria intermedia.* Five species of diatoms *Cymbella tumida*, *Cyclotella striata*, *Aulacoseira granulata*, *Synedra acus* and *Synedra ulna* recorded from all the months during the study. *Cyclotella meneghiniana, Cyclotella striata, Euglena proxima, Fragilaria intermedia, Aulacoseira granulata, Navicula cuspidata, Synedra ulna* and *Trachelomonas armata* were present in all the stations. *Cyclotella striata, Aulacoseira granulata* and *Synedra ulna* were present in all stations and months from the study. Out of the 257 taxa recorded from the present study, one species is new report to India and 14 species are new to Kerala are listed in table 3.

5.4 Quantitative analysis of phytoplankton

Month wise and station wise distribution on the number of taxa during the study period is given in tables 5 and 6. The highest number of phytoplankton taxa recorded at station 7 (353120 cells/L) and lowest at stations 9 (34840 cells/L) and 10 (31020 cells/L). Month wise highest amount of phytoplankton during May (217260 cells/L) and lowest in June (25330 cells/L) and July (27110 cells/L).

Spatial and temporal distribution of phytoplankton belonging to various taxonomic groups such as chlorophyceae, bacillariophyceae, xanthophyceae, euglenophyceae, cyanophyceae and dinophyceae illustrated in figures 13, 14, 15 and 16. Spatial distribution of number of taxa in bacillariophyceae highest in stations 7 (42), 6 (39) and 5 (38) respectively. All the physico chemical parameters high in station 7. Least number of taxa in stations 9 (19) and 10 (21). Total number of cells also high in station 7 and least in station 10. Monthly wise distribution of taxa and number of cells high in May (pre monsoon) followed by December (post monsoon) and lower in June (Monsoon). pH as a cofactor which influences the population of bacillariophyceae. Alkaline pH favors the abundance of diatoms stated by (Patrick 1949; Pawar et al. 2006; Gupta 2002). In the present study, pH has maximum in May and at station 7, which supported the good number of diatoms in that area. In the present investigation, temperature attain its maximum in May (pre monsoon) and least in monsoon. High temperature favors the growth of diatoms (Srinivasan 1967; Biswas 1936). Direct relationship between nitrate and bacillariophyceae observed in the study. Rao (1953) reported the similar findings. Conductivity, TDS, phosphate and silicate also high in May which favors the growth of diatoms. The dominant species are *Synedra ulna*, *S.acus*, *Fragilaria intermedia*, *Surirella robusta*, *Pinnularia lundii*, *Nitzschia obtusa*, *Navicula cuspidata*, *Cymbella tumida* and *Cyclotella striata.* The station wise abundance was ranged between 23990 cells L^{-1} at station 10 and 177400 cells L^{-1} at station 7. Monthly range of total cells abundance between 10730 cells L^{-1} in July and 146090 cells L^{-1} in May.

Chlorophyceae were recorded in high number throughout the study period, but peak proliferation seen in pre monsoon. High temperature and alkaline nature of river also favors the growth of c

hlorophyceae. Jose and Francis (2007) studied the effect of parameters on the distribution of Chlorophyceae. Maximum values of parameters in pre monsoon season which harbored the good number of chlorophyceae members. The abundance of the total cells ranged from 1650 cells L^{-1} at station 9 and 64770 cells L^{-1} at station 7. Monthly wise abundance ranged between 6160 cells L^{-1} in June and 12410 cells L^{-1} in

April and May. Most dominant species include *Cosmarium quadrum*, *C.blyttii*, *Scenedesmus quadricauda*, *S.acuminatus* and *S.perforatus*.

Next dominant group is euglenophyceae in the present study. Throughout the study they attain maximum peak value. High density of euglenophyceae were recorded during pre monsoon when all the parameters are high and dissolved oxygen low. Low DO encourages the multiplication of this group (Pawar et al. 2006). High temperature is suitable for the luxuriant growth of euglenophyceae (Gupta et al. 2018). Presence of sufficient amount of organic matter and low DO in pre monsoon most appropriate for the proliferation of euglenophyceae. The dominant species are *Euglena acus, E.proxima, E.splendens, Trachelomonas volvocina* and *T.hispida.* The abundance of cells ranged between 27800 cells L^{-1} at station 9 and 89080 cells L^{-1} at station 7. Monthly range between 4500 cells L^{-1} in July and 43710 cells L^{-1} in May.

Cyanophyceae were recorded high number in stations 6 and 7 during pre-monsoon. Alkaline pH and high temperature are luxurious for the growth of cyanophyceae (Pingale and Deshmukh 2005; Jindal and Sharma 2011a, 2011b). Influence of nutrients especially nitrate and phosphate also have role in the regulation of cyanophyceae growth (Banakar et al. 2020). The values of nutrients are low compared with other parameters. The dominant species are *Microcystis aeruginosa*, *Oscillatoria limosa* and *Chroococcus turgidus*. Abundance of cells was ranged between 300 cells L^{-1} at station 10 and 20270 cells L^{-1} at station 7. Monthly range of total cells between 1220 cells L^{-1} in October and 14820 cells L^{-1} in May. Least representation for dinophyceae and xanthophyceae from the selected stations during the period of study.

5.5 Community structure

The species diversity is an index of community diversity that include both species richness and relative abundance of species. In ecological studies species diversity gives clear and scientific knowledge about the communities and ecosystems. The species composition, diversity, distribution and abundance of phytoplankton varies with the chemical and physical properties of water. The ecological diversity generally measured by using species richness and evenness.

5.5.1 Diversity indices

Highest number of taxa in May at station 7 and lowest in June station 9. The number of individuals of a species in relation to the total number of individuals of all the species means the dominance.

Species diversity measured by Shannon index is directly related to the number of species in the sample and the homogeneity of the species distribution (Krebs 1994). The higher species diversity results the greater stability of the ecosystem. The Shannon and Wiener's diversity index of the stations study showed comparatively higher values during May and lower value in June. Station wise indices value high in 7 and low in 9. This index used as a measure of organic pollution level of an ecosystem (Trivedi and Goel 1984; Prasad and Singh 1982; Nandan and Patel 1986). The relationship between the diversity index and the pollution level of water bodies as 0-1 indicates heavy pollution, 1-2 moderate pollution, 2-3 light pollution and 3-4.5 slight pollution (Staub et al. 1970). The values obtained by using the Shannon index revealed that the present study area is highly polluted ecosystem.

The maximum Simpson's dominance index value during May and the minimum value during June. High value reported from station 7 and low in station 9 shown in tables 8 and 9. Least value of Simpson index signifies that there is the low probability that any two individuals drawn at random from a population belong to the same species. Low Simpson dominance index results in higher diversity and *vice versa* (Nandan and Sajeevan 2018). In the present study, more diversity observed during the month of June at station 9. The evenness index value ranged between during May and December. Station 7 represent high value and low in station 9. The maximum species richness index value during May and low during June. Station wise distribution high in 7 and least in 9. The diversity of species in an ecosystem is measured by the total number of species present. When comparing the total diversity profile in the study area, station 7 shows a high level of species richness in May. The increase in phytoplankton density in pre monsoon may be attributed to the rise in the temperature and concentration of available nutrients. Species richness correlated strongly with water temperature. Whereas decrease in the density during monsoon due to increased water level by rainwater and lowest temperature results in decreased photosynthetic efficiency of phytoplankton (Shinde et al. 2011).

5.5.2 Multivariate similarity Analysis

SIMPER analysis was performed to identify the most contributed stations and months in determining algal class as a temporal factor according to Bray-Curtis similarity. When comparing all algal classes, station 7 had the highest contribution percentage followed by stations 3, 5 and 6. Month wise similarity analysis reveals that the month of May has the highest contribution percentage followed by April and March (Table 10). ANOSYM similarity analysis within stations and months revealed that the distribution of phytoplankton varies significantly between stations.

According to hierarchical cluster analysis, phytoplankton composition in stations 9 and 10 differed from that of other stations and from that of the monsoon and post monsoon months. Canonical Correspondence Analysis (CCA) method was used to determine the relationship between environmental variables and phytoplankton distribution (Zhang et al. 2017). Environmental variables responsible for the phytoplankton community distribution were identified with CCA. The percentage of variance and eigenvalues in all the seasons were higher on axis 1 than axis 2. CCA plot had been drawn between 8 physico chemical parameters, 10 stations and 67 dominant species in three seasons- Pre monsoon, Monsoon and Post monsoon (Figures 19, 20 and 21).

In Pre monsoon, the eigenvalue for axis 1 (0.308) explained 21.92% correlation, and axis 2 (0.275) demonstrated 19.57% correlation between physico chemical parameters and dominant species of phytoplankton. pH and nitrate positively correlate on axis 1, exhibited maximum canonical value (0.16 and 0.45). In axis 2, all physico chemical parameters except silicate have close association of phytoplankton distribution with maximum canonical values for temperature and pH (0.474 and 0.193) respectively. CCA plot explained temperature, pH and TDS have strong relation with phytoplankton distribution in pre monsoon season than other variables indicated that their presence responsible for algae growth (Barinova et al. 2009). Among this highest value attributed to temperature and pH is the primary source for algal growth in pre monsoon. Statistically significant relationship in both axis because P-value (0.47 and 0.75) greater than 0.05. Organisms like *Euglena deses* fo. *intermedia*, *Cosmarium blyttii*, *Fragilaria construens* var. *venter*, *Lepocinclis playfairiana*, *Scenedesmus perforatus*, *Surirella biseriata*, *Synedra acus* and *Trachelomonas armata* shows positive correlation in axis 1 with maximum canonical values above 1.5. *Phacus curvicauda*, *Phacus splendens* and *Stauroneis anceps* shows positive correlation in axis 2 with maximum canonical values above 2.

In Monsoon, the eigenvalue for axis 1 (0.485) explained 23.02% correlation and axis 2 (0.449) demonstrated 21.31% correlation between physico chemical parameters and distribution of phytoplankton. Temperature, EC, TDS, nitrate and silicate have positive correlation on axis 1 with maximum canonical value for EC and silicate (0.43 and 0.36). In axis 2, temperature, nitrate and silicate have close association of phytoplankton distribution with maximum canonical values for nitrate and phosphate (0.53 and 0.37) respectively. CCA plot revealed that temperature, nitrate and silicate correlated with phytoplankton distribution in monsoon season. Statistically significant relationship in both axis because P-value (0.37 and 0.15) greater than 0.05. *Cosmarium obsoletum*, *Euglena deses* fo. *intermedia*, *Gomphonema montanum* var. *acuminatum*, *Nitzschia intermedia*, and *Trachelomonas armata* shows positive correlation in axis 1 with maximum canonical values above 2. *Gyrosigma kuetzingii*, *Lepocinclis playfairiana*, *Phacus lefevrei*, *Phacus splendens* and *Pinnularia major* var. *linearis* shows positive correlation in axis 2 with maximum canonical values above 2.

In Post monsoon, the eigenvalue for axis 1 (0.411) explained 26.05% correlation, and axis 2 (0.312) demonstrated 19.7% correlation between physico chemical parameters and phytoplankton. Temperature, nitrate, phosphate, silicate and DO positively correlate on axis 1, exhibited maximum canonical value for temperature and nitrate (0.47 and 0.25). In axis 2, temperature, pH, nitrate and phosphate have close association of phytoplankton distribution with maximum canonical values for temperature, phosphate and nitrate (0.35, 0.29 and 0.22) respectively. CCA plot explained temperature, pH, nitrate and phosphate have strong relation with phytoplankton distribution in post monsoon season. Among this highest value attributed to temperature and nitrate is the primary source for algal growth in post monsoon. Statistically significant relationship in both axis because P-value 0.98 and 0.92. *Cosmarium obsoletum*, *Cyclotella meneghiniana*, *Fragilaria construens* var. *venter* and *Pandorina morum* shows positive correlation in axis 1 with maximum canonical values above 1.5. *Cosmarium binum*, *Fragilaria construens* var. *venter* and *Lepocinclis playfairiana* shows positive correlation in axis 2 with maximum canonical values above 2.

5.6 Phytoplankton as pollution indicators

Algae forms a reliable biological indicators of water pollution. Biological indicators can serve as a useful tool for determining the degree of water pollution resulting from human settlements. The calculated value of diversity index (Boyd 1981) is shown in table 12. As per the index, values varied between 1.54 to 4.24. The values indicated that the water in the study area was moderately polluted. Less pollution occurs during June, and moderately polluted in the remaining months. This method was found to be reliable for the assessment of the pollution of water bodies (Jafari et al. 2010; Tessy and Sreekumar 2011a). On an average, the study area is moderately polluted.

Palmer (1969) developed algal genus index for the rating of organic pollution of a water body. It provides a list of 20 algal genera most tolerant to organic pollution and a number is assigned to each of them based on their relative tolerance to pollution. The number scored by each genus totalled to get the value of algal genus index. These indices are used for the detection and monitoring of water pollution (Nandan and Patel 1983, 1986; Biswas and Konar 2000; Vishnoi and Srivastava 2004; Suphan et al. 2012). Table 13 presents the index score list of genera found in the study area. The result of total score for each sampling stations from 1 to 10 are as follows- 19, 10, 19, 29, 30, 30, 32, 9, 4, 3 respectively. High organic pollution recorded in the stations 7, 6, 5 and 4 because of the presence of pollution tolerant algae like *Euglena*, *Oscillatoria, Scenedesmus, Navicula* and *Nitzschia* has been considered indicative of water bodies. The total score value of stations 1 and 3 reveals that the water quality is subjected to moderate organic pollution, while other four stations 2, 8, 9 and 10 score value indicates only light pollution. Cyanophycean members like *Oscillatoria, Microcystis* and *Phormidium* are also considered as the freshwater pollution algae (APHA 1998; Palmer 1969) are found in the study area. *Euglena*, a single species is enough than all others as a pollution-tolerant form.