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Phytoplankton diversity and Seasonal variations in the primary productivity of Durgada Halli Lake, Tumkur District, Karnataka

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Abstract
Lakes are one of the important sources of potential primary production in the world. Primary production is the most important biological phenomenon in nature on which the entire diverse array of life depends, either directly or indirectly. It is concerned with evaluation of the capacity of an ecosystem to build up primary organic compounds, using radiant and chemical energy, for transformation and flow to a higher-level trophic system. Phytoplanktons act as primary producers and their physiological activities are greatly controlled by physico-chemical characters of the water body. During photosynthesis, Primary producers produce a wide range of organic compounds, release oxygen as a byproduct to the surrounding waters. Measurement of primary productivity provides information about the photosynthetic production of organic matter and becomes the basis for the functioning of ecosystem. It is influenced by a combination of physical, biological factors and sunlight provides the energy for photosynthesis. It is adversely affected by anthropogenic activities**.** In the present study, seasonal variations of primary productivity in terms of NPP, GPP and CR of water was studied using Light and dark bottle method of Gardner and Gran (1927) for a period of one year from February-2014 to January-2015 at two sites of Durgada Halli lake.

Keywords: phytoplanktons, primary productivity, photosynthesis, GPP, NPP

Introduction

Primary productivity is defined as the rate at which organic matter is produced by producers in an ecosystem where low energy inorganic carbon is converted to high energy organic carbon form. During this process, living organisms manufacture simple organic compounds from various inorganic forms of carbon present on earth such as carbon dioxide, bicarbonates and carbonates. They also fix the energy of the sunlight while driving the flow of energy to the higher trophic level. The rate at which the energy accumulates as a result of photosynthesis is called primary productivity. In any water system the rate of organic carbon fixed through the chlorophyll bearing phytoplankton provided the basic information for assessing the productive function of the system (Odum, 1971) [1]**.** Productivity refers to the concept of organic matter synthesis potential and it is the ability of an area to support a biological population and sustain a level of growth and respiration (Raymount, 1966) [2].
The fundamental process involved in primary production is usually expressed by the following equation:

$$6CO_2 + 6H_2 + \text{Light energy} \Rightarrow C_6H_{12}O_6 + 6O_2$$

The primary productivity of a water body is the manifestation of its biological production and forms the basis for the ecosystem functioning. It plays an important role in providing energy and organic matters to the entire biological community (Odum, 1971) [1].
The primary productivity plays an important role in the penetration, absorption and distribution of light, heat and density stratification of the lakes (Cole, 1983) [3]. The estimation of primary productivity is predicted on the relationship between oxygen liberation and carbon fixation (Dash *et al.*, 2011) [4]. Physical, chemical, and biological characters have direct influence on primary productivity and in turn on the fish production (Chinnaiah and Madhu, 2010) [5]. Primary production is limited to depths to which sunlight can penetrate, regardless of any other factors (Wetzel, 2001) [6].
The estimation of primary productivity of an ecosystem is essential to understand its food chains and food web. The primary productivity is considered as vital and indispensable for ecosystem analysis as it integrates the cumulative effects of various physiological processes and interactions occurring simultaneously within the eco system. Measurements of the rate of primary production can be used as an important bioassay method for pollution studies. Phytoplankton primary productivity along with limno-chemical qualities could be utilized as indices of trophic status (Rao and Choube, 1990) [7].
Light, temperature and nutrients are the main limiting factors for primary production in an aquatic ecosystem. The physico-chemical features like temperature, pH, alkalinity, free CO_2, DO, electrical conductivity etc., determine its trophic status and influence the primary productivity of an aquatic ecosystem.

The value of primary productivity in waters is more influenced by light intensity than the nutrients (Nurfadillah *et al.*, 2019) [8] which in turn affect the phytoplankton. Therefore, it is necessary to study the presence of phytoplanktons and their relationship with the primary productivity. The purpose of this study is to study the seasonal variations in primary productivity and phytoplankton diversity to analyze the relationship of primary productivity and phytoplankton in Durgada Halli lake water.

Study area

Durgada Halli lake is located in between Tumakuru and Devarayana Durga hill station. It is a rainfed lake and situated between13°23'14"N 77°12'1"E. The lake is constructed for the purpose of irrigation and now a days it is used for various purposes like agriculture, fish culture and partially for domestic purposes. The satellite view of Durgada Halli lake was shown in Figure 1.

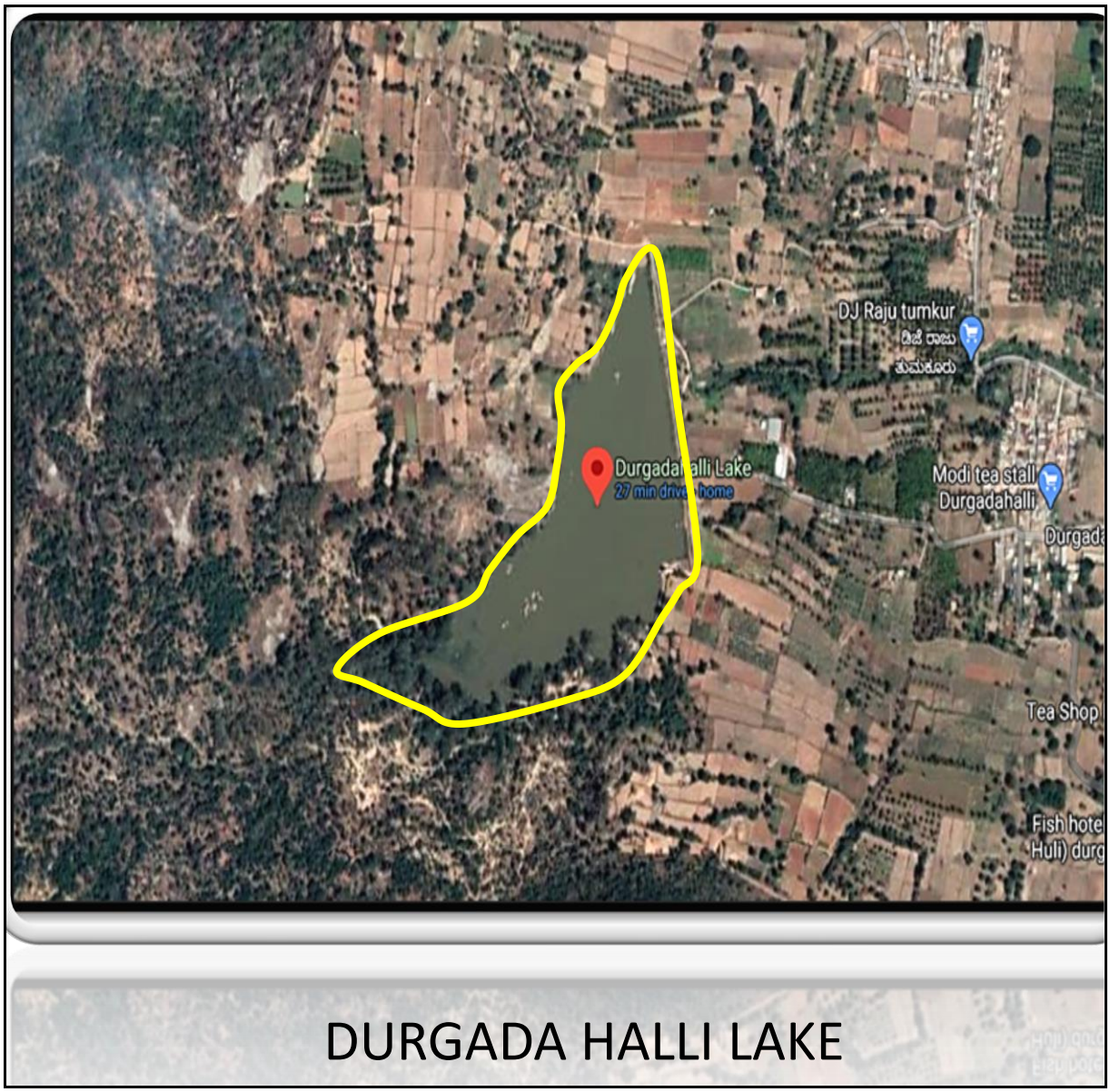

Fig 1: The satellite view of Durgada Halli Lake

Materials and Methods

For the phytoplanktons analysis, 50 liters of water sample were collected, filtered through 60µm mesh size plankton net. 50 ml of the concentrated water sample was collected from the bottle attached at the end of plankton net. Soon after the collection, the concentrated water sample was fixed and preserved in 4% formalin. Taxonomic identification of planktons was based on morphological and taxonomic key characters described by Fritch (1959), Desikachari (1959) and Prescott (1969) [9-11]. The Primary productivity of Durgada Halli is determined by using standard "Light and Dark bottle" method of Gardner and Gran (1927) [12] in the first week of every month for a period of one year from February-2014 to January- 2015. A set of one light and one dark bottle with a capacity of 250 ml were filled with surface water and closed tightly and the dark bottle was painted with black colour and covered with cloth bag of black colour to prevent the penetration of light. The bottles were suspended at about 15 cm below the water level. The initial dissolved oxygen was determined using the sample

from the third bottle. The primary productivity study was carried out after 9 am. The time of exposure (incubation period) was for the period of 4 hrs. After completion of incubation period, the samples were fixed with manganous sulphate and alkaline iodide at the site of the study area and then transferred to the laboratory for further estimation. The dissolved oxygen is determined in the initial bottle, light and dark bottle by Winkler's method (APHA, 2005) [13].

The Gross primary productivity, Net primary productivity and community respiration were estimated by using the following formulae:

$$\text{Gross primary productivity (GPP): } gC/m^3/hr = \frac{D_L - D_D \text{ X } 0.375}{Hr}$$

$$\text{Net primary productivity (NPP): } gC/m^3/hr = \frac{D_L - D_I \text{ X } 0.375}{Hr}$$

$$\text{Community respiration (CR): } gC/m^3/hr = \frac{D_I - D_D \text{ X } 0.375}{Hr}$$

Where,
D_L = Dissolved oxygen in light bottle in mg/l.
D_D = Dissolved oxygen in dark bottle in mg/l.
D_I = Dissolved oxygen in initial bottle in mg/l.
Hr = Duration of exposure (incubation period) in hrs.
0.375 = A factor value (1 g of oxygen is equal to 0.375g of carbon)

Results

In the present study, 51 species of phytoplanktons were identified under five groups- Chlorophyceae, Bacillariophyceae, Cyanophyceae, Desmidaceae and Euglenophyceae. Among these, Chlorophyceae shows its dominance. Chlorophyceae is represented by 18 species, Bacillariophyceae represented by 12 species, Cyanophyceae represented by 10 species, Desmidaceae represented by 08 species, Euglenophyceae represented by 4 species. Some of the representatives of phytoplanktons is represented in Fig.2. Percentage occurrence of phytoplankton species is presented in Fig.4. The results of seasonal variations of GPP, NPP and CR are depicted in Table.1, 2 and Fig.3.

Table 1: Seasonal variations of GPP, NPP and CR at site-1

Sl. No	**Parameters**		**Seasonal Mean values**		
		Range($gC/m^3/hr$)	**Summer**($gC/m^3/hr$)	**Monsoon**($gC/m^3/hr$)	($gC/m^3/hr$)
1.	GPP	0.39 - 0.15	0.70 ± 0.11	0.52 ± 0.15	0.39 ± 0.20
2.	NPP	0.19- 0.07	0.25 ± 0.02	0.22 ± 0.07	0.19 ± 0.73
3.	CR	0.29 - 0.18	0.45 ± 0.09	0.29 ± 0.07	0.3 ± 0.05

Table 2: Seasonal variations of GPP, NPP and CR at site-2

Sl. No	**Parameters**		**Seasonal Mean values**		
		Range($gC/m^3/hr$)	**Summer**($gC/m^3/hr$)	**Monsoon**($gC/m^3/hr$)	**Winter**($gC/m^3/hr$)
1.	GPP	0.37 - 0.23	0.50 ± 0.21	0.37 ± 0.08	0.42 ± 0.11
2.	NPP	0.14 - 0.07	0.23 ± 0.04	0.14 ± 0.05	0.16 ± 0.06
3.	CR	0.22 - 0.18	0.36 ± 0.09	0.22 ± 0.04	0.26 ± 0.05

Chlamydomonas species

Oocystis species

Nitzscia species Oscitalloria species

Fig 2: Some of the representatives of phytoplanktons of Durgada Halli Lake.

Gross primary productivity

In the present study, at site-1, GPP ranges from 0.39 gC/m^3/hr to 0.15 gC/m^3/hr. Seasonal mean and standard deviation values of GPP recorded 0.70 ± 0.11gC/m^3/hr during summer, 0.52 ± 0.15 gC/m^3/hr during monsoon, and 0.39 ± 0.20 gC/m^3/hr during winter. The maximum seasonal mean value of GPP was recorded in summer season and minimum value of GPP was recorded in winter season. At site-2, GPP ranges from 0.37 gC/m^3/hr to 0.23 gC/m^3/hr. Seasonal mean and standard deviation values of GPP recorded 0.50 ± 0.21gC/m^3/hr during summer, 0.37 ± 0.08gC/m^3/hr during monsoon, and 0.42 ± 0.11gC/m^3/hr during winter. The maximum seasonal mean value of GPP was recorded in summer season and minimum value of GPP was recorded in monsoon season.

Net Primary Productivity

In the present study, at site-1, NPP ranges from 0.19gC/m^3/hr to 0.075 gC/m^3/hr. Seasonal mean and standard deviation values of NPP recorded 0.25 ± 0.02gC/m^3/hr during summer, 0.22 ± 0.07 gC/m^3/hr during monsoon and 0.19 ± 0.73 gC/m^3/hr during winter. The maximum seasonal mean value of NPP was recorded in summer season and minimum value of NPP was recorded in monsoon season. At site2, NPP ranges from 0.14 gC/m^3/hr to 0.07 gC/m^3/hr. Seasonal mean and standard deviation values of NPP recorded 0.23 ± 0.04gC/m^3/hr during summer, 0.14 ± 0.05gC/m^3/hr during monsoon and 0.16 ± 0.06gC/m^3/hr during winter. The maximum seasonal mean value of NPP was recorded in summer season and minimum value of NPP was recorded in winter season.

Community Respiration

In the present study, at site-1, CR ranges from 0.29 gC/m^3/hr to 0.187 gC/m^3/hr., Seasonal mean and standard deviation values of CR recorded 0.45 ± 0.09gC/m^3/hr during summer, 0.29 ± 0.07gC/m^3/hr during monsoon and 0.3 ± 0.05gC/m^3/hr during winter. The maximum seasonal mean value of CR was recorded in summer season and minimum value of CR was recorded in winter season. At site2, CR ranges from 0.22 gC/m^3/hr to 0.18 gC/m^3/hr. Seasonal mean and standard deviation values of CR recorded 0.36 ± 0.09gC/m^3/hr during summer, 0.22 ± 0.04gC/m^3/hr during monsoon and 0.26 ± 0.05gC/m^3/hr during winter. The maximum seasonal mean value of NPP was recorded in summer season and minimum value of CR was recorded in monsoon season.

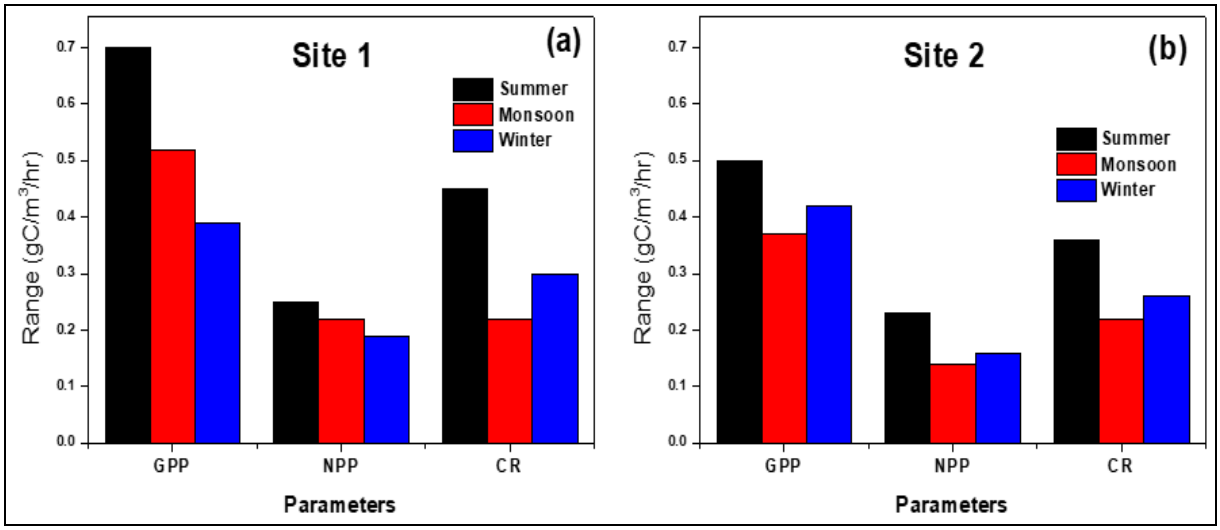

Fig 3: (a) Seasonal variations of GPP, NPP and CR at site 1 and (b) site 2.

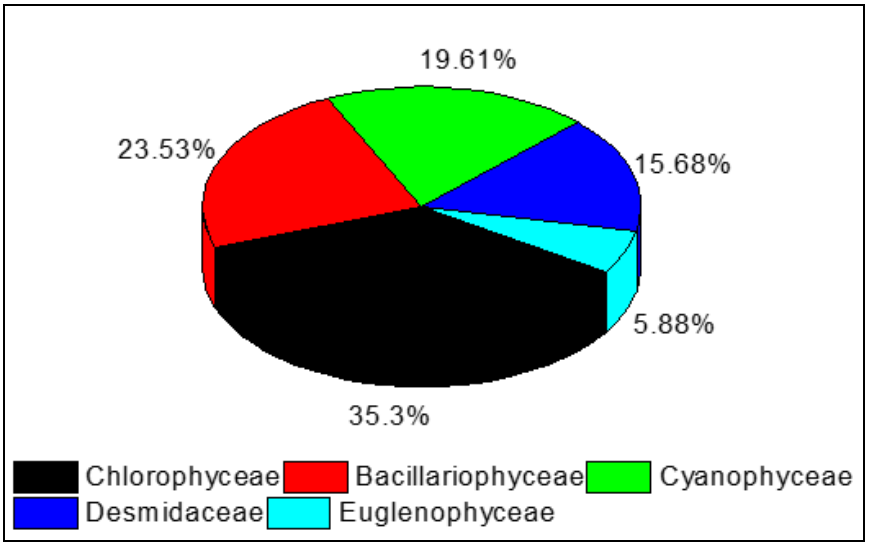

Fig 4: Percentage occurrence of phytoplankton species

Discussion

Primary production is the direct product of photosynthesis and primary productivity is the sum of all photosynthetic rates in an ecosystem. It gives information about the amount of energy available to support bioactivities of the system (Vollenweider *et al.,* 1974) [14].

Phytoplanktons act as primary producers and their physiological activities are greatly controlled by physico-chemical characters of the water body (Sahu *et al.,* 1995) [15]. Phytoplanktons serve as food for aquatic animals especially for fishes and also, they play an important role in regulating the ecological balance and water quality (Pandey *et al.*, 1994) [16].

Information about the primary productivity helps in understanding the interrelationship of food web and the amount of energy available to support bioactivity in the aquatic ecosystem (Kauer *et al.,* 2009) [17]. The nutrients such as phosphorus, nitrogen and silica are the important determinants of primary productivity.

Phytoplankton photosynthesis and community respiration are the determining factors of the carbon cycle that maintain balance between production and the consumption of oxygen and the magnitude of the net ecosystem production. (Urban *et al.,* 2004) [18].

GPP

Gross primary productivity is the total rate of photosynthesis including the organic matter used up in respiration during the measurement period. This is also known as total photosynthesis or total assimilation.

NPP

Net primary productivity is the rate of storage of organic matter in plant tissues in excess of the respiratory use by plants during the measurement period. This is also called as apparent photosynthesis or net assimilation.

CR

Community respiration is the total amount of carbon-dioxide that is produced by individuals' organisms in a given community,

In the present study, the values of primary productivity were low indicating the less nutrients in the water. The net primary productivity values were lower than the gross primary productivity as the phytoplanktons loose some amount of assimilated carbon during different metabolic activity. The low primary productivity may be due to the decreased addition of nutrients from the land and the low water temperature. Effect of temperature on the primary productivity varies with the light intensity. Primary productivity of the ponds mainly depends on the intensity and quality of light, carbon supply, availability of nutrients and biomass (Sonam Sharma and Yadav, 2021) [19]. Narasimharamulu and Benarjee (2014) [20] recorded GPP values ranged between 0.09 to 0.57 $gC/m^3/hr$, NPP values ranged 0.02 to 0.38 $gC/m^3/hr$ and CR values ranged between 0.13 to 0.54 $gC/m^3/hr$ in Nagaram Tank of Warangal District. Kaneez *et al.,* (2011) [21] studied primary productivity in Bosga and Khaji Kotnoor reservoirs and noticed mean GPP values 0.40, 0.26 and 0.21 mg CL^{-1} day^{-1} and 0.32, 0.14 and 0.16 mg CL^{-1} day^{-1} during summer, SWM and NEM respectively.

In the present study, GPP, NPP and CR values at site 1 and 2 showed similar trend of seasonal variations where maximum values were recorded during summer and minimum values during monsoon. Similar results were recorded by Mandal *et al.,* (2005) [22] who studied the fluctuations in the values of Gross primary productivity and Net primary productivity and observed the gradual increase during summer and winter and decrease during monsoon. They stated that the highest rate of productivity during summer may be due to bright sunlight with high temperature, high phytoplankton density and algal blooms. The lowest rate of productivity during monsoon could be attributed to the reduced photoperiod with low light intensity, temperature and less phytoplankton.

Narasimharamulu and Benarjee (2014) [20] conducted primary productivity studies in Nagaram Tank of Warangal District, Andhra Pradesh and observed GPP, NPP and CR changing significantly with seasons with increasing trend through the rainy season towards summer season. Lower values were observed during rainy season. Vashistha and Paulose (2016) [23] studied seasonal variation in primary productivity of Lake Siliserh, Rajasthan and recorded highest productivity in summer and opined that it may be due to lower water level, high pH, alkalinity, electrical conductivity, nutrients and plankton density.

In the present investigation, high values of primary productivity during summer may be due to bright light, high temperature and high phytoplankton density and low values during monsoon may be due to low light intensity, temperature, addition of nutrients with runoff water during monsoon rain and less phytoplankton density. This opinion was supported by Mruthyunjaya *et al*., (2016) [24] who studied primary productivity status in Ayyanakere Lake, Karnataka and reported GPP, NPP and CR were maximum in monsoon season and lowest in pre-monsoon season and opined that the lowest production in pre-monsoon season is due to the decrease in the water level and the higher production in monsoon is due to high phytoplankton content. Sahib (2002) [25] recorded the highest values of CR in April at Parapper reservoir and in March at Sasthamcotta Lake. Similar observations were made by Hujare and Mule (2007) [26] in two perennial tanks of Kolhapur District.

In the present study, 51 species of phytoplanktons were identified indicated the good diversity. In the present study, the percentage composition of phytoplankton species during the year 2014-2015 in Durgada Halli lake were Chlorophyceae 35.29%, Bacillariophyceae 23.52%, Cyanophyceae19.60%, Desmidaceae 15.68% and Euglenophyceae 5.88%. The trend of phytoplanktons with respect to number is found as Chlorophyceae> Bacillariophyceae>Cyanophyceae>Desmidaceae > Euglenophyceae.

Conclusion

The analysis of phytoplanktons and estimation of primary productivity of aquatic ecosystem is of great importance for fish culture management. In the pollution study, the phytoplanktons are represented as biological indicators of water quality. Phytoplanktons and primary productivity values of Durgada Halli lake shows that the lake is diversified with a greater number of species making it least polluted with good quality of water. It can be concluded that phytoplanktons have a significant effect on primary productivity which can be taken as an important factor for pollution studies.

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