International Research Journal of Environment Sciences ISSN 2319–1414
Vol. **3(4),** 34-41, April **(2014)** *Int. Res. J. Environment Sci.*

Phytoplankton Primary Productivity in Lentic Water Bodies of Bhadravathi Taluk, Shimoga District, Karnataka, India

Ajayan K.V.[1] and Parameswara Naik T.[2]
[1]Department of Studies and Research in Botany, Karnataka State Women's University-Bijapur-586108, Karnataka, INDIA
[2]Department of Botany and Seed Technology, Sahydri Science College (Auto), Kuvempu University, Shivamogga- 577203-Karnataka, INDIA

Available online at: www.isca.in, www.isca.me
Received 3rd March 2014, revised 11th March 2014, accepted 20th April 2014

Abstract

Phytoplankton primary productivity study is inevitable for the assessment of productivity of any aquatic systems. A comprehensive study was conducted for the period of two years from May 2010 to April 2012 in selected four lentic water bodies of Bhadravathi Taluk. The results were shown the productivity of four stations dynamic in their seasonal and annual means. Phosphate is limiting factor for determine the gross primary productivity in Siddapura Lake, it always have high productivity hence phosphate has highly significant positive correlation (r= 0.66) however, in Koppa Lake is less productivity in both years and have negative correlation (r=-0.63, r=-0.53). Nitrites was significant positive correlation (r=0.55, r=0.59) with gross primary productivity in Siddapura Lake and Koppa Lake and but in case of Koppa Lake, the phosphate is limiting factor. An attempt was taken the correlation coefficient of gross primary productivity with biomass of phytoplankton. Chlorophyll–a (biomass) highly significant positive correlation no more than in Kodihosure Lake (r=0.61, p>0.01); chlorophyll-b, highly positive correlation with gross primary productivity in Siddapura Lake (r = 0.36, p>0.05); Kodihosure Lake (r = 0.59, p>0.01) whereas, the chlorophyll-c content had not seen positive or negative correlations with gross primary productivity. The remarkable fact found to be noticed, the Devanarasipura Lake and Koppa Lake had not have any significant correlations with Chl.a, Chl.b and Chl.c. The primary productivity studies of phytoplankton in lentic water of Bhadravathi taluk is crucial for aqua cultural activities and management preferably in land fisheries.

Keywords: Gross primary productivity, Lentic water bodies, correlation coefficient

Introduction

Primary productivity is the rate, at which the sun's radiant energy is stored by photosynthetic and chemosynthetic activities of producers in the form of organic substances[1]. The Knowledge of phytoplankton spatial variations of primary production, nutrient concentration and community structure is fundamental to the understanding of ecosystem dynamics[2]. Although photosynthesis was a key factor of the global carbon cycle, its spatial and sequential variability were poorly understood[3]. Blue-green algae can be classified one of the primeval pioneer organisms. The stated that their ancestors are responsible for introducing free oxygen into the atmosphere[4].

Phytoplanktons are main primary producer in surface waters, so they circumstance are structure and density of consumers and also the physico-chemical characteristics of water. Moreover, phytoplanktonic organisms are sensitive indicators, as phytoplankton structure and metabolism changes quickly in response to environmental changes. Growth rate and variability of phytoplankton are subject to cyclic changes: fluctuation and succession[5,6]. Phytoplankton constitute a major part of aquatic vegetation, they being primary producers which support the growth of aquatic fauna, produce oxygen by photosynthetic process, some of them, because pollution by changing the quality of water in which they grow.

They are the primary producers in an aquatic ecosystem. They are good indices of water quality and capacity of water to sustain heterotrophic communities. Phytoplankton plays a vital role in biosynthesis of organic substance in lentic ecosystem, which directly dependence to all the living organisms in aquatic system as source of food. Even if they have no immediate effect on fish yield, they are at least fairly good indicators of the biological productivity[7]. A direct method for the evaluation of the potentiality of an aquatic biotope is the estimation of the charge of its production, where it begins the primary fixation of energy and its subsequent transfer to higher trophic levels[8]. Over 90% of atmospheric oxygen is produced by phytoplankton by the process of photosynthesis. It is a fact that this phytoplankton forms a major bulk of food material for all aquatic organisms directly and to human beings indirectly. Some forms of phytoplankton also act as biological indicators of water quality[9]. Several workers have studied lentic ecosystem in India with reference to physicochemical status and primary productivity[10-16]. The work has been undertaken to known the primary productivity in lentic water of Bhadravathi Taluk and also unconcealed the truth how lentic water bodies are play an important role in carbon sequestration processes.

Material and Methods

Sampling Area: The investigation was conducted at Bhadrathi Taluk of Shimoga district. Taluk is agribased as to be found a plenty of natural water bodies such as lakes, ponds and tanks. Geographical co-ordinates of four selected lentic water bodies as follows; Siddapura Lake-13°50' 13.1" N latitude, 75° 40' 54.5" E longitude and a mean sea level elevation are 573 meters. Devanarasipura Lake- it lays between 13˚ 84' 12.3" N latitude and 75˚ 72' 13.2" E longitude with a mean sea elevation is 607mts. Koppa Lake- it lays between 13˚ 58' 41.3" N latitude and 75˚ 42' 36.5" E longitudes with main sea level is 577 mts. The size of water bodies is 93.12 hectors; it is the largest water body of Bhadravathi taluk and Kodihosure Lake- it lays between 13˚ 56' 21.7" N latitude and 75˚ 47' 46.9" E longitudes with main sea level is 653 mts (figure 1).

Sampling Procedure: Estimation of primary productivity of phytoplankton by Winkler's dark and light bottle method: In order to estimate the primary productivity of phytoplankton in selected sample stations of Bhadravathi Taluk, a Winkler's dark and light bottle method was done. From each sample stations with different sampling points and all mixed together (composite sampling technique) in clean, two liter plastic containers at 15cm below from the water surface and enough water to fill 6 BOD bottles used for the primary production experiment. These bottles were carefully filled with the water samples under a blanket cover to minimize the effects of bright light on the sample to be incubated, and then stoppard while avoiding trapping air bubbles. Duplicate light bottles were used for each depth where incubation for photosynthesis was done. Three dark bottles were used and incubated below the lowest light bottle. The bottles were incubated for 4 hours at 10cm depths between 10A.M to 3 P.M. After incubation, the oxygen content in the exposed bottles were fixed immediately by adding 1 ml of the Winkler's reagent 1($MnSO_4$ solution) and the same volume of Winkler's reagent 2 (KI solution). These reagents were added below the surface of the sample bottles and the bottles closed and shaken vigorously. The sample bottles were kept under water in a bucket and transported to laboratory.

In the laboratory, 2 ml of concentrated H_2SO_4 was added to the samples and the bottles shaken to dissolve the precipitate. The solution was then transferred into an Erlenmeyer flask with 100ml each. (Solution did not have faint yellow added to 0.025N sodium thiosulphate solution until appear the faith yellow color). Added few drops of starch indicator and titrated against 0.025N sodium thiosulphate solution until the blue color of the solution disappeared marking the end point. The amount of dissolved oxygen was calculated using the formula which was given as follows[17].

$$O_2 \text{ concentration (mg/L)} = \frac{(\text{ml of titrant}) \times (\text{Normality of thiosulphate}) \times 8}{(\text{Vol. titrated}) \times (\text{ml of bottle -2})} \times 100$$

Changes in oxygen concentration due to gross photosynthesis were calculated by using the formula as given below:

Gross primary productivity (mg/l) = O_2 concentration (light)-O_2 concentration (dark)

Results and Discussion

In this investigation the gross primary productivity of Siddapura Lake ranged from a maximum of 46.98 µg/L in January 2011 to -7.932 µg/L in March 2012 (figure-5). In yearly average of gross primary productivity was observed to be the highest was 16.00 µg/L in 2010 to 2011 and the lowest was 8.38 µg/L in 2011 to 2012 (figure-1). Seasonal averages of gross primary productivity the maximum value was 21.97 µg/L in winter 2010 to 2011 whereas, the least value was 3.71 µg/L in winter 2011 to 2012 (figure-3). Two yearly seasonal average of gross primary productivity varied from a maximum of 15.37 µg/L in rainy to a minimum of 8.34µg/L in summer season (figure-4). It is very important in Siddapura lake as reported that understanding of the spatial variations of primary production, nutrient density and community structure was the fundamental to the understanding of ecosystem dynamics[18] this lake was mainly focused on aqua cultural activities. The primary productivity of phytoplankton under goes one-way ANOVA analysis and the results shown that there was no significant different in two consecutive years (table-2). Devanarasipura Lake is registered gross primary productivity a maximum of 26.569 µg/L in August 2010 and the lowest value was -22.819 µg/L in May 2011 (figure-5). The yearly average of gross primary productivity ranged from a maximum of 11.91µg/L in first year and significantly reduced to-3.28 µg/L in the second year (figure-2). Seasonal averages of gross primary productivity varied from the highest value was 15.17 µg/L in rainy season May 2010 to April 2011 to the least value was -4.027 µg/L in rainy season in May 2011 to April 2012 (figure-3). Taken in consideration of two year wise the maximum value was 7.75 µg/L in winter season and a minimum value was -0.67µg/L in summer season (figure-4). An account of one-way ANOVA of the gross primary productivity there was a significant difference in two consecutive years is $F=11.42$, $P< 0.002$ (table-2).

Table-1
Correlation coefficient of Gross primary productivity and biomass of phytoplankton

Sample Stations	Chlorophyll-a	Chlorophyll-b	Chlorophyll-c
Siddapura Lake	0.28	0.36**	-0.21
Devanarasipura Lake	-0.16	0.31	-0.16
Koppa Lake	0.33	0.27	-0.28
Kodihosure Lake	0.61*	0.59*	0.10

*Significant 0.01 level, ** Significant 0.05 level

Table-2
One-way ANOVA calculated Gross Primary Productivity of the stations

Sl. No.	Sample Stations	F	P
1	Siddapura Lake	1.98	0.17
2	Devanarasipura Lake	11.42	0.002*
3	Koppa Lake	0.59	0.45
4	Kodihosure Lake	7.10	0.016*

* Significant value

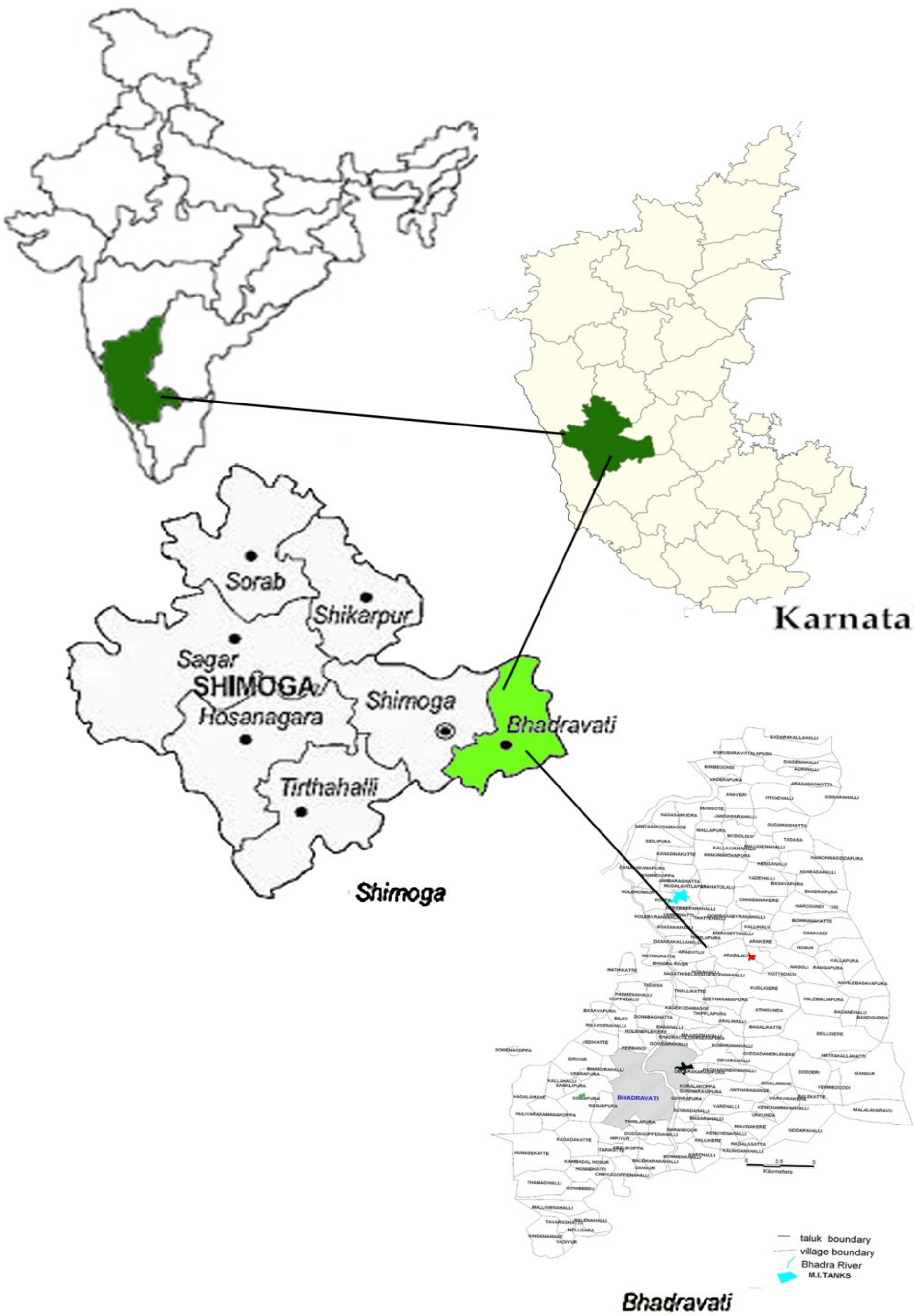

Figure-1
Study area with sampling sits

Table-3
Correlation coefficient with gross primary productivity and physico-chemical parameters in selected lentic water bodies

Sl. No.	Parameters	Siddapura Lake	Devanrasipura Lake	Koppa Lake	Kodihosure Lake	Siddapura Lake	Devanrasipura Lake	Koppa Lake	Kodihosure Lake
		2010 to 2011				2011 to 2012			
1	Air temperature	0.19	0.03	0.33	0.01	0.27	-0.34	0.61*	-0.26
2	Water temperature	0.50*	0.12	0.31	-0.01	0.63*	-0.53*	0.47	-0.61*
3	pH	-0.26	-0.47	-0.01	-0.06	-0.24	-0.53*	0.29	-0.41
4	Carbonate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Bicarbonate	-0.43	-0.04	0.23	-0.36	0.27	-0.25	0.69*	0.05
6	Turbidity	0.07	0.23	0.31	0.28	0.17	0.13	0.01	-0.13
7	Dissolved Oxygen	-0.57*	-0.17	-0.27	-0.05	-0.28	-0.06	0.10	0.05
8	BOD	-0.08	-0.57*	-0.18	-0.37	-0.24	-0.23	0.00	0.19
9	Free carbon dioxide	0.07	0.42	0.43	-0.20	-0.09	0.15	-0.17	-0.46
10	Conductivity	0.30	0.05	0.27	-0.02	-0.46	-0.18	0.14	0.04
11	TDS	0.10	-0.04	0.46	0.26	-0.19	-0.04	0.01	0.08
12	chloride	-0.37	0.06	0.29	0.10	0.40	-0.41	0.13	-0.68*
13	Total hardness	-0.25	-0.14	-0.34	0.10	-0.49	-0.17	-0.29	0.36
14	Calcium	-0.32	-0.71*	-0.29	0.12	-0.54	-0.51*	0.17	0.25
15	Magnesium	0.15	0.35	-0.17	0.03	-0.03	0.12	-0.40	0.00
16	Sodium	0.10	0.37	0.11	-0.70*	0.42	-0.17	-0.27	-0.12
17	potassium	-0.31	0.26	-0.30	0.07	0.46	-0.07	-0.40	0.39
18	Phosphate	-0.35	-0.39	-0.63*	0.22	0.66*	-0.04	-0.53*	0.07
19	Sulphates	-0.46	-0.18	-0.30	-0.23	-0.32	0.30	-0.49	0.26
20	Nitrates	0.23	-0.17	-0.03	-0.06	0.28	-0.16	-0.16	0.25
21	Nitrites	0.33	0.32	-0.21	0.27	0.55*	-0.24	0.59*	-0.09
22	Total Alkalinity	-0.43	-0.04	0.23	-0.36	0.30	-0.29	0.71	0.09
23	Iron	0.21	0.57*	0.07	-0.38	0.13	-0.35	0.34	-0.04

* indicates significant value

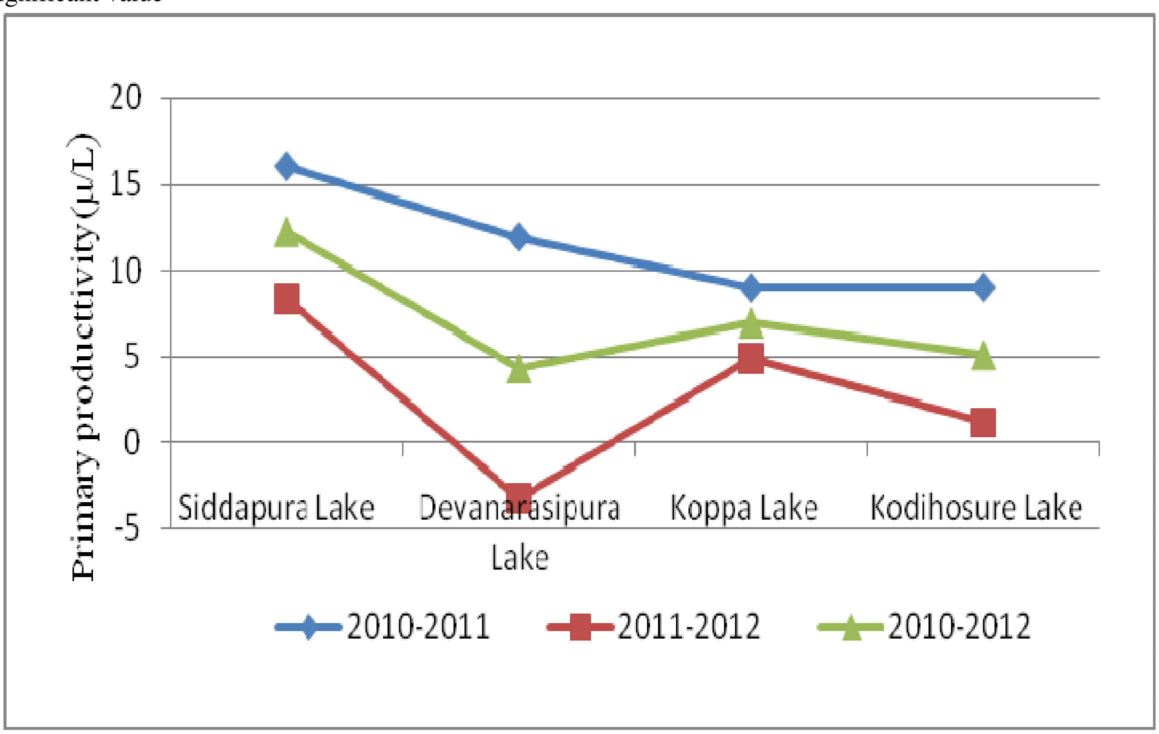

Figure-2
Yearly average of Gross Primary Productivity (µg/L) in all stations

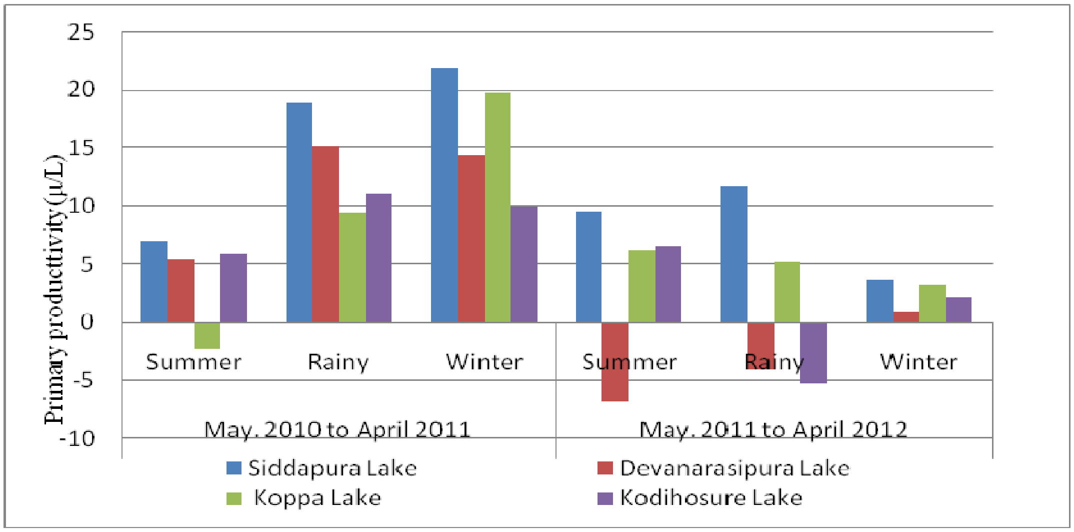

Figure-3
Seasonal average of Gross Primary Productivity (µg/L) in four stations

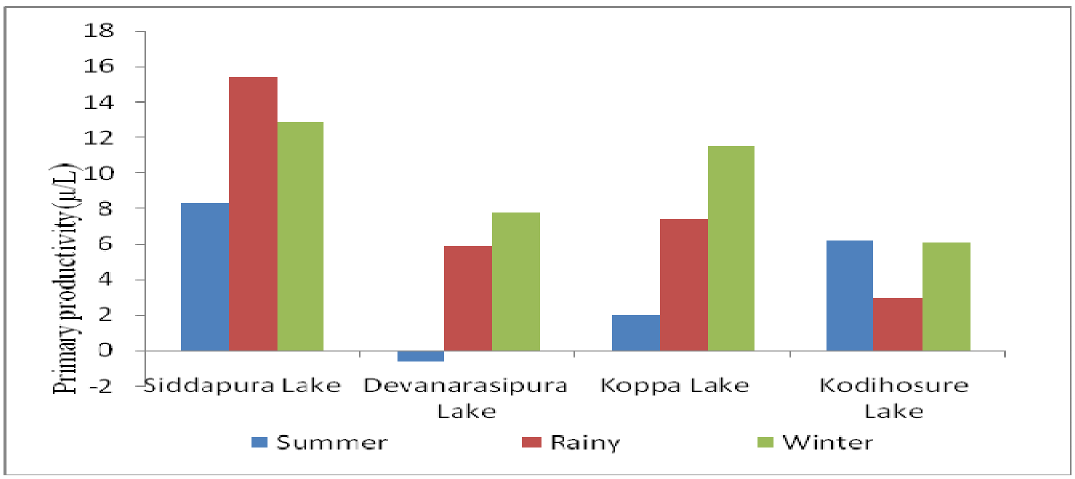

Figure-4
Two year seasonal averages of Primary productivity ((µg/L) in selected stations (2010 to 2012)

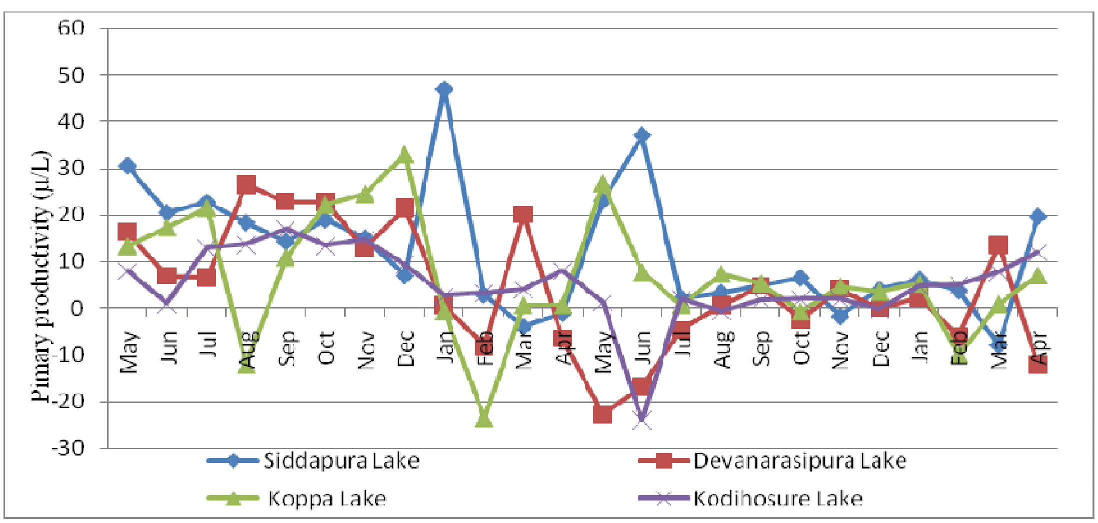

Figure-5
Monthly primary productivity (µg/L) in selected lentic water bodies during 2010 to 2012

The gross primary productivity of Koppa Lake was registered a maximum value 32.977 µg/L in December 2010 whereas, the minimum value -23.490 µg/L in February 2011 (figure-5). She revealed that phytoplankton populations were frequently structured by the physical and chemical variables of their surroundings[19]. These factors also are responsible for the heterogeneity in phytoplankton composition and biomass[20]. Taken in consideration of yearly wise the maximum value 8.99 µg/L in first year and minimum value 4.91 µg/L in second year (figure-2). Seasonal wise variation of gross primary productivity in this recorded a maximum (19.74 µg/L) in winter season and minimum (-2.20 µg/L) in summer season, same year May 2010 to April 2012 but different seasons (figure-3). In two yearly seasonal variation of gross primary productivity quantified a maximum of 11.48 µg/L in winter season but the minimum value was 2.00 µg/L in summer season (figure-5).The lake Koppa is comparatively deep lake so, the physical conditions also dominate because of the level of annual primary productivity is largely determined by the depth of mixing[21]. An account of one-way ANOVA of the gross primary productivity there was no significant different in two consecutive years (table-2). In the present investigation the gross primary productivity of Kodihosure Lake, monthly variation of gross primary productivity range starting a maximum of 16.923 µg/L in September 2010 to a minimum of -23.96 µg/L in January 2011 (figure-5). The yearly average value deviated from a maximum 9.02 µg/L in 2010-2011 and a minimum was 1.17 µg/L in 2011-2012 (figure-3). The seasonal wise a maximum value 11.12 µg/L and minimum value -5.20 µg/L recorded in same rainy seasons but in different years (figure-2). An account of two yearly wise the maximum rate of gross primary productivity registered 6.22 µg/L in summer season whereas, the low rate was 2.95 µg/L observed in rainy season (figure-4). An account of one-way ANOVA of the gross primary productivity there was a significant different in two consecutive years ($F=7.10$, $P<0.016$) (table-2). The ascending order of gross primary productivity in monthly average wises was Siddapura Lake> Koppa Lake> Kodihosure Lake > Devanarasipura Lake (figure-4). The present investigation shows that primary productivity of fresh water phytoplankton has a definite variation from seasonal to annual scale. It may be attributed to topography of study site, nutrient status of water bodies, space and time sampling.

According to him, a few shower in April-May which was helped for high nutrient inputs and moderately high water temperature prevailing during hot months might have induced high primary production in the Krishnasayer in West Bengal[22], those finding was somewhat agreed in present investigation May 2010 and 2011 comparatively high primary productivity in all stations expect station 2 in May 2011 and also disproved that April months none of the stations have been found higher primary productivity (figure-5).

The ascending order of gross primary productivity in monthly average bases from May 2010 to April2012 was Siddapura Lake >Koppa Lake>Kodihosure Lake >Devanarasipura Lake and another important features are first three stations are under fish culture sites it means that the selective harvesting phytoplankton by fish should be enhancing gross primary production whereas last one is not fish culture lake but densely with aquatic weeds it will decrease gross primary productivity of phytoplankton. This finding was strongly support by them; the variance of phytoplankton primary production explained by abiotic features is below 60%, suggesting that food-web interactions could be important too[23].

Coefficient of correlation relationship of gross primary productivity with physico-chemical parameters in this investigation the air temperature only Koppa Lake had highly positive correlated($r=0.61$) with gross primary productivity (table-3).Whereas, water temperature in Siddapura Lake both year they show p ositively correlated ($r=0.50$, $r=0.63$). The factors such as light, temperature and nutrients play an significant role in phytoplankton productivity in aquatic systems the results were supported by researcher[24,8] but other two stations contradiction to them (table-3) but Devanarasipura Lake and koppa lake (table-3 and 2) have highly negatively correlated $r=-0.53$, $r=-0.61$in second year respectively. pH was negatively correlated in Devanarasipura Lake ($r=-0.53$), dissolved oxygen (DO) also ($r=-0.57$) at station -1, biological oxygen demand (BOD) ($r=-0.57$) in Devanarasipura Lake but none of the other stations (table 3). In Kodihosure Lake, chloride highly negatively correlated ($r=-0.68$), calcium was negatively correlated with gross primary productivity in Devanarasipura Lake (table-3). In Kodihosure Lake, sodium shows highly negative correlation ($r=-0.70$) (table-3). Phosphate is limiting factor for determine the gross primary productivity in Siddapura Lake always have high productivity hence phosphate has highly significant positively correlated ($r=0.66$) however, in Koppa Lake both years they have negatively correlated ($r=-0.63$, $r=-0.53$) respectively (table-1 and 3). Nitrites was significant positive correlated ($r=0.55$, $r=0.59$) with gross primary productivity in Siddapura Lake and Koppa Lake respectively. Iron in only Devanarasipura Lake has significant positive correlation ($r=0.57$) but not elsewhere (table-3).

An attention-grabbing observation were noticed carbonates, bicarbonates, turbidity, free carbon dioxide, electrical conductivity, TDS, total hardness, magnesium, potassium, sulphates, nitrates and total alkalinity those were refusal of any significant correlation with gross primary productivity throughout period of investigation (table-3). Coefficient of correlation relationship of Gross primary productivity and biomass of phytoplankton it revealed that gross primary productivity with biomass of phytoplankton in senses of chlorophyll–a highly significantly positively correlated only in Kodihosure Lake ($r=0.61$, $p>0.01$); in case of chlorophyll-b, highly positively correlated with gross primary productivity in Siddapura Lake ($r=0.363$, $p>0.05$) and Kodihosure Lake ($r=0.586$, $p>0.01$) whereas, chlorophyll-c concentration had not seen positive or negative correlations with gross primary productivity. The remarkable fact noticed that, the Devanarasipura Lake and Koppa Lake had not have any significant correlations with chlorophyll-a, b and c (biomass of phytoplankton) (table-1). The great differences in diversity of phytoplankton biomass and structure might be related to ecological fluctuations of water bodies and competition on nutrients [25], predation by zooplankton and planktivorous fish[26].

Conclusion

The selected lentic water bodies were shown the disparity in their monthly, annual and seasonal primary productivities. The ANOVA analysis of Devanarsipura and Kodihosure lakes were shown the significant differences in their primary productivity but in case of Siddapura and Kodihosure lakes were insignificant in their primary productivity in two consecutive years it may be due to intensive aquaculture practices. The fish's raring and growing stations have more demand of edible phytoplankton community subsequently that will facilitate food profitable income. The monthly variation of primary productivity revealed that towards summer and winter months have high primary productivity but towards rainy it gradually decreases. It may be due to the dilution of essential macro-micro nutrients and low sun light and temperature. The primary productivity studies revealed that the selected stations belong to oligo-mesotrophic in nature and these kinds of work will helps the fisheries department for their broadcasting aqua cultural activities such as raring, introduction and harvesting these activities mainly dependences on availability of food sources (phytoplankton primary productivity).

References

1. Odum E.P., Fundamental of Ecology. W.B. Sunders, Toppan Co. Ltd., Tokyo, Japan **(1971)**
2. Bootsma H.A. and Hecky R.E., Conservation of the African Great Lakes: A limnological perspective, *Conserv. Biol. (Special Issue)*., **7**, 644–656 **(1993)**
3. Carr M.E., A comparison of global estimates of marine primary production from ocean color. Deep-Sea Research **II**., 741-770 **(2006)**
4. Dzik J., Dzieje życia na Ziemi. Wprowadzenie do paleobiologii, Wydawnictwo Naukowe PWN, Warszawa **(2003)**
5. Reynolds C.S., The response of phytoplankton communities to changing lake environments, *Schweiz. Z. Hydrol*., **49**, 220 **(1987)**
6. Arhonditsis G.B., Winder M., Brett M.T. and Schindler D.E., Patterns and mechanisms of phytoplankton variability in Lake Washington (USA), *Water Research*, **38,** 4013 **(2004)**
7. Mukul Sinha, Sadguru Prakash and Khalid Ansari K., Seasonal dynamics of Phytoplankton population in relation to abiotic factors of a fresh water pond developed from wasteland of Brick-klin, *Asian J. Microbiology Biotech. Env. Sci.,* **4(1),** 43-45 **(2002)**
8. Wetzel R.G., Limnology. 2ed, Saunders Co., Philadelphia USA 767 **(1983)**
9. Patrick R., The effects of increasing light and temperature in the structure of diatom communities. Limnol. Oceanography., **16(2),** 405-421 **(1971)**
10. Feresin E.G., Arcifa M.S., Silva L.H.S. and Esguicero A.L.H., Primary productivity of the phytoplankton in a tropical Brazilian shallow lake: experiment in the lake and in mesocosms, *Acta Limnologica Brasiliensia*, **22(4),** 384-396 **(2010)**
11. Fatima K., Rajashekher M., Gayathri V.K., Ratandeep and Baburrao M., Primary productivity in inland reservoirs, Gulbarga district, Karnataka, South India, *J of Ecol and Envi Scie.,* **2(1),** 11-14 **(2011)**
12. Uveges V., Voros L., Padisak J. and Kovacs A.W., Primary production of epipsammic algal communities in Lake Balaton (Hungary), *Hydrobiologia*, **660**, 17-27 **(2011)**
13. Devi Moirangthem Banita, DasTapati and Gupta Susmita., Limnological Studies of Temple Ponds in Cachar District, Assam, North East India, *Int. Res. J. Environment Sci.,* **2(10),** 49-57 **(2013)**
14. Yadav Janeshwar, Pathak R.K. and Khan Eliyas, Analysis of Water Quality using Physico-Chemical Parameters, Satak Reservoir in Khargone District, MP, India, *Int. Res. J. Environment Sci.,* **2(1),** 9-11 **(2013)**
15. Sharma K.K., Sharma R., Langer S. and Bangotra K., Phytoplankton as a Tool of Biomonitoring of Behlol Nullah, Jammu (J&K), India, *Int. Res. J. Environment Sci.,* **2(6),** 54-6 **(2013)**
16. Irfan Khursheed Shah and Humaira Shah, Physico-Chemical Dynamics in Littoral Zone of Nageen Basin of Dal Lake, Kashmir, India, *Int. Res. J. Environment Sci.***,** **2(3),** 11-14 **(2013)**
17. Wetzel R.G. and Linkens G.E., Limnological Analyses, 2 ed., Springer-Verlag, New York, **391**, 15-166 **(1991)**
18. Bootsma H.A. and Hecky R.E., Conservation of the African Great Lakes: A limnological perspective. Conserv. *Biol. (Special Issue),* **7**, 644-656 **(1993)**
19. Sheehan J.P., Effects of pollutants on community and ecosystem structure and dynamics, John Wiley Sons Ltd., New York, 51-99 **(1984)**
20. Ibrahim A.M., Abd El-Hakim N.F., Nagdy Z.A. and Ali N.A., Effect of fish pond fertilization systems on water physico-chemical properties and phyto and zooplankton communities, (Ain Shams Univ.), *J. Environ. Sci*., **7(1)**, 107-133 **(2003)**

21. Goldman C.R. and Jassby A., Spring mixing depth as a determinant of annual primary production in lakes, In M. M. Tilzer and Serruya C. (eds)., Large Lakes: Ecological Structure and Function, Springer-Verlag, NY., 125-13 **(1990)**

22. Chattopadhyay C. and Banerjee T.C., Water Temperature and Primary Production in the Euphotic Zone of a Tropical Shallow Freshwater Lake, *Asian J. Exp. Sci.,* **22(1),** 103-108 **(2008).**

23. Alvarez-Cobelas M. and Rojo C., Hypertrophic phytoplankton and the intermediate disturbance hypothesis, *Hydrobiologia*, **(1992)**

24. Hutchinson G.E., A Treatise on Limnology.Introduction to Lake Biology and the Limnoplankton, John Wiley and Sons, Inc., New York, USA 660 **(1967)**

25. D'Elia C.F., Sanders J.G. and Boynton W.R., Nutrient enrichment studies in a coastal plain estuary: phytoplankton growth in large-scale, continuous cultures, *Canad. J. Fish. Aquat. Sci.,* **43**, 397-406 **(1986)**

26. Verity P.G., Grazing of phototrophic nanoplankton by micro zooplankton in Narragansett Bay, *Mar. Ecol. Prog. Ser.,* **29,** 105-115**(1986)**