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Research Article

An Assessment of Phytoplankton in Nigeen Lake of Kashmir Himalaya

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Abstract

The present study deals with the evaluation of phytoplankton community of Nigeen lake which is one of the rare aquatic ecosystem wherein the human population live inside the lake in house boats which serves also an attraction for high end tourism. Having this feature under consideration and also lack of proper sewage system connectivity of the house boats, it was thought worthwhile to have a pilot assessment of phytoplankton community in the lake. During the study period, a total of 65 phytoplankton taxa were identified representing four classes namely Chlorophyceae (28), Bacillariophyceae (24), Cyanophyceae (8) and Euglenophyceae (5). Chlorophyceae was found to be the dominant group in terms of diversity. However, the class wise representation depicted following order of dominance in terms of density of phytoplankton: Bacillariophyceae>Chlorophyceae>Cyanophyceae>Euglenophyceae. The percentage contribution of density also followed the same pattern with Bacillariophyceae contributing (50%), followed by Chlorophyceae (38%), Cyanophyceae (9%) and Euglenophyceae (3%) in a decreasing order. The most common genera encountered among all the sites included; *Cymbella* sp., *Navicula* sp., *Tabellaria* sp., *Synedra* sp., *Amphora* sp., *Epithemia* sp., *Chlorella* sp., *Scenedesmus* sp., *Cosmarium* sp., *Tetraedron* sp., *Pediastrum* sp., *Oscillatoria* sp., *Anabaena* sp., *Phacus* sp. and *Trachelomonas* sp. Among the sites studied, the highest value (3.45) of Shannon-Wiener diversity index was recorded at site II and lowest (3.24) at site V. The minimum value of Simpson diversity index (0.95) was recorded for site IV and a maximum of (0.96) was maintained at site II.

Key words: Bacillariophyceae, Chlorophyceae, Cymbella, phytoplankton, Nigeen lake

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Nutrient enrichment of lakes is one among the major environmental problems in many countries (Oczkowski and Nixon, 2008). Excess plant nutrients primarily nitrogen (N) and phosphorus (P) disposed into lakes mainly as untreated or partially treated domestic sewage, runoff from agricultural fields etc. stimulates the growth of algae and higher plants, which ultimately leads to the deterioration of water quality and degradation of entire ecosystem (Guyer and Ilhan, 2011; Luo *et al*., 2011). Since, a biotic community is the product of the interplay of myriad of factors and processes and interaction of different physical, chemical and geo-morphological characteristics of any water body, biological assessment in the form of phytoplankton is therefore a useful alternative in assessing these ecosystems (Stevenson and Pan, 1999).

Trophic status of inland water bodies is often evaluated on the information regarding the concentration of the limiting nutrient (phosphorus), chlorophyll (an indicator of phytoplankton biomass) and transparency (dependent on both algal biomass and sediment resuspension, expressed as Secchi depth). One of the most conspicuous and the best-known changes associated with eutrophication is the mass development of cyanobacteria, be it N_2-fixing or nonfixing. Many species may develop toxic strains (e.g., *M. aeruginosa*, *Cylindrospermopsis raciborskii*) and thus, large blooms may directly harm both other aquatic organisms and humans (Reynolds, 1990). Planktonic green algae include a large number of microscopic organisms, unicellular or colonial, adapted to spend part or all of their lives in apparent suspension in the open water of lakes, ponds and rivers. Plankton face a wide variation in availability of energy and materials among different lakes and within a given lake at different times and depths. This variation is matched by the different strategies employed in obtaining resources by different taxa, at a phylogenetic or functional group level and by the flexibility to exploit different types of resources depending on their relative availability (Elliott *et al*., 2000). The phytoplankton are important as 'ecosystem engineers' that alter the availability of the materials within an inland water body (Reynolds, 2006).

Phytoplankton have long been used as the indicators of water quality. Because of their short life span, they respond quickly to the environmental changes and hence species composition indicates the quality of the water mass in which they are found (Raven, 1982). The biological spectrum of the lentic fresh water bodies are multidimensional where phytoplankton is useful in bio-monitoring the ecological disturbance caused by a number of physico-chemical factors, sewage pollutants and other anthropogenic factors. The Nigeen lake from of Kashmir, which some of the researchers believe to be one of the basins of world famous Dal lake has become the worst victim of anthropogenic pressure in the last few decades. As a result of increasing population within the catchment area, direct discharge of untreated human wastes from houseboats and settlements adjoining the lake, human encroachments etc. that over the period of time has revealed signs of ecological deterioration including other aquatic systems (Bhat and Kamili, 2004; Zutshi and Ticku, 2006; Solim and Wanganeo, 2008; Ganie *et al*., 2010; Baba *et al*., 2011; Lone *et al*., 2011; Bhat, 2013; Parvez and Bhat, 2014). The rationale behind the present attempt was to actually study the dynamics of the phytoplankton community in relation to the increasing inputs of nutrients mainly in the form of autochthonous untreated sewage. It is with this background an attempt was made to study the species composition and population density of phytoplankton community of Nigeen lake.

MATERIAL AND METHODS

Study area: Nigeen lake, an offshoot leading from the Dal lake located at a distance of 9 km to the North-East of the Srinagar city India fall in the latitude of 34°7'13"N and longitude of 74°49'40"E with an altitude of 1584 m a.m.s.l., covering an area of 4.5 km^2 (Rather *et al*., 2013). The lake is the main source of attraction for tourists and is exclusive in having number of houseboats, which provide excellent residing station for tourists and a source of income for lake dwellers. The houseboats are served by Shikaras (small boats) for transport and leisure. The lake is of the drainage type, being fed by a narrow water channel of Dal lake at Ashaibagh Bridge Sadiakadal in the North-East, while it drains into Gilsar and Khushalsar lake on its North-West side via Nallah Amir Khan. The water in Nigeen, in addition to being fed by Dal lake is also thought to be contributed by some springs within the lake bed and atmospheric precipitation. For the present investigation five sampling stations were selected to study the phytoplankton community of Nigeen lake (Fig. 1).

Description of study sites

Site I (Ashaibagh): This site is located at geographical coordinates of 34°06'53.0"N latitude and 74°50'09.5"E longitude near Ashaibagh Bridge in the North East side of Hazratbal basin receiving water from other basins of Dal lake and acts as an inlet source of Nigeen lake. This site serves as a parking station for Shikaras and is marked by the presence of floating gardens on one side. Submerged and free floating macrophytes are abundant.

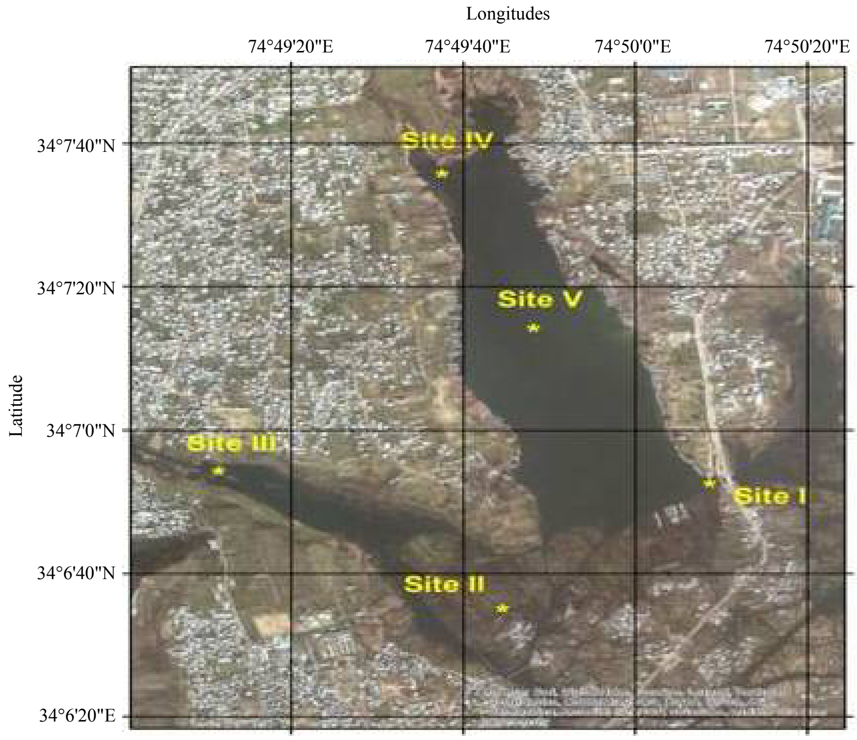

Fig. 1: Satellite image of study area and study sites

Site II (Khujyarbal): This site is located at geographical coordinates of 34°06'28.1"N latitude and 74°49'47.3"E longitude in the South West area of the lake. This site is marked by the presence of residential hamlets and is heavily impacted by the direct inflow of raw domestic sewage into the lake. It has proliferous growth of submerged and free floating macrophytes. Dense algal mats were also witnessed at this site.

Site III (Nallah Amir Khan): This site is located at geographical coordinates of 34°06'50.2"N latitude and 74°49'13.5"E longitude in the close proximity of the recently installed sewage treatment plant and acts as an outflow of Nigeen lake where from it drains into the Gilsar and Khushalsar lake. Submerged and free floating macrophytes are abundant.

Site IV (Bottabagh): This site is located at geographical coordinates of 34°07'37.33"N latitude and 74°49'38.2"E longitude towards the littoral zone of the lake. The site is marked by the presence of murky water harbouring rich algal growth.

Site V (Centre of Nigeen lake): This site is located at geographical coordinates of 34°07'14.2"N latitude and 74°49'49.3"E longitude near central deep zone of the lake with the maximum depth of about 6 m. This site is surrounded by a number of house boats and supports dense macrophytic vegetation.

The sampling was carried out during five months of the year, 2014. Two different approaches were opted for phytoplankton sampling for qualitative and quantitative estimations. Horizontal hauling was employed to a larger distance over the lake water at a particular site to get a statistically representative sample for qualitative purposes. Phytoplankton samples for quantitative analysis on the other hand were collected by sieving 100 L of water through a plankton net (No. 25, mesh size 64 μm) at different points at particular site in a composite manner. The plankton samples collected were then transferred to the properly labelled vials. Initially utmost care was given to identify the live phytoplankton. The samples were then preserved by fixing in 4% formalin (APHA., 1998). The aliquot in the tube was taken to be 50 mL. Identification of the phytoplankton was done with the help of standard works by Prescott (1939), Smith (1950), Edmondson (1992), Cox (1996), APHA (1998) and Biggs and Kilroy (2000). The quantitative estimation of phytoplankton was done under microscope by using Sedgwick Rafter cell of (1 mL capacity). The unicellular algae were counted as individuals where as 100 μm was taken as a unit in case of filamentous algae and in colonial forms like Volvox, Microcystis, Pandorina, Gomphosphaeria etc., the counting unit was a colony.

Shannon and Wiener (1963), Simpson (1949) and Margalef (1951) indices were used to describe the numerical structure of the algal community. The species similarity between various sites was calculated by Sorenson similarity coefficient (Sorenson, 1948).

RESULTS AND DISCUSSION

In the present investigation, a total of 65 taxa of phytoplankton were identified. The study revealed that Chlorophyceae (28 taxa) and Bacillariophyceae (24 taxa) were the major contributors whereas, Cyanophyceae (8 taxa) and Euglenophyceae (5 taxa) were the least contributors (Table 1). However, the class wise representation depicted following order of dominance in term of density of phytoplankton: Bacillariophyceae>Chlorophyceae>Cyanophyceae>Eugleno phyceae. The relative density of various groups at five different sites ranged between 48-55% (Baccillariophyceae), 31-43% (Chlorophyceae), 5-13% (Cyanophyceae) and 2-4% (Euglenophyceae) (Fig. 2). Based on the percentage contribution of different algal classes during whole study period, the algae belonging to Bacillariophyceae (50%) formed the bulk of phytoplankton followed by Chlorophyceae (38%), Cyanophyceae (9%) and Euglenophyceae ((3%) Fig. 3).

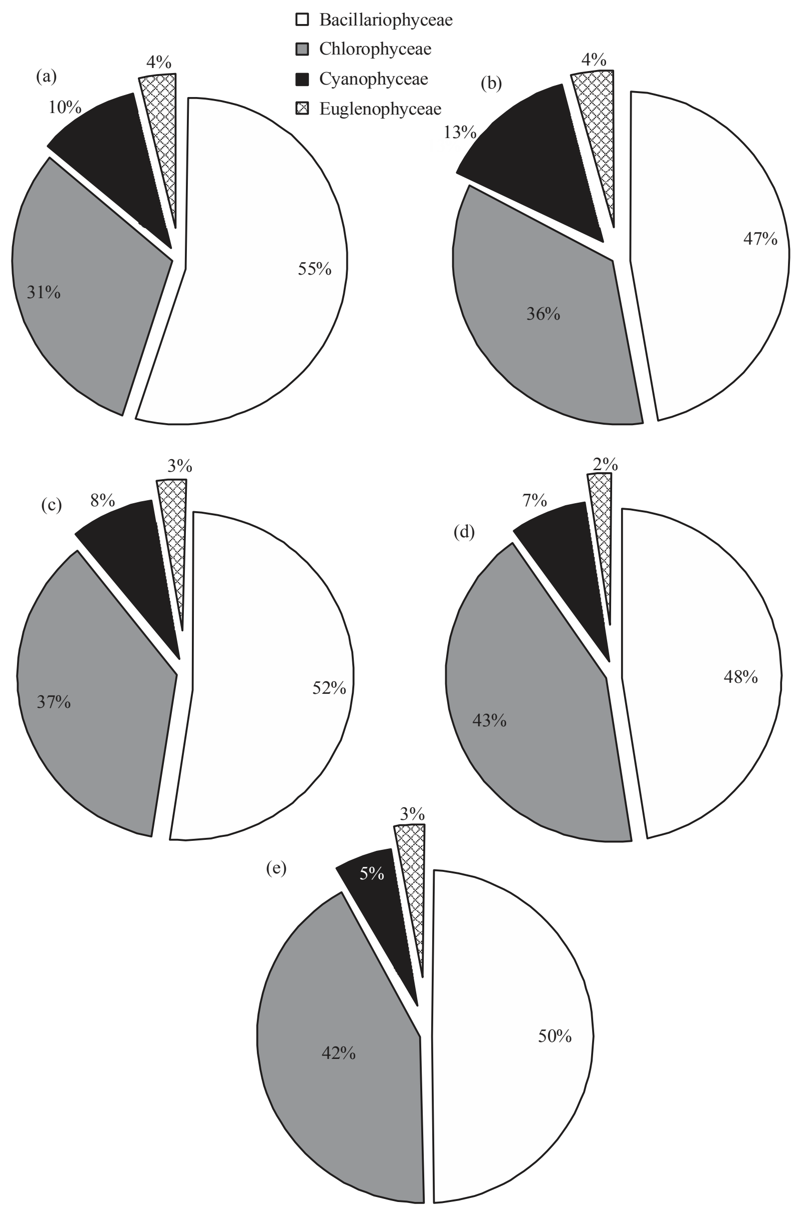

Fig. 2(a-e): Relative density of different classes of phytoplankton at five different study sites

The most abundant species among Bacillariophyceae in terms of mean population density were *Cymbella* sp., *Navicula* sp., *Tabellaria* sp., *Fragilaria* sp., *Amphora* sp. and *Synedra* sp., while *Amphipleura* sp., *Surirella* sp., *Asterionella* sp., *Pinnularia* sp. and *Frustulia* sp. were least abundant. In Chlorophyceae the most abundant species in terms of mean population density were *Chlorella* sp., *Cosmarium* sp., *Scenedesmus* sp., *Pediastrum* sp., *Tetraedron* sp. and *Chlorococcum* sp. and least abundant were *Volvox* sp., *Closterium* sp., *Ankistrodesmus* sp., *Tribonema* sp. and *Rhizoclonium* sp. Similarly, among Cyanophyceae, *Anabaena* sp. and *Oscillatoria* sp. were the most abundant in terms of mean population density, while *Spirulina* sp., *Gomphosphaeria* sp. and *Calothrix* sp. were the least abundant species. Euglenophyceae in the present study was the least represented group with five taxa only and among these *Phacus* sp. and *Trachelomonas* sp. were most abundant, while *Lepocinclis* sp., *Euglena* sp., *Colacium* sp. and were the least abundant species (Fig. 4).

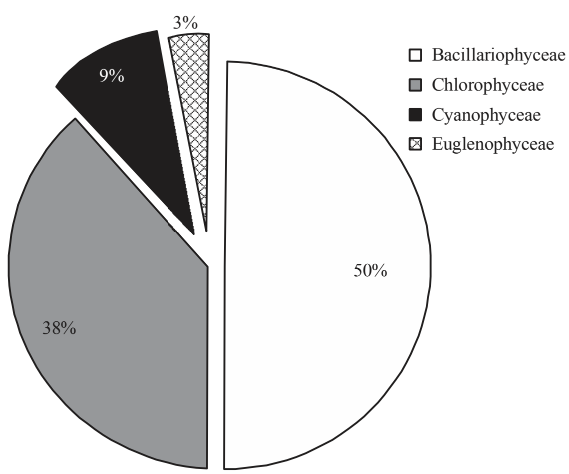

Fig. 3: Percentage contribution of different classes of phytoplankton in Nigeen lake during entire study period

During the present study, the highest number of taxa were recorded each at site I and site II (40) followed by site IV (38), site III (36) and site V (31) (Table 1). The highest Shannon- Wiener diversity index was recorded for site II (3.45) followed by site I (3.37), site III (3.32), site IV (3.29) and the minimum was of site V (3.24). The minimum value of Simpson diversity index (0.95) was recorded for site IV and a maximum of (0.96) was maintained at site II. The maximum and minimum value of Margalef index was recorded for site II (4.34) and site V (3.81), respectively (Fig. 5). There was a lot of species similarity between different study sites as reflected by high Sorenson similarity coefficient (Fig. 6).

The phytoplankton community was not found to be so diverse. It may be due to samples collected from the lake were not of large enough volume to be representative of overall species distribution. Further, it is pertinent to mention here that there is thorough mixing of lake water in the Nigeen and as such plankton at the mercy of currents are distributed and scattered from one place to another. On the other hand, cell count of plankton, have been found to reach the mark of 30,000 individuals L^{-1}, which is a clear sign of the impact of the human waste and untreated sewage entering into the lake.

Phytoplankton communities do not respond only to natural changes into the lake but may also present variations as a consequence of human interventions affecting the water body, either directly or through activities carried on in the basin as a whole. These influences affecting the lake result in modifications to the structure and composition of the phytoplankton. In the present study, Bacillariophyceae formed the most dominant group of phytoplankton in terms of density. Bacillariophyceae constitutes the most important group of algae (Wetzel, 1983) and has been reported to be dominant among phytoplankton in lakes and wetlands by several authors (Mir and Kachroo, 1982; Zutshi and Wanganeo, 1984; Sarwar and Zutshi, 1987). The population density of Bacillariophyceae varied from a minimum of 450 individuals L^{-1} in May at site V to a maximum of

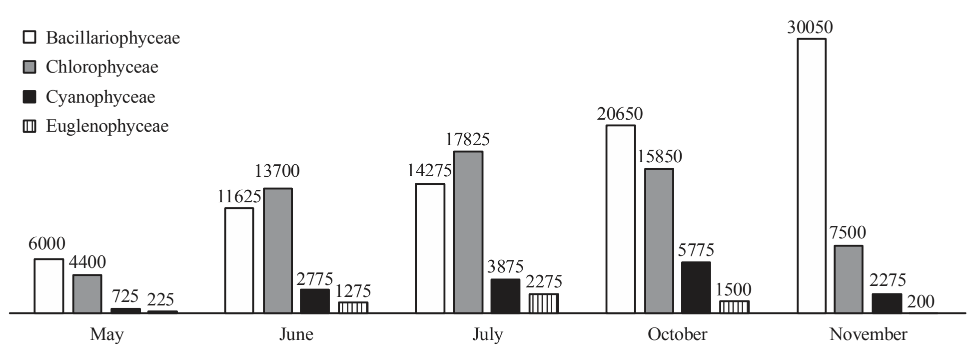

Fig. 4: Monthly variation in total count of phytoplankton (individual L^{-1}) at five different sites during May to November, 2014

11700 individuals L^{-1} in November at site I (Table 2). The highest population density of Bacillariophyceae or diatom group in the present investigation was recorded in November (Table 2) which could be attributed to the fact that they are able to grow under the condition of weak light and low temperature which are less suitable for other algae (Lund, 1965; Zafar, 1967; Goldman *et al*., 1968; Munawar, 1974; Ganai *et al*., 2010). Algal genera like *Cymbella* sp., *Synedra* sp., *Fragilaria* sp., *Gomphonema* sp., *Cocconeis* sp. and *Navicula* sp. which were recorded in the present lake are commonly found in organically polluted waters, thus indicating the organic load of the lake (Dickman and Kralina, 1975). The abundance of pollution tolerant taxa like *Cymbella* sp. and *Navicula* sp. at all the study sites indicates highest degree of organic pollution (Nandan and Aher, 2005).

Chlorophyceae formed the second most dominant group of phytoplankton. Some genera of green algae like *Scenedesmus* sp., *Pediastrum* sp., *Coelastrum* sp., *Tetraedron* sp. etc. have been reported to be abundant in eutrophic waters (Hutchinson, 1967). Most of these genera were found in the present lake and as such formed greater proportion of the green algae plankton. Taxa like; Coelastrum, Oocystis, Scenedesmus, Pandorina, Pediastrum, Zygnema, Chlorella, Tetraedron, Spirogyra and Tribonema have been reported to thrive in nutrient rich environs and majority of these green algae were recorded in the lake under study. The population density of Chlorophyceae reached its highest peak (4650 individuals L^{-1}) at site I in July, while as the lowest population density (400 individuals L^{-1}) was obtained at site V in May. During the study period, Chlorophyceae showed its peak value in July (Table 2). This could be attributed to the increase in temperature in addition to the increased P and N concentration (Kant and Kachroo, 1977; Ganai *et al*., 2010).

Cyanophyceae formed the third most dominant group of phytoplankton. In current study, occurrence of Microcystis at site I, site II, site III and site IV, which is considered as an indicator of eutrophic conditions (Rawson, 1956) may be

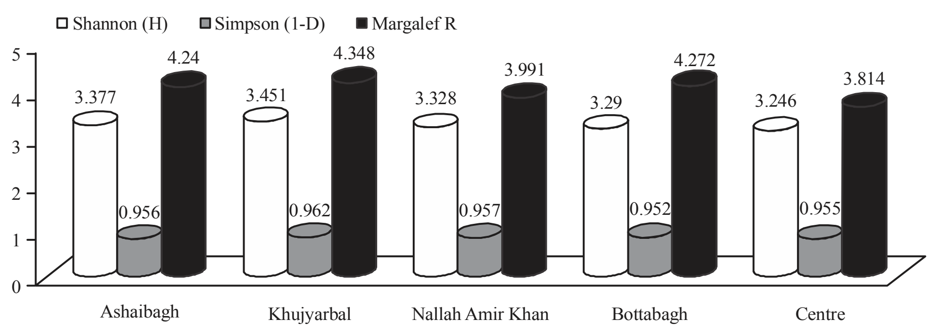

Fig. 5: Diversity indices of phytoplankton at five different study sites

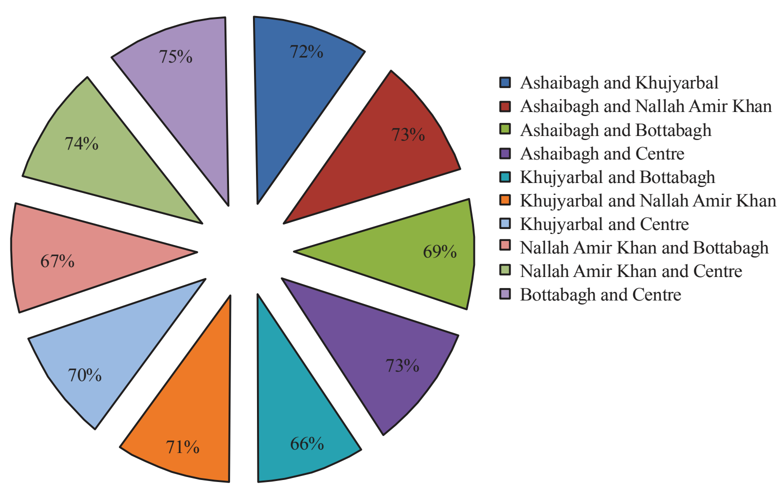

Fig. 6: Serenson's similarity coefficient of phytoplankton at different five study sites

Table 1: Monthly variations in population density (ind./l) of phytoplankton at different sites

Taxa	Sites	May	June	July	October	November	Total	Mean
Bacillariophyceae								
Amphora sp.	Site I	100	250	350	400	550	1650	330
	Site II	100	300	200	400	400	1400	280
	Site III	0	200	250	350	400	1200	240
	Site IV	100	150	250	400	600	1500	300
	Site V	0	50	150	300	175	675	135
Amphipleura sp.	Site I	0	0	0	150	200	350	70
	Site II	0	0	0	100	200	300	60
	Site III	0	0	0	0	0	0	0
	Site IV	0	100	0	0	200	300	60
	Site V	0	0	0	0	0	0	0
Asterionella sp.	Site I	0	0	0	150	300	450	90
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Achnanthidium sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	100	0	0	100	20
	Site V	0	0	0	0	0	0	0
Cymbella sp.	Site I	400	800	900	1050	2250	5400	1080
	Site II	400	300	600	700	1100	3100	620
	Site III	200	200	400	600	850	2250	450
	Site IV	200	300	400	600	500	2000	400
	Site V	75	50	100	400	300	925	185
Cocconeis sp.	Site I	0	200	400	200	300	1100	220
	Site II	100	200	100	100	250	750	150
	Site III	100	200	150	100	50	600	120
	Site IV	50	200	150	50	0	450	90
	Site V	0	150	50	50	0	250	50
Cyclotella sp.	Site I	200	250	300	300	200	1250	250
	Site II	0	100	50	50	50	250	50
	Site III	50	200	150	100	0	500	100
	Site IV	100	200	100	200	0	600	120
	Site V	50	100	75	50	25	300	60
Diatoma sp.	Site I	200	300	250	300	100	1150	230
	Site II	0	0	200	400	50	650	130
	Site III	0	200	100	300	100	700	140
	Site IV	0	0	100	200	0	300	60
	Site V	0	0	0	0	0	0	0
Diatomella sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	0	150	100	200	450	90
	Site IV	0	0	0	150	200	350	70
	Site V	0	0	0	50	0	50	10
Didymosphenia sp.	Site I	0	0	200	0	400	600	120
	Site II	0	0	0	0	0	0	0
	Site III	0	50	0	200	350	600	120
	Site IV	0	200	0	0	200	400	80
	Site V	0	0	100	0	125	225	45
Diploneis sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	100	0	0	100	20
	Site V	0	0	0	0	0	0	0
Epithemia sp.	Site I	100	200	200	300	400	1200	240
	Site II	100	150	200	300	400	1150	230
	Site III	100	100	150	250	400	1000	200
	Site IV	100	100	250	300	450	1200	240
	Site V	0	125	150	200	50	525	105

Table 1: Continue

Taxa	Sites	May	June	July	October	November	Total	Mean
Fragilaria sp.	Site I	300	500	400	400	500	2100	420
	Site II	100	200	300	400	600	1600	320
	Site III	300	300	400	200	600	1800	360
	Site IV	100	150	250	500	300	1300	260
	Site V	100	100	150	75	125	550	110
Frustulia sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	50	100	150	30
	Site V	0	0	0	0	0	0	0
Gomphonema sp.	Site I	0	200	100	0	800	1100	220
	Site II	0	100	250	350	500	1200	240
	Site III	50	100	150	200	300	800	160
	Site IV	0	0	0	0	0	0	0
	Site V	50	50	100	150	75	425	85
Gomphoneis sp.	Site I	0	0	0	0	600	600	120
	Site II	0	0	0	200	300	500	100
	Site III	0	0	0	100	200	300	60
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	50	75	125	250	50
Meridion sp.	Site I	0	0	0	0	250	250	50
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	100	200	300	60
	Site V	0	0	0	125	75	200	40
Mastogloia sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	100	0	0	0	100	20
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Navicula sp.	Site I	250	500	600	900	1000	3250	650
	Site II	200	500	650	700	850	2900	580
	Site III	150	400	350	600	900	2400	480
	Site IV	100	200	400	500	700	1900	380
	Site V	50	75	50	175	225	575	115
Nitzchia sp.	Site I	100	300	250	350	500	1500	300
	Site II	100	150	250	500	400	1400	280
	Site III	0	150	100	300	200	750	150
	Site IV	50	100	0	150	250	550	110
	Site V	0	25	0	150	0	175	35
Pinnularia sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	100	200	0	300	60
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	100	0	0	100	20
	Site V	0	0	0	0	0	0	0
Synedra sp.	Site I	100	200	250	300	500	1350	270
	Site II	100	100	250	300	400	1150	230
	Site III	200	150	250	350	450	1400	280
	Site IV	100	200	0	300	250	850	170
	Site V	50	0	100	150	200	500	100
Surirella sp.	Site I	0	0	0	150	300	450	90
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Tabellaria sp.	Site I	100	200	200	400	2550	3450	690
	Site II	150	250	300	400	750	1850	370
	Site III	200	100	250	500	800	1850	370
	Site IV	100	200	150	250	550	1250	250
	Site V	75	100	150	250	300	875	175
Total		6000	11625	14275	20650	30050	82600	16520

Table 1: Continue

Taxa	Sites	May	June	July	October	November	Total	Mean
Chlorophyceae								
Ankistrodesmus sp.	Site I	0	0	0	0	0	0	0
	Site II	0	200	150	0	0	350	70
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Cosmarium sp.	Site I	200	600	800	350	200	2150	430
	Site II	100	350	500	400	100	1450	290
	Site III	200	300	500	300	100	1400	280
	Site IV	200	800	1200	800	100	3100	620
	Site V	150	200	300	150	100	900	180
Chlorella sp.	Site I	250	600	800	950	600	3200	640
	Site II	200	500	650	750	300	2400	480
	Site III	100	400	600	700	400	2200	440
	Site IV	100	400	500	650	300	1950	390
	Site V	100	150	200	250	150	850	170
Chlorococcum sp.	Site I	0	200	200	400	200	1000	200
	Site II	100	200	300	350	250	1200	240
	Site III	100	200	100	400	300	1100	220
	Site IV	100	100	200	400	100	900	180
	Site V	0	0	125	50	50	225	45
Coelastrum sp.	Site I	0	0	0	0	0	0	0
	Site II	0	150	200	250	0	600	120
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	100	50	50	200	40
Closterium sp.	Site I	0	0	0	0	0	0	0
	Site II	0	150	250	0	0	400	80
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Closteriopsis sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	150	0	0	0	150	30
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	50	10
Hydrodictyon sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	100	250	350	70
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Mougeotia sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	150	200	300	100	750	150
	Site IV	0	0	100	200	0	300	60
	Site V	0	0	0	0	0	0	0
Oedogonium sp.	Site I	0	0	0	0	0	0	0
	Site II	0	200	250	200	50	700	140
	Site III	0	0	0	0	0	0	0
	Site IV	0	150	250	100	0	500	100
	Site V	0	100	75	125	0	300	60
Oocystis sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	50	100	0	150	30
Pediastrum sp.	Site I	100	200	400	300	100	1100	220
	Site II	150	300	350	250	0	1050	210
	Site III	200	350	400	250	100	1300	260
	Site IV	200	250	350	250	150	1200	240
	Site V	50	100	125	175	50	500	100

Table 1: Continue

Taxa	Sites	May	June	July	October	November	Total	Mean
Pandorina sp.	Site I	0	0	0	0	0	0	0
	Site II	100	400	250	400	100	1250	250
	Site III	50	150	250	200	50	700	140
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Protococcus sp.	Site I	0	0	200	0	0	200	40
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Rhizoclonium sp.	Site I	0	0	0	0	200	200	40
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Radiococcus sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	100	0	0	0	100	20
	Site V	0	0	0	50	0	50	10
Scenedesmus sp.	Site I	250	500	650	750	300	2450	490
	Site II	150	350	400	500	200	1600	320
	Site III	200	350	550	400	200	1700	340
	Site IV	150	400	500	650	250	1950	390
	Site V	100	150	250	200	150	850	170
Spirogyra sp.	Site I	50	200	100	100	100	550	110
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	100	50	50	200	40
	Site V	0	0	0	0	0	0	0
Selenastrum sp.	Site I	0	200	400	250	200	1050	210
	Site II	100	150	200	150	250	850	170
	Site III	0	100	200	100	200	600	120
	Site IV	0	0	0	0	0	0	0
	Site V	0	125	200	100	150	575	115
Staurastrum sp.	Site I	200	150	350	250	0	950	190
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	200	250	100	100	650	130
	Site V	0	150	50	125	100	425	85
Sphaerocystis sp.	Site I	0	0	0	0	0	0	0
	Site II	0	150	250	100	50	550	110
	Site III	0	0	0	0	0	0	0
	Site IV	0	200	200	0	0	400	80
	Site V	0	0	0	0	0	0	0
Schroederia sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	100	0	0	0	100	20
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Tetraedron sp.	Site I	100	350	400	500	150	1500	300
	Site II	150	400	300	250	100	1200	240
	Site III	100	400	500	400	100	1500	300
	Site IV	100	100	200	100	0	500	100
	Site V	0	75	150	125	100	450	90
Tribonema sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	150	200	0	0	350	70
	Site V	0	0	0	0	0	0	0

Table 1: Continue

Taxa	Sites	May	June	July	October	November	Total	Mean
Ulothrix sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	200	100	300	60
	Site V	0	0	0	0	0	0	0
Uronema sp.	Site I	0	0	0	0	0	0	0
	Site II	0	100	100	0	0	200	40
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Volvox sp.	Site I	0	100	150	0	0	250	50
	Site II	0	150	50	0	0	200	40
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Zygnema sp.	Site I	0	200	200	250	100	750	150
	Site II	0	0	0	0	0	0	0
	Site III	0	100	0	0	100	200	40
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Total		4400	13700	17825	15850	7500	59325	11865
Cyanophyceae								
Anabaena sp.	Site I	200	400	600	550	200	1950	390
	Site II	100	250	400	300	200	1250	250
	Site III	100	200	300	350	200	1150	230
	Site IV	0	150	200	400	100	850	170
	Site V	0	50	75	125	50	300	60
Calothrix sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	150	50	200	40
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Coccochloris sp.	Site I	0	0	0	0	0	0	0
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	200	100	300	60
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Gomphosphaeria sp.	Site I	0	0	0	0	0	0	0
	Site II	0	100	250	150	0	500	100
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Microcystis sp.	Site I	0	150	250	200	100	700	140
	Site II	50	150	250	300	0	750	150
	Site III	0	0	50	100	0	150	30
	Site IV	0	200	0	250	0	450	90
	Site V	0	0	0	0	0	0	0
Nostoc sp.	Site I	0	200	200	300	400	1100	220
	Site II	0	0	50	100	50	200	40
	Site III	50	50	100	100	0	300	60
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Oscillatoria sp.	Site I	100	200	200	400	100	1000	200
	Site II	100	250	500	650	250	1750	350
	Site III	0	100	150	300	150	700	140
	Site IV	0	100	100	500	100	800	160
	Site V	25	75	50	150	75	375	75

Table 1: Continue

Taxa	Sites	May	June	July	October	November	Total	Mean
Spirulina sp.	Site I	0	0	100	100	100	300	60
	Site II	0	150	50	100	50	350	70
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Total		725	2775	3875	5775	2275	15425	3085
Euglenophyceae								
Colacium sp.	Site I	0	0	100	0	0	100	20
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Euglena sp.	Site I	0	0	0	0	0	0	0
	Site II	0	50	100	200	0	350	70
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Lepocinclis sp.	Site I	100	100	200	100	0	500	100
	Site II	0	0	0	0	0	0	0
	Site III	0	0	0	0	0	0	0
	Site IV	0	0	0	0	0	0	0
	Site V	0	0	0	0	0	0	0
Phacus sp.	Site I	0	250	300	200	50	800	160
	Site II	100	100	250	200	100	750	150
	Site III	0	100	250	150	0	500	100
	Site IV	0	100	150	250	0	500	100
	Site V	25	50	75	125	0	275	55
Trachelomonas sp.	Site I	0	100	200	100	0	400	80
	Site II	0	200	300	150	50	700	140
	Site III	0	150	200	0	0	350	70
	Site IV	0	50	100	0	0	150	30
	Site V	0	25	50	25	0	100	20
Total		225	1275	2275	1500	200	5475	1095

Table 2: Number of phytoplankton taxa at five different study sites

Algal groups	Site I	Site II	Site III	Site IV	Site V
Bacillariophyceae	18	15	16	19	15
Chlorophyceae	13	15	13	14	12
Cyanophyceae	5	7	5	3	2
Euglenophyceae	4	3	2	2	2
Total	40	40	36	38	31

attributed to the highest degree of civic pollution at these study sites (Nandan and Aher, 2005). Further, the presence of Oscillatoria at all the study sites indicates pollutants of biological origin, which agrees with the observations of Gadag *et al*. (2005). The above study gains further support from the studies of Kumar (1990) and Zargar and Ghosh (2006) that excessive growth of certain algal genera viz., Anabaena and Oscillatoria is an indicative of nutrient enrichment of aquatic bodies. Among the sites studied the percentage composition of Cyanophyceae (13%) has been found to be higher at site II (Khujyarbal), which is marked by the presence of human settlements, where water is contaminated with sewage and faecal matter. Pearsall (1932) and Sedamkar and Angadi (2003) had correlated abundance of Cyanophyceae with high concentration of organic matter and nutrients.

Euglenophyceae in the present study formed the least represented group of phytoplankton and showed its peak development in July (Table 2), which can be attributed to the increasing temperature in addition to the level of organic matter (Hutchinson, 1967). Among the sites studied, Euglena was recorded only at site II indicating significant quantities of organic matter at this site, which may be attributed to the direct discharge of sewage from nearby human settlements. According to Hutchinson (1967), Euglena and Phacus are characteristics of waters having significant quantities of organic matter. The presence of both the taxa in the lake under study indicates the water body to be rich in organic matter.

Nigeen lake is subjected to pollution due to addition of fertilizers from floating gardens and domestic sewage from human habitation. Progressive enrichment of water with nutrients leads to mass production of algae, which in turn leads to the increased productivity and other undesirable biotic changes (Ahmad, 1996). A number of researcher have reported many algal species as indicators of water quality (Naik *et al*., 2005; Nandan and Aher, 2005; Zargar and Ghosh, 2006). Nandan and Aher (2005) has shown the algal genera, like Euglena, Oscillatoria, Scenedesmus, Navicula, Nitzschia and Microcystis to flourish in organically polluted waters. This almost comborates with the earlier study by Palmer (1969) who maintained that genera like Scenedesmus, Oscillatoria, Microcystis, Navicula, Nitzschia and Euglena mostly belonging to organically polluted waters. The very much presence of above taxa in the present water body suggests the lake to be organically polluted.

CONCLUSION

The Phytoplankton contribution towards the productivity in terms of cell number was mostly from Chlorophyceae and Bacillariophyceae with very minor contribution of less than 15% from Cyanophyceae and Euglenophyceae, which has been a usual trend in case of majority of Valley lakes. Chlorophyceae and Bacillariophyceae were more or less found equally in terms of species composition, while as the Cyanophyceae and Euglenophyceae contributed less number of phytoplankton in the Nigeen lake during the study period. The cell counts as found in the lake were enormously high thereby indicating the visible impact of sewage on the growth and multiplication of phytoplankton in the lake. The thick mats of algae dominated by Oscillatoria were found near site II and V possibly triggered by excessive enrichment from sewage of surrounding residential hamlets and houseboats. The signs of the floating of human waste, foul smell possibly due to hydrogen sulphide, decomposition of organic matter in the form of macrophytes but dominated by algal mats, anoxic conditions of the water were very visible during the sample visits at these sites. Since, there are various variables affecting the growth and multiplication of phytoplankton and therefore the species dynamics must be carefully evaluated and monitored further to reach on some concrete conclusions.

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