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Kusumlata Goswami
Department of Aquatic Environment Management, College of Fisheries, GBPUA&T, Pantnagar, Uttarakhand, India

M Das Trakroo
Department of Aquatic Environment Management, College of Fisheries, GBPUA&T, Pantnagar, Uttarakhand, India

Correspondence
Kusumlata Goswami
Department of Aquatic Environment Management, College of Fisheries, GBPUA&T, Pantnagar, Uttarakhand, India

An overview of qualitative and quantitative composition of phytoplankton community at Lake Nainital

Kusumlata Goswami and M Das Trakroo

Abstract
Lake Nainital is situated at Nainital district (known as Lake District of India) in Uttarakhand. The climate of Nainital is sub-tropical to sub-humid, which provides soothing environment for luxurious growth of planktons. Qualitative and quantitative structure of phytoplankton was assessed for a period of eight months from September, 2016 to April, 2017 for evaluation of their diversity at lake using diversity indices. On the basis of human interference three sites were selected. Site1 (S_1) was near pump house at *Thandi sadak*, which was operated to improve the dissolved oxygen content of the lake. Site 2 (S_2) was near Naina Devi Temple, where drainage of temple is flushed into the water. Site 3 (S_3) was at platform near Boat stand, where there was a lot of human intervention by tourist activities. The floristic composition of Nainital Lake consisted of total number of 41 different taxa belonging to 4 classess and the density of phytoplankton varied from 2×10^4 to 4.26×10^4 cells L^{-1}, with a mean population of 3.13×10^4 cells L^{-1}. Calculation of various diversity and evenness indices depicted that Site S_1 possess maximal diversity, whereas Site S_2 possess maximum density of phytoplankton.

Keywords: Diversity, evenness, indices, phytoplankton

Introduction
The lofty Himalayan mountain ranges in northern India provide accommodation to several well-known lakes. Uttarakhand, located at the foothills of the Himalaya is rich with several natural resources especially water with many glaciers, rivers, springs, lakes etc. Nainital is one of the major four lakes located in the hills of Kumaon along with Naukuchiyatal Lake, the Bhimtal Lake and the Sattal Lake. Cradled in the Himalayan foothills, Nainital acts as the gateway to *Kumaon* hills. Nainital is a popular destination in the northern tourist circuit and attracts thousands of tourists round the year due to its salubrious climate and scenic beauty. Freshwater ecosystems are considered as one of the most essential natural resources and the alarming rate of deterioration of these fresh water resources like lakes, ponds, rivers etc. is now a global problem. So, periodic examination of the freshwater bodies is very much essential for sustainable utilization of the water resources (Shah and Pandit, 2012) [1].

Phytoplankton are free floating unicellular, filamentous and colonial organisms that grow photo-auto tropically in aquatic environments and their diversity and distribution pattern are widely used as indicators of lentic water bodies (Negi and Rajput, 2015) [2]. Phytoplankton are first link of all aquatic food chain (Babatunde *et al*., 2014) [3]. Phytoplankton are considered good indicators of water quality and trophic conditions because of their rapid response to change in environmental and hydrological conditions due to their short life cycles and rapid reproduction rates. Seasonal variations in phytoplankton assemblage are closely related to seasonal changes in temperature, nutrient loads and light availability. Other meteorological (wind, rain and cloudiness) and hydrological (water level fluctuations) events also leads to shift in pattern of phytoplankton availability (Jindal *et al*., 2014) [4]. The diversity and richness of species are important components to evaluate the health of ecologic system. The health of lake ecosystems and their biological diversity are directly linked to the welfare of almost every component of the ecosystem (Bhat *et al*., 2013) [5].

Materials and Methods
Study Site
The study was conducted at Nainital Lake, which is a natural freshwater body, situated amidst the township of Nainital in Uttarakhand State of India. The lake is located at Kumaun Himalayas (between 29.24° N, 79.28° E and 29.4°N, 79.47°E) at an altitude of 1938 m above the mean sea level. The maximum length and width of the lake is 1.43 km and 0.45 km respectively.

The maximum depth of the lake is 27.3 m and average depth is 16.5 m (Mishra and Garg, 2011) [6]. Nainital exhibits temperate climate in winter and subtropical climate in summer season with mean monthly minimum and maximum temperatures of 0.5°C and 25°C. The lake receives runoff from hilly catchment and drainage from all surrounding sides. Nainital is divided into two parts, southern side of the lake is Tallital and Mallital, consists of the northern upper reaches.

Sampling Sites

Three sampling stations S_1, S_2 and S_3 were selected at different locations of lake (presented in Figure-1) depending on various anthropogenic influences. S_1 was near aerator plant, which was operated to improve the dissolved oxygen content of the lake, S_2 was near Naina Devi Temple, where drainage of temple was flushed into the water and S_3 was near Boating site, where there was lot of human intervention by activities of tourists.

Fig 1: Location of sampling stations at Lake Nainital of India (Source: Satellite view of Nainital, Google maps)

Plankton Sampling

Plankton samples were collected fortnightly, from the three selected sites. Collection of plankton was done by filtering 100 litres of water from the surface with minimal disturbance using plankton net made up of bolting silk No. 25. Plankton samples were concentrated to 10ml volume after preserving in Lugol's iodine (0.3ml/ 100ml sample).

Qualitative analysis

Plankton samples were observed under high power of the compound microscope and identification was done using reference books (Phillipose, 1960) [7], (Needham, 1974) [8], (Palmer, 1980) [9] and (Edmondson, 1992) [10].

Quantitative analysis

Quantitative estimation of phytoplankton was done using haemocytometer (APHA, 2012) [11]. The sample was put into the grooves of haemocytometer, covered with cover slip and observed under 40 X power of the microscope. Triplicates of each sample were counted and total phytoplankton number/ liter of water was calculated using the following formula:

$$\text{Phytoplankton number Litre}^{-1} = \frac{\text{Counts in central chamber}}{\text{Concentration factor}} \times 10^7$$

$$\text{Where, Concentration factor} = \frac{\text{Volume of water concentrated}}{\text{Volume of water made after concentration}}$$

Calculation of phytoplankton diversity

Biodiversity indices for calculation of species richness and evenness were calculated by using Menhinick index, Margalef index, Simpson index and Shannon Weiner index (Mirzaie *et al*., 2013) [12]. Palmer's Pollution index was calculated to estimate organic pollution.

Margalef's Index (Margalef, 1959) **[13]:** Margalef index relates the number of species to the total number of individuals. The fall in the value of Margalef index shows the rise in the level of pollution.

Margalef's Index (D_{Mg}) = S-1/ ln N

Where, S is total number of species observed
N is total number of individuals in the sample

Menhinick's Index (Menhinick, 1964) **[14]:** It is the ratio of the number of taxa to the square root of sample size.

Menhinick's Index (D_{Mn}) = S/ $\sqrt{N}$

Where, S is total number of species observed

N is total number of individuals in the sample

Shannon-Wiener diversity index (Shannon and Wiener, 1949) [15]: It is based on the information of statistic index, which means it assumes all the species are represented in a sample and that they are randomly sampled (represented in the sample).

Shannon-Wiener diversity index (H') = - $\sum p_i \ln p_i$

Where, p_i is the proportion of individuals found in the i^{th} species.

Simpson's Diversity Index (Simpson, 1949) **[16]:** It measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species).

Simpson's Diversity Index (D) = 1 - $\sum$ n (N-1) / N (N-1)

Where, n is the total number of organisms of a particular species
N is the total number of organisms of all species

Statistical Analysis

Monthly data of phytoplankton population was subjected to statistical analysis by using software SPSS version 16.0 and M S Excel.

Results and Discussion

Phytoplankton form the base of aquatic food chain and any type of alteration in physical and chemical properties of water due to seasonal fluctuation and degree of pollution can be better assessed by their evaluation. Study and monitoring of phytoplankton are useful for control of biological conditions of water (Ariyadej *et al*., 2004) [17]. In this investigation a total of 41 species of phytoplankton belonging to different classes were recorded. Out of the total 41 species, 20 species of Bacillariophyceae, 16 species of Chlorophyceae, 3 species of Cyanophyceae and 2 species of Euglenophyceae was observed. Observations on algal flora from water bodies of Kumaun Himalayas indicated that blue-green algae were high

in polluted water whereas green algae and diatoms were maximum in clean waters (Joshi, 2005) [18]. The species belonging to class Bacillariophyceae were found in abundance during the entire investigation period, among which *Fragilaria* sp., *Tabellaria* sp., *Gomphonema* spp., *Navicula* sp., *Amphora* sp. and *Caloneis* sp. were dominant. Other species of Bacillariophyceae which were frequently recorded were *Nitzschia* sp., *Cymbella* sp., *Gyrosigma* sp., *Melosira* sp., *Diatoma* sp., *Synedra* sp., *Cocconeis* sp., *Cyclotella* sp., *Pinnularia* sp., *Coscinodiscus* sp., *Denticula* sp. and *Stauroneis* sp. Bacillariophyceae was recorded as dominant class among them. The second dominant class among phytoplankton was Chlorophyceae, among which prevalent species were *Chlorella* sp., *Spirogyra* sp., *Cosmarium* sp., *Scenesdesmus* sp., *Ankistrodesmus* sp., *Zygnema* sp., *Mougeotia* sp., *Stigeoclonium* sp., *Cladophora* sp., *Pediastrum* sp., *Closterium* sp., *Eudorina* sp., *Pandorina* sp., *Chlamydomonas* sp., *Oedogonium* sp. and *Ulothrix* sp. This finding is similar to the findings in which a total of 25 genera of phytoplankton were recorded, belonging to three classes Bacillariophyceae (13 genera), Chlorophyceae (8 genera) and Cyanophyceae (4 genera) at Nainital lake from 2007 to 2009 (Negi and Rajput, 2015) [2]. Phytoplankton community structure and species diversity of Nangal wetland, Punjab, India shows that in fresh water ecosystems the Bacillariophyceae, Chlorophyceae and Cyanophyceae make up the three major groups of algae (Brraich and Kaur, 2015) [19]. The percentage contribution of different groups of phytoplankton in south coast of India and observed were observed as Bacillariophyceae > Chlorophyceae > Cyanophyceae > Euglenophyceae (Ajithamol *et al*., 2014) [20]. Some commonly recorded phytoplankton species of Lake Nainital are presented in Figure-2.

Fig 2: Commonly recorded Phytoplankton species at Lake Nainital

During the investigation period, the composition and density of phytoplankton community varied seasonally and maximum phytoplankton population was observed in the month of April with a density of 4.26×10^4 cells L^{-1}, while minimum population was found in the month of September with a density of 2×10^4 cells L^{-1}, as depicted in Figure-3. Among the three sites highest phytoplankton density was found at site S_2, which is 3.5×10^4 cells L^{-1} with a standard deviation of 8485.21 cells L^{-1}. This may be due to good nutrient level at S_2. Minimum density of phytoplankton (2.85×10^4 cells L^{-1}) was present at site S_3 which may be due to unfavourable conditions caused by higher anthropogenic influences. At all the sites maximum density of phytoplankton was observed in the month of April, which is due to intermixing of nutrients during spring season and release of nutrients by decomposition as summer proceeds. The maximum density of phytoplankton follows two peaks, summer peak in April and winter peak in December (Guru, 2007) [21]. The number of genera and species of different algal groups were maximum during summer, declined during monsoon and again increased during winter (Rani and Shivkumar, 2012) [22].

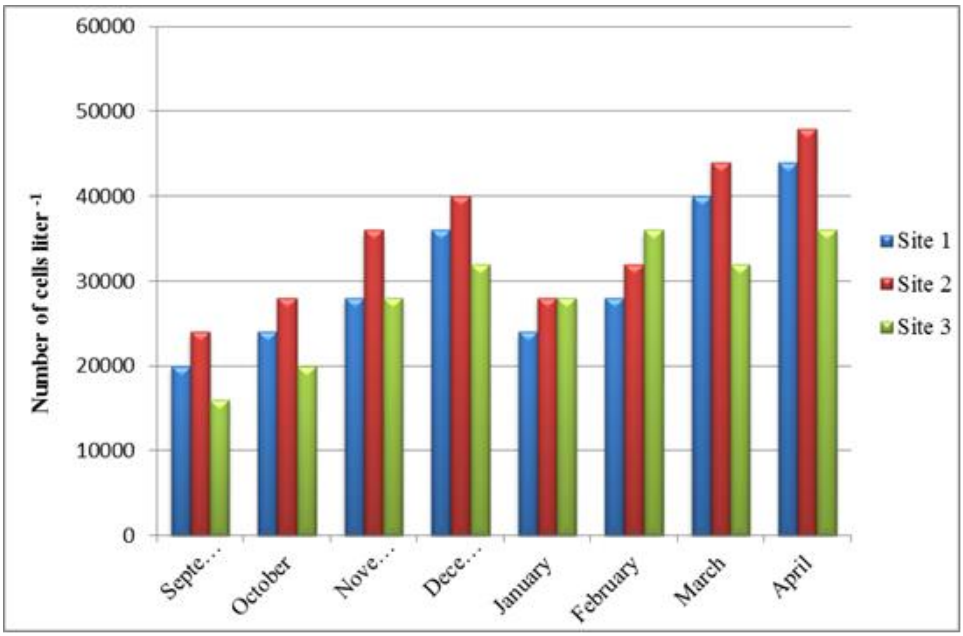

Fig 3: Mean monthly variation in the density of phytoplankton of Lake Nainital

Indices of data regarding species diversity and richness using biodiversity indices are tabulated in Table 1. The value of Margalef's index values are 3.03, 2.77 and 2.41 for S_1, S_2 and S_3 respectively while Menhinick's index at site S_1, S_2 and S_3 are 0.19, 0.16 and 0.14 respectively. According to Menhinick's and Margalef's richness index values, site S_1 was found to be most species diversified and Site S_3 as least species diversified. Earlier observations of Margalef's species richness index for assessment of phytoplankton diversity at lake Nainital shows highest richness (0.458) among Cyanophyceae followed by Bacillariophyceae and Chlorophyceae (Negi and Rajput, 2015) [2].

Table 1: Diversity indices based on abundance of phytoplankton at Lake Nainital

Biodiversity Parameters	Site 1	Site 2	Site 3
Margalef's Index	3.03	2.77	2.41
Menhinick's Index	0.19	0.16	0.14
Shannon-Weiner Index	3.44	3.39	3.21
Simpson's Index of Diversity	0.968	0.966	0.960

The value of Shannon- Weiner Index for site S_1, S_2 and S_3 were 3.44, 3.39 and 3.21, respectively, which indicates that site S_1 was found to be most species diversed followed by site S_2 and S_3. Calculations of phytoplanktonic Shannon's diversity index with reference to Mucalinda Sarovar, Bodh-Gaya observed highest index value (3.54) among Chlorophyceae and lowest index value (2.00) among Euglenophyceae indicating more species diversity among Chlorophycean members (Islam, 2008) [23]. Simpson's index of diversity also interprets same results that site S_1 was most species diversed, as its value was 0.968 for S_1, 0.966 for S_2 and 0.960 for S_3. This may be attributed to healthier environmental conditions and less anthropogenic influence at site S_1. Simpson diversity index of algal flora at Sharvati River Basin of Central Western Ghats indicated that Simpson diversity index varied from 0.12 at station 1 and 0.88 at station 10, depicting more diversity at station 10 than station 1 (Desai *et al*., 2008) [24].

Conclusion

The investigation of phytoplankton community of lake Nainital, indicates that the per cent composition of Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae were 46.67%, 38.33%, 10.67% and 4.33% respectively. The density of phytoplankton fluctuated from 2×10^4 cells L^{-1} to 4.26×10^4 cells L^{-1}. Maximum density of phytoplankton was observed in the month of April while minimum density was recorded in September. Calculation of various diversity and evenness indices depicted that site S_1 possess maximal diversity, whereas site S_2 possess maximum density of phytoplankton. Site S_1 exhibited optimum physico-chemical conditions as a result maximum diversity of species was observed, whereas due to continuous influx of nutrients, site S_2 possessed maximum density of phytoplankton. Site S_3 was least diversified both in terms of density and diversity due to maximum human interference and unfavourable conditions. So, it can be suggested that by reducing the pollution load, the rate of deterioration of water quality can be lowered. The physico-chemical conditions of water have direct bearing on biological properties of water body. Thus, improving the water quality will improve the phytoplankton scenario of lake Nainital.

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