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Assessment of Phytoplankton Diversity in Relation to Abiotic Factors of Nainital Lake of Kumaon Himalayas of Uttarakhand State, India

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ABSTRACT

The study was undertaken to assess the phytoplankton diversity in relation to abiotic factors of Nainital lake of Kumaon Himalayas of Uttarakhand State, India. The samples were collected from the three selected study sites for the period from May, 2007 to April, 2009. A total of 25 genera of phytoplankton were reported belonging to 3 groups viz., bacillariophyceae (13 species), chlorophyceae (8 genera) and cyanophyceae with 4 genera. Members of bacillariophyceae and chlorophyceae were found to dominant during winter and monsoon months at all the sites. Site II has the maximum number of phytoplankton followed by Site III and Site I. Bacillariophyceae were positively correlated with GPP, chlorophyceae and with zooplankton while negatively correlated with alkalinity and dissolved solids and with chlorides at all the sites. Chlorophyceae was found to be positively correlated with hardness, GPP, bacillariophyceae and zooplankton while chlorophyceae was negatively correlated with alkalinity, total dissolved solids and chlorides. Cyanophyceae was positively correlated with GPP, NPP while negatively correlated with free CO_2 and total dissolved solids. Maximum species richness was recorded as 0.458 for cyanophyceae at Site-I followed by bacillariophyceae (0.366) and minimum was observed in chlorophyceae (0.182) at Site-III. As far as species diversity is concerned, maximum diversity was observed in bacillariophyceae (2.329) and minimum in cyanophyceae (1.335). Abundance percentage was recorded maximum (56.91%) in chlorophyceae at Site-III and minimum as 2.52% in case of cyanophyceae.

Key words: Phytoplankton, lake, chlorophyceae, abiotic factors

INTRODUCTION

Phytoplankton are defined as free floating unicellular, filamentous and colonial organism that grow photo-autotrophically in aquatic environments. They are the basic of food chains and food webs which directly provide food for zooplankton, fishes and some aquatic animals (Millman *et al*., 2005; Shubert, 1984). Plankton abundance and diversity are widely used as biological indicators of still water quality in the lakes and reservoirs. They are sensitive to watershed conditions and exhibit sufficient stability in assemblage structure over time to make them useful as long-term monitors of lake health and indicators of water quality. Raina and Vass (1993) opined that the density of plankton in a water body is a useful index of water quality although density may fluctuate widely with changes in the seasons.

The density and species composition of phytoplankton in tropical lakes and reservoirs demonstrate particular annual biological characteristics (Palmer *et al*., 1977; Shubert, 1984; Washington, 1984; Pongswat *et al*., 2004). Phytoplankton succession in open lakes depends on the availability of nutrient, hydraulic retention time, temperature, light, intensity and transparency. Phytoplankton communities usually undergo a fairly predictable annual cycle but some species may be grow explosively and form blooms (Toman, 1996; Hinder *et al*., 1999; Vaulot, 2001). Light limitation by high turbidity is another factor that frequently controls phytoplankton growth either during the whole year or seasonally (Ariyadej *et al*., 2004; Domingues *et al*., 2005).

Nainital is located at 29°24' N latitude and 79°29' E longitude at an elevation of 1938 mts above sea level in the Kumaon foothills of the outer Himalayas. Nainital lake supplies the large quantity of water for city for drinking purpose although increasing population of Nainital town and the spurt in tourist activity has, however, resulted in various forms of degradation of the lake including sedimentation and eutrophication. Hence, a study was undertaken to assess the phytoplankton diversity in relation to abiotic factors, species diversity and composition and seasonal variation of phytoplankton in Nainital lake, in order to established primary data that can be used for its sustainable fisheries management.

MATERIAL AND METHODS

Water samples were collected from Nainital lake at monthly intervals for a period of two years from May, 2007 until April, 2009 for the analysis of air temperature, water temperature, pH, dissolved oxygen, electrical conductivity and total dissolved solids. The physico-chemical parameters were analyzed by standard method APHA. (1998) Phytoplankton samples were collected by towing a plankton net (mouth diameter 0.35 mm) made up of bolting silk (no.30; mesh size 48 μ) for half an hour. The samples were collected in black polythene bags and immediately preserved with 4% formalin for quantitative and qualitative analysis. Plankton counting was made by drop method. Phytoplankton was identified by consulting standard references like APHA. (1998) and Ward and Whipple (1992).

Species diversity index (H') was calculated using Shannon and Weiner (1949) and Pielous has been made Species diversity was calculated as per standard methods (Shannon and Wiener, 1963).

Margalef species richness:

$$R = (S-1)/\ln N$$

where, S is No. of species, N is Total number of individual.

Shannon diversity index:

$$H = \Sigma pi \ln pi$$

Pi = Ni/N Ni = Number of individual of ith species; N= $\sum$ ni.

Evenness index:

$$E = H/\ln S$$

where, S is No. of species, Abundance (RA) is percentage of catch of fish across different sites was worked out as:

$$\text{RA of individual species} = \frac{\text{No. of samples of particular species}}{\text{Total number of individual in the samples}} \times 100$$

RESULTS

Values of physic-chemical parameters were presented in the Table 1 and list of phytoplankton were included in the Table 2. During the course of study a total of 25 genera of phytoplankton

Table 1: Mean values of physico-chemical parameters of Lake Nainital at different study sites

	Air temperature			Water temperature			pH			DO		
Stations	W	S	R	W	S	R	W	S	R	W	S	R
1	14.7	20	20.6	12.7	18.6	18.3	8.4	7.8	8.2	9.1	8.4	6.6
2	14.7	20	20.5	12.7	18.6	18.5	8.3	7.7	8.1	9.4	8.5	6.9
3	14.7	20	20.6	12.7	18.6	18.3	8.4	7.8	8.1	8.9	8.1	6.7
	Free CO_2			Hardness			TDS			Alkalinity		
Stations	W	S	R	W	S	R	W	S	R	W	S	R
1	0.0	0.24	0.21	387.0	359.8	421.3	232.1	375.8	263.2	450.5	507.3	410.5
2	0.0	0.31	0.32	395.8	357.2	414.3	248.2	359.5	251.6	452.6	524.5	407.3
3	0.0	0.46	0.33	395.3	363.6	426.6	256.7	390.0	264.2	463.5	504.2	408.7
	Chloride			Phosphate			Nitrate			Turbidity		
Stations	W	S	R	W	S	R	W	S	R	W	S	R
1	6.90	10.2	7.6	0.53	0.57	0.55	0.42	0.47	0.50	228.7	234.2	252.1
2	7.13	10.8	8.0	0.72	0.76	0.78	0.58	0.66	0.68	185.0	170.0	169.7
3	6.80	10.7	8.0	0.67	0.75	0.76	0.66	0.78	0.75	152.2	145.3	139.3

Table 2: Species richness, diversity, abundance and evenness of Nainital Lake of Kumaon Himalaya, Uttarakhand

	Bacillariophyceae		Chlorophyceae		Cyanophyceae	
Sites	2007-2008	2008-2009	2007-2008	2008-2009	2007-2008	2008-2009
Site I						
Species richness*	0.347	0.334	0.230	0.222	0.458	0.365
Evenness	0.856	0.885	0.790	0.785	0.528	0.520
Species diversity	2.197	2.270	2.026	2.014	1.355	1.335
Abundance (%)	46.700	46.110	50.760	50.210	2.523	3.666
Site II						
Species richness	0.322	0.310	0.216	0.203	0.313	0.280
Evenness	1.051	1.060	0.940	0.928	0.588	0.611
Species diversity	2.309	2.329	2.066	2.040	1.292	1.358
Abundance (%)	50.510	44.770	53.730	50.030	5.051	5.191
Site III						
Species richness	0.332	0.319	0.219	0.182	0.366	0.305
Evenness	1.655	1.670	1.481	1.374	0.892	0.965
Species diversity	2.295	2.315	2.053	1.905	1.237	1.338
Abundance (%)	47.270	39.070	52.130	56.910	3.688	4.003

*Particular measure of species richness is known as D, the Menhinick's index and calculated as the formula D = s/ÖN where s = Total number of species found, N = Total number of individuals of species

belonging to three groups viz. bacillariophyceae (13 genera), chlorophyceae (8 genera) and cyanophyceae (4 genera) were reported from the three selected study sites in Nainital lake. Among these, site II has the maximum number of phytoplankton recorded followed by site III and site I. The values of mean physico-chemical parameters of water are represented in Table 1. Among the 13 genera of bacillariophyceae investigated from the Nainital lake, *Diatoma, Nevicula, Pinnularia* were found to be dominant, followed by *Ankistrodesmus, Amphora, Cymbella, Denticula, Fragillaria, Gomphonema* and *Synedra*. However *Tabellaria, Archnanthaes* and *Epithelmia* were reported only during monsoon season. Maximum number of bacillariophyceae was reported in the month of September, 2008 and minimum in March, 2008. Bacillariophyceae were positively correlated with GPP (0.861, 0.872, 0.832) with chlorophyceae (0.955, 0.963, 0.966) and with zooplankton (0.869, 0.871, 0.916) at all the sites while negatively correlated with alkalinity (-0.577, -0.522) at sites II and III, with dissolved solids (-0.567-0.561, -0.554) and with chlorides (-0.542, -0.532, -0.526) at all the sites.

Chlorophyceae: Among chlorophyceae, *Chlorella, Cladophora* and *Spirogyra* were found dominant while *Closterium, Hydrodityon, Microspora, Ulohtrix* and *Vaucheria* were found to be abundant. Maximum number of chlorophyceae was reported in September, 2008 and minimum in May, 2007. Chlorophyceae was found to be positively correlated with hardness (0.597, 0.534) at sites I and III and with GPP (0.920, 0.916, 0.903), bacillariophyceae (0.955, 0.963, 0.966) and zooplankton (0.781, 0.785, 0.861) at all the sites. Chlorophyceae was negatively correlated with alkalinity (-0.552) at site II with total dissolved solids (-0.611, -0.649, -0.629) and with chlorides (-0.604, -0.585, -0.570) at sites I, II and III, respectively.

Cyanophyceae: *Nostoc* was recorded as the dominant genera from all the three selected sites of the lake. *Anabeana* and *Microcystis* were also reported throughout the year but rarely found at site I and remain concentrated at site II and III. *Oscillatoria* was only recorded during post monsoon and winters. The maximum number of cyanophyceae was observed in January, 2009 and minimum in May, 2007. Cyanophyceae was positively correlated with GPP (0.516) at site III and with NPP (0.518, 0.550) at sites II and III while it was negatively correlated with free CO_2 (-0.541) at site III and with total dissolved solids (-0.549) at Site I. Site-wise species richness, evenness, species diversity and abundance percentage were also calculated (Table 3). Maximum species richness was recorded as 0.458 for cyanophyceae at site-I followed by bacillariophyceae (0.366) and minimum was observed in chlorophyceae (0.182) at site-III.

As far as species diversity is concerned, maximum diversity was observed in bacillariophyceae (2.329) and minimum in cyanophyceae (1.335). Abundance percentage was recorded maximum (56.91%) in chlorophyceae at site-III and minimum as 2.52% in case of cyanophyceae (Fig. 1).

DISCUSSION

Few studies have been conducted on the diversity and seasonal abundance of NPP which may constitute a fraction of the total phytoplankton community and found abundant in the surface water of tropical lakes playing an important role in maintaining the ecology and water quality of freshwater ecosystems (Parker and Hatcher, 1974).

Venu and Seshavatharam (1984) studied the phytoplankton production in relation to physic-chemical conditions in lake Kondakarla and reported that physical factors like water depth, percentage light transmission, turbidity and few nutrient factors like chlorides, sulphate and

Table 3: List of recorded phytoplankton species at Nainital lake

Taxa	Site I	Site II	Site III
Bacillariophyceae			
Ankistrodasmus	+	+	+
Ampora	++	++	++
Achanthes	-	+	+
Cymbella	++	++	++
Denticula	++	++	++
Diatoma	#	#	#
Epithemia	-	+	+
Fragillaria	++	++	++
Gomphonema	+	++	+
Nevicula	#	#	#
Pinnularia	+	+	
Chlorella	#	#	#
Closterium	++	++	++
Cladophora	++	#	++
Hydrodictyon	++	++	++
Microspora	++	++	++
Spirogyra	#	#	#
Ulothrix	++	#	++
Vaucheria	++	++	++
Cyanophyceae			
Gonantozygon	-	+	+
Chlorella	#	#	#
Losterium	+	++	++
Cladophora	++	#	++
Hydrodictyon	++	++	++
Microspora	++	++	++
Spirogyra	#	#	#
Ulothrix	++	#	++
Vaucheria	++	++	++
Cyanophyceae			
Anabaena	+	+	+
Microcystis	+	+	+
Nostoc	+	+	+
Oscillatoria	+	+	+

+: Reported, ++: Abundant, #: Dominant

magnesium showed significant relationship to plankton production. Bloom of cyanophycean algae in the lake is an obvious sign of cultural eutrophication which is basically caused by addition of sewage effluents (Horne and Goldman, 1994). In many temperate lakes, the maxima of phytoplankton abundance and blooms were detected in summer (Maeda *et al*., 1992) or in spring and summer (Talling and Parker, 2002). Nutrient limitation is also an important factor for phytoplankton abundance in shallow freshwater lakes (Scheffer, 1998; Hubble and Harper, 2002; Hirose *et al*., 2003). Phytoplankton abundance was limited by the concentration of nitrogen rather than by the concentration of phosphorus (Stockner and Shortreed, 1998).

Physico-chemical parameters and quantity of nutrients in water play significant role in the distributional patterns and species composition of plankton. In aquatic habitat, the penetration of light, temperature, salinity, pH, hardness, phosphates and nitrates are the important factors for growth and density of phytoplankton, on which zooplankton and high consumer depend for their

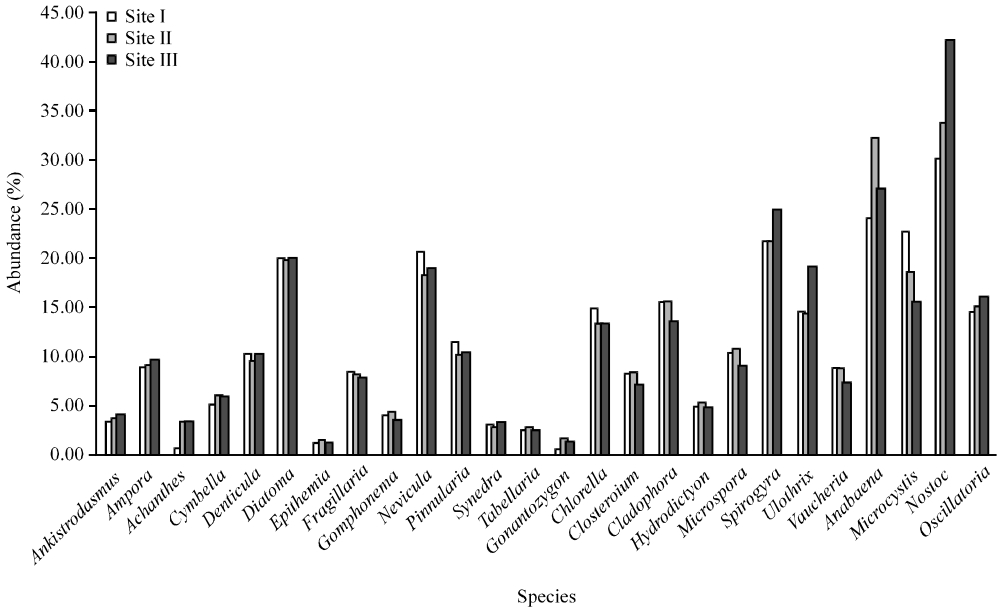

Fig. 1: Percentage abundance of species in all three sites in the Nainital lake

existence (Mahar *et al.*, 2009). Al-Hassan (2001) studied the quality of water in the regulating lake of Mosul dam and concluded that the nutrients concentration (Phosphate and nitrate) increased to the limits developed the algal growth and led it to eutrophic state.

Ariyadej *et al.* (2004) studied phytoplankton diversity and its relationship to the physic-chemical environment of Banglang reservoir of Yala Province and opined that phytoplankton diversity increases with increased nutrient concentration. They also reported that when the nutrient concentration reached up to 3.5 mg L^{-1}, the phytoplankton density also accelerated and diversity index (H') increases from 2.985 up to 3.875 but no such relationship was recorded in Nainital lake, where the reverse trend was reported in summers with low phosphate concentration and high diversity index. Xavier *et al.* (2007) studied eutrophication and phytoplankton dynamics of two man made lakes of Portugal and concluded that higher phytoplankton density is responsible for the eutrophication of lake water. In the present investigation, maximum density of phytoplankton was recorded more in Nainital lake as compared to Bhimtal lake which is found to be in the state of eutrophication.

Al-Tayyar *et al.* (2008) studied some environmental features of phytoplankton in Mosul Dam lake and reported that the lake is undergoing cultural eutrophication on the basis of algal abundance with bacillariophyta having maximum number of 1400 cells mL^{-1} and chlorophyta with 550 cells mL^{-1}. Rouf *et al.* (2008) have studied the temporal changes in the algal communities in drowned tropical forest reservoir and lake in Malaysia and reported the bacillariophyceae as the dominant group. Similar observations were made during the present study with bacillariophyceae as a dominant group in both the lakes under investigation.

CONCLUSION

The study exhibited no definite monthly pattern of species richness, evenness and diversity. While dominance is relatively high during winter seasons. The results indicated no significance relationship between individual of abiotic factors on species.

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