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RESEARCH ARTICLE

Effect of climate changing pattern on phytoplankton biomass in Bhimtal lake of Kumaun Himalaya

D. S. Malik and Shikha Panwar

Department of Zoology & Environmental Sciences, Gurukula Kangri University, Haridwar (Uttarakhand) India.

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Corresponding Author

D. S. Malik

ABSTRACT

Climate changes are recognized as important environmental regulatory factors to assess the primary productivity in relation to changing pattern of abiotic and biotic characteristics in lake ecosystem. Bhimtal Lake is the largest lake approximately 85.26 ha among all Kumaun lakes in Uttarakhand. The comparative data of last twenty years of Bhimtal lake catchment basin revealed that air temperature has been increased 1.5 to 2.1 °C in summer, 0.2 to 0.8 °C in winter, relative humidity increased 4-6% in summer and rainfall pattern changed erratically in rainy season. The surface water temperature of lake showed an increasing pattern as 0.8 to 2.6 °C, pH value decreased 0.2 to 0.5 in winter and increased 0.4 to 0.6 in summer and dissolved oxygen level showed a decreasing trend as 0.4 to 0.7 mg/l in winter. The lake ecosystem productivity mainly depends upon the phytoplankton species composition and their biomass as primary producers in the food web cycle. The changing pattern of phytoplankton indicated that biomass of Chlorophyceae and Bacilleriophyceae families were decreasing as 1.99 and 1.08% respectively in Bhimtal lake. The biomass of Cynophyceae was increasing as 0.45% and contributing the algal blooming in summer season. The phytoplankton species composition exhibited their correlationship with pH, water temperature, dissolved oxygen and other nutrient parameters of lake water. The present research paper emphasized on the effects of climatic variables on phytoplankton biomass in Bhimtal lake of Kumaun region. The present research will be contributed significantly to assess the current change status of ecosystem productivity of Bhimtal lake with different time scale.

INTRODUCTION

Climate change is recognized as an ecological threat on biological productivity of aquatic ecosystem. Climate can be considered the major factor determining the distribution of species at a continental scale (Pearson and Dawson, 2003). Small variations in climate can have ecological and biological effects on biota, especially in extreme habitats at the limit of their environmental tolerances. Lakes, being fragile ecosystems are vulnerable to continuous changing pattern of climate since two decade. Long term climate change and large scale climate fluctuations are a crucial attribute of global climate change, and a wide range of studies have shown links between fluctuations in climate and ecological processes that affect phytoplankton dynamics (Behrenfeld *et al.*, 2006; Paerl and Huisman, 2008).

Climate change driven physical fluctuations exert strong impacts on aquatic ecosystems because climate is modifying the abiotic and biotic environment. Phytoplankton forms a highly diverse group of aquatic microorganisms and contributes as vital source of energy through primary producers, serves as a direct source of food to the other biotic organisms. Phytoplankton are the initial or primary biological component from which the energy is transferred to higher organisms through food chain (Boyd, 1982; Rajesh *et al.*, 2002) and the abundance and species composition of phytoplankton in an aquatic ecosystem are regulated by many physico-chemical factors such as pH, light, temperature, salinity, turbidity and nutrients (Buzzi, 1999; Veereshakumar and Hosmani, 2006).

Climate directly affects light, turbulence and water temperature of lakes and influences the phytoplankton productivity because of changes in these factors, indirect effects are of climate change on lakes are grazing because if zooplankton biomass is enhanced in warmer water this will lead to a reduction in the phytoplankton biomass. The most significant climatic effects on phytoplankton species composition will very likely be mediated through changes in thermal stratification patterns such as the extent of the growing season and vertical mixing processes (Schindler *et al.,* 1996; Rodriguez *et al.,* 2001; Diehl *et al.,* 2002; Smol *et al.,* 2005).

Phytoplankton dynamics are linked to annual fluctuations of temperature, water column stratification, light availability and consumption (Sommer *et al.,* 1986; Claern, 1996). Changing climatic conditions can modify these environmental factors and alter phytoplankton species composition, morphology, physiology and biomass. Interaction between climate and phytoplankton are complex and synergistic because other factors such as resource availability, density dependence and predation strongly control the abundance, distribution and size structure of the community. Impacts of climate change on phytoplankton are mainly manifested as shifts in seasonal dynamics, species composition and population size structure. Several factors are known to affect phytoplankton species coexistence at a local scale, such as productivity (Leibold, 1996), nutrient supply ratios (Tilman, 1982; Sommer,1993) and under water light climate (Huisman *et al.,* 2004, Stomp *et al.,* 2007).

The present study has focused on changing patterns of meteorological data since two decade based on calculation of change detection in air temperature, relative humidity and rainfalls in and around Bhimtal lake. The ecological dynamics of Bhimtal lake are changing due to many natural and anthropogenic attributes and exhibited the changing pattern of phytoplankton biomass and their distribution in Bhimtal lake as on long term effects. The present research paper emphasized the change variations of climate factors and their affects on ecological and biological variables specially phytoplankton biomass of Bhimtal lake ecosystem to denote the present trophic and ecosystem productivity status.

MATERIAL AND METHODS

Bhimtal Lake is situated between 29°21’ N latitude and 79°24’ E longitude in the Kumaun region of Indian sub-continent. Bhimtal Lake is the largest lake approximately 85.26 ha surface area in all Kumaun lakes and located at a distance of 22 km from Nainital. The lake is warm monomictic under subtropical region. The morphometric characteristics of Bhimtal lake are depicted in Table 1. The meteorological observations were recorded regularly by digital weather monitoring station. The lake water samples for physico- chemical analysis were collected at monthly intervals from different sampling sites from the Bhimtal lake (Fig. 1).

Surface plankton’s were collected using conical hand plankton net with a specimen tube of 10 ml capacity. The collected samples were filtered through Whatman No. 44 filter paper. The filter paper was carefully washed free of the phytoplankton specimens. The phytoplankton organisms were counted using the haemocytometric technique following Stephens and Gillespie (1976). The phytoplankton abundance data for each sampling date and for all species are expressed as (1) number of plankton units, (2) total cell numbers, and (3) total volume (live weight biomass). All species were counted in terms of single units whether colonical (*Dictyosphaerium, Pediastrum*) or solitary species (*Ankistrodesmus, Synedra*), and these are defined as the plankton units. A record was kept of the mean number of cells per plankton unit in each species, and in this way total cell numbers were calculated. The dimensions of the counting units were measured in each sample. The average cell volume per morphological unit was computed by assuming an appropriate geometric shape (Vollenweider, 1969 and Edler, 1979). The cell volume was assumed to be occupied by protoplasm and liquid having a specific gravity near 1.0 (Nauwerck, 1963) and was converted on this basis to wet biomass. Phytoplankton were identified as followed by Palmer (1972), Needham and Needham (1978) and Edmondson (1992). Past research data of meteorological, physico-chemical and biological parameters were collected from other ecological research workers and cited in different research papers (Pant *et al.,* 1983,1985,1987; Kanwal and Pathani 2012) and different research organizations i.e. ARIES, Nainital; Taser research institute Bhimtal and Directorate of cold water fisheries research (DCFR) at Bhimtal.

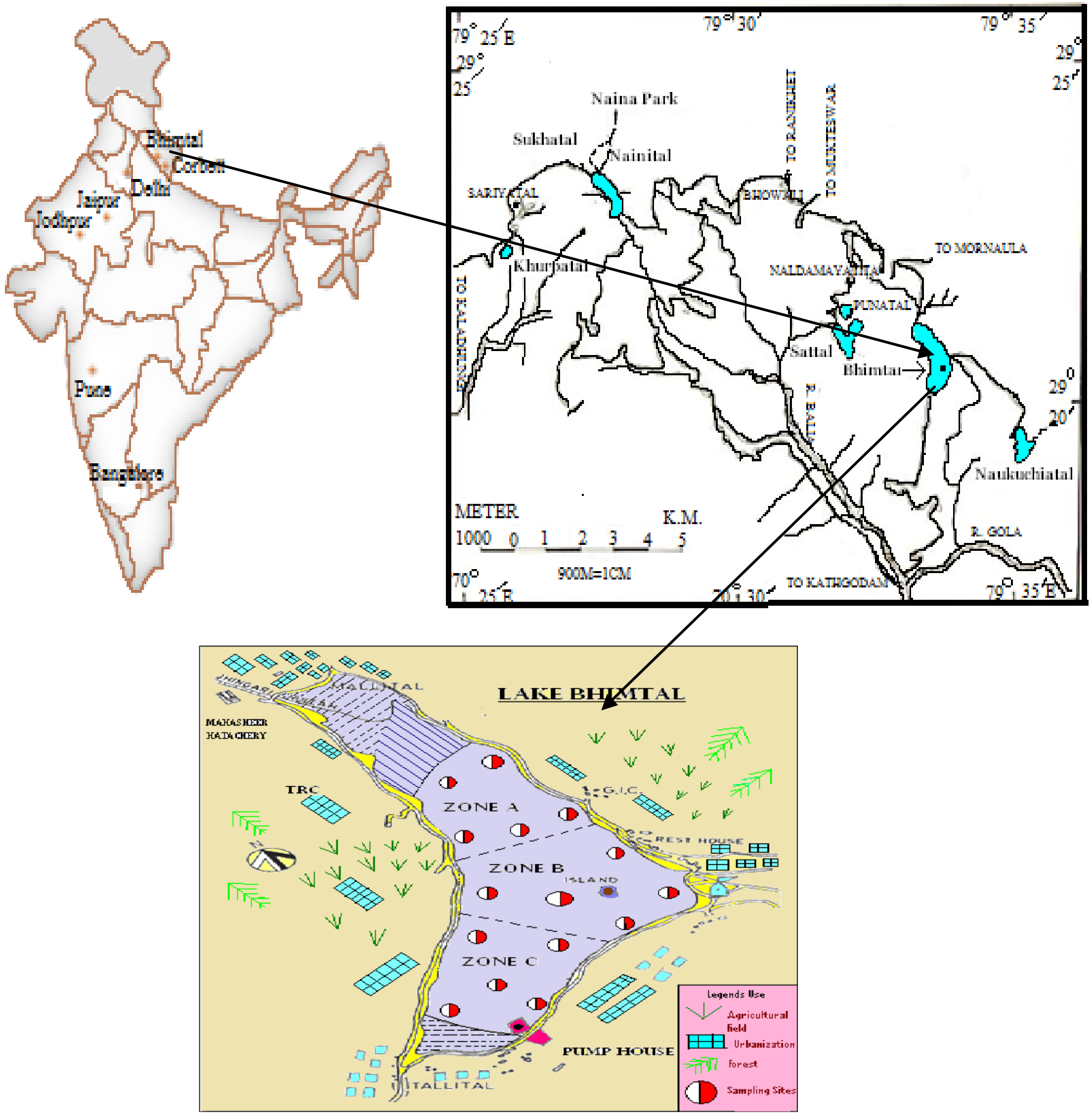


Fig. 1: Map showing geographical position and sampling stations in lake Bhimtal.

RESULT AND DISCUSSION

Bhimtal lake ecosystem is very vulnerable to climate change on particular geographic scale in Indian subcontinent. The climate changing pattern has contributed significantly to alter or change the magnitude of physical, chemical and biological characteristics of lake ecosystem. The Bhimtal lake is warm monomictic and mesotrophic nature due to its thermal stratification and nutrient accumulation as the inflow of organic substances as mentioned by Hutchinson (1967). The climate of Bhimtal lake is comparatively warmer than at the other lakes in the Kumaun region due to its place between the temperate and tropical geographical position. The Bhimtal lake attitudinally has been reflected the characteristics of the temperate and latitudinal that of the tropical region. The relationship of climate changing patterns among different atmospheric attributes contributed significantly to alter water quality, ecological and biological characteristics of Bhimtal lake (Fig.4). The changing pattern of meteorological and physico-chemical characteristics of Bhimtal lake were recorded and depicted in Table 2 & 3.

Temperatures in lake ecosystems are closely coupled to air temperature (Meisner *et al.*,1988; Boyd and Tucker,1998) .Thus, it is obvious that an increase in air temperature is expected to be followed by similar increase in water temperature. The maximum and minimum temperatures were recorded in June and January respectively.

Climate –driven changes in the physical and chemical characteristics of a lake induce taxon-specific responses of phytoplankton, as well as other organisms (Moss *et al.,* 2003; Adrian *et al.,* 2006; Thackeray *et al.,* 2008). The surface water temperature of Bhimtal lake showed an increasing pattern as 0.8°C to 2.6 °C in last twenty years. Since two decades, air temperature has been increased 1.5 to 2.1 °C in summer, 0.2 to 0.8 °C in winter in and around Bhimtal lake of Kumaun region. Similar changing trends of air temperature were also recorded in other catchment basins of lower Kumaun regions by Pathani (1995), Mahar (2002), Bhatt and Pathak (1992).Temperature directly affects plant metabolism, which consists of both photosynthetic and respiratory activity, while metabolic rates of primary producers are primarily limited by photosynthesis (Dewar *et al.,* 1999). Thus, increases in water temperature due to climate change will result in increased oxygen demand and can also increase the productivity of lake by increasing algal growth, bacterial metabolism and nutrient cycling rates (Ficke *et al.,* 2005). Since the 1960, epilmnion of many lakes around the world has warmed by 0.2°C to 2°C and the hypolimnion (which reflects long-term trends) has increased by 0.2 to 0.72 °C (IPCC, 2001). According to Melack (1979), the temporal variations of phytoplankton in lakes are related to differences in rainfall. With this consideration, the Bhimtal lake which receives sufficient erratic rainfall and associated runoff from hilly terrains during July to September months results in enhanced concentration of suspended sediment, inorganic substances and dissolved organic matter, which in turn impacts the volume of plankton species diversity and productivity of Bhimtal lake in lesser Himalayan region**.**

The phytoplankton have contributed significantly to produce the oxygen level to sustain the life cycles of all biotic communities in lake ecosystem. Dissolved oxygen is most significant factor for growth of nutrients, water quality assessment and important regulator of metabolic processes of organisms and community as a whole in lake ecosystem (Hutchinson, 1967). Dissolved oxygen is governed by photosynthetic activity and aeration rate (Gautam *et al.,* 1993). A minimum acceptable level is considered to be 5 mg/l dissolved oxygen in lake water (Ellis *et al.,* 1946). In the present study, dissolved oxygen level showed a decreasing trend as 0.4 to 0.7 mg/l in Bhimtal lake since last twenty years. The low level of dissolved oxygen in Bhimtal lake during summer months, reflects richness of organic matter, which consumes large amount of dissolved oxygen in the process of decomposition. The surface water were saturated with dissolved oxygen throughout the year except during winter at Mallital zone of Bhimtal lake. Additionally, increases in amount of dissolved CO_2 would result into higher rates of photosynthesis. In past twenty years, the pH value decreased 0.2 to 0.5 in winter and increased 0.4 to 0.6 in summer in Bhimtal lake. Wani and Subla, (1990) reported that the pH values above 8.0 in natural waters are produced by photosynthetic rate that demands more carbon di oxide than quantities furnished by respiration and decomposition.

In last twenty years, BOD showed increased with a rate of 0.76mg/l in summer season by the presence of nitrites and nitrates in Bhimtal lake water by domestic liquid wastes entering through the inlet at mallital zone of lake. The nitrate value increased 0.02 to 0.03mg/l in winter season during the last twenty years and lower concentration of nitrate in summer was due to utilization by plankton and aquatic plants. Similar trends of seasonal variation of nutrients were recorded in other lakes by Kannan, (1978). Nitrate content in natural waters is likely to vary due to imput of nutrient concentration of domestic as well as municipal liquid waste. The increase could be correlated with a decline in phytoplankton biomass in the lake during winter season. As phytoplankton deplete, the utilization or uptake of NO_3-N is also reduced. In present study, the analyses of NO_3-N contents revealed a definite pattern of seasonal fluctuation starting with peak 0.072mg/l in winter season (Jan.-Dec.) and then declining to the least 0.068mg/l during rainy season in Bhimtal lake. Phosphate is one of the limiting factors for phytoplankton productivity, because of geochemical shortage of phosphate in drainage basins. Low phosphate may be attributed to locking up of phosphate in dense phytoplankton and macrophytic vegetation (Wani *et al.,* 1990). During plankton multiplication automatically phosphate concentration is decreased (Moss *et al.,* 1989). Phosphate was observed as high 0.035 mg/l in summer season and minimum level 0.019 mg/l during winter, 2012. and showed the change value of phosphate in increasing order between 0.01-0.02 since last twenty year in Bhimtal lake (Table 2 & Fig. 2).

The diversity of phytoplankton in lake ecosystem serves as a reliable productivity index for its trophic status on biological scale. The present study shows that Bhimtal lake occupied the good number of species composition of different groups of phytoplankton and phytoplankton group consisted of the assemblage of diatoms, green algae, blue green algae etc. The richness and availability of phytoplankton in Bhimtal lake was exhibited by about 50 species recorded earlier by different research scientists (Pant, 1983; Sharma *et al.,* 1982; Malik, 2012). The various factors such as rainfall, light, temperature, nutrients (Particularly PO_4^- and nitrogen-nitrate) were observed to play the important roles in the periodicity of phytoplankton and their species richness. The species-wise dominance was in order of Chlorophyceae (28 species), Bacillariophyceae (12 species), Cynophyceae (7 species), Dinophyceae (2 species) and Chryesophyceae (1 species). The dominant genera recorded were *Closterium, Staurastrum, Pediastrum, Scenedesmus, Ceratium, Peridinium, Melosira, Fragilaria, Synedra and Cymbella. Chlorophyceae* family were mainly constituted by *Clostridium sianensis, C. humicola, Chlamydomonas*. The temperature and plankton biomass production showed positively correlated with the similar trends as continuous change detection. The percentage of phytoplankton groups and their biomass in Bhimtal lake in different seasons from the period 1993 to 2012 were represented in table 4 & 5 and Fig.3**.** Diatoms represented Chlorophyceae and Bacilleriophyceae were decreased as 1.99 and 1.08% respectively in Bhimtal lake. Tripathy and Panday (1990) reported that high water temperature, phosphate, nitrate, low DO and CO_2 supported the growth of Chlorophyceae and Diatoms in lakes. In Bhimtal lake, Dinophyceae and Chryophyceae were decreasing as 0.18% and 0.25%. respectively and biomass of cynophyceae was increasing as 0.45% with contributing algal blooming in summer season. The dominance of green algal occurred in winter months (November to January). There is evidence that some phytoplankton species are physiologically vulnerable to temperature spikes. Dinoflagellates reached very high values concerning biomass contributing 90% respectively to the total phytoplankton standing stock. This could be another ecological and seasonal variable for the decrease the phytoplankton biomass in the Bhimtal lake. The diatoms occurred in fluctuating numbers at a temperature range of 14 to 29°C and optimum growth of diatoms were observed between 21°C and 29°C exhibited the category of temperate form of meso-euro thermic ecosystem of Bhimtal lake. Sharma et al (1982) observed the least value of dinoflagellates biomass ($<10\mu gl^{-1}$) in Bhimtal lake. Disappearance of dinoflagellates and their replacement by blue greens exhibited the eutrophic status. In the present study, a temperate range of 23-27°C of water temperature appeared to be the most favorable for the growth of the blue green algae. Contrary to number, phytoplankton biomass was high in low temperature during winter season in Bhimtal lake. Certain aspects of phytoplankton community of some Kumaun lakes have been studied by Sharma *et al.,* (1982); Pant *et al.,* (1983). While analyzing the changing trends of the phytoplankton as per the observed data of the last 20 years in Kashmir lakes by Zutshi *et al.,* (1980), the cholorophycean taxa have been decreased while as cyanophycean taxa showed increased trends in Kashmir lakes. Domis *et al.,* (2007) suggested that cyanophytes densities have been increased following a temperature rise, where as chlorophytes and diatoms will not benefit from warming effects of climate. Singh (1968) stated that temperature, pH, alkalinity have been emphasized to be significant factors for controlling distribution of cyanophyceae but blue-green algae contributed insignificantly in lakes. The peak density of *volvocales* coincided with high alkalinity and pH (Rao, 1955).

In aquatic ecosystem, calculating phytoplankton biomass are significantly important for determining ecological status. In Bhimtal lake, the total phytoplankton biomass was observed high in summer, low in winter and varied in between 0.50-50.30mg/m^3. Based on classification system of Vollenweider (1969) as ultra-oligotrophic:<1g/m^3,mesotrophic:3to 5g/m^3,highly eutrophic:>10g/m^3 . Bhimtal has moderate amount of nutrients and categorized as a mesotrophic lake due to consistent accumulation of high nutrients level and remained increased trends of phytoplankton biomass (5.2-7.3 g/m^3) as an indication towards eutrophication of ecological characteristics of Bhimtal lake.

The present observations revealed that the relationship of climate changing patterns among different atmospheric attributes contributed significantly to alter water quality and biological characteristics of Bhimtal lake. The long term effects of changing pattern of climatic conditions contributed as a change or shift phytoplankton species composition and their biomass in Bhimtal lake. The present ecological and nutrient dynamics in Bhimtal lake has showed that trophic status is changing towards eutrophication under subtropical condition .The present research paper emphasized the interrelationship of climatic variations with phytoplankton characteristics denoted that primary production of Bhimtal lake is decreasing continuously and indicated an ecological alarm for the survival of higher groups of faunal diversity in Bhimtal lake of Kumaun Himalaya.

Table 1: Morphometric characteristics of Bhimtal lake.

Parameters	**Observations**
Altitude (m)	1332
Longitude	79°34’E
Latitude	29º21’N
Length(m)	1915.5
Width(m)	486.5
Mean Depth(m)	17.9
Surface area (ha)	85.26
Catchment area (Km^2)	11.70
Shoreline (m)	4025
Volume of water (m^3)	4064.9

Table 2: Changing pattern of Meteorological parameters of Bhimtal lake (Period 1993 to 2012).

Parameters/Season	**1993**	**2002**	**2012**	**Change value**	**Changing pattern**
Air Temp. (°C)					
Summer	25.6	26.2	27.3	1.7	Increase
Rainy	25.2	25.6	27.7	2.5	Increase
Winter	13.2	13.2	13.8	0.6	Increase
Humidity (%)					
Summer	62.3	56.5	54.9	-7.4	Decrease
Rainy	89.6	92.3	98.2	8.6	Increase
Winter	61.5	58.0	63.2	1.7	Increase
Rainfall (mm)					
Summer	51.6	51.4	22.1	-29.5	Decrease
Rainy	550.9	493.7	472.1	-78.8	Decrease
Winter	00	0.6	41.2	40.6	Increase

Table 3: Changing pattern of Physico-chemical parameters in Bhimtal lake (Period 1993 to 2012).

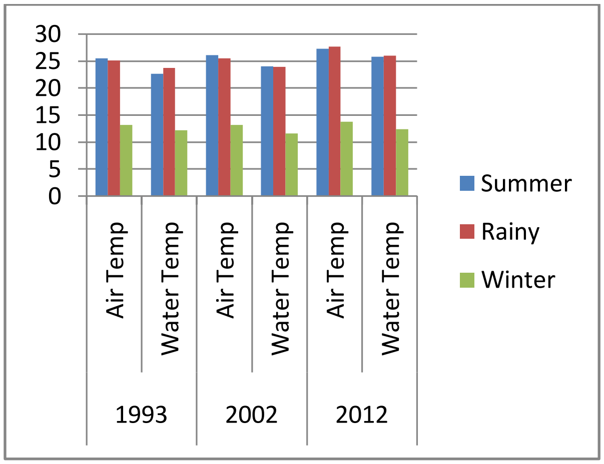
Parameters/Season	1993	2002	2012	Change value	Changing pattern
Water Temp. (°C)				3.2	
Summer	22.7	24.1	25.9	2. 3	Increase
Rainy	23.8	24.0	26.1	0.2	Increase
Winter	12.21	11.60	12.40		Increase
pH					
Summer	8.8	8.6	8.4	-0.4	Decrease
Rainy	8.7	8.7	8.9	-	No change
Winter	7.5	7.4	7.7	0.2	Increase
Dissolved Oxygen (mg/l)					
Summer					
Rainy	10.2	9.9	9.6	0.3	Decrease
Winter	9.9	9.8	9.4	0.4	Decrease
	10.5	10.2	9.9	0.3	Decrease
BOD (mg/l)					
Summer	3.45	3.94	4.21	0.76	Increase
Rainy	2.45	3.02	3.10	0.65	Increase
Winter	2.45	2.84	3.02	0.57	Increase
Nitrate Nitrogen (mg/l)					
Summer					
Rainy	0.048	0.052	0.080	0.01	Increase
Winter	0.045	0.052	0.068	0.01	Increase
	0.050	0.054	0.072	0.02	Increase
Phosphate (mg/l)					
Summer	0.018	0.028	0.035	0.02	Increase
Rainy	0.012	0.017	0.025	0.01	Increase
Winter	0.008	0.010	0.019	0.01	Increase

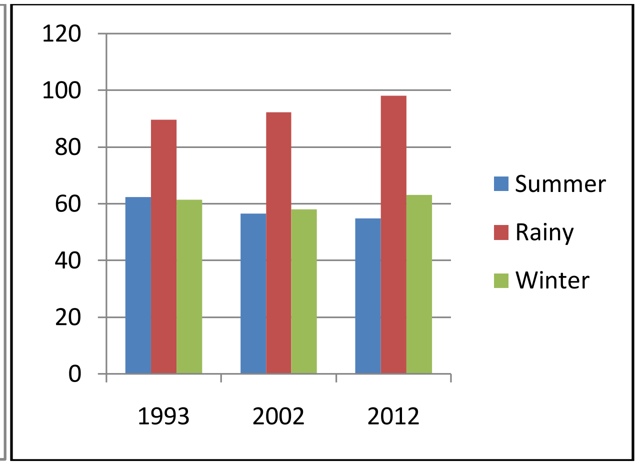
Table 4: Distribution of Phytoplankton biomass in different seasons of lake Bhimtal.

Name of groups	Phytoplanktonic Biomass (mg/m^3)									Changing pattern
	1993			2002			2012			
	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	
Chlorophyceae	220	180	270	210	178	237	210	158	218	Decrease
Bacillariophyceae	108	78	112	11 2	70	113	115	76	105	Increase
Dinophyceae	2858	2465	2132	3854	3362	3058	6083	5164	6032	Increase
Chryophyceae	42	43	43	44	45	40	45	41	47	Increase
Cynophyceae	24	20	18	22	21	16	50	17	21	Decrease
Total	3252.7	2787.3	2435.7	4850.6	3685.1	3466.1	7181.1	5476.3	6450.3	Increase

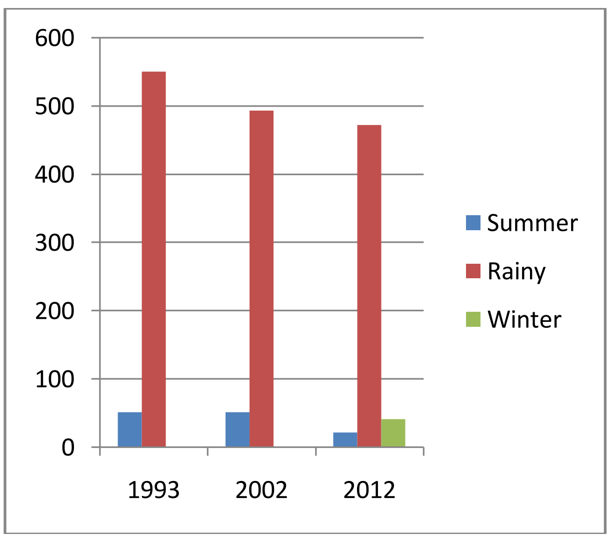
Table 5: Percentage of phytoplankton groups in different seasons from the period 1993 to 2012.

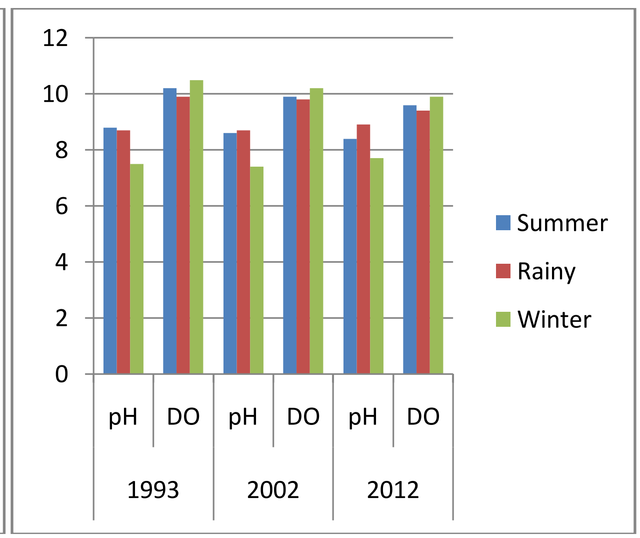
Name of Groups	**1993**			**2002**			**2012**			**Changing pattern**
	Summer	**Rainy**	**Winter**	**Summer**	**Rainy**	**Winter**	**Summer**	**Rainy**	**Winter**	
Chlorophyceae	46.92	46	45.82	45.29	46.21	47.01	45.01	48.66	47.31	Decrease
Bacilleriophyceae	33.68	34.2	34.98	33.48	34.00	33.20	32.6	30.98	29.66	Decrease
Dinophyceae	14.3	13.58	13.02	13.91	14.74	13.88	14.12	14.28	14.09	Decrease
Chryophyceae	3.45	3.26	3.02	3.21	3.69	3.14	3.05	3.00	4.08	Increase
Cynophyceae	1.56	2.00	1.9	1.25	1.69	2.01	1.95	2.04	2.08	Increase



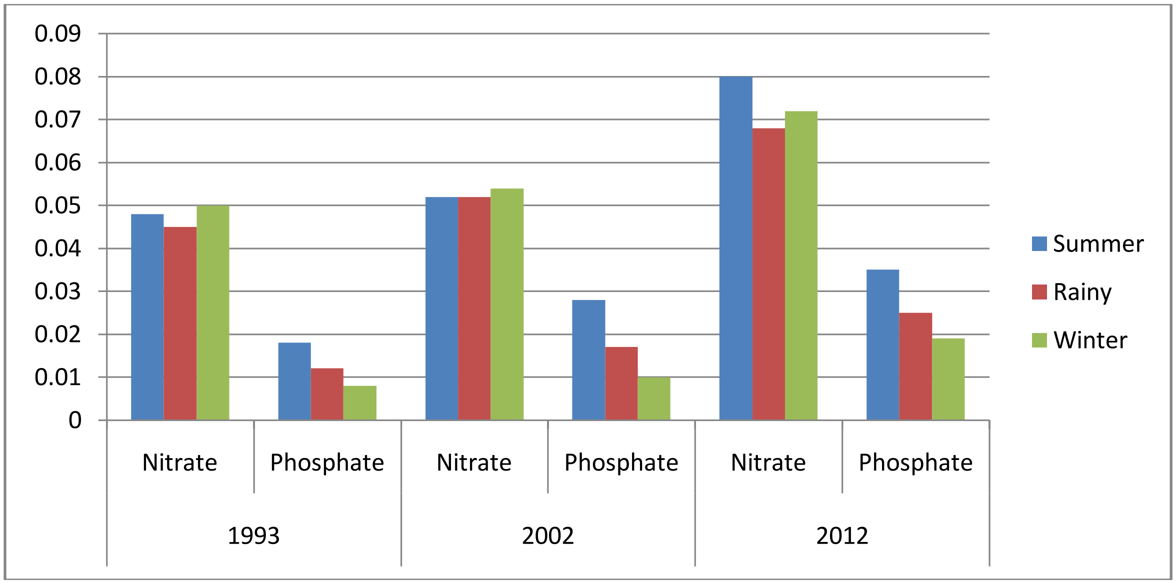


(a) Temperature **(b)Humidity**





(c) Rainfall **(d) pH & DO**



(e) Nitrate & Phosphate

Fig. 2. Seasonal variation in some physico-chemical parameters (a - e) in Bhimtal lake.

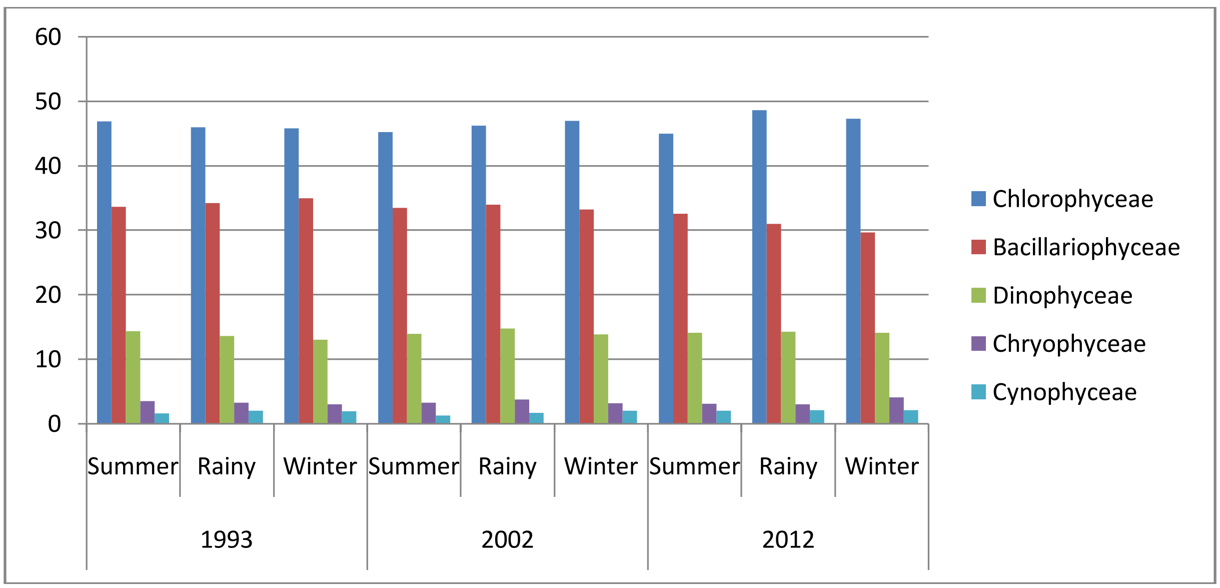


Fig. 3. Seasonal variation of phytoplankton groups in Bhimtal lake.

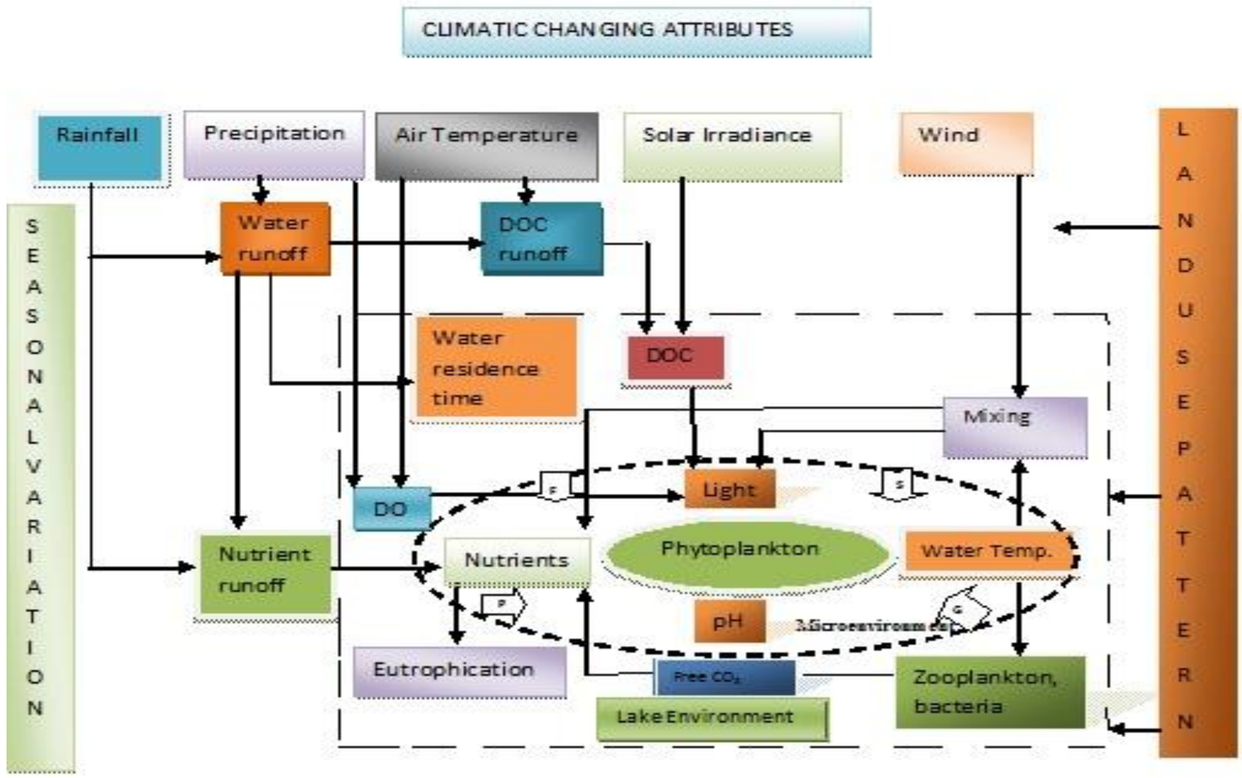


Fig. 4: Flow Chart showing the relationships of climate changing attributes with ecological characteristics in lake ecosystem.

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