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Water quality and its impact on phytoplankton diversity: A case study of tehri reservoir, Garhwal Himalayas

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Abstract

Water quality parameters play an important and major role in determining the diversity of phytoplankton in any aquatic ecosystem. The present study was conducted to measure the correlation between various physico-chemical parameters and phytoplankton assemblages structure in selected zones of the Tehri reservoir. Results of the present study clearly showed an increased concentration of some physico-chemical parameters i.e. total dissolved solids, turbidity, and electric conductivity during the monsoon season which has a contrary influence on the density of phytoplankton. The multi correlation was also calculated between important physico-chemical parameters and phytoplankton density. Dissolved oxygen showed a very high positive correlation with phytoplankton diversity. It was also observed that during the monsoon season, a high load of sediment in the reservoir area affects the growth of phytoplankton and also decrease their number. Canonical Correspondence Analysis (CCA) was calculated between some important water quality parameters and dominant taxa of phytoplankton which indicated the direct influence of various physico-chemical parameters on diversity and distribution of phytoplankton in Tehri reservoir at Garhwal Himalayas.

Keyword Phytoplankton, Water quality, Tehri reservoir, and Garhwal Himalayas.

Introduction

Phytoplankton are micro, free-floating, unicellular colonies that produce photo-autotrophically in aquatic environments. Phytoplankton play a crucial role in the primary production and global nutrient cycles in any aquatic ecosystem (Malik, *et al.*, (2018) Kumar, *et al.*,(2019) Kamboj *et al.*, (2020)) by making up the main producers. They are present mainly on the upper part of the water column, down to the limit of penetration of light. The assemblage structure and abundance of the phytoplankton populations are mostly controlled by various water quality parameters and inorganic nutrients (Sharma *et. a.*, 2018). Phytoplankton are very sensitive towards changes in their ecosystem and respond quickly to any disturbance caused, thus plankton species are used as indicators of water quality (Malik *et al.*, 2020). Phytoplankton are also important in maintaining the food chain as a primary

food supply source in any aquatic ecosystem. They are the primary source for the transfer of energy to higher organisms through the food chain (Saifullah *et al.*, 2014). The physico-chemical parameters are the key factors for controlling the dynamics and assemblage structure of the phytoplankton of the freshwater ecosystem (Kumar *et al.*, 2018). Different changes and disturbances in water quality in freshwater ecosystems cause a significant impact on the population dynamics of phytoplankton species. Cyclical disparities in these parameters have an imperative role in the distribution, periodicity, quantitative, and qualitative composition of freshwater biota. Physico-chemical parameters and phytoplankton diversity of any water body are interrelated and often obsessed by the surrounding land use and land cover pattern that determine the quality of water at point sources that enter the freshwater streams (Chang, 2002).

Nutrient also plays significant role in the distributional decoration and species composition of phytoplankton (Malik *et al.*, 2018., Malik *et al.*, 2020).

Materials and Methods

The Tehri Dam is one of the tallest dams in India. The Tehri reservoir is constructed for multi-purposes i.e. irrigation, water supply for municipal activities, and mainly for the generation of hydroelectricity. The geographical coordinates of the dam site are 30° 22' 40" N and 78° 28' 50" E longitude. Four sampling zones in the Tehri reservoir were selected due to different ecological conditions. Monthly sampling was undertaken between 07:30 to 10:30 a.m. from the depth of 10 to 20 cm during a period of one year from September 2018 to August 2019, representing three seasons (winter season mainly November–February), summer season (March–June) monsoon season (July–October). The water temperature was determined with the help of a digital thermometer (Testo 1113-TMH), pH was measured in-situ by using a pen-type meter (HANNA = HI98107). Dissolved oxygen, total dissolved solids (TDS) were analyzed by using standard methods (APHA, 2012 and Trivedi and Goel., 1992). For phytoplankton analysis, one liter of sample water was collected and filtered through silk plankton net of mesh size 20 µm and was immediately preserved in opaque sample bottles containing 4% formalin solution for analysis by using the Sedgwick Rafter counting cell. Karl Pearson’s correlation coefficient was performed using Microsoft Excel 2007 to determine the relationship between the various physico-chemical attributes and different phytoplankton assemblages. Canonical Correspondence Analysis (CCA) was performed using Paleontological Statistics (PAST, Version 3.06) Software to determine the relationship between dominant phytoplankton taxa and physico-chemical parameters. Dominant phytoplankton species were selected based on density (individuals L⁻¹).

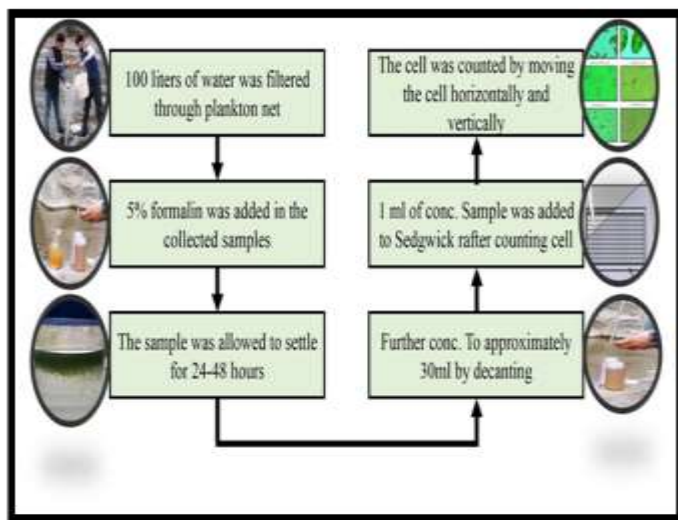


Fig. 1 Procedure for Plankton estimation

Calculation

$$\text{No. of plankton / ml} = \frac{\text{No. of organism counted}}{\text{No. of replicates taken}}$$

$$(\text{Plankton/l}) = \frac{(a \times 1000)c}{L}$$

Where,

- n = no. of plankton/ liter of water
- a = Average number of plankton in one small counting chamber of S-R cell
- c = ml of plankton concentrates
- I = volume of original water filtered in liter

Identification of phytoplankton species

From the concentrated sample, the permanent slides of the phytoplankton was prepared. The permanent slides were placed under a digital microscope and identification was done by using 10X, 20X, 40X and 100X resolution. The images of the phytoplankton species were captured by using a digital camera. Later on, the phytoplankton was identified by (Edmondson, 1959) and (Needham and Needham, 1978).

Diversity Indices

For the data of species, diversity indices were calculated using the Shannon-Wiener Index (1949).

$$(H) = \sum_{i=1} \left(\frac{n_i}{N} \right) \text{Log}_2 \left(\frac{n_i}{N} \right)$$

Where,

- H’= Shannon Diversity Index,
- n_i = Total no of individuals of the species
- N = Total no of individuals of all species

Species Evenness

$$(J') = H' / H'_{\text{max}}$$

Where

- H’= number of derived from the Shannon diversity index
- H’_{max} = maximum possible value of H’.

(If every species was equally likely, equal to:

$$H'_{\text{max}} = \sum_{i=1}^S \frac{1}{S} \ln 1/s = \ln S.$$

Simpson's Diversity index

$$(D) = \frac{\sum n(n - 1)}{N(N - 1)}$$

Where,

n = total number of organisms of a particular species

N = total number of organisms of all species

Results and Discussion

In the present investigation Physico-chemical factors viz. water temperature, pH, Total dissolved solids, DO, and BOD was estimated to check the water quality (fig. 2 to 7).

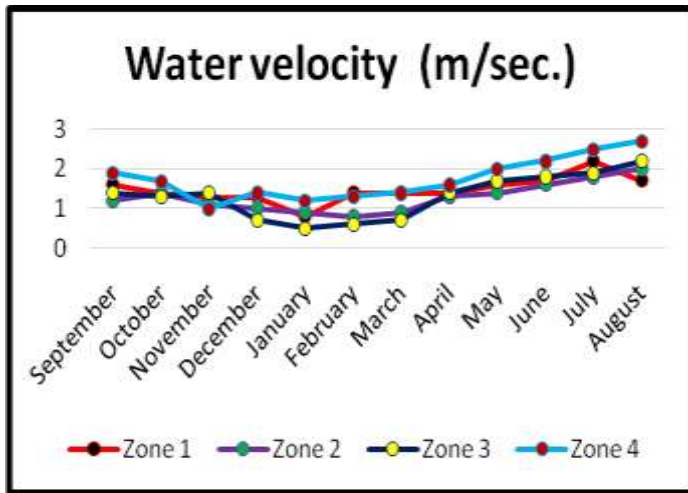


Fig. 2 Monthly variation in water velocity of the selected sampling zones

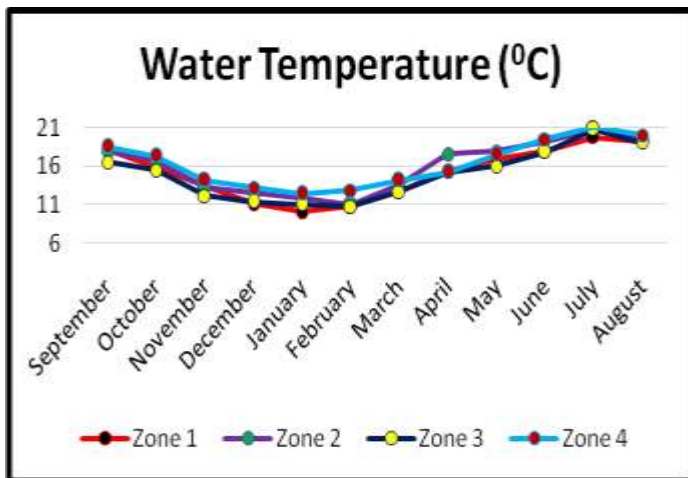


Fig. 3 Monthly variation in water temperature of the selected sampling zone

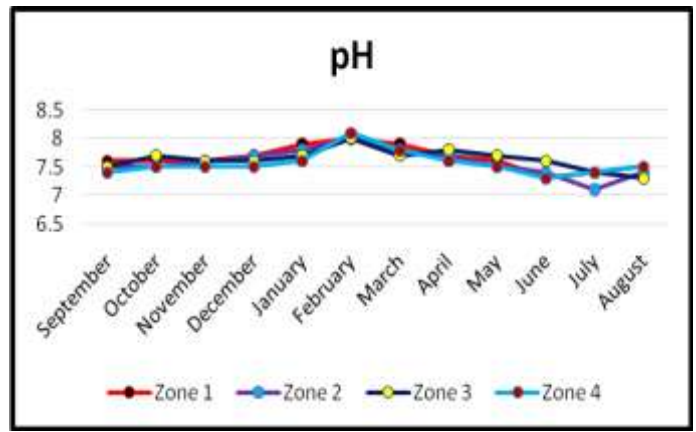


Fig. 4 Monthly variation in pH of the selected sampling zone during 2018-2019

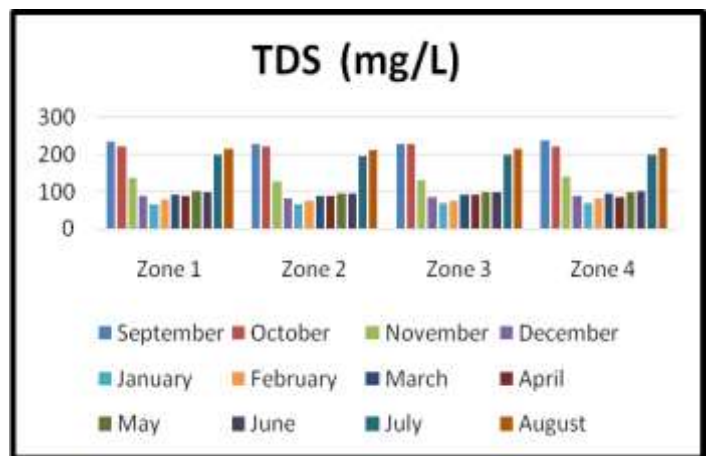


Fig. 5 Monthly variation in TDS of the selected sampling zones during 2018-2019

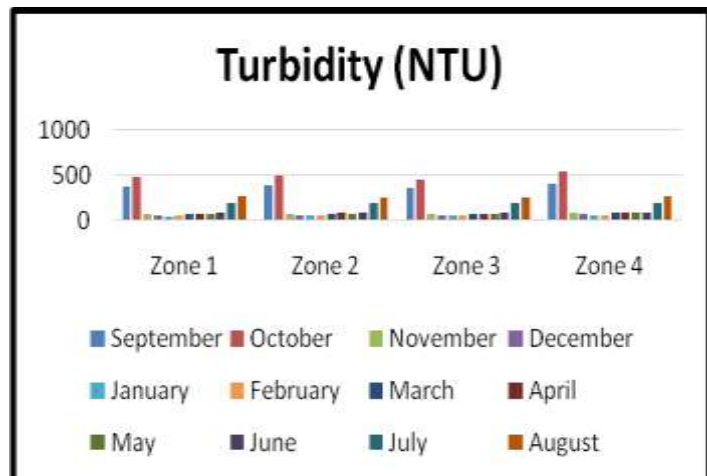


Fig. 6 Monthly variation in turbidity of the selected sampling zones during 2018-2019

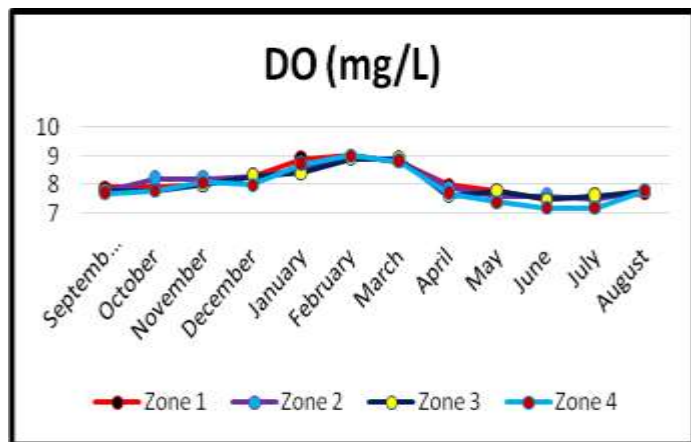


Fig. 7 Monthly variation in DO of the selected sampling zones during 2018-2019

Statistical analysis of important water quality parameters that causes a direct impact upon the distribution and ecology of various phytoplankton diversity in the Tehri reservoir was done (Fig. 8). Monthly field survey and sampling was carried for the collection of physicochemical samples and phytoplankton species inhabiting the Tehri reservoir during the period of one year from September 2018 to August 2019. Seasonal fluctuation of phytoplankton was observed at selected sampling zones (Fig. 9). Water temperature is an important factor in any aquatic environment affecting biological processes. The water temperature plays an important role in the solubility of gases and salt and also controls the physical, chemical, and biological qualities of the aquatic ecosystem. In the present study, water temperature recorded ranged from 10.9 ± 0.14 to $21.2 \pm 1.5^\circ\text{C}$.

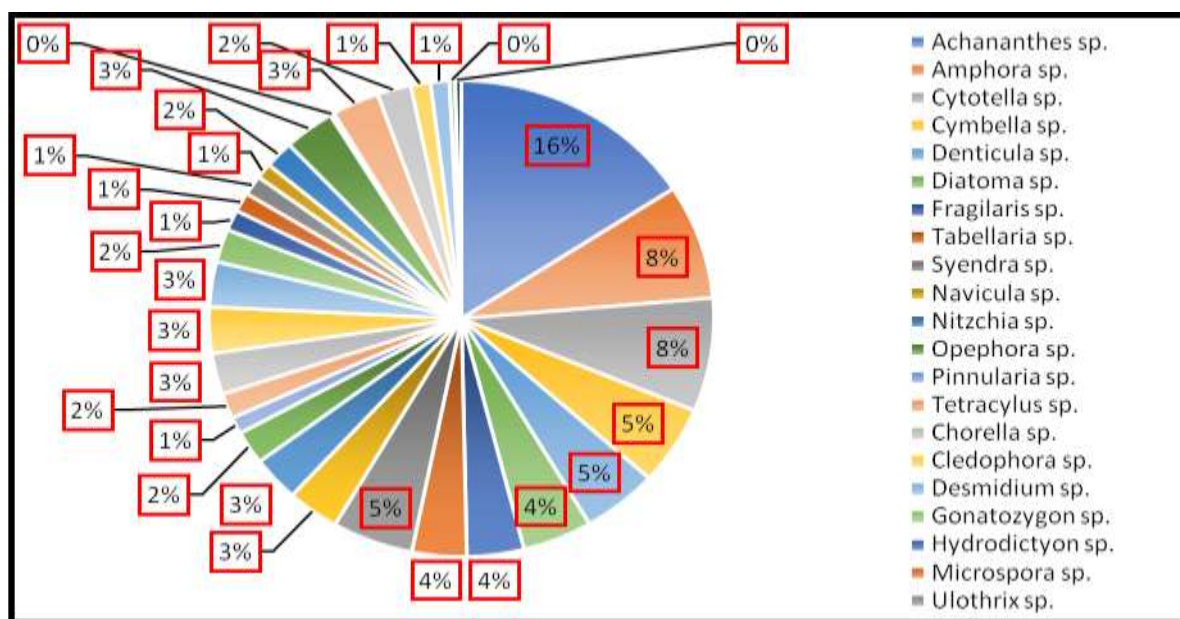


Fig. 8 Temporal and spatial abundance of phytoplankton species at Tehri reservoir

Minimum water temperature was recorded $10.9 \pm 0.14^\circ\text{C}$ at Zone 1 during January where the maximum water temperature was found $21.2 \pm 1.5^\circ\text{C}$ at Zone 3 during July, it can be due to the direct relationship between bright sunshine, its duration, and air temperature. The observed variation in water temperature may be due to the clear sky besides high air temperature. The maximum water temperature was noticed in the summer season and the minimum in the winter season at all sampling zones. The maximum water temperature in the summer season was recorded because of the low water level, high air temperature, and clean atmosphere. pH is the chemical indicator of the alkalinity of any aquatic ecosystem. Maximum values of pH were observed in February during the winter season and minimum values of pH were recorded in June and July during the monsoon season. In the present study annual average values

of pH at selected sampling zones varied between 7.2 ± 0.21 to 8.2 ± 0.25 due to the availability of many types of carbonates and bicarbonates in water enhance dissolve carbon dioxide level by dissociation and acts as a raw material for photosynthesis. Minimum values of total dissolved solids were recorded from January during the winter season from all sampling zones. Maximum values of total dissolved solids were observed during the monsoon season in August at all sampling zones. Whereas annual average values of total dissolved solids ranged between 63.7 ± 3.24 to 235 ± 2.21 mg/l. (Mishra *et al.*, 2003) observed total dissolved solids ranged between 32 mg/l to 299 mg/l in river Ganga and the similar trend was also observed (Sharma *et al.*, 2018; Kamboj and Kamboj, 2020; Kamboj *et al.*, 2020; Malik *et al.*, 2020). Electrical conductivity is a total concentration of salts present in the water body.

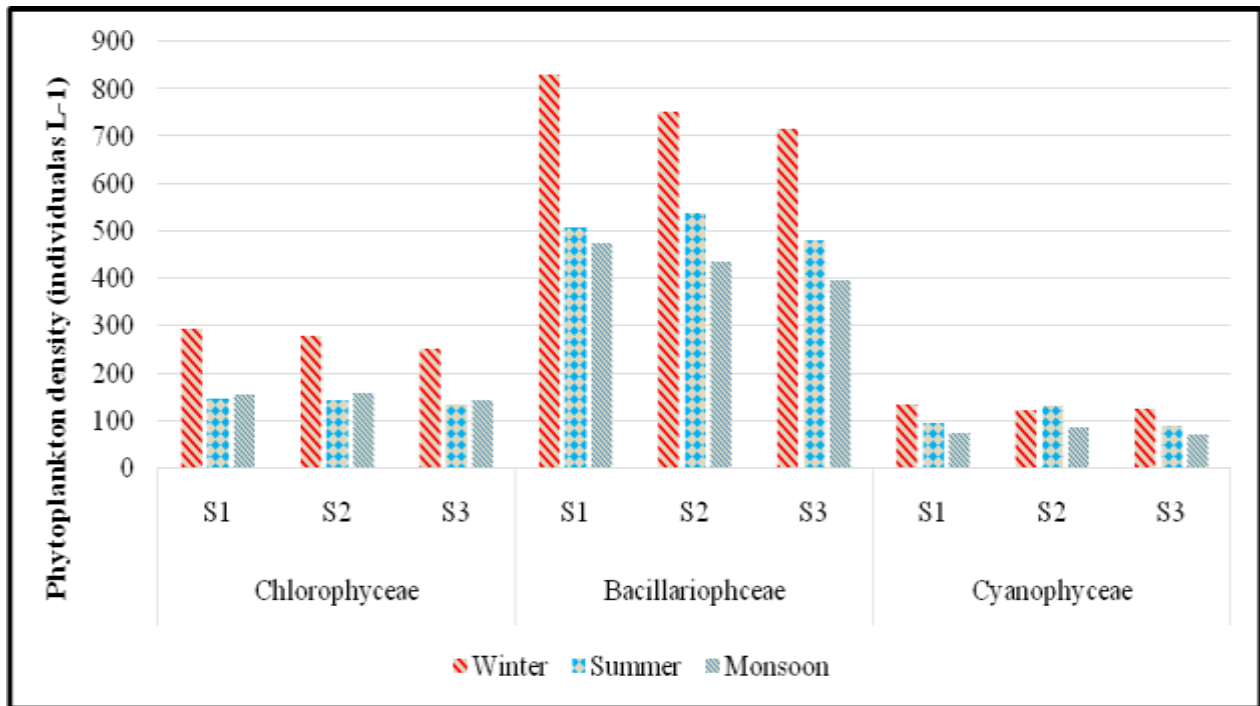


Figure 9: Major group and density of phytoplankton (annual mean) at different study zones

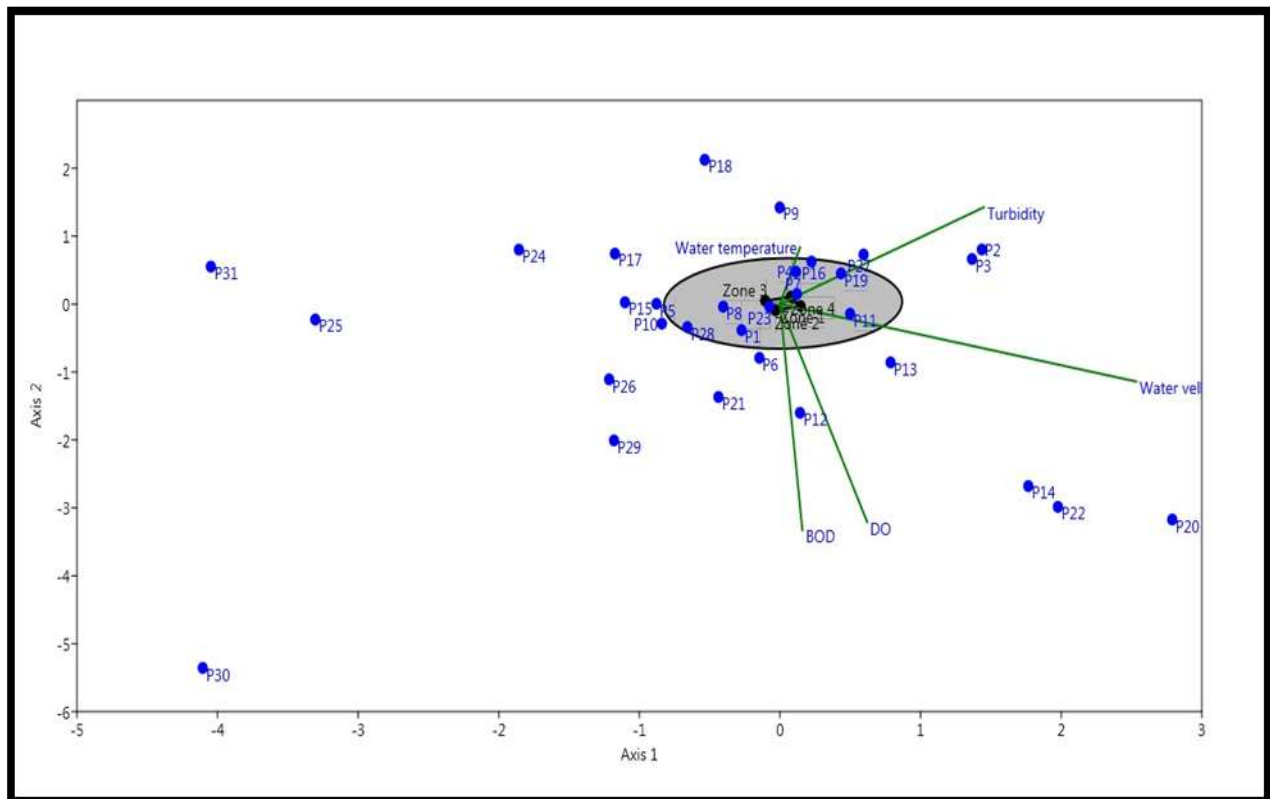


Fig. 10 CCA biplot between physico-chemical parameters and phytoplankton species

Freshwater bodies in their natural state have very low conductivity values, whereas polluted water showed higher values of conductivity (Trivedy *et al.*, 1985). In the present study, the Electrical conductivity of the Tehri reservoir was

ranged as 109.0 ± 0.2 to $369.8 \pm 0.78 \mu\text{mhos/cm}^2$ during 2018-19. The maximum EC value was recorded in the monsoon season at zone 3, because of the high influx of nutrients through the inlet and the minimum value was recorded in the

winter season at Zone 1. A similar trend about the electric conductivity was also reported by (Badola and Singh, 1981) and (Dobriyal *et al.*, 1985) in the hill streams of Garhwal Himalaya. Dissolved oxygen helps to measure the present oxygen levels for all water bodies and the productivity of aquatic systems (Wetzel, 1983). Dissolved oxygen is an important environmental parameter that decides the ecological health of a reservoir and protects aquatic life (Chang, 2002); (Kamboj and Kamboj, 2020). On an annual average basis, maximum (9.20 mg/l) dissolved oxygen was recorded at S3 and minimum (9.02 mg/l) at S2. High dissolved oxygen was recorded during the winter season at all the zones. It may be due to the high photosynthetic rate of phytoplankton communities in clear water that results in higher values of dissolved oxygen (Sharma and Rathore, 2000; Ravindra *et al.*, 2003). Higher dissolved oxygen in the winter season and lower oxygen in monsoon were also recorded in the Ganga river (Sharma *et al.*, 2019) and also in the Bhagirathi River reported by (Malik *et al.*, 2018). In the present study, the BOD value has fluctuated between $1.0 \pm 0.30 - 2.06 \pm 0.90$ mg/l during 2018-19. The highest value of BOD was observed in the summer season due to high temperature favors microbial activity, while the lowest during the winter season in all the sampling zones. A similar observation was reported by (Bhadra *et al.*, 2005) in the Ganga river basin.

Phytoplankton Community

Thirty-one genera of phytoplankton were recorded in the Tehri reservoir represented by five groups, Bacillariophyceae (14 genera), Chlorophyceae (11 genera) Myxophyceae (4 genera), Euglenophyceae (1 genera) and Xanthophyceae (1 genera). Maximum density (984 N/L) of phytoplankton was observed at S1 and minimum (134N/L) at S3 (Fig. 2). The maximum number was counted for *Achananthes sp.* (876 individuals) and minimum for *Chlamydomonas sp.* (13 individuals) which are 16.012% and 0.238% of total individuals respectively. The dominant genera of Bacillariophyceae were recorded as *Achananthes sp.*, *Amphora sp.*, *Cytotella sp.*, *Cymbella sp.*, *Denticula sp.*, *Diatom sp.*, and *Syendra sp.*, recorded at selected sampling zone. The dominant genera of Chlorophyceae were recorded as *Chorella sp.*, *Cledophora sp.*, *Desmidium sp.* *Closterium sp.*, *Gonatozygon sp.* and *Spirogyra sp.* present at selected sampling zone. The maximum density of phytoplankton was recorded during the winter months (January–February) in the Tehri reservoir (Fig. 8 and Fig. 9). It starts declining from March onwards and attains the lowest peak during July–August (monsoon months). Again, phytoplankton showed an increase in their density in the post-monsoon season and attains peak in the winter season (Fig. 9). Malik *et al.*, (2018) also reported a high density of phytoplankton during the winter months in Bhagirathi River, Garhwal Himalayas. The environmental health of a particular aquatic ecosystem depends upon spatial–temporal distribution, species composition, relative abundance, and biomass of phytoplankton (Khattak *et al.*, 2005). It was revealed from the present study that phytoplankton abundance showed the same trend between different sites while phytoplankton

compositions were different at all three sites. This may be due to variations in water quality between different sites (Patrick, 1977). The highest 0.9413 Simpson index (1-D) was found at zone 3 and the lowest 0.9377 was found at zone 1. Higher 0.9502 Simpson index (1-D) values were found in June were the lowest 0.938 during February. The highest 3.128 Shannon index (H) was found at zone 2 and the lowest 3.054 was found at zone 4. Higher 3.196 Shannon index (H) values were found in July were the lowest 2.992 in March. The highest 0.7365 evenness value was found at zone 2 and the lowest 0.6874 was found at zone 4. The highest 0.7944 evenness value was found in June and the lowest 0.713 in February.

CCA analysis of species abundance and water parameters

The results obtained from the first two axes were plotted (Fig. 10). The vector length of a given variable indicates the importance of the variable in CCA analysis and the longest vector of water temperature showed significant correlation with zone Z3. Vector length of dissolved oxygen showed significant correlation with zone Z2 and Z3 where water velocity showed a significant relation with zone Z1. High values of water temperature are positively correlated with

Table 1. CCA biplot scores of physico-chemical parameters and phytoplankton species

	September 2018 to August 2019			
	Axis 1	Axis 2	Axis 1	Axis 2
P1	-0.302	-0.316	P22	0.315
P2	1.855	0.458	P23	-0.151
P3	1.130	-0.141	P24	-1.757
P4	0.452	0.881	P25	-2.794
P5	-0.829	-0.249	P26	-1.368
P6	-0.158	-0.524	P27	0.929
P7	0.106	-0.026	P28	-0.790
P8	-0.071	-0.261	P29	-0.676
P9	0.140	1.742	P30	-4.402
P10	-0.373	1.271	P31	-3.857
P11	0.487	-0.781	Zone 1	0.141
P12	-0.596	-0.489	Zone 2	-0.047
P13	0.280	-0.913	Zone 3	-0.110
P14	-1.203	-0.505	Zone 4	0.120
P15	-1.343	-0.335	Water temperature	0.811
P16	0.265	-0.618	Turbidity	0.618
P17	0.157	-0.070	DO	-0.294
P18	-0.280	1.477	BOD	-0.145
P19	-0.020	1.186	Water velocity	0.633
P20	2.963	-4.810	Eigen value	0.010
P21	-1.036	0.589	Percentage of variance	61.3

Coccolithis sp., *Amphora sp.*, and *Cytotella sp.* High values of DO are positively correlated with *Achananthes sp.*, *Diatoms sp.*, and *Tabellaria sp.* High values of water velocity are positively correlated with *Cledophora sp.*, *Desmidium sp.*, *Pinnularia sp.*, and *Zygnema sp.* High values of BOD are positively correlated with *Syendra sp.*, *Navicula sp.*, *Gonatozygon sp.*, *Hydrodictyon sp.* and *Closterium sp.* Eigen value of axis 1 (0.010) explained 61.3% relationship between environmental parameters and phytoplankton community. Whereas, Eigen value of axis 2 (0.004) explained 23.13% relationship. During 2017-2018, the results were obtained from the first two axis (Table 1).

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Authors' contributions

Amit Kumar Sharma, Vishal Kamboj, Arvind Kumar Sharma, Rishi Thakur and Munish Sharma have contributed significantly to the conception and design of the study, the interpretation of data, drafting and revision of the manuscript. All authors read and approved the final manuscript.

Conflict of Interest

The authors hereby declare no conflict of interest.

Consent for publication

The authors declare that the work has consent for publication.

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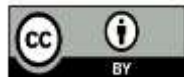
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