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Seasonal Variations of Algae in Relation to the Water Quality at Kingfisher Lake, Central Nepal

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Abstract

Algae can be found in the sea, freshwater and wastewater all around the world. Although the majority is microscopic, some are large. In this study, a total of 44 samples, were collected in two seasons (pre-monsoon and post-monsoon) in the years 2021-2022 from Kingfisher Lake, located in the Bharatpur, Chitwan District. A total of 51 algal species belonging to six classes were recorded. Information on the distribution of algal flora of Kingfisher Lake was collected and the data revealed that the dominant members belong to the classes Bacillariophyceae and Zygnematophyceae, each having 15 species; followed by Chlorophyceae, Cyanophyceae and Euglenophyceae. Similarly, the physico-chemical parameters of water were measured by a digital portable multiparameter (HI98194) in the field. Water temperature was low during post-monsoon season. Electrical conductivity, Total Dissolved Solids (TDS), Oxidation Reduction Potential and Dissolved Oxygen were high in post-monsoon season while the pH of the lake water was alkaline and low pH in post-monsoon season. The number of algal species was found higher in pre-monsoon season than in post-monsoon season. The study showed that the lake is rich in algal species. Presence of the species like *Closterium* sp. and *Oscillatoria* sp. indicate that the lake is eutrophicated and polluted. Thus, further investigations were needed.

Keywords: Algal flora, Physico-chemical, Post-monsoon, Pre-monsoon

Introduction

Algae are a complex and heterogeneous group of organisms characterized by their photosynthetic nature and their simple reproduction mechanisms (Balakrishnan et al., 2014). They can often be found in aquatic (freshwater and marine) as well as certain terrestrial habitats; they can survive extreme environments (light, salinity and temperature). Having a paramount role as primary producers in the ocean and food web, they perform significant ecological functions (capturing carbon, providing habitat, being a part of the food web etc.) (Balakrishnan et al., 2014).

The seasonal fluctuations in algal diversity in any water body is due to differential response of different algal species to changing levels of light, temperature, nutrients etc. with the change in seasons of a year. Any aquatic environment has physico-chemical parameters which greatly influence the biotic component. The occurrence and abundance of these algae varies seasonally and their study provides a relevant focus for research on eutrophication of water bodies and its adverse impact on aquatic life. Study on diversity of algae serves as a useful tool in assessing water quality and understanding the fundamental characteristics of a water body (Gopinath & Kumar, 2015). The changes in physico-chemical parameters and algal community are mainly due to seasonal changes.

Beeshazari Lake and its associated lakes are the open water areas and represent one of the largest freshwater lake complexes in the low land region of Nepal (Pant et al., 2020). Literature regarding the algae of that region is very scanty. Rai et al. 2008 studied desmids from Beeshazari Lake while Roka et al. (2022) studied seasonal variation of algal diversity in response to water quality in Beeshazari Lake only. The present study is aimed to assess the presence of algae in the Kingfisher Lake, one of the associated lakes in Beeshazari lake complex as a water quality criterion with reference to water bodies polluted by various anthropogenic activities.

Materials and Methods

Study area

Kingfisher Lake (27.617105°N latitude, 84.420051°E longitude, 285 m asl) is situated within the buffer zone of the Chitwan National Park. It has 4 ponds named Kingfisher 1, 2, 3 and 4 (Figure 1). This lake falls into one of the associated lakes in Beeshazari lake complex. The lake complex is 15 km away from the Narayanghat Bazar and covers an area of about 32 Km^2, including mosaic of diverse habitats; open water bodies, marshes, swamps, grassland and forest (Pant et al., 2020). Considering the ecological economic and aesthetic importance of the lake complex, it was included in the Ramsar list in 2003 one of the Ramsar site of Nepal in Chitwan district of Central Nepal.

The lake is also used for tourism and some construction projects, such as trail boats, can be found in the area. The main recharge sources of water in the Beeshazari and associated lakes including Kingfisher Lake are the Khageri irrigation canal, rainwater and three major rivers - Narayani, Rapti and Rew with several small lakes, marshy lands and pools.

Climate of the area is subtropical and characterized by two distinct seasons namely summer and winter. The mean maximum and minimum temperature precipitation recorded were 19.8°C and 35.1°C, respectively, despite the fact that this area receives approximately 2000-2500 mm of rainfall per year (Pant et al., 2020). The aquatic macrophytes found in the lake include *Eichhornia crassipes*, *Hydrilla verticillata*, *Nelumbo nucifera*, *Pistia stratiotes*, *Potamogeton* sp. etc.

Sample collection, preservation and identification

Samples for this study were collected two times, during pre-monsoon season (March, 2021) and post-monsoon season (September, 2022). A total of 44 algae samples were collected from shoreline of the lake. The algal samples were collected directly in polythene sampling bottles by handpicking and by squeezing the roots of floating aquatic macrophytes. Each collected sample was preservative-treated with 4% formaldehyde solution (Anderson & Karlson, 2017) immediately after collection, with proper tagging and labeling.

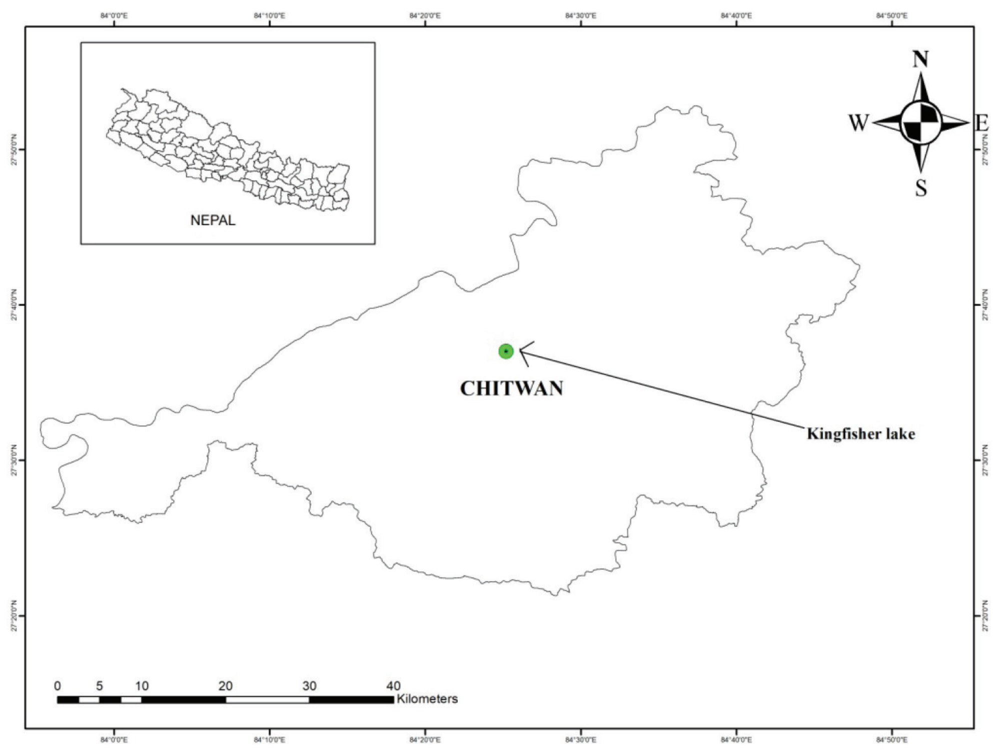


Figure 1: Location map of study site

At the time of collection, the water pH, temperature, dissolved oxygen (DO), conductivity and total dissolved solid (TDS) were determined *in-situ* by an electric kit multi-parameter probe (Hanna Instruments, HI98194). Taxonomic identification upto the species level was carried out with the help of standard books and monographs like Prescott & Scott (1952), Scott & Prescott (1961) and taxonomy was updated using the online database Guiry & Guiry (2022).

Data analysis

Spearman correlation coefficient was calculated to evaluate the relationships between the physicochemical parameters of water and algae. Cluster analysis was used to classify sampling sites (based on physicochemical parameters of water) into groups, where sites in one cluster are more similar in water quality. Data analysis was performed using R software (version 3.2.1) (R Core Team, 2017).

Results and Discussion

Physico-chemical parameters

The physico-chemical parameters differed seasonally (Table 1). Pre-monsoon water temperature was 33.15°C and post-monsoon water temperature was 31.09°C. In both seasons, the pH range showed alkaline. It was recorded maximum (8.26) during pre-monsoon season. Electric conductivity, total dissolved solid (TDS), oxidation reduction potential and dissolved oxygen were high in post-monsoon season. Resistivity and atmospheric pressure were nearly equal in both seasons.

Spearman correlation matrix

The spearman correlation matrix of physico-chemical parameters of water quality in both pre-monsoon and post-monsoon seasons showed that they are independent and not correlated with each other (Table 2 and 3).

Cluster analysis

The result of the cluster analysis showed that the sample plots are divided into four groups (Figure 2). The four groups are categorized according to the similarity and differences of each sampling point with respect to physico-chemical properties of water. Figure 2 showed the details of four clusters but the plot number included in one cluster are different in pre-monsoon and post-monsoon season. With clustering results of hierarchical CA, the centers of four clusters were calculated and sampling plots were classified into four levels. Greater the level, higher the values of physico-chemical properties of water.

Table 1: Physico-chemical parameters of pre-monsoon and post-monsoon season during 2021-2022

Physico-chemical parameters	Seasons	Mean value	Standard deviation (±)
Temperature (°C)	pre-monsoon	**33.15**	1.53
	post-monsoon	31.09	0.74
pH	pre-monsoon	**8.26**	0.056
	post-monsoon	7.33	0.24
Conductivity (s/cm)	pre-monsoon	70.55	1.07
	post-monsoon	**83.22**	0.59
Total Dissolved Solid (mg)	pre-monsoon	35.54	1.84
	post-monsoon	**43**	1.69
Atmospheric pressure (ppm)	pre-monsoon	0.9800	0.0009
	post-monsoon	**0.9830**	0.0012
Oxidation Reduction Potential (mv)	pre-monsoon	93.43	0.50
	post-monsoon	**210.39**	0.16
Dissolved Oxygen (ppm)	pre-monsoon	0.10	0.027
	post-monsoon	**6.36**	1.12
Resistivity (M ohm/cm)	pre-monsoon	0.014	0.0008
	post-monsoon	0.0113	0.0009

Note: Units of physico-chemical parameters are indicated in parenthesis; Bold letter indicates highest values

Table 2: Spearman correlation coefficient (r) of physico-chemical variables in pre-monsoon season

	Temperature	pH	Conductivity	Total dissolved solid (TDS)	Atmospheric pressure	Oxidation reduction potential	Dissolved oxygen (DO)	Resistivity
Temperature	1							
pH	0.13	1						
Conductivity	0.34	0.02	1					
Total dissolved solid (TDS)	-0.20	-0.14	0.10	1				
Atmospheric pressure	-0.28	0.01	0.12	0.45	1			
Oxidation reduction potential	-0.16	-0.16	-0.21	-0.21	0.15	1		
Dissolved oxygen (DO)	-0.18	-0.04	-0.23	-0.06	-0.21	0.37	1	
Resistivity	0.08	-0.02	-0.38	-0.11	-0.22	0.23	0.43	1

Table 3: Spearman correlation coefficient (r) of physico-chemical variables in post-monsoon season

	Temperature	pH	Conductivity	Total dissolved solid (TDS)	Atmospheric pressure	Oxidation reduction potential	Dissolved oxygen (DO)	Resistivity
Temperature	1							
pH	0.07	1						
Conductivity	-0.05	0.17	1					
Total dissolved solid (TDS)	0.3	0.14	0.59	1				
Atmospheric pressure (ppm)	0.01	0.12	-0.23	-0.39	1			
Oxidation reduction potential	0.28	-0.15	0.29	-0.65	-0.3	1		
Dissolved oxygen (DO)	0.31	0.01	0.29	0.059	-0.52	0.52	1	
Resistivity	-0.3	-0.27	-0.31	-0.52	0.44	-0.38	-0.35	1

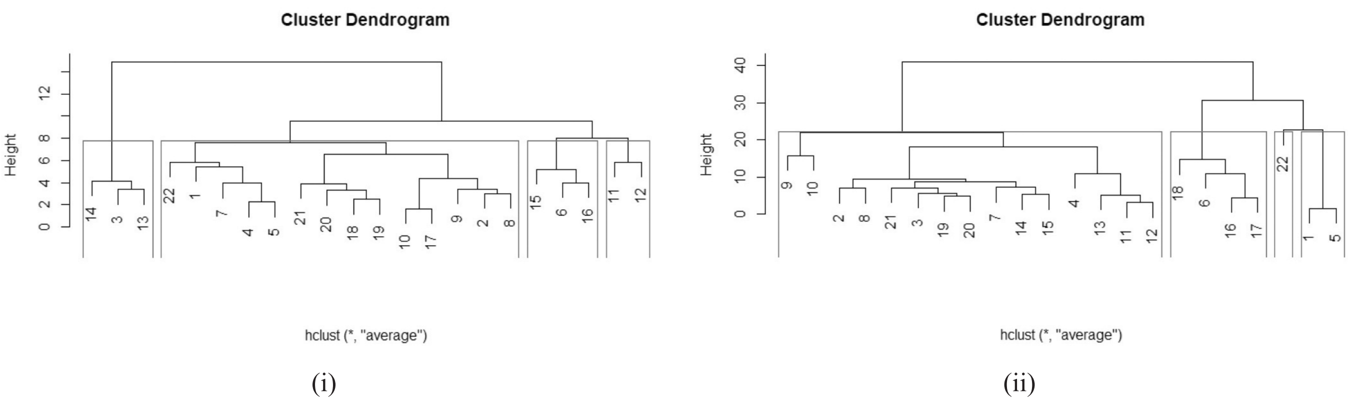
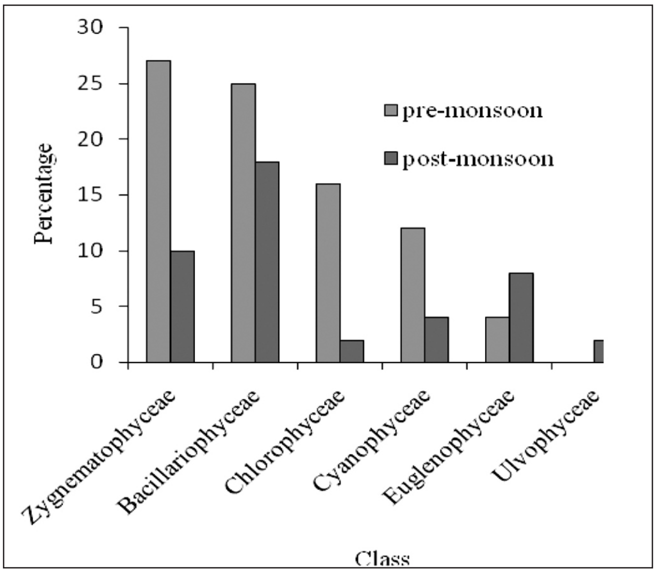


Figure 2: The cluster analysis result of the sampled plots, i) pre-monsoon season, ii) post-monsoon season

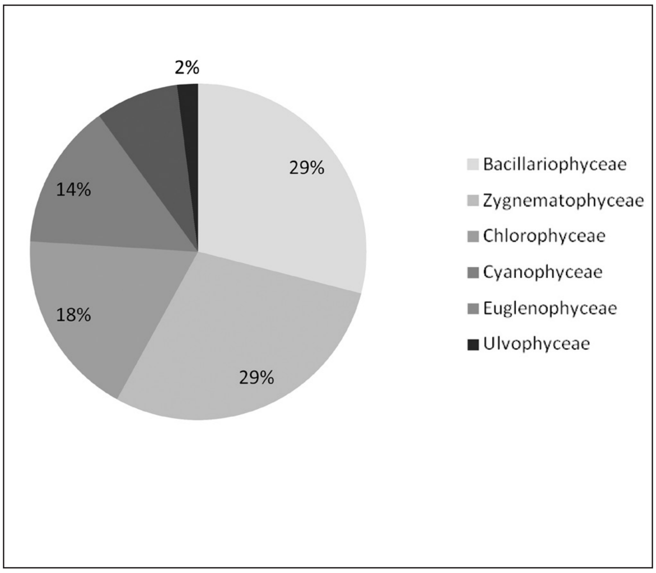
Algal community structure

The observations revealed the dominance of Bacillariophyceae and Zygnematophyceae members followed by Chlorophyceae, Cyanophyceae, Euglenophyceae and Ulvophyceae in Kingfisher Lake in both seasons (Figure 3A). Similarly, dominance of different classes of algal species expressed as the percentage of total species across both seasons were reported as Bacillariophyceae (29%) followed by Zygnematophyceae (29%), Chlorophyceae (18%), Cyanophyceae (14%), Euglenophyceae (8%) and Ulvophyceae (2%) (Figure 3B).

During pre-monsoon and post-monsoon seasons, a total of 51 algal species belonging to 6 classes were recorded from Kingfisher Lake (Table 4). Class Bacillariophyceae and Zygnematophyceae were represented by maximum number of species (15 spp. each) followed by Chlorophyceae (9 spp.), Cyanophyceae (7 spp.), Euglenophyceae (4 spp.) and Ulvophyceae (1 sp.). Number of algal species also varied with seasons. The pre-monsoon season had a higher number than the post-monsoon season. The dominant genera recorded were *Cosmarium* and *Closterium* from Zygnematophyceae and *Oscillatoria* from Cyanophyceae.



A



B

Figure 3: A. Percentage share of each class in pre-monsoon and post-monsoon seasons, **B.** Percentage share of total species across different classes in both seasons

Table 4: List of algae recorded in pre-monsoon and post-monsoon season

S.N.	Name of species	Pre-monsoon	Post-monsoon	Class
1	*Cylindrospermum* sp.	+	-	Cyanophyceae
2	*Lyngbya* sp.	-	+	Cyanophyceae
3	*Oscillatoria princeps* Vaucher ex Gomont	+	-	Cyanophyceae
4	*Oscillatoria* sp.	+	+	Cyanophyceae
5	*Phormidium* sp.	+	-	Cyanophyceae
6	*Scytonema* sp.	+	-	Cyanophyceae
7	*Spirulina* sp.	+	-	Cyanophyceae
8	*Ankistrodesmus falcatus* (Corda) Ralfs	+	+	Chlorophyceae
9	*Coelastrum* sp.	+	-	Chlorophyceae
10	*Eudorina* sp.	+	-	Chlorophyceae
11	*Oedogonium* sp.	+	-	Chlorophyceae
12	*Pediastrum duplex* Meyen	+	-	Chlorophyceae
13	*Pediastrum tetras* var. *tetraodon* (Corda) Hansgirg	+	-	Chlorophyceae
14	*Scenedesmus longus* Meyen	+	-	Chlorophyceae

S.N.	Name of species	Pre-monsoon	Post-monsoon	Class
15	*Scenedesmus quadricauda* Chodat	+	-	Chlorophyceae
16	*Sphaerocystis* sp.	+	-	Chlorophyceae
17	*Actinotaenium* sp.	+	+	Zygnematophyceae
18	*Closterium incurvum* Brebisson	+	-	Zygnematophyceae
19	*Closterium lunula* Ehrenberg & Hemprich ex Ralfs	+	-	Zygnematophyceae
20	*Closterium moniliferum* Ehrenberg ex Ralfs	+	+	Zygnematophyceae
21	*Closterium ralfsii* Brebisson ex Ralfs	+	-	Zygnematophyceae
22	*Cosmarium granatum* Brebisson ex Ralfs	+	-	Zygnematophyceae
23	*Cosmarium impressulum* Elfving	+	-	Zygnematophyceae
24	*Cosmarium javanicum* Nordstedt	+	-	Zygnematophyceae
25	*Cosmarium nitidulum* De Notaris	+	-	Zygnematophyceae
26	*Cosmarium pyramidatum* Brebisson ex Ralfs	+	-	Zygnematophyceae
27	*Euastrum bidentatum* Nageli	+		Zygnematophyceae
28	*Mougeotia* sp.	+	+	Zygnematophyceae
29	*Pleurotaenium* sp.	+	-	Zygnematophyceae
30	*Spirogyra* sp.	+	+	Zygnematophyceae
31	*Staurastrum* sp.	-	+	Zygnematophyceae
32	*Euglena polymorpha* D.A.Dangeard	+	-	Euglenophyceae
33	*Euglena* sp.	-	+	Euglenophyceae
34	*Phacus* sp.	-	+	Euglenophyceae
35	*Trachelomonas* sp.	+	+	Euglenophyceae
36	*Ulothrix* sp.	-	+	Ulvophyceae
37	*Amphora* sp.	+	-	Bacillariophyceae
38	*Cymbella* sp.	+	-	Bacillariophyceae
39	*Eunotia* sp.	-	+	Bacillariophyceae
40	*Fragilaria crotonensis* Kitton	+	-	Bacillariophyceae
41	*Fragilaria* sp.	+	+	Bacillariophyceae
42	*Gomphonema rhombicum* Fricke	-	+	Bacillariophyceae
43	*Gomphonema* sp.	+	+	Bacillariophyceae
44	*Gomphonema sphaerophorum* Ehrenberg	+	-	Bacillariophyceae
45	*Gyrosigma kuetzingii* (Grunow) Cleve	+		Bacillariophyceae
46	*Nitzschia* sp.	+	+	Bacillariophyceae
47	*Pinnularia* sp.	+	+	Bacillariophyceae
48	*Pinnularia viridis* (Nitzsch) Ehrenberg	+	+	Bacillariophyceae
49	*Synedra* sp.	+	-	Bacillariophyceae
50	*Ulnaria* sp.	+	+	Bacillariophyceae
51	*Ulnaria ulna* (Nitzsch) Compere	-	+	Bacillariophyceae

Fluctuations in physico-chemical parameters of water

The pH of the lake water was alkaline (Table 1) and the lower pH in the post-monsoon season might be due to the entry of rain water, sediment and organic matter from surrounding areas, which might have resulted in an increase in respiration and decomposition rate and lowered the pH level. A similar result was reported by Hajong and Ramanujam (2018) in Dachi Lake, Meghalaya. Water temperature was low during post-monsoon season and higher in pre-monsoon seasons were reported by (Chand et al., 2019). Electric conductivity, Total Dissolved Solid (TDS), Oxidation Reduction Potential and Dissolved Oxygen were high in post-monsoon season which could be due to decomposition of organic matter, entry of nutrient and soil particles from adjoining areas of the lake. Boateng and Aboagye (2013) in Amponsah Lake reported high conductivity values in summer and low in winter and explained that the fluctuations in conductivity values were due to variations in the decomposition rate of organic matter. High dissolved oxygen in post-monsoon season might be due to high photosynthetic rate of phytoplankton communities. Low Dissolved Oxygen during the pre-monsoon season was also reported by Tian et al. (2012) in which the rise in temperature led to an increase in the bacterial population and the consumption of atmospheric oxygen.

Seasonal variation of algal diversity in Lake

Altogether, 51 species (Table 4) belonging to six classes were recorded during this study. Higher number of algal species in pre-monsoon season and comparatively lower number of algal species in post-monsoon season could be due to changes in pH and Dissolved Oxygen and entry of runoff from the surroundings. Entry of runoff with organic matter and nutrients prevented the rapid growth of algae (Ghosh et al., 2012). The dominance of different algal classes in this lake was reported as Bacillariophyceae and Zygnematophyceae (29% each), Chlorophyceae (18%), Cyanophyceae (14%), Euglenophyceae (8%) and Ulvophyceae (2%) (Figure 3B). Jyotsna et al. (2015) also observed maximum members of Bacillariophyceae in Karagam Lake, Srikakulam, Andhra Pradesh, India. Similarly, Vyas and Kumar (1968) observed higher Euglenophyceae population in post-monsoon season. The Euglenophyceae, though found in less numbers, showed marked periodicity and abrupt disappearance (Hujare, 2008). In present study, Euglenophyceae members also showed marked periodicity in post-monsoon season. RDA analysis of physico-chemical parameters and algal species (Appendix 2) showed that the algal species were concentrated at the centre of axis and seasonal changes observed in algal number could not be driven by eight physico-chemical parameters measured by multiparameter probe and might be related to micronutrients of water like alkalinity, concentration of phosphate etc. Pokhrel et al. (2021) reported that some algal species were concentrated towards the combined effect of temperature, free CO_2, concentration of phosphate and Dissolved Oxygen.

Genus *Cosmarium* and *Closterium* were dominant in both seasons, possibly because desmids were more prevalent in oligotrophic lakes and ponds and the desmid community thrives in alkaline pH. Desmids are considered as the group of phytoplankton that are very sensitive to environmental changes and their growth is restricted to the eutrophic condition of water (Gayathri et al., 2011). Dominance of pollution tolerant genera like *Closterium* sp. and *Oscillatoria* sp. also supports the view to categorize the lake as eutrophic in nature (Shekhar et al., 2008).

Sample clustering

The physico-chemical properties of water (Figure 2) were used to group samples into different clusters and sub-clusters in both seasons, implying that physico-chemical data were required for this type of study. The PCA diagram (Appendix 1) also supports this result, i.e., physico-chemical variables are not auto-correlated with each other.

Conclusion

This study revealed that Kingfisher Lake is rich in algal flora. The number of algal species were found to be higher in pre-monsoon season than in post-monsoon season. Zygnematophyceae and Bacillariophyceae were the dominant classes. High dominance of the pollution indicator plankton like *Closterium* sp. and *Oscillatoria* sp. suggest that the lake is eutrophicated and organically polluted. If the magnitude of pollution of the lake persists or increases like this, the quality of water and biota of the lake will decline dramatically, posing a major threat to humanity. It is urgently necessary to restore, enhance and manage this priceless lake for the sake of both people and the environment. Additionally, this is a pioneer work conducted in Nepal. So, data collected from only two seasons was not sufficient to determine the richness of algal species. Therefore, monthly studies should be conducted to document the seasonal variation of algae. In addition, resistivity of water adversely affects the presence of algal species in the post monsoon season according to the conducted statistical analysis.

Author Contributions

First author visited the site and prepared first manuscript; second and third authors helped in the identification of the species and provided valuable suggestions in finalizing the manuscript; fourth author prepared the study area map.

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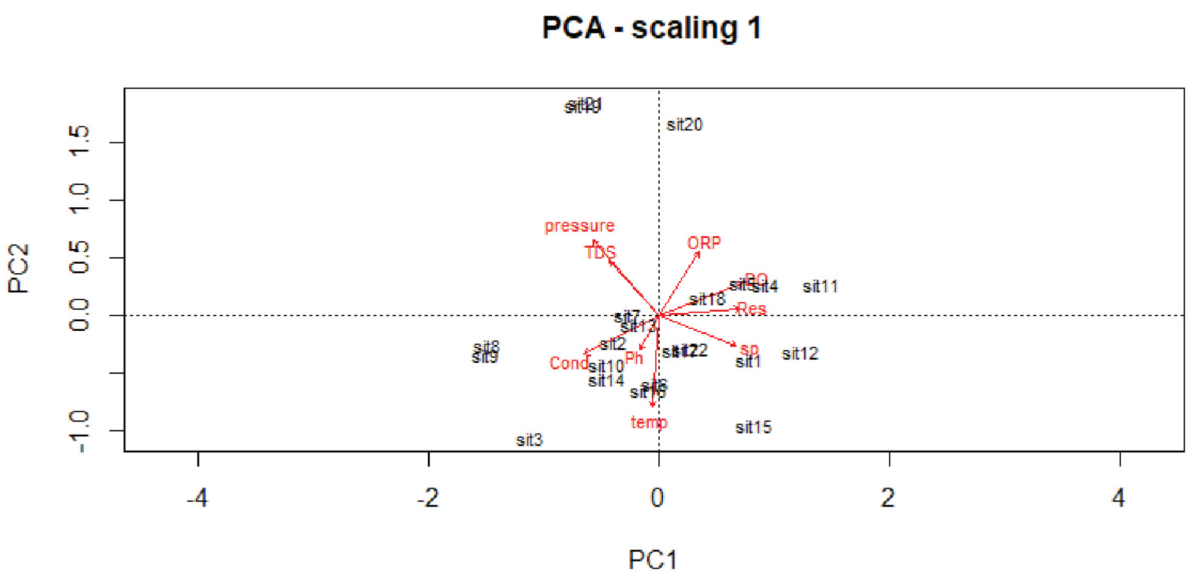
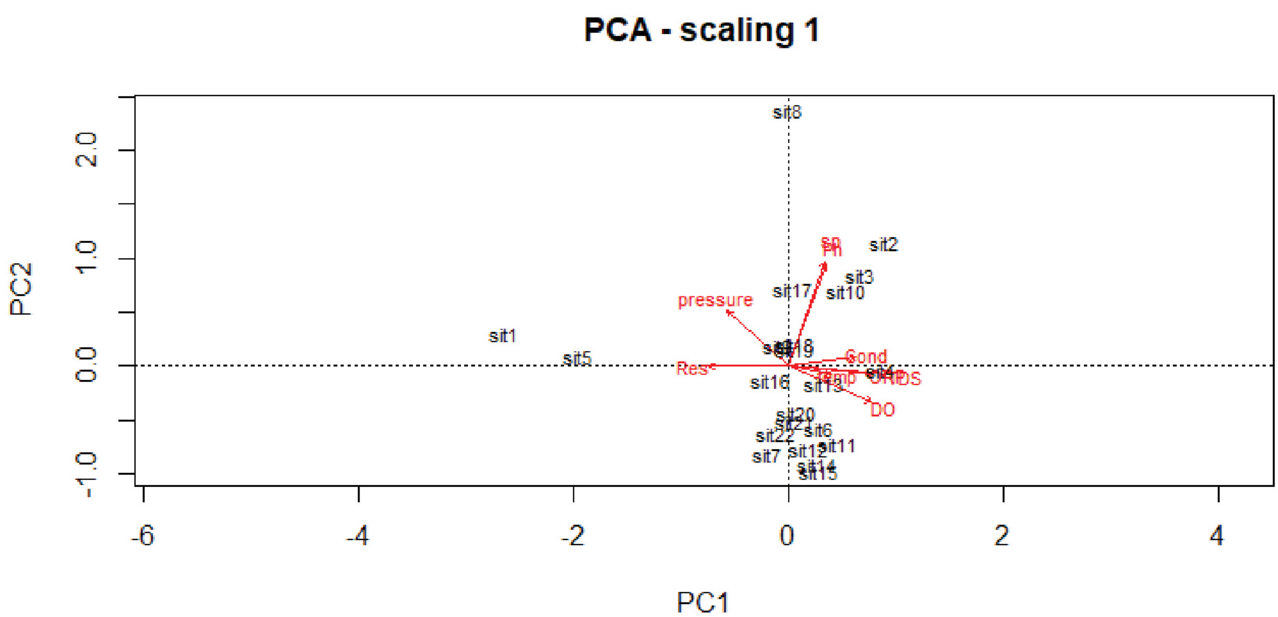
Appendix 1: PCA diagram of physico-chemical variables and sample plots, **A.** pre-monsoon season, **B.** post-monsoon season

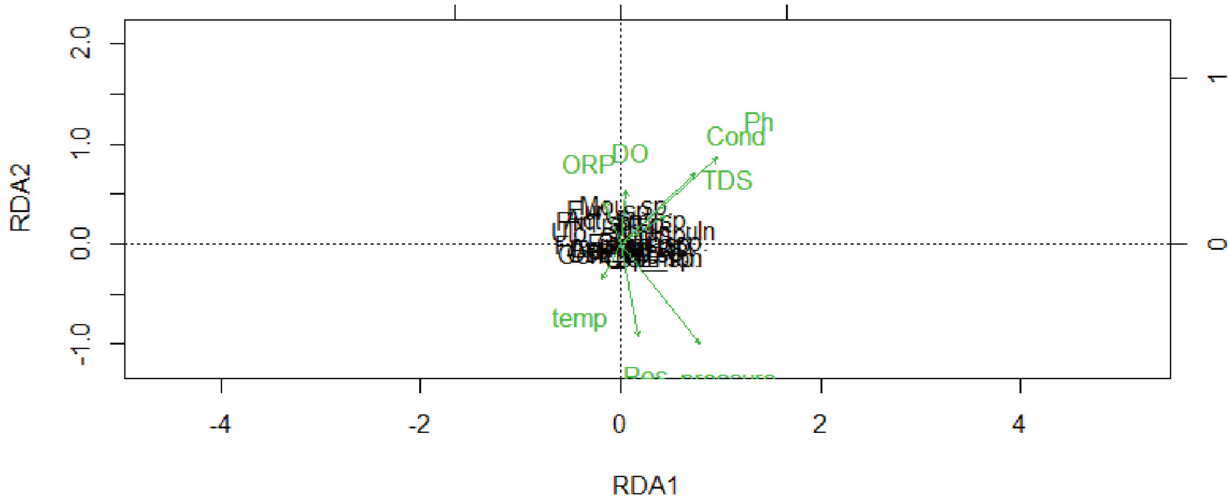


(A)

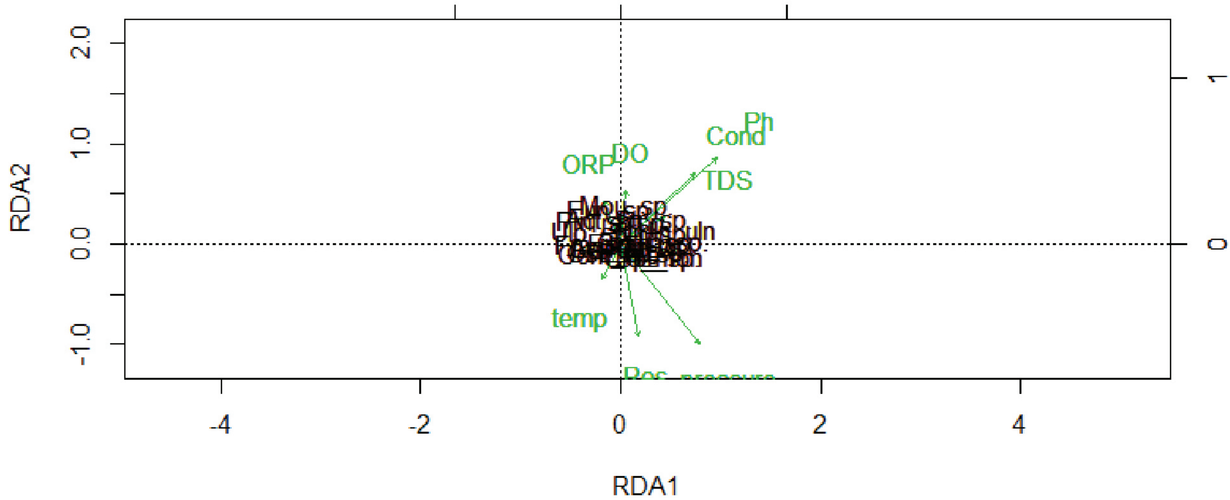


(B)

Appendix 2: RDA diagram of physico-chemical variables and algal species, **A.** pre-monsoon season, **B.** post-monsoon season



(A)



(B)