



Seasonal phytoplankton diversity and abundance at Eight Major Lakes of Pokhara valley

Md. Akbal Husen*, Naresh Khanal, Alisha Basnet, Rabina Shahi

Department of Fishery, Fishery Research Station, Begnas, Pokhara, Nepal

Abstract

This study investigated the phytoplankton species diversity and abundance during pre-monsoon and post-monsoon season in eight major lakes of the Pokhara Valley in Nepal. A total of 56 phytoplankton genera belonging to eight classes were recorded, where Bacillariophyceae and Chlorophyceae being the dominant groups. The phytoplankton density was significantly higher during the pre-monsoon season compared to the post-monsoon season across all lakes. Rupa lake was with higher ($p < 0.05$) species richness throughout both season. The Shannon-Wiener diversity index (H') ranged from 1.48 to 3.17, indicating moderate pollution levels in these lakes. The Pielou's evenness index (J) was generally low, suggesting the presence of ecological stress. The findings highlight the importance of phytoplankton as primary producers and efficient bioindicators for assessing the water quality of these lakes. The results also suggest that the abundance of phytoplankton in all the lakes is suitable for the culture of planktivorous fishes.

Keywords: Diversity, season, density, phytoplankton, genera

Introduction

Lakes serve as excellent model systems for studying metacommunity ecology due to their environmental variability and rich biological diversity (Cottenie *et al.*, 2003; Soininen *et al.*, 2011; Heino *et al.*, 2017; Almeida-Gomes *et al.*, 2020)^[1, 2, 3, 4] while, phytoplankton is a key indicator for assessing the ecological status of lakes and is widely used in various monitoring surveys (EC, 2000; Zheng and DiGiacomo 2018; Poddar *et al.*, 2019)^[5, 6, 7].

Phytoplanktons are microscopic, photosynthesizing organisms that thrive in all sunlit waters and form the base of the aquatic food chain. They play a vital role in the global ecosystem by converting carbon dioxide into carbohydrates and oxygen through the process of photosynthesis (Cetinić *et al.* 2024)^[8]. These communities are highly diverse, containing various taxonomic groups such as diatoms, dinoflagellates, green algae, cyanobacteria, and more (Reynolds, 2006)^[9]. Traditional taxonomy describes the evolution of phytoplankton communities over seasonal or nutritional gradients. At the fundamental level of taxonomy, species are typically defined by distinct morphological and physiological traits. However, making predictions at the species level is notoriously challenging, and may even be impossible (Reynolds, 2000)^[10]. As a result, higher taxonomic groups (such as diatoms and cyanobacteria) are commonly used to assess phytoplankton distribution (Wetzel, 2001)^[11].

Diversity is undeniably one of the most widely used quantitative markers of communities. Diversity measurements can describe system attributes like the complexity, stability, and functioning of ecosystems (Hacker and Gaines, 1997)^[12]. As a result, they became part of various multimetric indices used to assess biological quality (Hering *et al.*, 2006; Stoddard *et al.*, 2008; Carvalho *et al.*, 2013)^[13, 14, 15]. Phytoplankton biomass is a crucial indicator of algal abundance and water quality, serving as a bio-indicator for determining eutrophication levels (Zheng and DiGiacomo 2017; Poddar *et al.*, 2019)^[6, 7].

Several studies have been conducted on the dynamics of phytoplankton in the lakes of the Pokhara Valley (Swar and Fernando 1980; Swar 1981; Mulmi and Rai 1988; Rai 2000; Gurung *et al.*, 2006; Dhakal *et al.*, 2011; Bastakoti and Timilsina 2020). However, there has been limited research carried on seasonal phytoplankton in lakes such as Dipang, Neureni, and Maldi. Thus, the aim of the current study was to assess the phytoplankton species diversity, richness, and abundance in pre-monsoon and post-monsoon in eight lakes of Pokhara valley.

Materials and Method

Description of study area

The present study was carried out in 8 major lakes (Phewa, Begnas, Rupa, Khaste, Dipang, Neureni, Maldi, and Gunde) of Pokhara Valley in Kaski district of Nepal.

Table 1: Table showing description of Lakes of Pokhara Valley (MoFE, 2018)^[16]

Lake	Latitude	Longitude	Catchment area (km ²)	Water body (km ²)	Altitude(m)
Phewa	28.1943-28.2902	83.8004-83.9898	119.39	4.33	763-2482
Begnas	28.1621-28.2167	84.0814-84.1332	18.6	3.13	647-1447
Rupa	28.1390-28.2061	84.1004-84.1699	26.02	1.11	580-1420
Khaste	28.1908-28.2115	84.0449-84.0603	2.69	0.13	739-1186
Neureni	28.1889-28.1950	84.0465-84.0533	0.18	0.027	742-866
Dipang	28.1777-28.2025	84.0645-84.0821	2.39	0.14	687-1269
Gunde	28.1889-28.2001	84.0392-84.0476	0.61	0.08	741-948
Maldi	28.1753-28.1952	84.0785-84.0895	1.6	0.007	672-1123

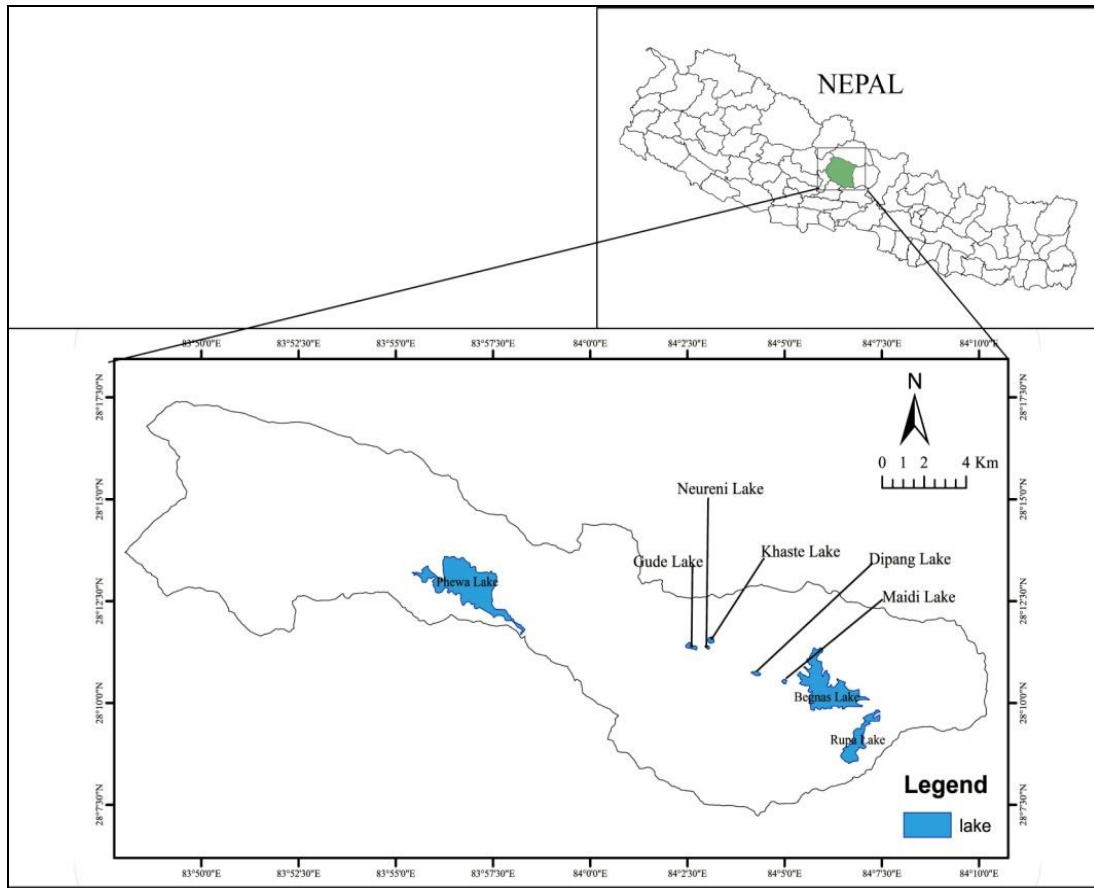


Fig 1: Map of Nepal showing sampling lakes.

Sample Collection

The water samples were collected in two different seasons post-monsoon (November, 2023) and pre-monsoon (April, 2024). For bigger lakes (Phewa, Begnas, and Rupa) water sample was collected from five sites at various depths i.e. 0m, 2.5m, 5m, 7.5m, and 10m for Phewa and Begnas, and 0m, 2.5m and 3.5m for Rupa lake, while, for Khaste and Dipang from 0m and 2.5m and lastly for Neureni, Mairi, and Gunde from 0m and 1.5m from three sites using 4 litre Vandorn water sampler. Collected water sample (200 mL) was fixed with acid Lugol's solution and concentrated to 0.2 to 0.4 mL for few hours and enumerated quantitatively with Sedgewick rafter chamber, using a microscope at 10x magnification (Nakanishi 1992; Rai 2000) [17, 18]. Identification of phytoplankton was done by John *et al.* (2002) [19]. Cell numbers were expressed in number per milliliter (No.mL⁻¹). The community structure of the phytoplankton was

examined by using the Shannon-Wiener Index (H') for species diversity (Shannon and Weaver, 1949) [20]. The evenness (J) was calculated as proposed by Pielou (Pielou, 1966) [21] to prevent the weighting of the H index by rare species. The data were summarized using Microsoft Excel var. 2015 and SPSS var. 29.

Results

Phytoplankton Species Diversity

A total of 56 genus of phytoplankton were recorded from 8 Lakes throughout the study period with 8 classes, comprising 16 species of Bacillariophyceae, 13 species of Chlorophyceae, 10 species of Cyanophyceae, 5 species of Zygnematophyceae, 5 species of Trebouxiophyceae, 2 species of Dinophyceae, 2 species of Euglenophyceae, and 3 species of Chrysophyceae (Table 2). Bacillariophyceae and Chlorophyceae were highly dominant in all the lakes in both seasons.

Table 2: Taxonomic composition and seasonal distribution of phytoplankton's in eight Lakes.

Species	Phewa		Begnas		Rupa		Khaste		Neureni		Dipang		Mairi		Gunde	
	Pr	Ps	Pr	Ps	Pr	Ps	Pr	Ps	Pr	Ps	Pr	Ps	Pr	Ps	Pr	Ps
Bacillariophyceae																
<i>Navicula</i> sp.	+	+	++	+	+	+	+	-	++	+	+	-	+	-	+	+
<i>Nitzschia</i> sp.	+	+	+	+	+	+	+	-	+	+	+	+	-	+	-	+
<i>Tabellaria</i> sp.	++	++	++	++	*	*	+	++	+	+	++	+	++	-	+	+
<i>Melosira</i> sp.	+	+	-	+	-	+	+	+	-	-	-	-	+	-	-	+
<i>Surirella</i> sp.	-	+	+	++	+	+	+	+	+	-	+	+	-	-	+	-
<i>Fragilaria</i> sp.	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+
<i>Pinnularia</i> sp.	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+
<i>Gomphonema</i> sp.	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-
<i>Amphora</i> sp.	-	-	-	-	+	-	-	-	-	-	+	-	+	-	-	-

<i>Diploneis</i> sp.	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
<i>Attheya</i> sp.	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-
<i>Asterionella</i> sp.	-	-	-	-	+	+	-	-	-	-	+	-	+	+	-	-	-
<i>Caloneis</i> sp.	-	-	+	-	-	-	+	-	+	-	-	-	+	-	-	-	-
<i>Synedra</i> sp.	+	-	+	-	+	-	+	-	-	-	+	-	+	-	+	+	+
<i>Cymbella</i> sp.	+	-	+	+	+	-	-	-	-	-	+	-	+	-	-	-	-
<i>Cyclotella</i> sp.	+	+	+	-	+	+	+	-	+	+	+	+	+	+	-	+	-
Chlorophyceae																	
<i>Scendesmus</i> sp.	++	*	++	*	*	+	+	+	++	+	++	++	++	+	++	++	++
<i>Pediastrum</i> sp.	+	-	++	++	+	+	+	+	+	-	+	++	+	+	+	+	+
<i>Selenastrum</i> sp.	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Tetraedron</i> sp.	-	+	+	+	-	+	-	-	-	-	-	+	-	-	-	-	-
<i>Kirchneriella</i> sp.	-	+	+	+	+	-	-	+	-	-	+	+	+	+	+	+	-
<i>Spirogyra</i> sp.	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-	-	-
<i>Pandorina</i> sp.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Dictyosphaerium</i> sp.	+	+	-	-	-	+	-	-	-	+	-	-	-	+	-	-	+
<i>Crucigenia</i> sp.	+	-	+	+	+	+	+	+	+	-	+	+	+	-	+	+	+
<i>Ankistrodesmus</i> sp.	+	+	++	++	+	++	+	+	+	+	+	+	+	+	+	+	+
<i>Coelastrum</i> sp.	+	-	+	+	-	+	-	+	-	-	-	+	+	-	-	-	-
<i>Micractinium</i> sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
<i>Oedogonium</i> sp.	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-
Trebouxiophyceae																	
<i>Acanthosphaera</i> sp.	+	+	+	-	-	+	+	-	-	-	-	-	-	-	-	+	+
<i>Chlorella</i> sp.	++	++	-	+	*	+	-	+	+	+	+	++	+	-	+	-	-
<i>Oocystis</i> sp.	+	-	-	-	+	+	-	+	-	+	+	-	-	+	-	+	+
<i>Quadrigula</i> sp.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Chodatella</i> sp.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Zygnematophyceae																	
<i>Staurastrum</i> sp.	++	*	++	*	*	++	+	-	+	+	++	*	*	+	*	+	++
<i>Cosmarium</i> sp.	-	-	-	-	+	+	-	+	-	-	-	+	-	-	-	-	+
<i>Spondylosium</i> sp.	-	-	-	-	+	-	+	-	-	-	+	-	-	-	-	-	-
<i>Closterium</i> sp.	+	-	+	+	-	+	-	-	-	+	-	+	-	+	-	+	+
<i>Xanthidium</i> sp.	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euglenophyceae																	
<i>Euglena</i> sp.	+	+	+	+	+	+	++	+	+	+	+	+	+	+	-	+	+
<i>Phacus</i> sp.	+	+	-	+	+	+	+	+	+	+	+	+	+	-	-	+	-
Cyanophyceae																	
<i>Aphanocapsa</i> sp.	+	+	++	-	+	+	-	-	-	+	+	-	+	-	-	-	-
<i>Anabaena</i> sp.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Merismopedia</i> sp.	+	+	-	+	+	+	-	+	-	+	+	-	+	-	+	-	-
<i>Microcystis</i> sp.	+	+	++	-	+	+	-	-	+	-	+	+	-	-	-	-	-
<i>Oscillatoria</i> sp.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Chroococcus</i> sp.	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
<i>Spirulina</i> sp.	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-
<i>Arthrospira</i> sp.	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-
<i>Nostoc</i> sp.	+	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-
<i>Phormidium</i> sp.	+	-	+	-	+	-	+	-	-	-	+	-	-	-	-	+	-
Dinophyceae																	
<i>Peridinium</i> sp.	+	+	-	-	+	-	-	-	-	-	+	-	+	-	+	+	+
<i>Ceratium</i> sp.	-	+	-	+	+	-	-	-	-	-	+	-	+	-	+	-	-
Chrysophyceae																	
<i>Dinobryon</i> sp.	+	*	+	+	-	+	-	+	+	+	+	+	-	+	+	+	+
<i>Uroglenopsis</i> sp.	-	-	-	-	-	-	+	+	+	-	+	-	-	-	-	-	+
<i>Mallomonas</i> sp.	-	+	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-

Abbreviations: (-) = Absent, (1-250) No. /mL = (+), (250-500) No. /mL = (++) , >500 No. /mL = (*), Ps = Post-Monsoon, Pr = Pre-Monsoon

Total number of Phytoplankton species in eight lakes.
 The total number of Phytoplankton species in post-monsoon and pre-monsoon from eight lakes is represented in Fig 2. During pre-monsoon season, 51 species of Phytoplankton were recorded, while, in post-monsoon 56 species were encountered. In overall, Rupa Lake was with highest

number of Phytoplankton species followed by Phewa, Begnas, Dipang, Maldi, Khaste, Gude and Neureni with 44, 38, 37, 34, 30, 29, 28, and 27 numbers of species respectively. With the exception of Neureni, more species were recorded in pre-monsoon than in post-monsoon.

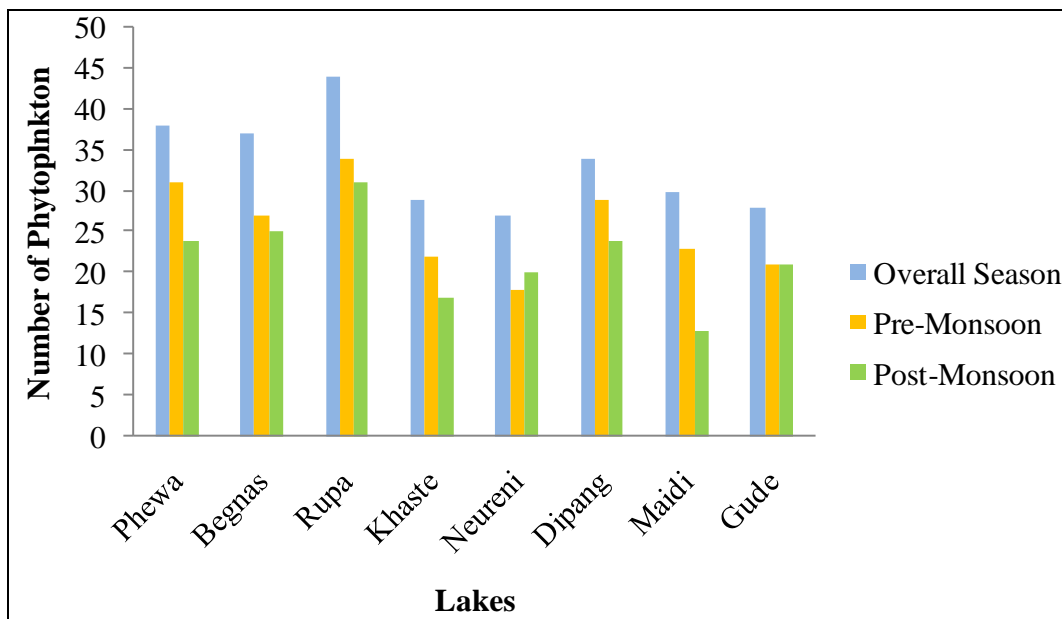


Fig 2: Total number of Phytoplankton species recorded from eight lakes

Phytoplankton Abundance

The mean density of phytoplankton of 8 lakes is presented in Table (3). The result showed that, in both season, the mean density of total phytoplankton was significantly higher

($p < 0.05$) in Rupa, while, Maldi, Gude and Neureni were with significantly lower densities ($p < 0.05$). Consequently, total mean density of phytoplankton in pre monsoon was higher than in post monsoon in all lakes.

Table 3: Mean density of Phytoplankton during Pre and Post-Monsoon

Lakes	Phytoplankton density (No./mL)	
	Post-monsoon	Pre-monsoon
Phewa	3930±39.71	4058±36.89
Begnas	4635±57.66	5438±43.66
Rupa	7044±581.84	13722±246.38
Khaste	2182±52.42	2927±28.91
Neureni	1451±63.16	2204±45.29
Dipang	2651±50.79	3242±61.22
Gunde	2202±42.93	2401±45.72
Maldi	1068±52.50	2681±47.82

Percentage contribution of different plankton in Pre-monsoon and Post monsoon

The percentage contribution of phytoplankton groups in Pre-monsoon and Post monsoon is presented in (Fig 4 and 5). During both season, the community was dominated by

Bacillariophyceae and Chlorophyceae corresponding to more than 50% of total phytoplankton abundance in almost all the lakes. In Rupa Lake, *Tabellaria* sp. accounted more than 50% of total abundance in both season.

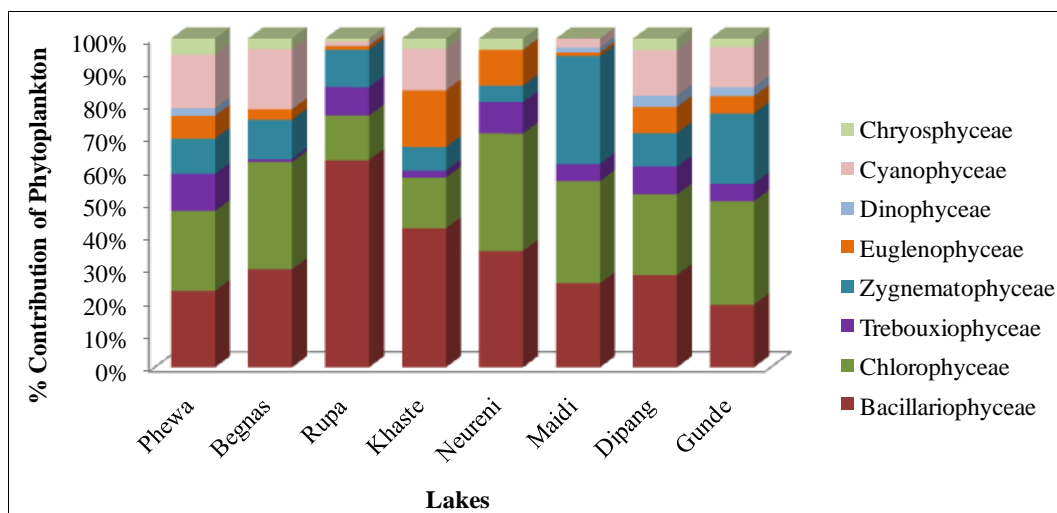


Fig 3: Percentage contribution of phytoplankton in pre-monsoon season

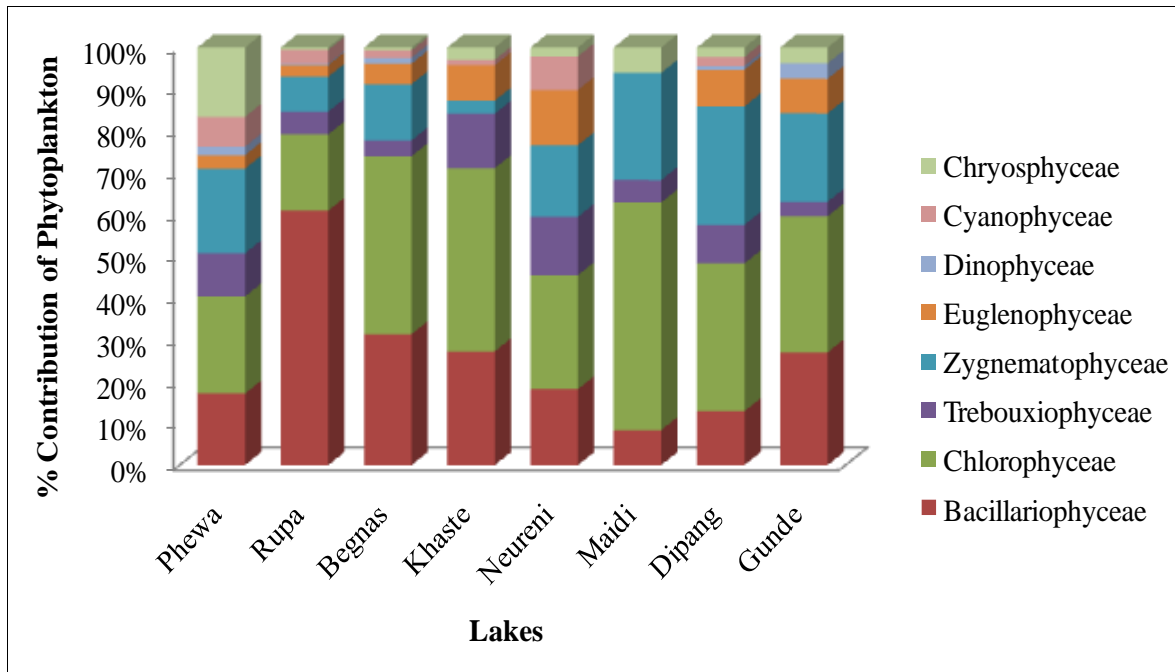


Fig 4: Percentage contribution of phytoplankton in post-monsoon season

Shannon-Wiener Index (H') and Pielou's Species Evenness (J)

The Shannon-Wiener Index (H') and Pielou's Species Evenness (J) is presented in (Fig 5, 6). The value of Shannon-Wiener Index (H') usually ranges from 1.5 to 3.5 (Shannon and Weaver, 1949) [20]. The values of the (H') recorded in post-monsoon were highest in Rupa and lowest in Maidi Lake. Similarly, the value of H' recorded in pre-monsoon was highest in Phewa and lowest in Rupa.

In post monsoon, the value of J of phytoplankton in Phewa was 0 which showed relative abundances of the species diverge from evenness while, the value of J of

phytoplankton in Begnas was highest which showed perfect evenness of species.

In pre-monsoon, J of phytoplankton in Rupa was the lowest despite of being higher in number, which implies that one species is dominant over other which was *Tabellaria* (8398 No./mL). Dipang with higher value of Pielou evenness index (J) showed greater evenness in pre-monsoon as compared to other lakes. Rupa Lake showed highest phytoplankton species richness in overall season, followed by Begnas and Phewa whereas; Gude and Neureni showed lowest species richness.

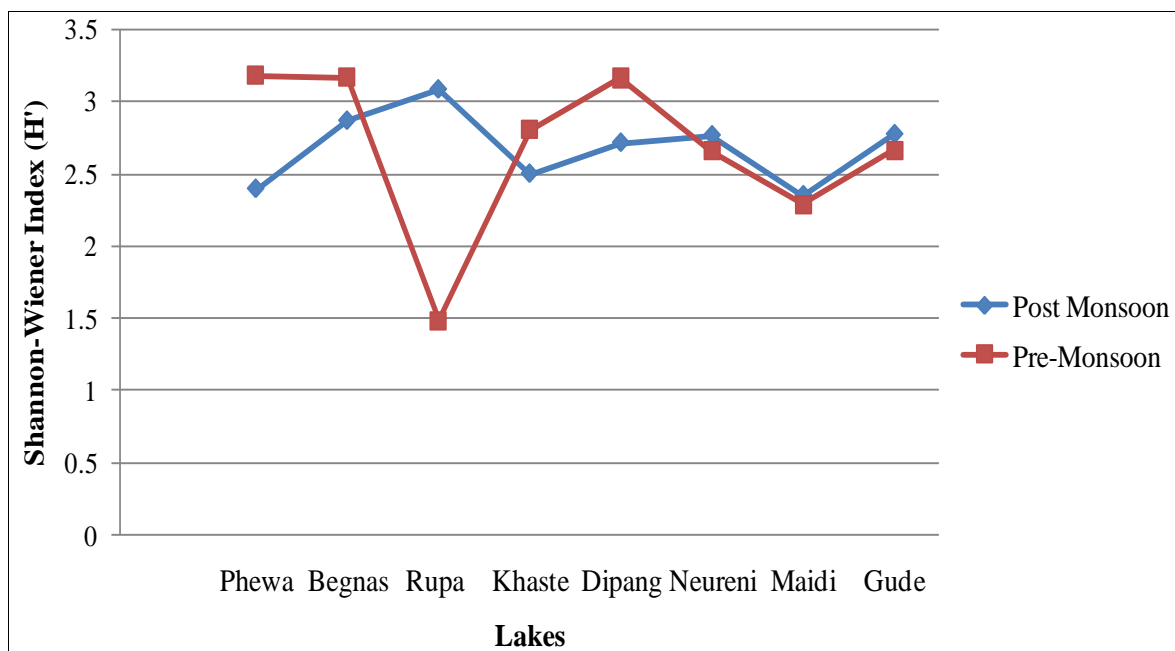


Fig 5: Range of Shannon Wiener Diversity Index (H')

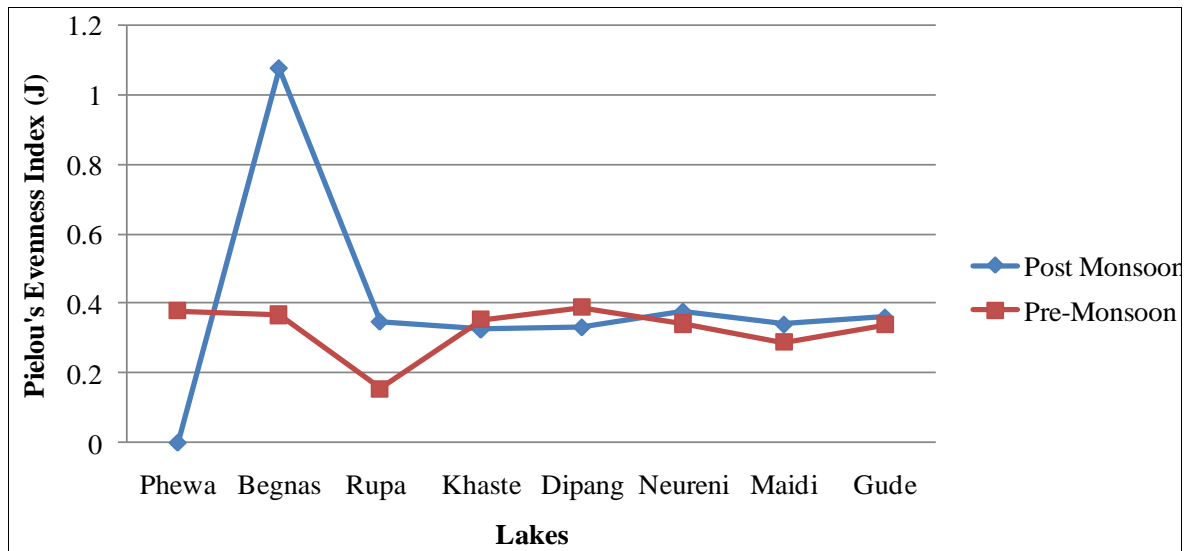


Fig 6: Range of Pielou's Evenness Index (J)

Discussion

A total 56 species of phytoplankton were recorded from 8 Lakes with 8 classes, comprising 16 species of Bacillariophyceae, 13 species of Chlorophyceae, 10 species of Cyanophyceae, 5 species of Zygnematophyceae, 5 species of Trebouxiophyceae, 2 species of Dinophyceae, 2 species of Euglenophyceae, and 3 species of Chrysoophyceae throughout the sampling period.

In present study, a total 44 genera of phytoplankton from 8 groups were recorded from Rupa Lake. Dhakal *et al.*, (2011) [22] recorded 25 phytoplankton species from seven phyla in Rupa Lake. In Phewa Lake, 38 genera of phytoplankton were recorded, while, Gurung *et al.*, (2006) [23] recorded 24 genera of phytoplankton. A total 29 genera of phytoplankton were recorded from Khaste Lake in our study. Bastakoti and Timilsina (2020) [24] recorded altogether 24 genera of phytoplankton from Khaste Lake. Greater diversity of species was recorded in the present study as compared to previous studies from Phewa, Rupa and Khaste.

Gautam *et al.*, (2016) [25] recorded 20 species of phytoplankton that represented by seven families Bacillariophyceae (41%) was most dominant family followed by Chlorophyceae (24%) and Cyanophyceae (15%) during whole study period from Rupa Lake. According to Rai (2000) [18], Bacillariophyceae (*Tabellaria* sp.), Cyanophyceae, and Chlorophyceae were dominating groups in Lake Rupa. We also got similar findings in Rupa Lake, where Bacillariophyceae and Chlorophyceae were the dominating groups. According to Hutchinson (1967) [26] diatoms are the most important members of fresh water plankton, being present in significant numbers.

According to the present study, nearly all of the lakes had higher phytoplankton densities during the pre-monsoon season. Numerous studies have looked at how water temperature affects phytoplankton in freshwater environments, and the results show that it significantly controls the seasonal distribution of phytoplankton (Munawar, 1991; Richardson *et al.*, 2000) [27, 28]. According to Bhatnagar and Devi (2013) [29], diverse plankton composition with adequate biomass (> 2000) within desirable range of plankton (2000 – 6000) is considered favorable for fish farming. In our study, plankton biomass was greater than 2000/L in all lakes which mean all the lakes are suitable for aquaculture.

The diversity of a community depends on the Species Richness and Species Evenness (Ekhtor and Alika, 2016) [30]. There is a negative correlation between Shannon-Weiner Index and the pollution. As per the species diversity scale of Wilhm and Dorris (1968) [31] ($H > 3$ = clean water, $H = 1-3$ = moderately polluted, $H < 1$ = heavily polluted) almost all lakes are moderately polluted. The J value of almost all lake was less than 0.5 except Begnas, According to Ismail and Zaidin (2015) [32] and Frutos *et al.*, (2009) [33], if the Pielou Index values are less than 0.5, it could be an indicator of the presence of ecological stress.

Conclusion

A total 56 species of phytoplankton with 8 classes, comprising Bacillariophyceae (16), Chlorophyceae (13), Cyanophyceae (10), Zygnematophyceae (5), Trebouxiophyceae (5), Dinophyceae (3), Euglenophyceae (2), and Chrysoophyceae (2) were recorded. The Bacillariophyceae and Chlorophyceae were identified as seasonally dominated in these lakes. The present study showed moderate pollution level in these lakes. The lake management strategies should be initiated for sustainable fisheries harvest from these lakes.

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