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SEASONAL VARIATION OF MACROPHYTES RELATED TO HYDROCHEMICAL PARAMETERS IN GHODAGHODI LAKE, NEPAL

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Abstract

The occurrence of macrophyte and values of water quality parameters indicate the ecological nature and the present status of the lake. In the present research hydrochemical parameters of water and macrophytes diversity in Ghodaghodi lake, Kailali District were studied. Water samples were collected from lake, during the Premonsoon (May) and the Postmonsoon (November) seasons. Hydrochemical parameters *viz*. temperature, pH, dissolved oxygen, alkalinity, the concentration of nitrates and phosphates, free CO_2, hardness, conductivity, total dissolved solids of water were analyzed to characterize the water quality of the lake. In addition, macrophytes in the lake were collected and identified. CO_2, hardness, temperature and depth were also found to be high during pre-monsoon and these parameters have low values during post-monsoon season. pH, conductivity, alkalinity, DO and TDS, value (±SD) was found to be high during post-monsoon with value and low during pre-monsoon. Total 37 macrophytes species belonging to 22 families were recorded. Out of which only one macroscopic species of algae, two pteridophytes, one bryophyte and 33 angiosperms were recorded. Emergent and members of Poaceae family were dominating during pre-monsoon and post-monsoon. In terms of growth forms, emergents were dominant indicated that higher nutrients content (PO_4, NO_3). Overall, higher number of macrophytes were recorded during pre-monsoon than post-monsoon season. Macrophytic floral composition changes with seasonal changes of hydrochemical parameters. Therefore, periodic monitoring of water quality with respect to macrophyte diversity is needed for the conservation of the lake.

Key words: Macrophytes, Premonsoon, Postmonsoon, Water quality.

Introduction

Aquatic macrophytes include macroalgae, mosses, ferns and aquatic angiosperms (Dhanam & Elayaraj, 2015). These have different growth forms i.e., submerged, free - floating, rooted floating left and emergent. Aquatic macrophytes in different growth forms represent the most important biotic element of the littoral zone in a lake ecosystem. The manifold role of aquatic macrophytes in lake ecology is linked to their distribution and biomass, which in turn is a synergy of various environmental factors (Nurminen, 2003).

Aquatic macrophytes play a significant role in maintaining water quality (Bhusal & Devkota, 2020). Their presence may enhance water quality due to their ability to absorb excessive loads of nutrients. Aquatic floating macrophytes take up inorganic nutrients, mainly nitrogen and phosphorus, by the roots, although uptake through the leaves may also be significant. With moderate nutrient loading, the biomass and proportion of aquatic macrophytes increase and plants can fill the entire water column (Zingel *et al*., 2006). The role of macrophytes tends to be greatest when plants fill the entire water column and when the growing season is long. Algae and other plants need different physiochemical parameters for their growth. The parameters that can be quantified viz., frequency, density, coverage and importance value index are the quantitative parameters (Kershaw, 1973). Quantitative parameters provide knowledge on the distribution pattern of species, homogeneity or heterogeneity of a community and dominancy of species (Burlakoti & Karmacharya, 2004).

Aquatic communities reflect the anthropogenic influence and are very useful to detect and assess human impacts (Solak *et al*., 2012). Aquatic macrophytes also reflect the nutrient status of their immediate habitat by their presence/absence and abundance and thus can be effectively used as biological indicators (Suominen, 1968).

Studies relating to aquatic and wetland flora have been carried out by previous researchers in various parts of Nepal (Sah, 1997; Bhandari, 1998; Burlakoti & Karmacharya, 2004; Kunwar & Devkota, 2012; Bhusal & Devkota, 2020; Pokhrel *et al*., 2021). Several scattered reports are available on the lowland lakes of Nepal; however seasonal diversity of aquatic macrophytes are comparatively less studied in Ghodaghodi lake, which is one of the most concerned wetlands. It is one of the largest interconnected natural lakes in the plain land of Nepal and is the lake listed on the Ramsar area. The important and direct benefit from this lake to local people is fishing and collection of medicinally important plants like *Nelumbo nucifera*, *Trapa quadrispinosa*, *Shorea robusta*) forest, scrubland, and agricultural land (Sah & Heinen, 2001). Different anthropogenic threats are causing the changes in the physico-chemical properties of this lake.

The diversity and the distribution of wetland flora and fauna are affected by the changes in water chemistry (Deshkar *et al*., 2010). Seasonal water quality influence distribution of macrophytes (Burlakoti & Karmacharya, 2004). So quantitative analysis is expected to find out the composition, distribution and dominancy of the macrophytes in Ghodaghodi Lake. Hence, the present study aimed to assess the richness and composition of macrophytes of the lake with respect to the hydrochemical characteristics of water in terms of seasonal variation. This study is expected to be helpful in designing a plan for the sustainable management of the lake.

Material and Methods

Study site: Present study was carried out in four sites of Ghodaghodi Lake (28º 41' 03" N latitude and 80º 56' 43" E longitude; altitude 205 m asl; area 138 ha.; depth 4 m); lies in Ghodaghodi municipality, Kailali district. The area is remarkable for its rich biodiversity and connectivity between the Terai plains and the Siwalik of Nepal. Details of sites are described in (Table 1), while area is shown in (Fig. 1).

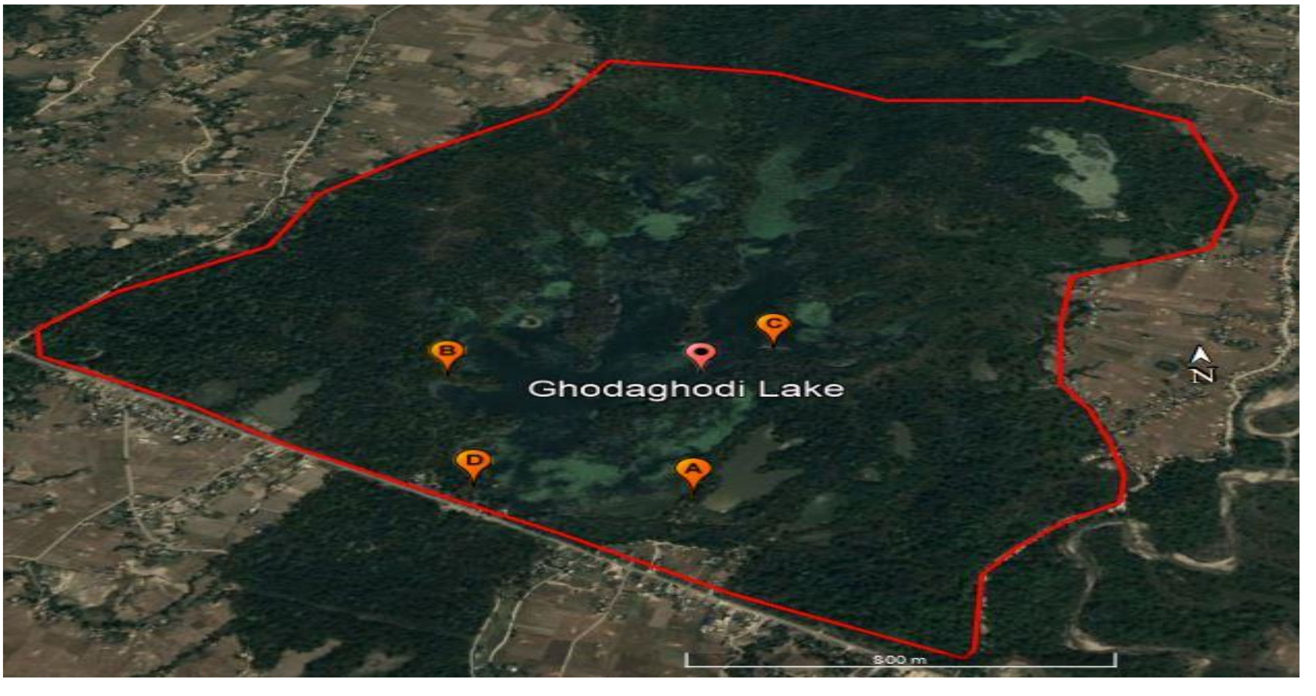

Fig. 1. Map of **a)** Nepal showing Kailali district, **b)** Kailali district showing Ghodaghodi municipalities, **c)** Location of sampling sites (Map prepared by QGIS).

Water sampling method: Water samples were collected from four sites (Table 1) at the depth of 0.5 m of lake during pre-monsoon (May) and post-monsoon (November) season 2018. Thirty-two quadrats (1m×1m size|) per season were laid down randomly with more or less 20-25 m distance apart from each other. All the sampling bottles were rinsed with the respective lake water before taking the water samples. Thirty-two samples of water, 8 from each site of lake were collected during each sampling period. The parameters like temperature, pH, DO, conductivity, total solid matter and depth_of lake, were measured on the spot. Free CO_2, alkalinity, hardness, nitrate and phosphate were done in the laboratory of Central Department of Botany, Tribhuvan University, Kirtipur, Nepal. Sampling, preservation and analysis of water quality parameters were carried out following standard methods for examination (Anon., 2005). Results of hydrochemical parameters of water samples are presented in (Table 2).

Collection and identification of aquatic macrophytes: For the determination of composition, distribution and dominancy of aquatic macrophytes, random sampling method was applied. It was applied along 4 directions in lake with the help of 1m × 1m quadrats at an interval of 20 m distance at the shoreline. Eight quadrats in each site (altogether 32 quadrats per season) total 64 quadrat were plotted in Lake. Identification of mesoflora was made by consulting relevant literatures, taxonomists and cross checking of specimens with the herbarium specimens housed in the National Herbarium and Plant Laboratories (KATH). Quantitative parameters such as frequency, density, coverage and Importance value Index (IVI), described by Zobel *et al*., (1987) were determined. IVI was introduced by Curtis and McIntosh (1951). The following formula was used to calculate IVI:

$$IVI = RF + RD + RC$$

where; RF-Relative Frequency, RD- Relative density and RC-Relative coverage

Composition of mesoflora is shown in (Table 3), while IVI of dominant species is given in (Table 4).

Data analysis: The independent sample T-test was performed to analyze differences in the mean value of water parameters between seasons. Shannon-Weiner diversity index was calculated to show the diversity of species at two seasons. Canonical Correspondence Analysis (CCA) was performed to access the species environment relationship. CANACO version 4.5 (Ter *et al*., 1995) was used for CCA ordination.

Results and Discussion

Hydrochemical parameters of lake water: Results of physiochemical analysis of water samples are presented in Table 2. In the present study, the mean value of water temperature was higher in pre monsoon season (28.85±0.49) than in post- monsoon season (16.99±0.98) (Table 2), which supported the results of previous researchers (Thapa & Saund, 2013; Chaudhary & Devkota, 2018; Pokhrel *et al*., 2021). A high temperature of surface water was observed in the pre-monsoon season, which could be due to the influence of atmospheric temperature. In lentic environments, one of the important limiting factors is temperature that affects the chemical and biological reactions in the water (Anon., 2005).

DO is one of the key factors in determining the health of the lentic environments including the survival of the aquatic organisms Average value of DO in water sample of lake was 3.2 mg/L. The value of DO level below 5 mg/L is considered to be insufficient for the survivability of many organisms. During the pre-monsoon season, the DO level showed somewhat decreased which might be due to a high temperature in the environment. It is because the high atmosphere temperature is responsible for the high rate of decomposition of organic matters involving the utilization of oxygen (Badge & Verma, 1995). It is reported the DO below 2.5 mg/L is considered lethal to the fish community of the water body (Oli, 1996). The mean values of DO in both seasons were below the guideline values (Anon., 2011).

The pH has a major role in both lentic and lotic environments for determining the speciation of inorganic chemicals and influencing biotic life. In the present study the mean value of pH was higher in the post- monsoon season (8.19 ±0.30) than in pre monsoon season (7.20 ±0.24). The value of pH is higher might be due to higher temperatures and other geochemical processes (Qaisar *et al*., 2018). The pH value generally fluctuates daily due to complex interaction of alkalinity, hardness, carbon dioxide, photosynthesis, respiration.

Table 1. Description of sampling sites.

Site A	Eastern site near the green tower which is surrounded by tall trees and also by small herbs near the edges. It is less disturbed area
Site B	Western site which is far from temple. It is disturbed area as people do illegal fishing
Site C	The Northern site which was also surrounded by tall trees and also by small herbs near the edge. It is the station for breeding of crocodile and is not so disturbed like other station
Site D	Southern site near the temple which was also disturbed. View tower is also present there so there is disturbance by human activities

Table 2. Physico-chemical characteristics (mean±SD) of water of Lake in two seasons.

Parameters	Pre-monsoon	Post-monsoon	Average	F	Sig (p)
Temp (ºC)	28.85 ± 0.49	16.99 ± 0.98	22.92 ± 0.74	13.824	**0.000**
DO (mg/L)	3.04 ± 0.48	3.36 ± 1.10	3.2 ± 0.79	23.908	**0.000**
PO_4 (mg/L)	0.51 ± 0.21	0.16 ± 0.02	0.33 ± 0.11	52.205	**0.000**
Totl_Hrdn (mg/L)	233.56 ± 64.80	148.75 ± 53.41	191.16 ± 59.37	2.878	0.095
Free CO_2 (mg/L)	162.77 ± 51.85	93.81 ± 46.76	128.29 ± 49.31	0.928	0.326
Totl_alka (mg/L)	162.81 ± 34.92	192 ± 51.12	177.41 ± 43.02	1.858	0.178
Nitrate (mg/L)	0.10 ± 0.03	0.09 ± 0.02	0.09 ± 0.02	0.160	0.690
TDS (ppm)	90.34 ± 18.35	92.53 ± 5.20	91.43 ± 23.55	2.322	0.133
Cond (µs/cm)	178.25 ± 28.75	183.16 ± 17.32	180.71 ± 23.03	1.008	0.319
pH	7.20 ± 0.24	8.19 ± 0.30	7.69 ± 0.27	0.110	0.741
Depth (m)	1.02 ± 0.15	0.83 ± 0.32	0.93 ± 0.23	0.628	**0.012**

F value and significance value (p) were determined by Independent Sample T-test. (DO= Dissolved Oxygen, PO_4= Phosphate, Totl_Hrdn= Total Hardness, Free_CO_2= Free Carbon dioxide, Totl_alka= Total Alkalinity, TDS= Total dissolved solid, Cond= Conductivity, Temp= Temperature)

Principally, Electrical Conductivity (EC) is a measurement of ionic strength and it depends on the presence of ions, their concentrations, mobility, and temperature. The mean value of conductivity was lower in the post monsoon season (183.16 ±17.32 µS cm^{-1}) than in pre-monsoon season (178.25±28.75 µS cm^{-1}). Similar results were reported by Pant *et al*., (2020) and Pokhrel *et al*., (2021) but the average conductivity of the reservoir seems to have decreased in the present study in comparison to values recorded by Pokhrel *et al*., (2021). That may be due to the decomposition of organic matter, input of ions, inlet, temperature of the water and total solids. High EC value in the pre-monsoon season might be due to a decrease in water level in the lake, whereas the low value of EC in the post-monsoon season might be due to consumption of the electrolytes and ions by aquatic plants (Thapa & Saund, 2013; Pant *et al*., 2020). The relatively high value of EC is due to agricultural runoff and other anthropic interferences from the vicinity.

The highest value of TDS (92.53 ±5.20 mg dm^{-3}) was observed in post monsoon and the lowest (90.34 ± 18.35mg dm^{-3}) in the pre monsoon season, the results were similar to those in Jagadishpur reservoir (Pokhrel *et al*., 2021) which was also a tropical lake. TDS might be increased in water due to the intensification of anthropogenic activity.

The mean value of alkalinity was higher in the pre monsoon season (192 ± 51.12 mg /L) than in the post monsoon season (162.81 ± 34.92 mg/ L). Similar results had been reported by Niroula *et al*., (2010) and Chaudhary & Devkota (2018). Higher alkalinity value in the pre monsoon season might be due to smaller water volume and more bicarbonate ions during dry season than in the post monsoon season. This kind of seasonal variation could be due to the flushing and dilution by late monsoon rainfall along with surface runoff.

The free carbon dioxide concentration depends on the respiration of plants and photosynthesis rate (Choudhary *et al*., 2014). The mean value of free CO_2 was higher in pre monsoon season (162.77 ±51.85 mg/L) than in the post monsoon season (93.81 ±46.76 mg/L), similar findings were reported by Chaudhary & Devkota (2018) and Pokhrel *et al*., (2021). In the present study the free CO_2 value exceeded 25 mg/L, which affected the sustainability of aquatic organisms (Thomas *et al*., 2015). The free CO_2 content in water increases with an increase in temperature and depth (Agrawal, 1999). Maximum free CO_2 during pre- monsoon season might be due to higher temperature and decomposition of organic matter by microbes at the bottom (Patra *et al*., 2010).

Total hardness in water affects the hydrochemical as well as biological characteristics in the lentic environment. The mean value of hardness was recorded higher in the pre monsoon season (233.56 ±64.80 mg / L) than in post-monsoon season (148.75 ±53.41mg/L) (Table 3). The high value of hardness in pre monsoon season might be due to high temperature, which increased the concentration of salts by excessive evaporation. The same relation was noted by Chaudhary & Devkota (2018) and Pokhrel *et al*., (2021). Freshwater can be classified into the following groups based on hardness: soft: 0-60 mg/L, moderate hard: 61-120 mg/L, hard: 121-160 mg/L, and very hard: >180 mg/L. As average value of hardness of water of Ghodaghodi late (above 180 mg/L)' using these criteria, the water quality of the Ghodaghodi lake was found to be in very hard category. Relatively, higher values of total hardness in both seasons might be due to the addition of calcium and magnesium content from surrounding lands.

Phosphorus plays an important role in the development of aquatic plants (Martin, 1987 and is considered as the limiting factor of eutrophication in temperate lakes (Vollenweider *et al*., 1980). The value of phosphate was higher in the pre monsoon season (0.51 ±0.21 mg/L) than the postmonsoon season (0.16 ±0.02 mg/L), Higher concentration of phosphates during premonsoon season may be due to agricultural runoff which carries fertilizers, increasing the nutrient content in the lake. The phosphate value was found to be lower in the post-monsoon season, this might be due to the use of the nutrient by macrophytes and phytoplankton and might also be due to the microbial degradation of total phosphorous by bacteria (Li *et al*., 2009). The recorded concentration of nitrates was higher in the pre monsoon season (0.10 ±0.03 mg/L) than in the postmonsoon season (0.09 ±0.02 mg/L). Similar results were reported by Niroula *et al*., (2010), Thirupathaiah *et al*., (2012) for Beeshazar and lower lake Manair reservoir respectively. The mean value for depth was more during pre-monsoon while low during post-monsoon. The lower values of depth during post monsoon season might be due to the deposition of waste material.

Macrophytes diversity: Environmental gradients including hydrochemical variables play a vital role in determining the abundance and diversity of the aquatic macrophytes (Takamura *et al*., 2003). Altogether 37 macrophyte species were found during the research period of Ghodaghodi Lake.

As Ghodaghodi lake complex comprises other large and small oxbow lakes with an area of 2500 ha, Siwakoti & Karki (2009) found 95 aquatic macrophytes while Lamsal *et al*., (2014) found 45 species of aquatic macrophytes along Ghodaghodi lake complex. Less number of macrophytes in comparison to previous study might due to smaller coverage of the study sites. Emergent species were the most dominant growth form of macrophyte in both season of Lake. These studies partly support observations by Kolada (2014), who observed an increased share of emergent vegetation in the littoral zone with increasing eutrophication. Growth of emergent species becomes very dense with an increase in eutrophication and alkalinity of lakes, floating leaf species get replaced by emergent macrophyte (Makela & Arvola, 2004).

Among angiosperm, Poaceae was dominant in both seasons followed by Rubiaceae during pre-monsoon while by Araceae during post-monsoon (Table 3). Dominance of Poaceae may be due to its effective long-distance dispersal, successful establishment biology, ecological flexibility and capacity to modify environments by changing the nature of fire and mammalian herbivory (Linder *et al*., 2018).

Table 3. Vegetation composition of two seasons of Ghodaghodi Lake.

S. No.	Name of species	Family (Group)	Growth form	Season	
				Pre	Post
1.	*Ageratum houstonianum* Mill.	Asteraceae (Angiosperm)	E	+	+
2.	*Alterenthera sessilis* (L.) DC.	Amaranhaceae (Angiosperm)	E	+	-
3.	*Arundo donax* L.	Poaceae (Angiosperm)	E	-	+
4.	*Azolla pinnata* R.Br.	Salviniaceae (Pteridophytes)	Ff	+	+
5.	*Caldesia parnassifolia* (L.) Parl	Alismataceae (Angiosperm)	N	-	+
6.	*Centella asiatica* (L.) Urb.	Apiaceae (Angiosperm)	E	+	+
7.	*Ceratopteris thalictroides* (L.) Brogn.	Pteridaceae (Pteridophytes)	Ff	+	-
8.	*Chara* sp.	Chararacea*e* (Algae)	S	+	+
9.	*Colocasia esculenta* (L.) Schott	Araceae (Angiosperm)	E	-	+
10.	*Cyanodon dactylon* (L.) Pers.	Poaceae (Angiosperm)	E	+	+
11.	*Cyperus* sp.	Cyperaceae (Angiosperm)	E	-	+
12.	*Digitaria ciliaris* (Retz.) Koeler	Poaceae (Angiosperm)	E	+	-
13.	*Echinochloa colona* (L.)Link	Poaceae (Angiosperm)	E	+	-
14.	*Ecliptia alba*. (Hask.) **Hassk**.	Asteraceae (Angiosperm)	E	+	-
15.	*Fimbristilis dichotoma* (L.) Vahl	Cyperaceae (Angiosperm)	E	+	-
16.	*Fimbristylis aestivalis* Vahl	Cyperaceae (Angiosperm)	E	+	-
17.	*Hedyotis diffusa* Will.	Rubiaceae (Angiosperm)	E	+	-
18.	*Hydrilla verticillata* (L.f.) Royle	Hydrocharitaceae (Angiosperm)	S	+	+
19.	*Hygrohiza aristata* (Retz.) Nees ex Wight & Arn.,	Poaceae (Angiosperm)	E	+	-
20.	*Imperata cylindrica* (L.) P. Beauv	Poaceae (Angiosperm)	E	+	-
21.	*Ipomoea carnea ssp fistulosa* (Mart.ex.Choisy) D.F. Austin	Convolvulaceae (Angiosperm)	E	+	+
22.	*Lemna minor* L.	Araceae (Angiosperm)	Ff	+	+
23.	*Ludwigia adscendens* (L.) H. Hara	Onagraceae (Angiosperm)	E	+	+
24.	*Nelumbo nucifera* Gaertn.	Nelumbonaceae (Angiosperm)	N	+	+
25.	*Nymphoides hydrophylla* (Lour.) Kuntze	Menyanthaceae (Angiosperm)	N	+	-
26.	*Oldenlandia corymbosa* Linn.	Rubiaceae (Angiosperm)	E	+	-
27.	*Panicum dichotomiflorum* Michx	Poaceae (Angiosperm)	E	-	+
28.	*Paspalum distichum* L.	Poaceae (Angiosperm)	E	+	-
29.	*Persicaria kawagoeana* (Makino) Nakai	Polygonaceae (Angiosperm)	E	+	+
30.	*Pistia stratiotes* L.	Araceae (Angiosperm)	Ff	+	+
31.	*Potamogeton gramenius* L.	Potamogetonaceae (Angiosperm)	S	+	-
32.	*Potamogeton natans* L.	Potamogetonaceae (Angiosperm)	S	+	-
33.	*Ricciocarpus natans* L.	Ricciaceae (Bryophytes)	Ff	-	+
34.	*Thelypteris prolifera* (Retz) C.F. Redd	Thelypteridaceae (Angiosperm)	E	-	+
35.	*Trapa quadrispinosa* Roxb.	Trapaceae (Angiosperm)	N	+	+
36.	Unidentified sp*1?*	Poaceae (Angiosperm)	E	+	-
37.	*Urena lobata* L.	Malvaceae (Angiosperm)	E	+	+
Total			**37**	**30**	**21**

Note: (E-Emergent, Ff-Free floating and S-Submerged, N – Nympheids)

The highest species of dicotyledons and monocotyledons may be attributed due to the influence of tropical climate. The lack of shady and moist habitat may have limited only three pteridophyte species. Only one macrospcopic alga was found during the research period. By growth form, emergent forms were found to be the highest in number followed by the rooted floating and submerged species (Table 3) which was similar to the findings of Chaudhary & Devkota (2021).

The value of IVI is directly related to the distribution and dominance of species in a community. Out of 37 species recorded only 17 species were dominant, of which 5 species were common in both season, 4 species were present only during post- monsoon while 7 species were present during pre- monsoon season.

During pre-monsoon, *Nelumbo nucifera* and *Trapa quardispinosa* exhibited the highest value of IVI, with value 58.99 and 38.02 respectively (Table 4) while *Oldendia corymbosa* showed lowest IVI. *Nelumbo nucifera* survives, grows and develops well in shallow sites than deep water sites (Nohara & Tsuchiya, 1990). The highest IVI of *Nelumbo nucifera* (a threatened species of

Ghodaghodi Lake) can be attributed to their high potential in shallow lakes.

During post-monsoon, the highest IVI value was shown by *Chara* sp. (IVI, 49.11). and *Cyperus* sp. (IVI 43.92) (Table 4), while the lowest value of IVI was shown by *Ageratum houstonianum*. *Hydrilla verticillata*, a submerged species had shown its growth during both seasons. The dense growth of *Hydrilla verticillata* can be attributed to the high growth potential of this species in sedimentation prone areas (Sharma & Singh, 2017).

Shannon-Weiner index value was found to be highest during pre-monsoon, while lowest during post-monsoon. Large value indicates greater diversity as well as more equitable distribution of species, while low index values are associated to indicate pollution (Ghosh & Biswas, 2015). High diversity value may be due to high nutrient content (Keddy, 2010) during pre-monsoon. With the rain in monsoon, the lake water got mixed with rainwater and got diluted eventually resulting in decrease of nutrient in post-monsoon. Due to low nutrient level in post-monsoon than pre-monsoon the diversity index became low in post-monsoon (Table 4).

Table 4. IVI values of dominant species and diversity index values during pre and post-monsoon season.

IVI values of dominant species

Name of species	**Pre-Monsoon**	**Post-Monsoon**
Nelumbo nucifera Gaertn.	58.99	12.67
Trapa quadrispinosa Roxb.	38.02	-
Azolla pinnata R.Br.	34.65	24.87
Arundo donax L.	-	20.07
Lemna minor L.	33.66	-
Caldesia parnassifolia (L.) Parl.	-	12.33
Ceratopteris thalictroides (L.) Brogn.	21.34	-
Ludwigia adscendens (L.) H. Hara	20.70	20.78
Hydrilla verticillata (L.f.) Royle	12.00	39.25
Chara sp. L.	10.94	49.11
Potamogeton gramenius L.	10.76	-
Echinochloa colona (L.)	8.35	-
Cyperus sp. L.	-	43.92
Hygrohiza aristata (Retz.)	6.31	-
Pistia stratiotes L.	5.58	-
Persicaria kawagoeana (Makino) Nakai	5.02	23.58
Thelypteris prolifera (Retz.) C.F. Reed	-	9.03
Variation in species diversity index values among seasons		
Diversity Index	2.12	1.95

Shannon-Weiner diversity index was calculated in both seasons (Table 4). There was found higher species diversity during pre-monsoon (2.12) than post-monsoon (1.95)

The influence of hydrochemical factors on macrophytes: The CCA ordination showed the relationship between macrophytes and different hydrochemical parameters (Table 5). Forward selection and Monte Carlo Permutation test revealed that temperature was the most important variable (*p=0.0001*) governing the macrophyte composition (Table 5). Inorganic phosphorous was the second most significant variable (*p=0.0084*) (Table 5). Lake with high nitrogen and phosphorous concentrations supported the growth of aquatic macrophytes like *Lersia hexandra*, *Trapa bispinosa* and *Eichornia crassipes* (Niraula, 2012). *Ricciocarpus natans*, *Cyperus* sp, *Thelypteris prolifera* were found near total nitrogen and were influenced by this parameter. *Ageratum houstanianum* an invasive species was found to be influenced by conductivity and TDS. Lake with high DO concentration can support the growth of *Hymenachne pseudoenterrupta*, *Spermacoe alata*, *Persicaria hydropper* and *Mikania micrantha* (Bhusal & Devkota, 2020). Here *Echinochloa colona, Colocasia esculenta, Lemna minor, Digitaria ciliaris* showed positive affinity towards DO.

Swamps and marsh formation in the lake are the stages of the succession of oxbow lakes (Burlakoti & Karmacharya, 2004). The high rate of decomposition of macrophytes due to high nutrient concentration as well as dominant growth of emergent macrophytes reduces the water quality. Dominance of emergent macrophytes in Ghodaghodi Lake in terms of growth form indicates encroachment of littoral vegetation (Burlarkoti & Karmacharya, 2004; Ghosh & Biswas, 2015). Emergent macrophytes can serve as an indicator of lakes disappearances due to overgrowth because a large proportion of emergent macrophytes observed over a long-term scale can reflect the degree of advancement of lake overgrowing (Lawniczak & Achtenberg, 2018). The variation of macrophytes flora composition depended on physical and chemical parameters and seasonal changes (Pokhrel *et al*., 2021).

Table 5. Relative importance of environment on macrophyte composition analyzed based on CCA analysis.

Environmental variables	**Abbreviation**	**F**	***p***
Dissolved Oxygen (mg/L)	DO	1.423	0.0874
PO_4 (mg/L)	Pi	1.869	**0.0084**
Total Hardness (mg/L)	Totl_Hrdn	1.406	0.1029
Free Carbondioxide (mg/L)	Free_CO_2	1.139	0.2939
Total Alkalinity (mg/L)	Totl_alka	0.870	0.6400
Nitrate as Nitrogen (mg/L)	Nitrate	1.018	0.4274
Total Dissolved Solid (ppm)	TDS	1.856	0.1098
Conductivity (µs/cm)	Cond	2.479	**0.0101**
pH	pH	0.515	0.9398
Depth (m)	Depth	1.861	**0.0118**
Temperature (°C)	Temp	3.312	**0.0001**

*Bolds letter represent statistically significant values

Conclusion

Due to the promotion of the lake site as an ecotourism area, anthropogenic activities could further deteriorate the lentic quality and biodiversity of the lake. Particularly, the main regulating factors of physico-chemical features of lake like commercial fishing, excessive use of pesticides and chemical fertilizer, irrigation, bathing, washing cloth, and ultimately impact the abundance and composition of the macrophytes. Therefore, prompt action should be taken with proper regulation to protect lake natural environment.

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