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Environmental variables and macrophytes of lakes of the Chitwan National Park, Central Nepal

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Abstract: Wetlands are areas where water is the primary factor controlling the environment, associated plant and animal life. The present study has been conducted to investigate the environmental variables of water and to make a quantitative analysis of aquatic macrophytes. Five lakes, i.e. Tamor, Beeshazar, Kingfisher, Athaieshazar and Chepang of the Chitwan National Park were studied during the post-monsoon season. Four different sites were studied for each lake. 12 replica of water samples were collected from each site of the lakes and environmental variables of water i.e. pH, temperature, dissolved oxygen, total alkalinity, conductivity, total hardness, nitrate, inorganic phosphorus, total solid matter and free CO_2 were analyzed. Macrophyte floras were collected during field sampling with the help of a 1m×1m light wooden quadrat and herbaria were prepared following the standard technique. Altogether 10 quadrats (five paired quadrats) were plotted in each site of the study area. Data obtained from water analysis and macrophytes were analyzed by SPSS statistics 20 and CANACO version 4.5. Higher values of nitrate and inorganic phosphorus were found in Beeshazar Lake and Tamor Lake, i.e. 4.41 ±0.52 mg dm^{-3} and 2.93 ±0.29 mg dm^{-3}, respectively. In most of the lakes, macrophyte species, mostly *Eichhornia crassipes* was found to be dominant in terms of the importance value index (IVI), whereas in Tamor Lake, *Spirodela polyrhiza* was dominant. All the studied lakes were in the hypereutrophic category on the basis of nitrate and phosphorus concentration. Runoff of polluted water with agricultural fertilizers, pesticides and untreated industrial discharge as well as domestic wastes from the Khageri canal and excessive growth of invasive macrophytes are major threats to the studied lakes. The luxuriant growth of invasive macrophytes like *Eichhornia crassipes* also revealed the productive nature of the lakes and they can be taken as ecological indicators of organic pollution.

Key words: Beeshazar, hypereutrophic, invasive, Importance Value Index (IVI), Tamor

Introduction

Wetlands have been described as *"the kidneys of the landscape"*, because of their functions in the hydrological and chemical cycles, and as *"biological supermarkets"* because of the extensive food webs and rich biodiversity they support. Thus, they are known as one of the world's most productive environments (Barbier et al. 1997). They help in flood protection; improve water quality by buffering sediments, nutrients and contaminants coming from inflowing water; support local and migratory animals and provide a wide variety of foods (Groom et al. 2006).

The quality of an aquatic ecosystem is mostly dependent on the physical and chemical qualities of water as well as biological diversity within the system (Kunwar and Devkota 2012). Aquatic macrophytes in different growth forms (i.e. submerged, free floating, rooted floating leaved and emergent) are macroscopic forms of aquatic vegetation, they include macro algae, mosses, ferns and angiosperms found in aquatic habitats which represent the most important biotic element in a lake ecosystem and are affected by a variety of abiotic factors including water nutrients (Ghosh and Biswas 2015). According to Kershaw (1973) quantitative parameters are those that can be quantified viz., frequency, density, coverage, importance value index (IVI) and the measurement of these parameters is important because it provides knowledge on the distribution pattern of species, homogeneity or heterogeneity of a community and dominancy of species (Burlakoti 2003). Wetlands are among the most threatened

habitats mainly due to drainage, land reclamation, pollution and over-exploitation of wetland species. What is more, the accumulation of nitrogen, phosphorus, and pesticides from surface runoff (agricultural non-point sources) also leads to severe degradation of wetlands, especially lakes (RCS 2016).

Nepal's wetlands are among the most vulnerable and most threatened of habitats. Although many efforts have recently been made to protect wetlands, physical, chemical, and biological parameters of many of them are still inadequately known. Information on aquatic plants and wetland flora is limited as compared to other plant groups. Numerous researches have been conducted to study the ecology of Beeshazar Lake as vehicles are easily available to reach this lake but other lakes have not been much explored ecologically. Information on environmental variables of water and macrophytes of lakes with the hypothesis "Change in the nutrient content of a lake will alter the abundance of macrophyte species" will be beneficial while making plans for the conservation and management of the five different lakes of the Chitwan National Park (CNP).

Materials and Methods

Study area

The Chitwan National Park (latitude 27°37'00'' N and longitude 84°25'59'' E) is located in Central Nepal with a core area of 932 km^2 and a buffer zone of 750 km^2. Its elevation ranges from 150 m to 815 m above mean sea level and represents an inner Doon Valley. The park is about 160 km far from the capital city (Kathmandu). Kasara and Sauraha (main entry point) are 24 km and 18 km away from Bharatpur airport, respectively.

The studied lakes fall into the tropical climate region and are dominated by a summer monsoon climate. The monsoon begins in late June and continues until early October and brings nearly 80% of the rainfall. The average annual rainfall is 2600 mm and maximum rainfall is 452 mm and the average annual atmospheric temperature is 24°C. It has typical sub-tropical vegetation. The main surrounding forest is dominated by *Shorea robusta* and prominent associated aquatic vegetation includes *Eichhornia crassipes*, *Trapa bispinosa, Hydrilla verticillata*, *Ipomoea carnea* ssp. *fistulosa* (Karki et al. 2015).

Among five studied lakes, Tamor Lake (total area: 14.12 ha, altitude: 165 m a.s.l.) lies south of Kasara Headquarter. It lies within the core area of the national park and is far from any human settlement areas. Beeshazar Lake (total area: 29.82 ha, altitude: 183 m a.s.l.), Kingfisher Lake (total area: 5.5 ha, altitude: 173 m a.s.l.), Athaieshazar Lake (total area: 1.29 ha, altitude: 176 m a.s.l.) and Chepang Lake (total area: 1.98 ha, altitude: 183 m a.s.l.) are situated within the Barandabhar forest. These lakes are located in an area of high urban density and near the human trail area and are an integral part of the Khageri Canal. The location of all the studied lakes can be seen in Figure 1.

Environmental variables of water

Water samples at the depth of 0.5 m were collected during the post-monsoon season (October-November, 2017). Four different sites were studied for each lake. 12 replicas of water samples were collected from each site of the lakes. Altogether, 48 water samples were collected from each lake. These sites were selected based on anthropogenic effect and accessibility for the quantitative study of macrophytes and to collect water samples. Using a mercury thermometer of -10 to 50°C with 0.2°C the least count water temperature and pH, with the help of pocket-sized pH-meter, Model pH 009 with an accuracy of ±1, were measured on the spot. Water samples for dissolved oxygen were fixed by adding 2 ml manganous sulfate and 2 ml alkaline iodide. Water samples were brought to the laboratory in an ice box and free carbon dioxide, total hardness, total alkalinity, dissolved oxygen (DO), nitrate, inorganic phosphorus, total solid matter and conductivity were determined immediately using APHA methods (Rice et al. 2012) in the ecology laboratory of the central Department of Botany. Table 1 shows the methods and instruments used for determination of physio-chemical parameters.

Collection and identification of aquatic macrophytes

The purposive random sampling method was applied along four transects in each lake with the help of a 1×1m light wooden quadrat (Ghosh and Biswas 2015) and plotted in each transect of the shoreline at an interval of 1 m distance. Altogether, 10 quadrats (five paired quadrats) in each site and

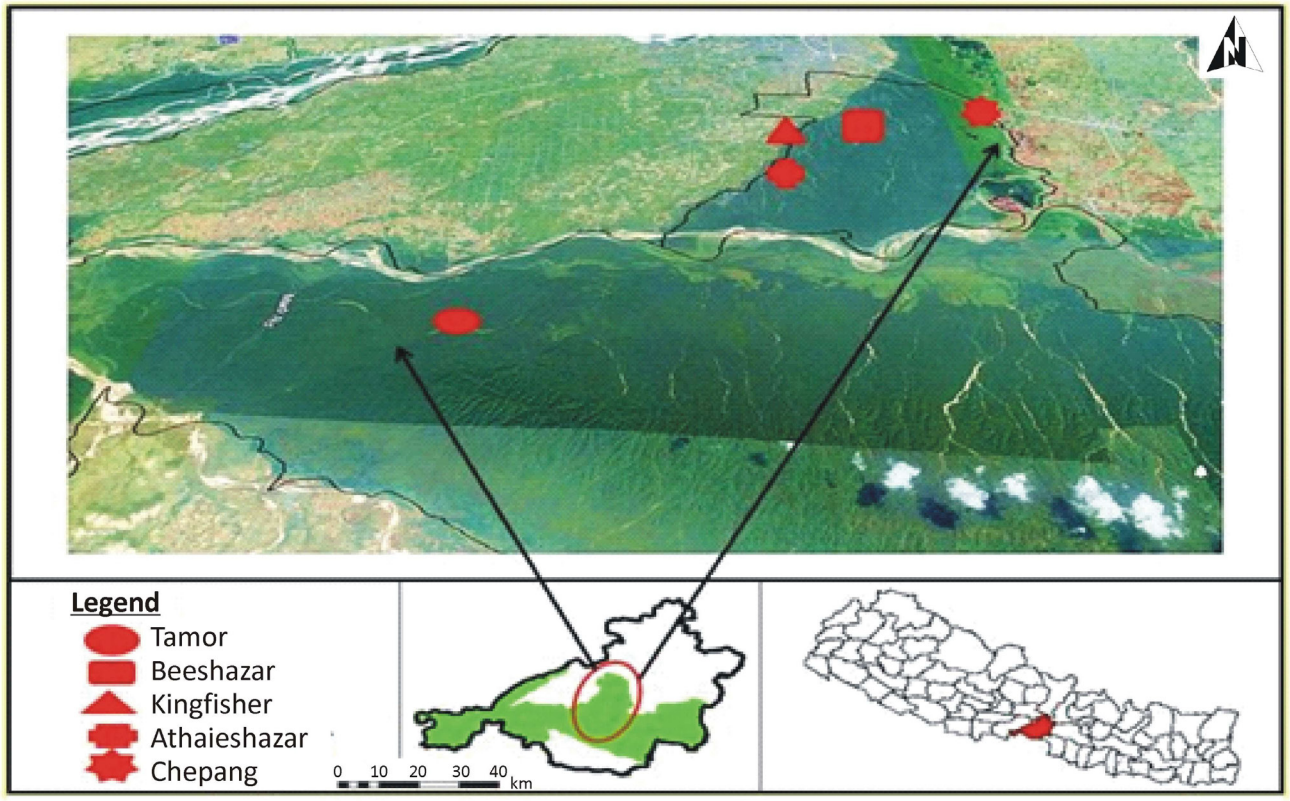

Fig. 1. Location map of studied lakes

40 quadrats in each lake were plotted to analyze frequency (F) and relative frequency (RF), density (D) and relative density (RD), coverage (C) and relative coverage (RC) and the Importance Value Index (IVI). IVI was introduced by Curtis and McIntosh (1951) as an index of vegetation importance within a stand. It is the function of relative frequency, relative density and relative coverage of each species. This index provides a quantitative basis for the classification of community. The IVI value of any species in a community ranges between 0 and 300. The following formula was used to calculate IVI:

$$IVI = RF + RD + RC . \quad [1]$$

Identification 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).

Macrophyte species diversity in the lake was computed using the Shannon and Weiner Diversity Index. This is a widely used method of calculating biotic diversity in aquatic ecosystems (Ghosh and Biswas 2015). A diversity index was obtained for each lake using the Shannon Wiener index (H) calculated according to following formula:

$$H = -\sum[(p_i) \times (\ln p_i)] , \quad [2]$$

where: p_i is the proportion of individuals of species *"i"*.

Results

The highest and lowest value for DO was found in Kingfisher and Chepang, respectively. The highest value of inorganic phosphorus was found in Tamor and the lowest in Chepang. The highest values for total hardness, free CO_2 and total alkalinity were found in Athaieshazar and the lowest values for these were found in Beeshazar, Tamor and Kingfisher, respectively. The highest and lowest values for nitrate were found in Beeshazar and Kingfisher. The highest values for total solid matter, conductivity, pH and temperature were found in Kingfisher, Athaieshazar, Tamor and Beeshazar, respectively and the lowest values for these parameters were

Table 1. Methods (Rice et al. 2012) and instruments used for determination of physico-chemical parameters of lakes' water

Parameter	Method	Instrument
Temperature	–	Mercury Thermometer
pH	–	pH-Meter (model pH 009)
DO	Winkler's Iodometric Method	–
Free CO_2	Phenolphthalein-Titration	–
Total Hardness	EDTA Method	–
Total Alkalinity	Acid-Base Titration	–
Total Solid Matter	Complete Evaporation Method	–
Conductivity	–	Conductivity meter (model 191)
Nitrate	Phenol Disulphonic acid method	Spectrophotometer (Milton Roy Spectronic 21)
Inorganic Phosphorus	Ammonium Molybdate Solution Method	Spectrophotometer (Milton Roy Spectronic 21)

found in Tamor, Chepang, Kingfisher and Kingfisher (Table 2).

Among the five studied lakes, two lakes, i.e. Kingfisher and Athaieshazar had moderately hard water (i.e. hardness value ranges between 75-150 mg dm^{-3}) whereas the other three lakes, i.e. Tamor, Beeshazar and Chepang had soft water (i.e. hardness value ranges between 0-75 mg dm^{-3}) (Table 2). The study showed that three lakes, i.e. Tamor, Kingfisher and Athaieshazar had good water quality and two lakes, i.e. Beeshazar and Chepang had poor water quality in terms of DO.

All the studied lakes fell into the hypereutrophic category for nitrate and phosphorus concentration on the basis of trophic level proposed by Forsberg and Ryding (1980).

Throughout the studied lakes, the Poaceae family had the highest number of species belonging to dicotyledons (*Chromolaena odorata*, *Clerodendrum viscosum*, *Desmodium confertum*, *Lantana camara*, *Sida rhombifolia*) (Fig. 2). Shannon Wiener's diversity Index (H) indicated that macrophyte species diversity was the highest (2.29) in Chepang Lake (Table 3). In Tamor Lake, *Spirodela polyrhiza* had the highest value in terms of IVI and in all other four lakes, *Eichhornia crassipes* had highest IVI value (Table 4).

Among the five studied lakes, the highest invasive species (*Eichhornia crassipes*, *Ageratum houstonianum*, *Ipomoea carnea* ssp *fistulosa*, *Lantana camara*, *Mikania micrantha*) proportion was found in Athaieshazar Lake and the lowest in Tamor Lake (Fig. 3).

There was no significant relationship (i.e. p

Table 2. Extreme and mean (± standard deviation, SD) values of physico-chemical parameters of water in the studied lakes

Parameter	Lake														
	Tamor			Beeshazar			Kingfisher			Athaieshazar			Chepang		
	Min.	Max.	Mean ±SD	Min.	Max.	Mean ±SD	Min.	Max.	Mean ±SD	Min.	Max.	Mean ±SD	Min.	Max.	Mean ±SD
DO [mg dm^{-3}]	5.7	9.4	6.7±0.3	2.8	10.8	5.2±0.8	4.1	9.7	6.8±0.5	4.6	9.2	6.54±0.42	1.4	8.7	4.6±0.6
IP [mg dm^{-3}]	1.5	4.4	2.9±0.3	1.7	3.2	2.5±0.2	1.7	2.6	2.2±0.1	2.2	3.2	2.7±0.1	1.45	3.0	2.1±0.1
TH [mg dm^{-3}]	52	86	60.5±3.0	42	74	53.5±3.4	52	138	81.3±7.9	124	152	133.5±2.5	42	94	57.7±5.9
CO_2 [mg dm^{-3}]	49.9	105.9	69.8±4.8	44.0	93.9	70.9±5.0	61.93	107.87	86.7±4.0	105.9	197.8	142.0±7.2	51.9	105.9	79.2±4.4
TA [mg dm^{-3}]	50	120	74.2±5.9	50	80	62.5±2.2	30	80	53.3±5.1	110	180	147.5±6.8	40	80	58.3±3.2
Nitrate [mg dm^{-3}]	1.1	7.1	3.4±0.6	1.5	6.4	4.4±0.5	1.6	2.5	1.9±0.1	2.2	3.3	2.7±0.1	1.2	9.0	4.2±0.8
TSM [mg dm^{-3}]	200	400	233.3±22.5	200	600	350.0±55.7	200	800	433.3±59.5	200	600	350.0±43.5	200	800	333.3±51.3
Cond. [µS cm^{-1}]	48.9	65.2	57.1±7.1	40.75	57.1	48.5±8.5	48.9	57.1	49.6±9.6	122.3	138.6	129.7±45.5	32.6	57.1	45.5±5.9
pH	7.9	9.3	8.5±0.2	6.8	8.2	7.4±0.2	6.6	7.0	6.8±0.0	7.0	7.4	7.2±0.0	6.6	7.0	6.8±0.1
Temperature [°C]	29	30	29.3±0.1	27	36	30.3±1.0	25	28	27.0±0.4	27	33	29.0±0.7	26	28	27.3±0.3

Abbreviations: DO – dissolved oxygen, IP – inorganic phosphorous, TH – total hardness, TA – total alkalinity, TSM – total solid matter

Table 3. Variation in species diversity index values among studied lakes (bold value indicate highest value)

Lake	Shannon Wiener's Diversity Index
Tamor	2.03 ±0.030
Beeshazar	2.26 ±0.012
Kingfisher	2.28 ±0.008
Athaieshazar	2.26 ±0.012
Chepang	2.29 ±0.005

Table 4. Importance Value Index (IVI) of macrophytes in studied lakes

Lake	Plant species	IVI
Tamor	*Spirodela polyrhiza* (L.) Schleid.	227.17
Beeshazar	*Eichhornia crassipes* (Mart.) Solms	158.54
Kingfisher	*Eichhornia crassipes* (Mart.) Solms	219.01
Athaieshazar	*Eichhornia crassipes* (Mart.) Solms	231.21
Chepang	*Eichhornia crassipes* (Mart.) Solms	274.01

>0.01) between nutrient content in the lake and the cover of invasive plant species (Fig. 4).

Based on growth form, numbers of emergent macrophytes (*Ipomoea carnea* ssp *fistulosa*, *Cyrtococcum accrescens*, *Hymenachne pseudointerrupta*, *Persicaria hydropiper*, *Leersia hexandra*, *Colocasia esculenta*) were high in most of lakes except for Chepang Lake where free floating macrophytes (*Eichhornia crassipes*, *Pistia stratiotes*, *Azolla pinnata*, *Lemna perpusilla*, *Spirodela polyrhiza*) were dominant.

RDA ordination explains the relationship between plots, macrophytes and different environmental variables (Fig. 5). Forward selection and the Monte Carlo permutation test revealed that pH and conductivity were the most important variable (p = 0.0001) governing macrophyte composition. DO was the third most significant variable (p = 0.0029). From RDA analysis it was found that lakes with high nitrate concentrations are characterized by the growth of *Ipomoea carnea* ssp *fistulosa*, *Spirodela polyrhiza, Thelypteris prolifera*. Lakes with a high amount of inorganic phosphorus concentrations support the growth of *Leersia hexandra, Ludwigia adscendens, Acmella paniculata* and lakes with high DO concentrations supported the growth of *Spermacoce alata, Persicaria hydropiper, Mikania micrantha* and *Hymenachne pseudointerrupta* (Fig. 5B). The names of the studied plant species are listed in

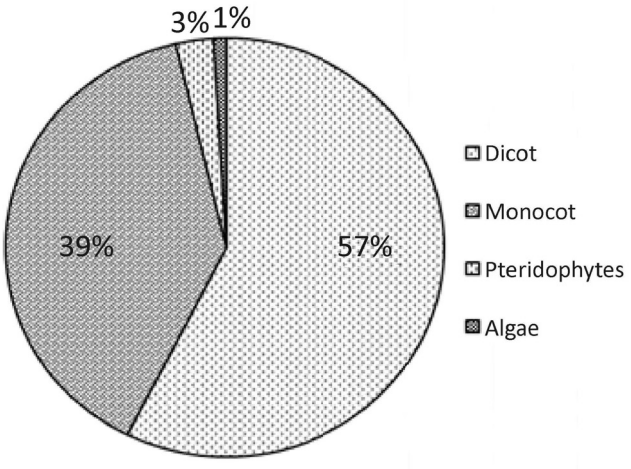

Fig. 2. Percentage of species by taxonomic groups

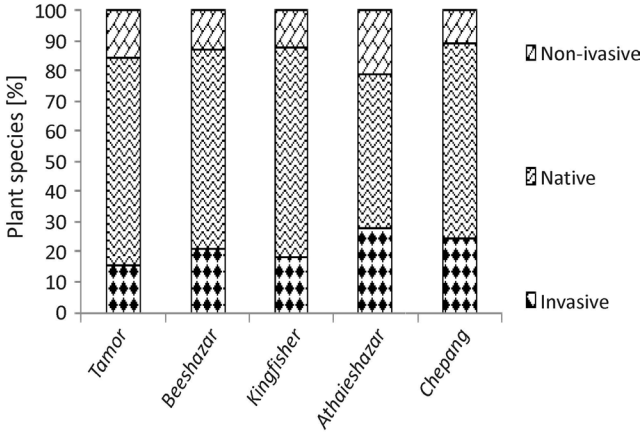

Fig. 3. Proportion of invasive, non-invasive and native species

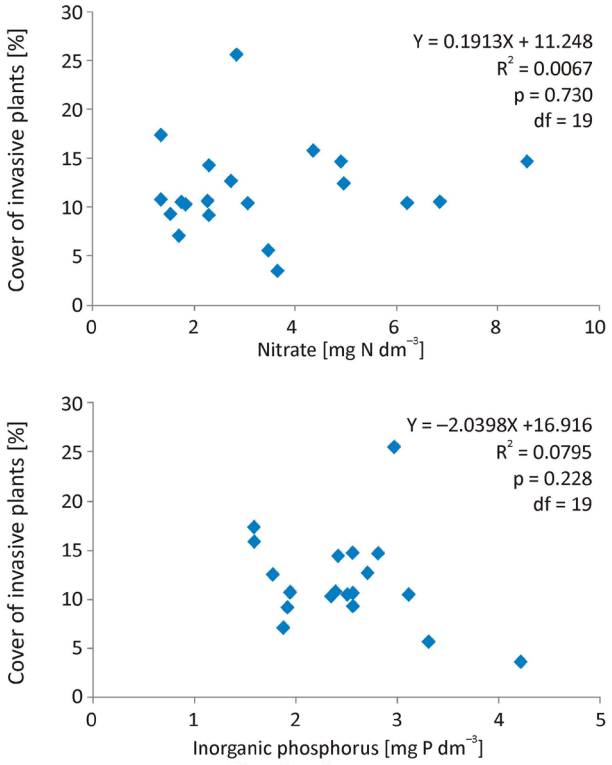

Fig. 4. Relation of nutrients (mg dm^{-3}) with cover of invasive plant species (%)

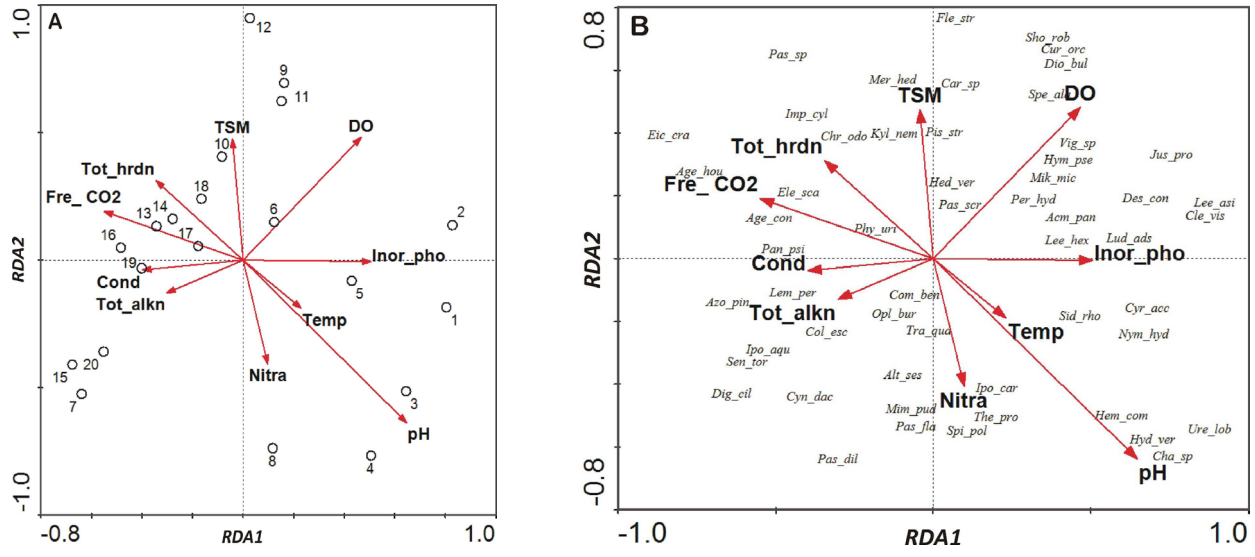

Fig. 5. RDA biplots for studied plots and environmental variables (A), and species along with environmental variables (B). Abbreviations used: DO – Dissolved Oxygen, Tot_hrdn – Total Hardness, Nitra – Nitrate, Tot_alkn – Total Alkalinity, Inor_pho – Inorganic phosphorus, TSM – Total Solid Matter, Cond – Conductivity, Temp – Temperature. All plant species abbreviations are given in Table 5

Table 5. Names of plant species and their abbreviation

Plant species	Abbrev.	Plant species	Abbrev.
Acmella paniculata (Wallich ex Candolle) R.K. Jansen	Acm_pan	*Kyllinga nemoralis* (J.R. & G. Forst.) Dandy ex Hutch. & Dalziel	Kyl_nem
Ageratum conyzoides L.	Age_con	*Leea asiatica* (L.) Ridsdale	Lee_asi
Ageratum houstonianum Mill.	Age_hou	*Leersia hexandra* Swartz.	Lee_hex
Alternanthera sessilis (L).	Alt_ses	*Ludwigia adscendens* (L.) H. Hara	Lud_ads
Azolla pinnata R. Br.	Azo_pin	*Lemna perpusilla* Torr.	Lem_per
Carex sp.	Car_sp	*Merremia hederacea* (Burm. f.) Hallier f.	Mer_hed
Chara sp.	Cha_sp	*Mikania micrantha* Kunth	Mik_mic
Chromolaena odorata (Spreng) King & Rob.	Chr_odo	*Mimosa pudica* L.	Mim_pud
Clerodendrum viscosum Vent.	Cle_vis	*Nymphoides hydrophyllum* (Lour.) Kuntze	Nym_hyd
Colocasia esculenta (L.) Schott	Col_esc	*Oplismenus burmannii* (Retz.) P. Beauv.	Opl_bur
Commelina benghalensis L.	Com_ben	*Paspalum scrobiculatum* L.	Pas_scr
Curculigo orchioides Gaertn.	Cur_orc	*Paspalidium flavidum* (Retz.) A. Camus	Pas_fla
Cynodon dactylon (L.) Pers.	Cyn_dac	*Paspalum dilatatum* Poir.	Pas_dil
Cyrtococcum accrescens (Trin.) Stapf	Cyr_acc	*Paspalidium* sp.	Pas_sp
Desmodium confertum DC.	Des_con	*Panicum psilopodium* Trin.	Pan_psi
Digitaria ciliaris (Retz.) Koeler	Dig_cil	*Persicaria hydropiper* (L.) Spach	Per_hyd
Dioscorea bulbifera L.	Dio_bul	*Phyllanthus urinaria* L.	Phy_uri
Eichhornia crassipes (Mart.) Solms	Eic_cra	*Pistia stratiotes* L.	Pis_str
Elephantopus scaber L.	Ele_sca	*Senna tora* (L.) Roxb.	Sen_tor
Flemingia strobilifera (L.) W.T. Aiton	Fle_str	*Shorea robusta* Gaertner f. (seedling)	Sho_rob
Hedyotis verticillata (L.) Lam.	Hed_ver	*Sida rhombifolia* L.	Sid_rho
Hemarthria compressa (L.f.) R. Br.	Her_com	*Spermacoce alata* Aubl.	Spe_ala
Hymenachne pseudointerrupta C. Muell.	Hym_pse	*Spirodela polyrhiza* (L.) Schleid.	Spi_pol
Hydrilla verticillata (L.f.) Royle	Hyd_ver	*Thelypteris prolifera* (Retz.) C.F. Reed	The_pro
Imperata cylindrica (L.) P. Beauv.	Imp_cyl	*Trapa quadrispinosa* Roxb.	Tra_qua
Ipomoea aquatica Forssk.	Ipo_aqu	*Urena lobata* L.	Ure_lob
Ipomoea carnea ssp *fistulosa* (Mart. ex Choisy) D.F. Austin	Ipo_car	*Vigna* sp.	Vig_sp
Justicia procumbens L.	Jus_pro		

Table 5.

Discussion

Among the studied lakes, the high DO value in Kingfisher might be due to low temperature and high aeration rate (Burlakoti 2003) and the low DO in Chepang might be due to the high coverage of surface water by macrophytes (Mathur et al. 2005) which revealed the increase in organic pollution of this lake.

A higher value of inorganic phosphorus was found in Tamor lake; this may be because the runoff water could carry phosphorous from forest (Bhattarai et al. 2008) as Tamor Lake is located in an area of low urban density and in the core area of the CNP. The high value could also be due to natural disasters like flooding. A lower value was found in Chepang Lake, perhaps as a result of the high consumption of available phosphate by macrophyte species (Parinet et al. 2004).

The higher value of nitrate found in Beeshazar Lake may be due to the runoff of polluted water with agricultural fertilizers, pesticides and untreated industrial discharge as well as domestic wastes from the Khageri canal (Burlakoti 2003) and it could also be related to higher microbial decomposition, while the lower value in Kingfisher Lake may be

due to lower microbial activities (denitrification) as it had lower temperature as compared to other studied lakes.

The high total hardness in Athaieshazar might be due to contents released from dead mollusc shells (Khan and Chowdhury 1994) and it is possible that the low value in Beeshazar is associated with the low release of calcium and magnesium ions from sediments and rocks (Jinwal and Dixit 2008).

A higher value of free CO_2 was found in Athaieshazar (142.00 ±7.18 mg dm^{-3}). In the present study, the increase in free carbon dioxide can be attributed to the higher rate of decomposition of macrophytes and the favorable temperature (Sukhija 2007); a lower free CO_2 value was found in Tamor Lake (69.75 ±4.78 mg dm^{-3}). CO_2 production was less in Tamor Lake possibly owing to the slow decomposition of organic matter (Patra et al. 2010).

The highest total alkalinity (147.50 ±6.76 mg dm^{-3}) among the studied lakes was found in Athaieshazar. A similar value was obtained in Beeshazar Lake during the rainy season by Burlakoti (2003). The degradation of plants as well as other organisms might be one of the reasons for the increase in bicarbonate and thus the alkalinity (Chaurasia and Pandey 2007). Kingfisher Lake had the lowest value (53.33 ±5.12 mg dm^{-3}) of total alkalinity. Total alkalinity showed strong positive correlation with conductivity in the present study.

As the Kingfisher Lake is situated near the residential area of Tikauli, the high value of TSM in the lake might be a result of the addition of domestic waste water, garbage and sewage etc. into the natural surface water of lake from nearby residential area. A lower value of TSM (233.33 ±22.47 mg dm^{-3}) was found in Tamor Lake, which is situated in an area of low urban density.

The conductivity value (129.72 ±45.50 µS cm^{-1}) was found to be high in Athaieshazar Lake. This could be due to ionic concentration or dissolved inorganic substances (Mathur et al. 2008) present in the lake. The low conductivity (45.50 ±5.90 µS cm^{-1}) in Chepang Lake might be responsible for the soft nature of the water (Mustapha 2008) and also owing to the high uptake of ions by organisms for their metabolism (Mustapha and Omotosho 2005).

pH was found to be in the alkaline range (7.23 ±0.04 to 8.48 ±0.15) for three lakes i.e. Tamor, Beeshazar and Athaieshazar, while acidic values (6.80 ±0.03) was found for two lakes i.e. Kingfisher and Chepang. The water temperature in the present study ranged from 25 to 36°C.

The dominance of the Poaceae family may be due to its effective long-distance dispersal, successful establishment biology, ecological flexibility, resilience to disturbance and capacity to modify the environment by changing the nature of fire and mammalian herbivory (Linder et al. 2018) and the high number of dicotyledons may be attributed to the influence of the tropical climate (Burlakoti 2003).

The high Shannon Wiener diversity Index (H) value indicates greater diversity, as well as more equitable distribution of species in the Chepang Lake as compared to the other studied lakes. Diversity and anthropogenic disturbances are inversely related to each other (Ghosh and Biswas 2015).

The dominance of *Spirodela polyrrhiza* in Tamor Lake might be associated with high phosphorus concentration (Takamura et al. 2003). Dominance as well as a higher IVI value of *Eichhornia crassipes* was associated with human interference and the mixing of irrigation (Khageri) canal water which contains *Eichhornia crassipes* (Burlakoti 2003) in most of the studied lakes.

Among the five studied lakes, the proportion of invasive species was found to be the highest in Athaieshazar Lake, i.e. 28%. In comparison to the other lakes, Athaieshazar Lake is located in an area of high urban density and is close to the human trail area; frequent human disturbances could be the reason for high proportion of invasive species (Van Winkle 2014) in this lake.

In the present study, the hypothesis related to naturalized invasive macrophyte species was statistically rejected i.e. that an increase in the nutrient content of lake water will increase the abundance of macrophyte plant species in the lake. This could be because of the more frequent removal of macrophytes from the lakes.

Emergent plants were the most dominant growth form of macrophytes in most of the lakes. These studies partly support observations by Kolada (2014), who observed an increased share of emergent vegetation in the littoral zone with increasing eutrophication.

Conclusion

In conclusion, richness in nitrate and phosphorus values ranked all the studied lakes as hy-

pereutrophic. The dominance of emergent, in terms of IVI value, over other growth forms indicates the encroachment of littoral vegetation, reducing the core area of the studied lakes. Variations on the environmental variables of water of lakes implies the cumulative effect of excessive growth of the invasive macrophytes, high human and wild animal disturbances as well as natural disasters. The luxuriant growth of the invasive macrophytes also revealed the productive nature of the lakes and they can be taken as ecological indicators of organic pollution.

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