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Physico-chemical characterizations of surface water and underlying sediments and limnological status of Beeshazari Lake, a Ramsar site at Chitwan, Nepal

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Abstract

Beeshazari Lake, a Ramsar site at Chitwan in central Nepal of international concern and importance, provides suitable habitats for many globally threatened or endangered flora and fauna but the lake of proper monitoring and management practices have caused the severe degradation of the lake. In the present study, physico-chemical characterizations of surface water and bottom sediments were made to assess the limnological status of the lake. The study was conducted for a period of three consecutive years (2016-2018). The mean levels of temperature, transparency, pH, DO, NO_3^--N, TN, TP, GPP and Fe in the lake water were found to be 23.7 ^{0}C, 1.1 m, 6.5, 4.1 mg/L, 217.9 µg/L, 1386.4 µg/L, 208.0 µg/L, 36.4 g C/m^2/yr and 0.5 mg/L respectively. The lake water was found unfavorable to aquatic animals due to low pH and transparency, depleted DO level and high levels of TN and TP. Similarly, the mean levels of temperature, pH, TN, available P, OM and Fe in the underlying sediments of the lake were recorded as 24.0 ^{0}C, 6.2, 3.7 g/Kg, 85.2 mg/Kg, 72.0 g/Kg and 29.0 mg/g respectively. The elevated levels of OM, TN and available P in the lake sediments are potential nutrient sources to the surface water. Moreover, the eutrophic nature of the lake was by transparency and nitrogen criteria and hyper-eutrophic by phosphorus criteria. Correlation analysis revealed positive as well as negative correlations among some of the water quality parameters as well as sediment parameters. From the present study, we conclude that Beeshazari Lake is in urgent need of effective planning and policies, strategies and management practices for its conservation in the long run so that the present limnological status of the lake could be improved.

Keywords: Beeshazari lake, ramsar site, underlying sediments, water quality parameters, trophic status, limnology.

Introduction

Wetlands play vital roles in providing suitable habitats for a large number of globally threatened or endangered flora and fauna and also support high biodiversity[1]. While the wetlands provide ecological services to these living creatures, many aquatic organisms in wetland ecosystems act as bio-indicators for evaluating ecological condition of water bodies[2]. The environmental status of the wetland area is therefore evaluated based on their existence[3].

Wetlands not only provide suitable habitat for wildlife species but also a variety of foods to them. They also help in flood control, recharge the groundwater and buffer the bottom sediments improving water quality and retain nutrients from incoming waters[4]. However, the wetlands habitats are threatened by human intervention such as land reclamation, clearing of jungle, illegal hunting, over grazing and exploitation of wetlands species and increased pollution. Besides, the runoff agriculture with excessive quantities of nutrients and pesticides has also degraded the wetlands severely[5]. Considering the degradation of wetlands at an alarming rate worldwide, it was in 1971 the Ramsar Convention on Wetlands was signed with a view to extend international supports for the preservation and conservation of critical wetlands and their resources.

The limnological status of wetlands is often evaluated by water quality in addition to underlying sediments. Likewise, the aquatic life of different species of fish, zooplanktons, and other living creatures are often influenced by the lake water quality as the primary factor[6]. The physico-chemical parameters influence the distribution of aquatic biota as well as the floristic and faunal diversity of wetlands[7]. Besides, organic matter and minerals get accumulated at the bottom sediments that act as a reservoir for potential nutrient source to the lake system[8]. The organic matters that accumulate in water and bottom sediments

can cause eutrophication leading to the deterioration of the water quality and quantity.

Beeshazari Lake, a Ramsar site located in Chitwan district, was enlisted in Ramsar convention in 23rd August 2003 because of its' rich biodiversity and the need felt for its immediate protection and conservation[9]. The lake system has been a suitable habitat for 40 species of globally threatened birds and 15 species of nationally threatened birds[10]. However, Beeshazari Lake is currently facing the problem of extinction very soon due to inefficiency in management practices. There is a massive growth of aquatic macrophytes like algae and water hyacinth throughout the year that has covered the wide open areas of the lake. As a result, the lake system has suffered from deterioration of surface water quality and underlying sediments with emergence of ecological problems.

There are very limited literatures on water quality, underlying sediments, and lake productivity supporting the management and conservation aspects of Beeshazari Lake. The present study was, therefore undertaken to fill up those information gaps. The main objectives of the study were to assess some of the physico-chemical parameters of the surface water and underlying sediments and then to evaluate the limnological status of Beeshazari Lake. Physico-chemical parameters such as temperature, transparency, pH, dissolved oxygen (DO), nitrate, total nitrogen (TN) and total phosphorus (TP), GPP and iron (Fe) of surface water were determined along with temperature, pH, organic matter (OM) content, TN concentration, and available phosphorus and iron (Fe) level of bottom sediments. Besides, the study aimed to find correlations among the parameters of both the water and sediments.

Materials and methods

Study area: Beeshazari Lake is considered as the lowland region of Nepal ranking the second largest by area (Figure-1). The lake is situated inside the buffer zone of Chitwan National Park at an altitude of 286m, latitude of 27˚37'0"N, longitude of 84˚25'59"E and 5km south of Bharatpur city[11]. Ratnanagar Municipality at the east borders the lake, Bharatpur Metropolitan city at the west, the East West Highway at the north and the Rapti river at the south[12]. The lake has spread to an area of 3.2 km^2 and 1 km^2 as an open water area with 3m as an average depth. Sources of water inlets to the Beeshazari Lake are from the adjoining Khageri canal during rainy seasons. Average rainfall at the lake is reported as 2200 mm per annum with June as the beginning of monsoon season that extends till October. The average temperature during winter is recorded as 8˚C and summer as 35˚C[13].

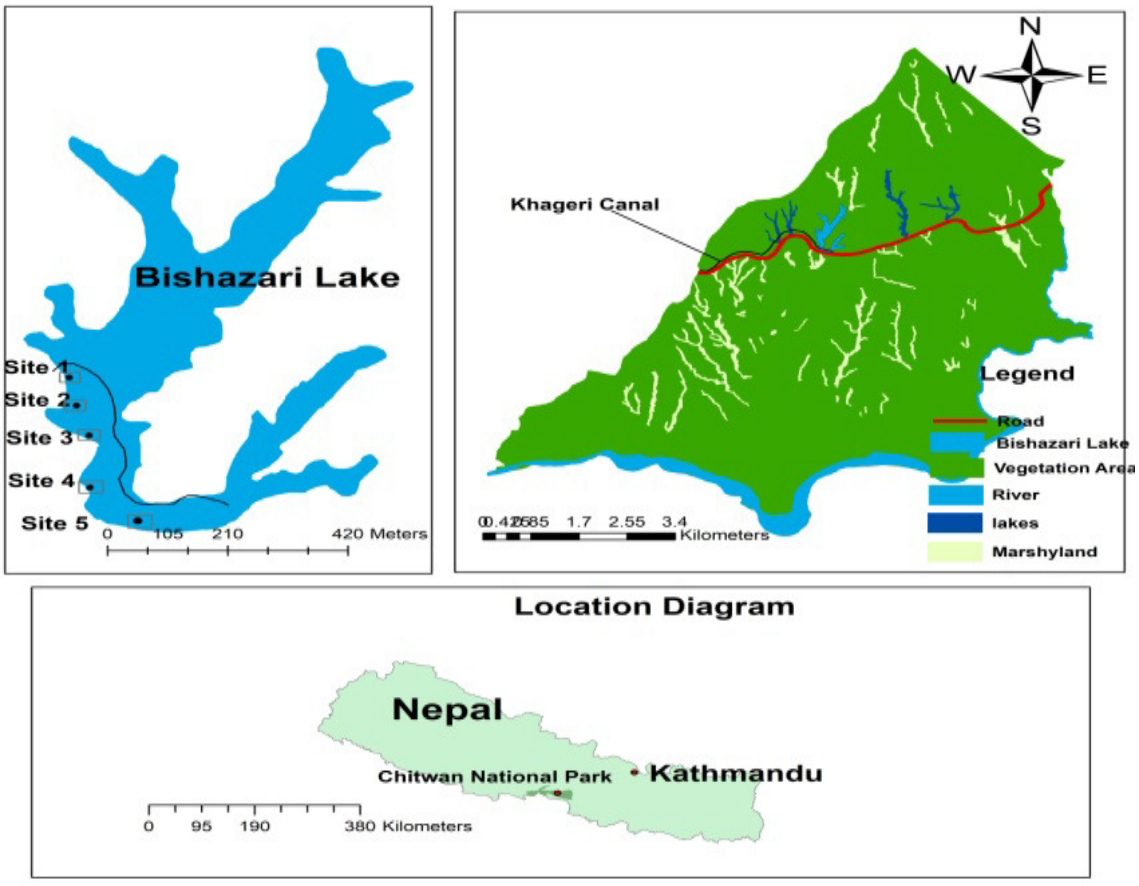

Figure-1: A GIS based location map of Beeshazari Lake along with samplings sites.

Different birds migrate to Beeshazari Lake from the Northern pole of the earth in search of suitable environment. In winter the north poles are very cold and to escape from the massive cold, birds migrate to Bishazari Lake. The lake is, therefore very attractive for the bird lover and serves as an important bird watching center. The Beeshazar Lake is also a habitat of several threatened fauna including vulnerable marsh crocodile (*Crocodylus palustris*), critically endangered gharial (*Gavialis gangeticus*) and several types of fish and waterfowl[14].

The lake system is enriched with 17 types of Graminae species, 13 species of Leguminosae family and 199 species of vegetation[15,16]. Around the lake is also dominated by tree species like sal (*Shorea robusta*). Aquatic vegetations such as water chestnut (*Trapa bispinosa*), water hyacinth (*Eichhornia crassipes*), morning glory (*Ipomea carnea*), evening primrose (*Ludwigia adscendens*), southern cut grass (*Leersia hexandra*), duckweed (*Lemna spp.*) and water velvet (*Azolla imbricate*) are distributed around the lake[17]. During the period of the study, the area was found to be covered mostly by these aquatic plants.

Collection of water and sediment samples: A GIS based sampling map of Beeshazari Lake was prepared to locate five major sampling sites (Figure-1). The sampling sites at the open lake area included inlet, outlet and three others shown by dot representation in the figure. The depth of the lake at the sampling sites ranged from 0.5 to 2.5m with abundance of macrophytes covering the open area of the lake. The water appeared clear at site 1 and relatively turbid near the inlet (site 5), the point of water inlet from the Khageri Canal during the monsoon period. For analysis of multiple water quality parameters, samples of water were collected biannually (winter and summer) from the sites for a period of three consecutive years (2016 to 2018). The samples were collected during morning hours (6:00 to 10:00am) to avoid any kind of disturbance.

Temperature and pH were recorded in situ using mercuric thermometer and digital pH meter respectively. Bottom sediments were collected simultaneously with a soil sampler with a sampling area of 0.025 m^2. Precautions and standard methods were adopted for sampling and preservation of water samples and underlying sediments[18] and analysis of physico-chemical parameters[19], respectively (Table-1).

Statistical Analysis: An IBM-PC computer was used for data processing and analysis. A descriptive statistics such as mean and standard deviation were calculated wherever applicable. Besides, Pearson's correlation analysis was also performed to test any significant positive or negative correlations among the selected parameters for water and sediments.

Results and discussion

Physico-chemical characteristics of surface water: Table-2 shows enumeration of nine physico-chemical parameters of Beeshazari Lake water.

Table-1: Methods used for physico-chemical characterizations of water and sediments.

Physico-chemical parameters	Materials/ Methods
Temperature	Mercuric thermometer
Transparency	Secchi disk
pH	Digital pH meter
DO	Wrinkler's Iodometric Method
NO_3^--N	Stannous chloride reduction method/ Colorometric
TN	Kjeldahl (Organic), Colorimetric (Inorganic)
TP	Phenol disulphonic acid method/ Colorimetric
OM	Walkley- Black Method
Primary Productivity	Light and dark bottle method
Fe	1,10 phenanthroline method/ Colorimetric

Temperature: For the period of study (2016-2018), Beeshazari Lake showed fluctuation in water temperature with range between 14.5 and 32.8˚C in winter and summer respectively. The three years' mean temperature of the lake water was recorded 23.7 ± 0.5˚C which is the most favorable condition to majority of plant and animal communities in the lake for their survival, reproduction and growth. It is reported that the metabolic rates and biological activity of aquatic organisms can be affected by water temperature[20]. The Beeshazari Lake exhibits no thermal stratification due to very shallow nature with location having a tropical climate[21]. As for spatial variation in terms of water temperature, only slight difference in temperature was obtained among the sampling sites of the lake.

Transparency: The level of transparency is affected by particles suspended and/or dissolved in water. The aesthetic quality of lakes can considerably be diminished by high turbidity. Reduction in food supplies, gill malfunction and degrading spawning beds are some of the notable harmful impacts due to poor transparency[22]. Results revealed that the range of transparency among the sampling sites was found to be between 0.6 and 1.6 m. The mean transparency (2016-2018) in Beeshazari Lake was recorded as 1.10 ± 0.40m. The poor transparency was mainly because of suspended and dissolved solid particles rather than free floating aquatic plant species. This may cause reduction in light penetration through the lake water and hence retard the rate of photosynthesis.

pH: pH of water may be altered due to anthropogenic activities as well as microbial deposition of organic matter[22]. The highly alkaline nature of freshwater may significantly affect the metabolic activity of fish, damage to gills, skin and eyes and

even death. Acidic condition also brings about adverse effect on fish and many aquatic macro invertebrates. It is reported that a pH values of 7.0-8.0 is often suitable for diverse aquatic ecosystem[23]. Results revealed that the mean pH of the Beeshazari Lake water was found to be 6.5 ± 0.2 which is slightly acidic in nature meeting the category as of open lakes[24]. The results may be attributed to photosynthetic process, buffering water capacity, and the combined effects of temperature, CO_2 balance and ion liberation[25]. A pH value between 6.5 and 8.5 is often considered suitable[23]. When these limits are taken into consideration, the three years' average pH value of the lake water was found to be favorable for aquatic animals. A slight fluctuation in pH values was, however manifesting among the sampling sites (range between 6.2 and 6.8).

Dissolved Oxygen (DO): DO is one of the important chemical parameters in water quality assessment which often reveals the bio-physical processes existing in the water body. Water saturated with DO is essential for biological life in the lake water. Results revealed that Beeshazari Lake water was found to have 4.1 ± 0.5mg/L as three years' mean DO level. However, DO level among the sampling sites fluctuated between 3.4 to 4.6 mg/L during the period. The mean value is relatively below the guideline value of 5mg/l for fresh water[23]. The depleted level of DO in Beeshazari Lake water may be due to the massive growth of aquatic plants in open area retarding the rate of photosynthetic process. Besides, the subsequent decomposition of dead aquatic plants and animals by micro-organisms may deplete the level of DO in the lake. Low oxygen in water is detrimental to fish and other aquatic creatures in water. In summer, the value of DO level was found well below 4mg/L and more than 6mg/l during winter season. It is reported that DO value between 3.5 and 6.0mg/L is considered poor. Most vertebrates and invertebrates suffer from stressful conditions at DO level below 5mg/L[23]. In view of this, the mean DO level of Beeshazari Lake water was considerably poor.

Nutrient contents (Nitrogen and Phosphorus): Nitrate is formed by microbial oxidation of nitrogen containing organic matters present in municipal sewage and industrial wastes. It is the oxidized form of nitrogen. Run-off agriculture usually contains high concentration of nitrate due to application of nitrate fertilizers. Besides, nitrogen fixing organisms through nitrogen fixation produce nitrate which may be a potential contributor for nitrate content in the late water[26]. The three years' mean concentration of NO_3^--N and total nitrogen (TN) in Beeshazari Lake water was found to be 217.9 ± 26.9µg/L and 1386.4 ± 122.0µg/L respectively. However, some spatial variation in the concentration of both the parameters was observed among the sampling sites during the study period. The range between 192.8 and 260.8µg/L were noted for NO_3^--N and that in between 1200.4 and 1502.4µg/L for TN while comparing among the sampling sites. The high concentrations of NO_3^--N and TN reduce the aesthetic value of the lake since they promote massive growth of aquatic macrophytes on the open lake surface throughout the year. The microbial decomposition of such dead aquatic plants also provides evidence for depletion of DO level in the lake.

Similarly, high concentration of phosphorus (208.0 ± 23.3µg/L) in the Beeshazari Lake water like that of nitrogen, also support the reproduction and stimulates the growth of aquatic species such as water chestnut (*Trapa bispinosa*), water hyacinth (*Eichornia crassipes*) and southern cut grass (*Lersia hexandra*). It was found that the concentration of phosphorus varied between 190.0 and 245.5µg/L among the sites. The high concentration of nutrient like phosphorus in lake water is indicative of water pollution. Although the nutrients aid in crop production through irrigation, their presence in water promote nuisance algal growth and cause eutrophication. Like nitrogen, phosphorus in natural water as phosphates also serves as an essential element in the metabolic activities of animals and plants[26].

Table-2: Variation in water quality parameters at different sites of Beeshazari Lake (Mean ± SD; n = 30).

Parameters	Sampling sites					Mean of all sites
	1	2	3	4	5	
Temperature (^{0}C)	23.6 ± 6.3	24.0 ± 6.0	22.9 ± 5.8	24.2 ± 7.2	23.8 ± 7.6	23.7 ± 0.5
Transparency(m)	1.4 ± 0.2	0.6 ± 0.4	1.2 ± 0.6	1.6 ± 0.5	0.7 ± 0.2	1.1 ± 0.4
pH	6.8 ± 1.6	6.2 ± 0.8	6.6 ± 1.8	6.6 ± 1.4	6.5 ± 2.0	6.5 ± 0.2
DO (mg/L)	3.8 ± 1.8	3.4 ± 1.4	4.6 ± 1.0	4.4 ± 1.2	4.2 ± 2.0	4.1 ± 0.5
NO_3^--N (µg/L)	260.8 ± 120.6	210.4 ± 105.8	225.4 ± 98.6	200.2 ± 102.4	192.8 ± 80.6	217.9 ± 26.9
TN (µg/L)	1200.4 ± 268.6	1355.0 ± 358.0	1488.9 ± 405.7	1502.4 ± 440.8	1385.2 ± 510.4	1386.4 ± 122.0
TP (µg/L)	245.5 ± 20.7	195.8 ± 25.8	215.6 ± 38.6	190.0 ± 42.0	192.9 ± 20.3	208.0 ± 23.3
GPP (g C/m^2/yr)	32.4 ± 5.2	35.7 ± 10.5	30.0 ± 8.2	45.2 ± 12.6	38.8 ± 12.0	36.4 ± 5.9
Fe (mg/L)	0.25 ± 0.08	0.26 ± 0.07	0.31 ± 0.10	0.28 ± 0.04	0.44 ± 0.12	0.5 ± 0.1

Gross Primary Productivity (GPP): The range of GPP was found between 30.0 and 45.2g C/m^2/yr among the sampling sites of Beeshazari Lake. A slight excess of GPP was found at site 4 and relatively low at site 3. The three years' mean GPP of the lake was found to be 36.4 ± 5.9g C/m^2/yr. Since GPP between 25 and 75g C/ m^2/yr falls under mesotrophic status, Beeshazari Lake may therefore be classified under mesotrophic status accordingly[27]. The limited primary productivity at the lake may be due to the dominate role of the aquatic species in consuming sufficient quantities of nutrients such that these nutrients are not made available for the growth of phytoplankton limiting their biomass[28,29].

Iron (Fe): Iron is an essential nutrient required in trace amount for aquatic organisms but is often toxic at elevated level. Upon exceeding a certain threshold level, iron has a harmful effect on enzymatic as well as metabolic activity. Besides, it has a detrimental effect on the growth and reproduction of aquatic animals[22]. Natural water usually contains <1mg/L of iron but up to a level of 100mg/L in groundwater with low DO level. The iron concentration in Beeshazari Lake water was 0.5 ± 0.1mg/L as three years' mean value with range from 0.25 to 0.44mg/L among the sampling sites. Although the mean value of Fe in surface water is under acceptable level for aquatic environment, acidic water can leach out large quantity of iron from underlying sediments[30].

Physico-chemical characteristics of underlying sediments: Table-3 shows enumeration of six physico-chemical parameters of bottom sediments of Beeshazari Lake.

Temperature: The three years' mean temperature of underlying sediments of Beeshazar Lake was found to be 24.0 ± 0.4˚C which exhibited similarity with the water temperature. The spatial variation in terms of sediment temperature was also very narrow with range between 23.5 and 24.4˚C among the sampling sites. Sediments are often differentiated by the deposition of organic and inorganic substances that are transported and suspended to the overlying water. In shallow lakes, nutrient release to the overlying water is often accelerated by high sediment temperatures along with increase in rate of mineralization[31].

pH: In the present study, Beeshazari Lake showed three years' mean pH value of 6.2 ± 0.3 (slightly acidic) in its' underlying sediments. The acidic nature of the sediments can be attributed to high carbon content and organic substances which might also affect the microbial and fungal activities[32]. The pH of the underlying sediments at different sampling sites of Beeshazari Lake was found to be in range between 5.8 and 6.6. The values are quite favorable for microbial activities. The nutrients exchange between the water and sediments is regulated by pH[33] and low pH often stimulates the release of nutrient like phosphorus from the underlying sediments[34].

Nutrient contents (Nitrogen and Phosphorus): The mean nitrogen (TN) and available phosphorus (TP) concentration from all the sampling sites of Beeshazari Lake were found to be 3.7 ± 1.7g/kg and 85.2 ± 20.5mg/kg respectively. These mean values were estimated from the study of three consecutive periods (2016-2018). There are also some variation in the concentration of TN and available P probably due to varying degree of metabolic activities among the sampling sites. Site 4 showed higher value of TN (6.2g/Kg) while site 5 showed higher value of available P (120.1 mg/Kg). Phosphorus tends to accumulate at the bottom sediments since they are not used up through metabolic processes[35]. The phenomenon is against nitrogen and carbon which are generally lost during metabolic processes. In shallow lakes, the internal loading of nutrients occurs due to microbial mineralization[36]. Algal blooming and eutrophication in the lake are often initiated and accelerated by internal phosphorus recycling from the bottom sediments to the euphotic zone even when the external sources of phosphorus decrease[37]. Organic matter can control nitrogen level in the sediments by 90 per cent or even more of those existing in organic forms[38]. It is reported that 30 mg/Kg of available phosphorus in the sediment is considered poor; 30 to 60 mg/Kg as medium and > 60 mg/Kg as highly productive[39]. Considering this limit, the mean concentration of available phosphorus (85.2 mg/kg) in the Beeshazari Lake water is favorable for high productivity.

Table-3: Variation in properties of underlying sediments at different sites of Beeshazari Lake (Mean ± SD; n = 30).

Parameters	Sampling sites					Mean of all sites
	1	2	3	4	5	
Temperature (^{0}C)	23.8 ± 4.5	24.2 ± 5.8	23.5 ± 4.2	24.0 ± 6.9	24.4 ± 5.2	24.0 ± 0.4
pH	6.2 ± 1.5	5.8 ± 1.0	6.0 ± 1.8	6.6 ± 2.0	6.4 ± 1.8	6.2 ± 0.3
TN (g/Kg)	2.8 ± 0.8	2.0 ± 1.0	3.0 ± 0.8	6.2 ± 1.2	4.5 ± 0.8	3.7 ± 1.7
Available P (mg/Kg)	82.6 ± 8.1	66.3 ± 10.5	80.5 ± 14.9	76.6 ±18.2	120.1 ± 24.9	85.2 ± 20.5
OM (g/Kg)	46.2 ± 7.8	48.1 ± 6.3	55.5 ± 5.9	125.8 ± 17.2	84.4 ± 6.4	72.0 ± 33.8
Fe (mg/g)	26.4 ± 4.5	24.6 ± 7.4	28.7 ± 8.2	34.5 ± 5.6	30.6 ± 6.9	29.0 ± 3.4

Organic Matter (OM): The sampling sites of Beeshazari Lake recorded the concentration of OM in the range between 46.2 and 125.8 g/Kg. A consecutive period of three years revealed the mean of organic matter content in dry sediments with 72.0 ± 33.8 g/Kg. The elevated level of organic matters in the underlying sediments of the lake may be due to large deposition of dead aquatic plants as well as animals. These organic matter contents might be undergoing subsequent decomposition by micro-organisms, evidently supported by the depleted levels of DO at the Beeshazari Lake.

Iron (Fe): Iron has a fundamental role in bio-geochemistry of lake nutrients. While itself rarely limiting in freshwaters, iron acts as a catalyst of several photochemical reactions and is a substrate for several microbial groups (iron reducing bacteria, iron oxidizing bacteria) and can adsorb chemically other metals such as phosphorus, the main nutrient limiting primary production in lakes[30]. The concentration of Fe among the sampling sites was found to vary in the range between 24.6 and 34.5 mg/g. The three years' mean concentration of Fe was found to be 29.0 ± 3.4mg/g in the Beeshari Lake. The high concentration of Fe is toxic to aquatic organisms as their survival, growth and reproduction activities can be affected.

Correlation analysis among the parameters: Table-4 shows correlation analysis among nine parameters of water quality. Results revealed that temperature of water showed a significant negative correlation with DO (r=-0.764, p<0.05, n=0). A significant positive correlation was obtained between pH and Fe (r=0.687, p<0.05, n=30) (Table-4). TP exhibited significant positive correlation with DO (r= 0.678, p <0.05, n=30), nitrate (r =0.821, p < 0.05, n=30) and TN (r=0.910, p<0.05, n= 30). GPP showed significant positive correlation with both nitrate (r = 0.699, p< 0.05, n= 30) and TN (r= 0.710, p< 0.05, n=30). Likewise, results revealed significant positive correlation between TN and nitrate (r= 0.969, p< 0.05, n= 30).

Table-5 shows correlation analysis among six parameters of the underlying sediments. Analysis revealed a significant positive correlation between the available P and sediment temperature (r = 0.910, p<0.05, n=30) (Table-5). Fe showed a significant positive correlation with available P (r = 0.924, p < 0.05, n = 30) and OM (r =0.867, p < 0.05, n = 30). Likewise, results revealed a significant positive correlation between TN and OM (r = 0.892, p < 0.05, n = 30). There was no other strong correlations found among the parameters.

Table-4: Person's correlation analysis among parameters for water quality.

	Temperature	Transparency	pH	DO	NO_3^--N	TN	TP	GPP	Fe
Temperature	1.000	-0.499	0.518	-0.764*	0.452	0.512	0.554	0.510	0.542
Transparency	-0.499	1.000	0.421	0.465	0.128	-0.154	-0.199	0.210	0.448
pH	0.518	0.421	1.000	0.427	0.424	0.313	0.204	0.189	0.687*
DO	-0.764*	0.465	0.427	1.000	0.412	0.522	0.678*	0.322	0.258
NO_3^--N	0.452	0.128	0.424	0.412	1.000	0.969*	0.821*	0.699*	0.325
TN	0.512	-0.154	0.313	0.522	0.969*	1.000	0.910*	0.710*	0.465
TP	0.554	-0.199	0.204	0.678*	0.821*	0.910*	1.000	0.542	0.758*
GPP	0.510	0.210	0.189	0.322	0.699*	0.710*	0.542	1.000	0.512
Fe	0.542	0.448	0.687*	0.258	0.325	0.465	0.758*	0.512	1.000

Significance level: *****p<0.05.

Table-5: Person's correlation analysis among parameters for sediments.

	Temperature	pH	TN	Available P	OM	Fe
Temperature	1.000	-0.710	-0.324	0.889*	-0.282	0.442
pH	-0.710	1.000	0.562	-0.446	0.574	0.548
TN	-0.324	0.562	1.000	0.224	0.892*	0.382
Available P	0.889*	-0.446	0.224	1.000	0.236	0.924*
OM	-0.282	0.574	0.892*	0.236	1.000	0.867*
Fe	0.442	0.548	0.382	0.924*	0.867*	1.000

Significance level: *****p<0.05.

Trophic status: Table-6 shows the trophic status of lakes according to Forsberg and Rydling[40]. Based on the mean levels of transparency (1.1 m), TN (1386.4 µg/L) and TP (208.0µg/L) in surface water of Beeshazari Lake, it was found to be eutrophic in nature by transparency (1-2m) and nitrogen (600-1500 µg/L) and hypereutrophic by phosphorus criteria (> 100 µg/L). The results are also in consistent with the results demonstrated by Niraula[21] who also classified Beeshazari Lake as eutrophic and hyper-eutrophic in nature following the similar criteria.

Table-6: Trophic status of Beeshazari Lake according to Forsberg and Ryding (1980).

Transparency (m)	TN (µg/L)	TP (µg/L)	Trophic -status
> 4	< 400	< 15	Oligotrophic
2 - 4	400 – 600	15 – 25	Mesotrophic
1 - 2 (1.1)	600 – 1500 (1386.4)	25 – 100	Eutrophic
< 1	> 1500	> 100 (208.0)	Hypereutrophic

Conservation value and possible sources of pollution in Beeshazari Lake: Beeshazari Lake has water quality in degrading state due to nutrients overloading. The surrounding agricultural farms and lands were found to have injudicious use of huge quantities of nitrogen and phosphorus fertilizers every year. Hence, the agriculture runoff to the lake from the surrounding area is mainly liable to water quality degradation. During monsoon seasons, excessive amount of fertilizer is also washed away by precipitation into lowland regions covered by the lake. These situations have emerged conservation problems by creating a suitable environment for invasive alien plant species for their massive growth and the phenomenon is called eutrophication. Besides, Khageri canal is another potential source of inputs which carry fertilizers, pesticides and industrial effluents along with the water to the lake. Since treatment of waste water is poorly practiced in Nepal, the river receives huge amount of untreated effluents directly from most of the industries. Moreover, discharge of municipal sewage and wastes directly into the water way are also responsible for deteriorating water quality of the lake.

Evidently, there is a rapid growth of industrialization and urbanization in the bordering area of Beeshazari Lake. Hence, the lake can be foreseen in degrading state in the future too. Another problem in strengthening the conservation and management of Beeshazari Lake is the lack of strong policies, rules and regulations in the pertinent area. Although Beeshazari Lake is a part of the buffer zone and the restricted area in terms of human encroachment, its protection and management seem to be still a great challenge.

Conclusion

Assessment of water quality and underlying sediments was made to evaluate the limnological status of Beeshazari Lake. We conclude from the study that water quality status of Beeshazari Lake was found to be unfavorable to aquatic life. The slightly acidic nature of the lake water and depleted levels of DO are indication of stressful conditions for survival and growth of the aquatic organisms. This draws a great attention of people favoring the management of the lake and the conservation of vulnerable marsh crocodile (*Crocodylus palustris*), critically endangered gharial (*Gavialis gangeticus*) and several species of fish. Correlation analysis revealed positive as well as negative correlations among the water quality parameters as well as sediment parameters. The lake sediments were found to be enriched with organic matter and nutrients such as nitrogen and phosphorus which are the basis for possible nutrient sources to the overlying water. Transparency and nitrogen criteria revealed that the lake is eutrophic in nature and hyper-eutrophic by phosphorus criteria.

Beeshazari Lake is the wetland of international concern and importance. This lake system not only supports wetland ecosystems but people in the western Chitwan largely depend on it for irrigation. Hence, periodic examinations of physico-chemical properties and the limnological status of the lake are very much crucial for formulating plans and policies and in implementing management practices for the conservation of Beeshazari Lake in the long run in compliance with the obligations of the Ramsar Convention. Besides, appropriate efforts and effective measures must be undertaken to improve the present limnological status of the lake.

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References

1. Parchizadeh J. and Williams S.T. (2018). Waterbirds targeted in Iran's wetlands. *Science,* 359(6378), 877-878.

2. Green A.J. and Elmberg J. (2014). Ecosystem services provided by waterbirds. *Biological Review*, 89(1), 105-122.

3. Rajpar M. and Zakaria M. (2010). Indah wetland reserve, Selangor Peninsular Malaysia. *Journal of Biological Sciences,* 10(7), 658-666.

4. Groom M.J., Meffe B.K. and Carroll C.R. (2006). Principles of Conservation Biology. 3rd Edition, Sinauer Associates, Inc. Publishers, Sunderland.

5. Ramsar Convention Bureau (2002). The Ramsar Convention on Wetlands of International Importance. An

Introductory Ramsar Brochure, 3rd Edition. http://www.ramsar.org

6. Bratram J. and Ballence R. (1996). Water Quality Monitoring: A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programs, London.

7. Central Board of Immigration and Power of India (1999). Aquatic Weeds and Their Control in Water in India.

8. Tuzun I. and Ince O. (2006). Relationship between Water Flow Volume and In-Lake Total Phosphorus Concentrations via Dissolved Oxygen Concentrations and Temperature in a Warm Temperate Reservoir: Implications by Path Analysis. *Lakes and Reservoirs: Research and Management*, 11(2), 83-96.

9. Report (2018). Wetlands International, The Netherlands. What are wetlands? URL: http://www.wetlands.org. Accessed 31 December 2018.

10. Inskipp C., Baral H.S., Phuyal S., Bhatt T.R., Khatiwada M., Inskipp T., Khatiwada A., Gurung S., Singh P.B., Murray L., Poudyal L. and Amin R. (2016). The status of Nepal's birds: The national red list series. *Zoological Society of London, UK*. https://www.zsl.org/conservation/regions/asia/national-red-list-of-nepals-birds.

11. Lakenet (2019). Protecting and restoring the health of lakes throughout the world. URL: http://www.worldlakes.org/lakedetails.asp?lakeid=10577. Accessed 5 January 2019.

12. Thapa T.B. (2011). Habitat suitability evaluation for Leopard (Panthera pardus) using remote sensing and GIS in and around Chitwan National Park, Nepal. Faculty of Wildlife Sciences, Wildlife Institute of India, Dehradun and Department of Biosciences, Saurashtra University, Rajkot, Gujrat, India. (Ph.D. Thesis).

13. DHM (2005). Department of Hydrology and Metrology. Babar Mahal, Nepal.

14. Report (2006). International Conservation Union and Department of National Parks and Wildlife Conservation, "Ramsar Information Sheet. URL: http://www.wetlands.org/reports/dbdirect-org.cfm?site-id Accessed 2 January 2019.

15. Gilani H., Qamer F.M., Sohail M., Uddin K., Jain A. and Ning W. (2017). Review of ecosystem monitoring in Nepal and evolving earth observation technologies land cover change and its eco-environmental responses in Nepal. Springer, 165-183.

16. Khadka B.B., Acharya P.M. and Rajbhandari S.L. (2017). Population status and species diversity of wetland birds in the Rapti and Narayani rivers and associated wetlands of Chitwan National Park, Nepal. *Journal of Threatened Taxa*, 9(6), 10297-10306.

17. Bhattarai B.P. (2012). Distribution and diversity of storks in the adjoining areas of Chitwan National Park, Nepal. In Himalayan Biodiversity in the Changing World (Kindlmann, P. Ed.). Springer, Dordrecht, 97-114.

18. APHA, AWWA and WPCF (1995). Standard Methods for Examination of Water and Waste Water. 9th Edition, American Public Health Association, Washington DC.

19. Trivedy R.K. and Goel P.K. (1984). Chemical and Biological Methods for Water Pollution Studies. Department of Environmental Pollution, Y.K. College of Science, Karad, India.

20. Parihar S.S., Kumar A., Kumar A., Gupta R.N., Pathak M., Shrivastav A. and Pandey A.C. (2012). Physico-Chemical and Microbiological Analysis of Underground Water in and Around Gwalior City, MP, India. *Res. J. Recent Sci*., 1, 62-65.

21. Niraula R. (2012). Evaluation of the Limnological Status of Beeshazar Lake, a Ramsar Site in Central Nepal. *Journal of Water Resource and Protection*, 4, 256-263.

22. Hosmani S.P. and Bharati S.G. (1980). Limnological studies in ponds and lakes of Dharwad-Comparative phytoplankton ecology of water bodies. *Phykos*, 19(1), 27-43.

23. UNESCO-IUCN (2005). Water Quality Assessment in and around Keoladeo National Park, Bharatpur, Rajasthan, India. Technical Report Number 9, UNESCO-IUCN.

24. Wetzel G.R. (1987). Limnology: Lakes and River Ecosystems. 3rd Edition, Academic Press, San Diago.

25. Schutte K.H. and Elsworth J.F. (1954). The Significance of Large pH Fluctuation Observed in Some South African Lakes. *Ecology*, 42(1), 148-150.

26. Singh S.R. and Swarup K. (1979). Limnological studies of Suraha Lake (Ballia) II. Periodicity of phytoplankton. *J. Indian Bot. Soc.,* 58(4), 319-329.

27. Rodhe W. (1969). Crystallization of Eutrophication Concepts in Northern Europe. In: Proceedings of Symposium on Eu- trophication: Causes, Consequences, Correctives, National Academy of Sciences, Washington DC, 50-64.

28. Kaul W. and Trishal C.L. (1991). Ecology and Conservation of the Freshwater Lake of Kashmir. In: S. D. Misra, D. N. Sen and I. Ahmad, Eds., Evaluation and Conservation of Environment, GEO BIOS International, Jodhpur, India.

29. O'Dell K.M., Van Arman J., Welch B.M. and Hill S.D. (1995). Changes in Water Chemistry in a Macrophyte Dominated Lake before and after Herbicide Treatments. *Lake and Reservoir Management*, 11(4), 311-316.

30. Lovley D.R. (1997). Microbial Fe(III) reduction in subsurface environments. *FEMS Microbiology Reviews,* 20(3-4), 305-313.

31. Sondergaard M., Jensen J.P., Jeppesen E. and Moller P.H. (2002). Seasonal Dynamics in the Concentrations and Retention of Phosphorus in Shallow Danish Lakes after Reduced Loading. *Aquatic Ecosystem Health and Management*, 5(1), 19-29.

32. Sharma P.D. (1999). Ecology and Environment. 7th Edition, Rastogi Publications, Meerut, India.

33. Watts C.J. (2000). The Effects of Organic Matter on Sedimentary Phosphorus Release in an Australian Reservoir. *Hydrobiologia*, 431(1), 13-25.

34. Hu Q., Song J., Dong L., Li Z. and Zhu Y. (2001). Effects of pH and Eh on Nitrogen and Phosphorus Release from Sediments of West Lake. Proceedings of the Ninth International Conference on the Conservation and Management of Lakes, ILEC, Shiga.

35. Diazo A., Reddy K.R. and Moore P.A. (1994). Solubility of inorganic P in stream water as influenced by pH and Ca concentration. *Water Res*, 28, 1755-1763.

36. UNEP (1999). Planning and Management of Lakes and Reservoirs, an Integrated Approach to Eutrophication. International Environmental Technology Center, Osaka/Shinga.

37. Harremoes P. (1998). The Challenge of Managing Water and Material Balances in Relation to Eutrophication. *Water Science and Technology*, 37(3), 9-17.

38. Martinova M.V. (1993). Nitrogen and Phosphorus Compounds in Bottom Sediments: Mechanisms of Accumulation, Transformation and Release. *Hydrobiologia*, 252(1), 1-22.

39. Banerjea S.M. (1967). Water Quality and Soil Condition of Fish Pond in Some State of India in Relation to Fish Production. *Indian Journal of Fish*, 14(1), 115-144.

40. Forsberg C. and Ryding S.O. (1980). Eutrophication Parameters and Trophic State Indices in 30 Swedish Waste Receiving Lakes. A*chieves of Hydrobiology*, 89(1-2), 189-207.