ECOTONE VEGETATION AND WATER QUALITY OF RARA AND BEGNAS LAKES, NEPAL

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ABSTRACT

Land-water interfaces of lakes are highly dynamic and are responsible for the stability and maintenance of ecosystems. This study was carried out to understand the ecotone vegetation and the physico-chemical characteristics of waters of Begnas and Rara lakes of Nepal. For vegetation survey, line transects (perpendicular bi-sector to lake boundary), were used along the lake boundaries at an interval of 500 m; three quadrats of 1 m x 1 m size were laid on each line transect (off shore, boundary line, and on shore). All vegetation species in the sample quadrates were recorded. For probing water quality, lakes were divided into three blocks, then sampling was conducted on a consecutive day. Physico-chemical parameters —temperature, pH, electric conductivity (EC), dissolved oxygen (DO), total dissolved solid (TDS), ammonia, and nitrate—were measured. A total of 55 species under 38 families and 28 orders were recorded from ecotone of Begnas lake. In Rara lake, 56 species of 41 families and 22 orders were recorded. Poaceae was the dominant largest family in Begnas which was followed by Asteraceae. In Rara lake, Rosaceae was the dominant family which was followed by Pinaceae. Temperature, pH, and DO values decreased with depth, but EC and TDS e increased with depth, in both Begnas and Rara lakes. Ammonia and Nitrate were below the detectable limit of the instrument, indicating low nutrient contents of both lakes. The study established the baseline information about the diversity of ecotone vegetation; both the lakes show clear changes in physio-chemical parameters with lake depths.

Key words: Begnas, ecotone, floral diversity, physico-chemical, Rara.

INTRODUCTION

Water body could be defined as lakes according to their depth, temporality or in terms of their underwater topography (Onorato *et al.*, 2017). Lake ecology is intended to provide a general background to lake access by introducing basic concepts necessary to understand how the lake ecosystem functions. The lake ecology is described by fundamental physical, chemical and biological characteristics of lakes (Teneva *et al.*, 2014). The ecological function and services of wetlands are essential for the sustainable development of lives (Gurung *et al.*, 2009).

Ecotones are transition areas between different natural systems (ecosystems, landscapes), between natural and anthropogenic systems, between different media (water-land), and between biomes (Ivanova and Soukhovolsky, 2016). The ecological environment of land-lake ecotone is complex and changeable. It is an important water purification area and pollution buffer zone, where the microorganisms play an important role in the mediation of material cycle, nutrition transfer, and element transformation (Huang *et al.*, 2016). Wetland's ecotones are amongst the richest life supporting ecosystem

and they are most threatened due to various biotic stresses (Singh, 2013). Vegetation refers to the great diversity of plant species which occur in assemblages over the face of the earth (Johnston *et al.*, 2007). Floral assessment is an important criterion for the assessment of life forms and habitat for an area (Klosowski, 1993). Riparian vegetation is a typical element of the lake district landscapes (Ivanova and Soukhovolsky, 2016). In the world, wetlands and their associated species are under pressure of decline and system degradation. Change in land and water use, water discharge, environmental condition and structure can all have profound effects on the functioning of a lake (Olubode *et al.*, 2011). An understanding of individual plant species is the first step in developing indicators of the ecological condition of a lake (Johnston *et al.*, 2007) because the indices based on plant assemblages rely on the cumulative behavior of individual species (Klosowski, 1993). The lakeshore affects in the littoral zone and lake ecosystems (Lu *et al.*, 2016) which provides physical structure, alters water movements and hydrological processes and affects the transport of organic materials within the aquatic environment (Teneva *et al.*, 2014). Presence of exotic species threatened the native species and effects on the status of a lake (Palmik *et al.*, 2013).

Water quality generally means the component of water which must be present for optimum growth of aquatic organisms (Verma and Khan, 2015). It is very essential and important to test the water before it is used for drinking, domestic, agricultural or industrial purpose. Selection of parameters for testing of water solely depends upon for what purpose we are going to use that water and what extent we need its quality and purity (Patil *et al.*, 2012). Water quality assessment defines the status and trend in water quality, identify the specific problems of water quality and provide the strategy of management. Monitoring water quality is an essential activity that makes use of water sources (Udhayakumar *et al.,* 2016). The determinant of good growth in water body includes dissolved oxygen, hardness, turbidity, alkalinity, nutrients, and temperature. Conversely, other parameters like biological oxygen demand and chemical oxygen demand indicate pollution level of a given water body (Verma and Khan, 2015). All the aquatic life depends on the stability of water chemistry; thus, any significant changes in the lentic systems can lead to imbalance and adverse impacts on the organisms dwelling therein. Due to the increased human population, industrialization, use of fertilizers and man-made activity, water is highly polluted with different harmful contaminants (Patil *et al.*, 2012). Deterioration of the water quality is now a very big problem. Increasing water pollution causes not only the change of water quality but also threatens human health and the balance of aquatic ecosystems, economic development, and social prosperity (Verma and Khan, 2015). The present study attempts to determine the ecotone vegetation status and water quality of Rara and Begnas lakes. The study focused on the documentation of ecotone floral diversity and depth wise variation of physico-chemical parameters of water of the lakes.

MATERIALS AND METHODS

Study area

This study was conducted in two freshwater lakes of Nepal, Rara and Begnas lakes. These lakes were selected due to their locations in two different geographic settings with distinct climatic characteristics.

Begnas lake is the second largest lake of the Pokhara valley which is situated in

the subtropical region of central Nepal at an elevation of 650 m above the sea level. It lies in 28⁰10'26" North latitude and 84⁰05'50" East longitude, at Kaski district of Nepal. Begnas lake along with other eight lakes around its periphery (in Pokhara and Lekhnath) has been designed as the 10th Ramsar site of Nepal (Rai *et al.*, 2000).
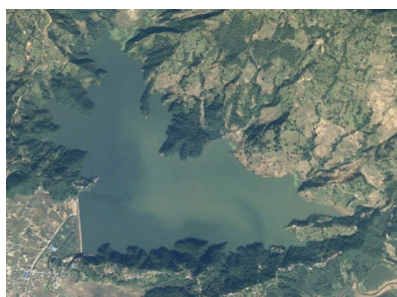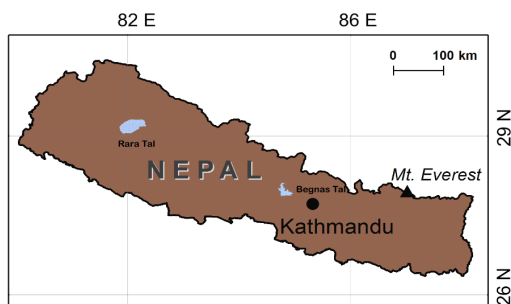

Fig. 1 Study sites: Begnas and Rara lake

Rara lake is the biggest and the deepest lake of Nepal. It is a high-altitude alpine lake, situated in Rara National Park, mid-western Nepal. It lies in 29⁰31'45" North latitude and 82⁰05'35" East longitude, at Mugu district of Nepal. The lake was declared as a Ramsar site in 2007. The lake has been a popular destination with a very

rough route in western Nepal for trekkers. The lake is surrounded by Rara National Park (RNP) with pine, spruce, and juniper forest.

Sampling design

The study was conducted by systematic sampling (USGS/NPS, 1994). Three lines transect at the ecotone of lakes i.e. onshore, boundary and offshore was established (Buckland *et al.*, 2007). Location, slope, altitude and aspect of sampling point were noted by using a compass and a global positioning system (GPS). At the interval of every 500 m, three quadrats of 1 m X 1 m were laid (USGS/NPS, 1994) on each line transect (one onshore-Q1, one on the land-water border line-Q2, one off shore-Q3) and all plant species recorded in the quadrates were noted. All the strata were noted i.e., trees, shrubs and herbs. The different plant species from the quadrate was also noted. The plant specimens under different families were collected as the herbarium specimens. The herbarium specimens were made only from Begnas lake, while we were unable to collect the herbarium from Rara lake due to ethical issues associated with the collection from the conservation area (Rara national park) lake. The data were further analyzed in accordance with family, order, generic and specific names. The collected specimens were thoroughly examined and identified (Shrestha, 1998); www.IPNI.org and http://www.efloras.org/flora_page.aspx?flora_id=110). The plant specimens were cross-checked with the photographs and herbarium specimens at National Herbarium and Plant Laboratory (NHPL).

Consecutive day sampling during the study period was used. The physico-chemical parameters, such as temperature, pH, conductivity, dissolved oxygen (DO), total dissolved solids (TDS), nitrate and ammonia were measured on the spot in different depths of

the water column. Grab sampling was adopted for physico-chemical parameter analysis of water by collecting water sample at a particular time and place that represents the composition of the source at that particular point and time.

In both Begnas and Rara lakes, three blocks of the lake were established to measure the physico-chemical parameters of water columns. Blocks are named as block "A", block "B" and block "C". In Begnas lake, block "A" was not connected to either inlet or outlet, block "B" was connected to an outlet of the lake and block "C" was connected to inlet of the lake. Grab sampling was done at the inlet, center and outlet in the lake. In Rara lake, block "A" was connected with an outlet, block "B" was connected with grazing field, and block "C" was connected mostly forest touching line. In each block, we marked the five sampling points. The GPS coordinates of each point were recorded. From each sampling point, the depth wise result of physico-chemical parameters was measured. All the sample collection techniques, quality control technique and analytical methods were followed by using the standard methods for the examination of water and wastewater (APHA, AWWA, and WEF, 1998).
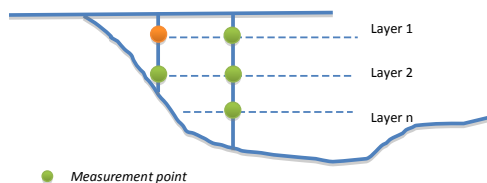

Fig. 2 Sampling design for the depth-wise physico-chemical data

Data analysis and interpretation

The collected data were subjected to further analysis. Ecotone vegetation and physico-chemical characteristics data of water were analyzed by using MS Excel. The data were analyzed by both quantitative (by using statistics) and qualitative (simply by narration) statistical tools, as applicable and presented in the figures and tables. A floristic similarity among the ecotone of Begnas and Rara lake was carried out using the Jaccard's similarity coefficients (JSC). For this purpose, plant species were compared by their pair and then, clustered on the basis of JSC = C/(A+B-C), where A and B are species number in samples and C is the number of species shared by the two samples. The mathematical work was done with a simple calculation. The descriptive language and tables were also used to analyze and were interpreted.

RESULTS AND DISCUSSION

State of ecotone vegetation

In ecotone of Begnas lake, a total of 59 plant species were recorded. Among the 59 species, four species were unidentified and the rests 55 species were of 38 families and 28 orders. The study found Poaceae and Asteraceae to be the largest family having 5 species in the ecotone of Begnas lake followed by Fabaceae with 4 species, Lamiaceae with 3 species and Poaceae, Drypteraceae, Malvaceae, Polygonaceae, and Myrtaceae with 2 species. Single species was found in other families. Similarly, Asterales and Poales were teh largest order having 6 species followed by Fabales, Polygonales, and Lamiales with 4 species, Malvales, Caryophyllales and Fagales with 3 species, Ranuculales and Myrtales with 2 species, and remaining orders had single species of flora.

Inside the Begnas lake, only 3 species were recorded. The 3 species recorded are *Eichhornia crassipes, Nymphoides hydrophyllum,* and Paani Jhar (in Nepalese language). At the inlet, there was a higher number of aquatic plants. There was a higher number of *E. crassipes, N. hydrophyllum,* and Paani Jhar. At the dam, mostly herb species and one tree of *Sapium*

insigne were recorded. At the forest side of all sampling plot, many individuals of *Pteridium revolutum* and tree species were recorded. Most of the trees were *Shorea robusta, Schima wallichi,* and *Castonopsis indica.* Over all forest near to Begnas lake was dominated by these three species of tree. At human disturbed area, there was higher number of herb species. Most of the species of *Paspalum distichum, Trifolium ripens, Cyperus rotondus,* and *Cynodon dactylon* were recorded in human disturbed, barren and agricultural disturbed area.

A total of 61 flora species were recorded from the ecotone of Rara lake. Among them, five species remained unidentified and rests of the 56 species belong to 41 families and 22 orders. The study found that Rosaceae was the largest family having 8 species followed by Pinaceae with 5 species, Asteraceae with 3 species and Poaceae, Cyperaceae, Polygonaceae, Papaveraceae, Primulaceae, Fabaceae and Berberidaceae with 2 species. Other families were found with single species. Similarly, the Rosales was the largest order having 8 species followed by Pinales with 7 species, Poales with 5 species, Caryophyllales and Ranuculales with 4 species, Ericales, Asterales, Lamiales and Gentianales with 3 species and Saxifragales and Fagales with 2 species. And remaining order of single species was recorded.

Regarding the diversity of the species in the ecotone of Rara lake, the least number of species was observed under the pine forest. The high number of herbaceous plant were recorded near to Millichaur along the side of pasture land. Only few numbers of aquatic species (macrophytes) were recorded in the lake. Only two aquatic species of *Phragmites karka* and Sebaro (local name) was observed in lake water. And species of family Cyperaeae and Polygonaceae were found in semi-aquatic habitats. Some ecotone

species was unidentified in both Begnas and Rara lakes and in some cases of species they were classified only at family level and some were unable to classify in family and order. Only four common species were recorded in ecotone of both lakes. The species common to both are *Centella asiatica* (L.) Urb., *Cynodon dactylon* (L.) Pers., *Dryopteris flix-mas* (L.) Schott, *Trifolium repens* L.

The species encountered in both the lakes represent three ecological groups: trees, shrubs and steppe vegetation. Herb species were mostly recorded. A higher number of species were recorded at the line transect of the boundary of the lake ecotone and a nearly equal number of species were recorded at the line transect of offshore. A small number of species was recorded at the line transects of onshore.
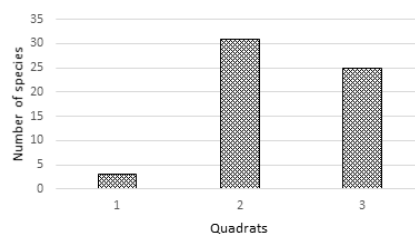

Fig. 3 Species number recorded at onshore, boundary and offshore of Begnas lake
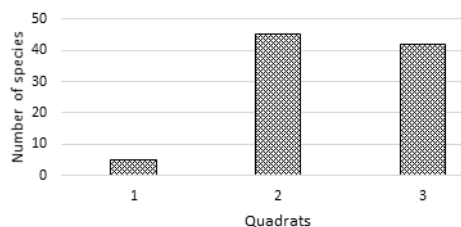

Fig. 4 Species number recorded at onshore, boundary and offshore of Rara lake

The present investigation revealed baseline information about floras status, invasiveness and endemism of plants around the ecotone of Begnas and Rara lake. The ecotone vegetation status was also manifested in plant habits which included herbs, shrubs, trees, climbers and

epiphytes with a clear dominance of herbaceous species (Talukdar, 2013). The result indicates that the ecotone vegetation is composed of various types of phytocoenoses, which are connected with the land-lake systems but most of the vegetation were of terrestrial habitat. The vegetation types found in Begnas and Rara lakes, often form characteristics zonation's, which distinguish themselves with respect to lake valley landscape. The spatial distinction of communities demonstrated that the riparian vegetation zone constituted an internally differentiated ecotone (Klosowski, 1993).

Both the lakes were found dominated by native plants (Lemein *et al.*, 2017) but at Begnas lake an invasive species of *Eichhornia crassipes* is also present. As *E. crassipes* stands the worst aquatic weed throughout the tropics and subtropics, increasing of *E. crassipes* is a sign of the increase in cultural eutrophication and siltation. But the low occurrence of *E. crassipes* in the lake can be attributed to the low impact of eutrophication in lake (Basnet, 2010). The distribution of invasive species characterizing stress including high runoff from intense agriculture, hydrologic and physical alteration and chemical pollution in Begnas lake. The spread of these alien and invasive weeds in the present study area is quite alarming to the conservation of native biodiversity. The presence of forest of *Shorea rubusta, Castonopsis indica* and *Schima wallichi* revealed that plant diversity in moist forest at the ecotone. Although medicinal importance and resource utilization of plant species is integral part of the livelihood, the study could not invent the medicinal value due to limit time. The species *C. dactylon* was the most efficient riparian species in conservation of soil, water and nutrients in surface runoff (Talukdar, 2013). In Rara three endemic species of Nepal, *Meconopsis regia* G. Taylor, *Primula poluminni*

Fletcher and *Cirsium flavisquamatum* Kitam were recorded l (Basnet, 2010).

Only the four species in the ecotone of both lakes were recorded as the common species. Less number of common species might be due to two lakes situated in the different geographic and climatic region (Lemein *et al.*, 2017). Jaccard's similarity index was found to be 3.44% which clearly showed that the communities under studies i.e. ecotone vegetation of Begnas and Rara was different from each other. The communities were dissimilar. So the communities were heterogeneous in nature (Palmik *et al.*, 2013). The dissimilarity of the communities was due to different climatic condition, temperature, nutrient content, human approaches and etc (Lemein *et al.*, 2017). The chemical and physical gradients influence the biota in many ways so species of ecotone of the lake does not depend on salinity alone but is the result of complex of factors (Reizopoulou *et al.*, 2013). Soil clay content and consequently, water retention capacity of the soil could have contributed to the occurrence of species (Olubode *et al.*, 2011). The variety of communities are obviously related to differences between the typical habitats around both lakes and the environmental conditions provided by the palaeshoreline (Nowak *et al.*, 2017). The differences in species composition could have been due to differences in edaphic factors. Farming and fishing activities which were actively carried out around the Begnas lake that is indicative of the influence of man related disturbances on the flora of the study sites. Variation in species composition of each lake suggests that the flora of different lakes was brought about by edaphic and anthropogenic factors in the areas (Olubode *et al.*, 2011).

The ecotone of the lake is characterized by extremely high concentrations of dissolved substances and spatially variation in chemical

composition with the seasonal fluctuation of water levels, the accumulation can be disadvantageous phenomenon since the waters of lakes become enriched with nutrients after the mineralization of the shore (Klosowski, 1993). Increase in nutrient content does not result in their immediate release into the river water, however, the processes of nutrient release are often initiated by the impact on riparian vegetation (Talukdar, 2013). The human and agricultural disturbances in Begnas lake, leading to changes in the water regime and initiation of erosive processes which have the strongest negative impact on riparian vegetation (Klosowski, 1993) and also it will be in Rara if any step not taken against the disturbances.

Physio-chemical parameters of water

The present study involved in the analysis of water quality in terms of physio-chemical parameters of Begnas and Rara lakes of Nepal. The information was collected up to 5m depth and 10m depth for Begnas lake and Rara lake respectively. Even in few meters' depth variations in all the parameters were clearly observed in Begnas lake. In the case of Rara lake, a low variation of the parameters within the depth of 10 meters was observed. The results of both lakes were obtained as follows.

Water temperature: Rara lake being the lake in the higher altitude itself has a low temperature in comparison with the temperature of Begnas lake. The study showed that the temperature of Rara lake decreased slightly from 17.7 °C to 16.7 °C going 10 m depth in the temperature in comparison to the temperature of Begnas lake from 29.5 °C to 27.1 °C going 5m depth. The average temperature of Begnas was found at 28.3 °C and Rara 17.1 C. The temperature decreased with the increase of depths. The temperatures of both lakes are as shown in figure 5.
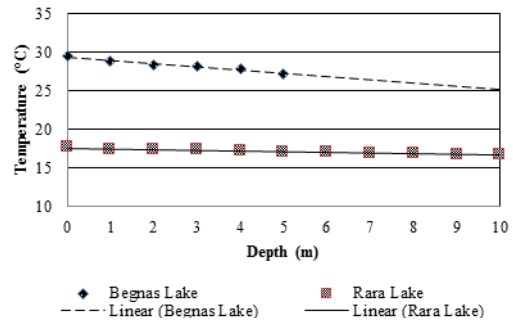

Fig. 5 Temperature variation in Begnas and Rara lakes

pH: In Begnas lake, the pH was recorded between 6.2 and 5.2 and in Rara lake, between 6.6 and 6.3. There was not much of change in the pH with a depth of Rara lake. The high pH was recorded at the surface of the lake and found decreasing with increasing of depth. The mean pH was found 5.9 in Begnas lake and 6.3 in Rara lake. The pH of both lakes is as shown in figure 6.
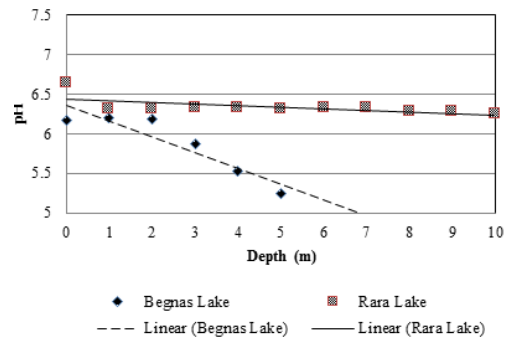

Fig. 6 pH variation in Begnas and Rara lakes

Dissolved oxygen: The dissolved oxygen in Begnas lake was 7.3 to 6.5% and that of Rara lake was found to be 6.4 to 5.8%. The mean DO in Begnas was found 7.1 and 6.2% in Rara lake. The DO was found decreasing with the increase of depths in both lakes. The DO of both lakes is as shown in figure 7.
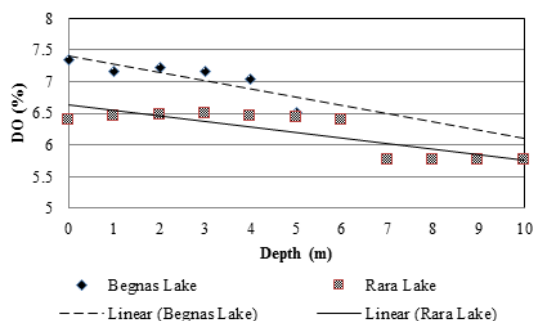
Fig. 7 DO variation in Begnas and Rara lakes

Electrical conductivity: The electrical conductivity in Rara lake was found to be from 19.50 to 25.37 µS/cm and that of Begnas lake was 30.33 to 38.78 µS/cm. It was seen in both the lakes that the electrical conductivity was increasing with the increase in depth. This result showed that Begnas lake had higher EC value than the permissible limit and Rara lake had within the limit. The mean EC was found 35.05 µS/cm in Begnas lake and 23.24 µS/cm in Rara lake. The EC of both lakes is as shown in figure 8.
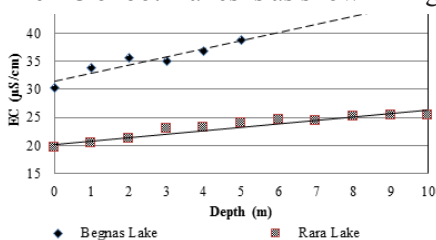

Fig. 8 EC variation in Begnas and Rara lakes

Total dissolved solid: The total dissolved solid of Rara lake was 9.44 to 13.93 mg/l and Begnas lake 14.11 to 17.89 mg/l. The mean TDS was found 16.12 mg/l in Begnas and 11.81 mg/l in Rara. Since there were few aquatic- lives and few external influences in the Rara lake, this lake had less total dissolved solid. On the other hand, Begnas lake had high total dissolved solid in comparison to Rara lake because of the presence of high aquatic life due to optimum temperature and because of external influences. The TDS of both lakes are as shown in figure 9.
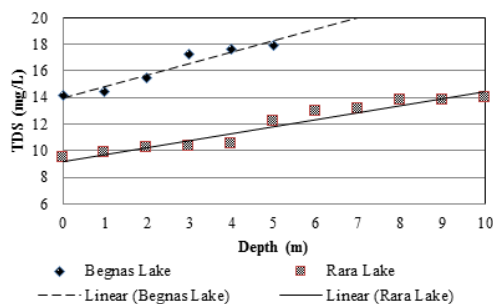

Fig. 9 TDS variation in Begnas and Rara lakes

In both lakes, the trace amount of ammonia and nitrate was found. So, the nutrient content in both lakes was less amount. The result in both the lakes showed that the temperature of the plots decreases with an increase in the depth. Temperature effects on the chemical and biological reaction in water (Patil *et al.*, 2012). The sunlight couldn't penetrate to the bottom of the lake if the lake is too deep. With increasing of the depth, the light intensity decreased. This caused the decrease in the temperature with increase in depth. Temperature, directly and indirectly, influenced to abiotic and biotic components of the aquatic ecosystem (Verma and Khan, 2015).

Change in pH showed that there were a few chemical and biological reactions in water (Rai, 2000). The water of Begnas lake has become highly acidic in comparison with the result of the study of Rai (2000). The result showed that the nature of water of both the lake had completely changed. In the case of Begnas lake, there was more chemical and biological reaction in water than that of Rara lake. The altitude difference might be one of the reasons for this result (Raut *et al.*, 2012). Because of the altitude difference, there was a difference in temperature between these two lakes, and the temperature is responsible for the chemical and biological reactions (Alam *et al.*, 2017). The decrease in pH i.e. increase in acidity might be because of the surface flow of different types of chemical

fertilizers, pesticides etc. from the surrounding agricultural lands. The human influences also had been increased; this might also be a cause for the increase in the acidic nature of both the lakes (Patil *et al.*, 2012). The study also showed that the acidic nature of the lakes increases with the increase in depth, one of the causes might be due to high TDS content in the depth than in the surface (Udhayakumar *et al.*, 2016). The pH of Begnas lake was highly acidic with increase in depth as compared with the pH of Rara lake. The dissolved oxygen is less in Begnas lake in comparison with the result obtained by Rai (2000). The dissolved oxygen was higher in Begnas lake than in Rara lake. This showed that the aquatic life was less in Rara lake than in Begnas lake (Rai, 2000). The high DO was seen in high temperature, it might be due to bright sunlight influence on the percentage of soluble photosynthesis by phytoplankton, utilizing carbondioxide and giving off oxygen (Patil *et al.*, 2012). The survival rate of aquatic life was found high in Begnas lake (Raut *et al.*, 2012). Dissolved oxygen levels are considered as the most important and commonly employed measurement of water quality and indicator of a water body's ability to support desirable aquatic life. Like terrestrial animals, fish and other aquatic organisms need oxygen to live (Patil *et al.*, 2012). Rara lake was oligotrophic based on DO estimation but Begnas lake was slightly polluted. Due to less dissolved oxygen in Rara lake, the aquatic life is less and the activity under water is also low. In the case of Begnas lake, the aquatic life is remarkably high and the underwater activity is also in comparison with that of Rara lake. It is correlated with water body directly and indirectly for the information of bacterial activity, photosynthesis, availability of nutrients and stratification (Kora *et al.*, 2017). As per WHO standard DO value of 5 mg/l is ideal. The dissolved oxygen is responsible for the presence of aquatic life and all biological reactions in water. The higher value of dissolved oxygen could impart good aesthetic taste to drinking water (Raut *et al.*, 2012). The dissolved oxygen also decreases with the increase in rate of oxidation of organic matter and metabolic rate of organisms (Kora *et al.*, 2017).

The electric conductivity seemed to be higher as deeper the lake becomes. This might be because of TDS settling down at the bottom (Verma and Khan, 2015). The cations and anions might be in a higher amount in the TDS. In both the lakes, the electric conductivity was increasing with depth but Begnas lake showed higher conductivity than Rara lake. The cause behind this result might be because of the human influences at Begnas lake (Raut *et al.*, 2012). This also might suggest Rara lake being slightly acidic than Begnas lake. It could be concluded from the result that near the bottom of the lake there was a higher concentration of the ionized salts (Verma and Khan, 2015).

The increase in the total dissolved solid with depth because these were standing water bodies and the dissolved solid tends to settle at the bottom of the lake. The total dissolved solids in Begnas lake was higher than that of Rara lake. TDS indicates the salinity behavior of water. The total dissolved solids in water were due to the presence of all inorganic and organic substances (Patil *et al.*, 2012). Begnas lake seems to have the presence of more inorganic and organic substances. Higher values of TDS might be because of human interference and the runoff from the agricultural lands (Raut *et al.*, 2012). The high percentage of TDS also imparts alkalinity nature to water (Patil *et al.*, 2012).

The domestic sewage was received slightly high in Begnas lake due to surface runoff from the agricultural land and human disturbances. The

agriculture effluents were not presented in Rara lake but there is a presence of animal excreta due to grazing nearby the lake. These clearly indicate that there is less presence of nutrient i.e. nitrate and ammonia in both the lakes. This study shows that both the lakes are slightly influenced by anthropogenic activities.

CONCLUSIONS

This study established baseline information about the diversity of ecotone vegetation in Begnas and Rara lakes of Nepal. Most of the species were of terrestrial habitat. Both Begnas and Rara, lakes showed clear changes in physico-chemical parameters with lake depths and study showed both the lakes are influenced by anthropogenic activities. This study may give vital clues in the conservation of floral diversity and natural ecosystem of the two lakes and their surroundings.

ACKNOWLEDGEMENTS

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