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Current Status of Macrophyte Diversity and Distribution in Manasbal Lake, Kashmir, India

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Abstract

The current research focuses on the documenting of aquatic macrophytes from Manasbal Lake. Macrophytic survey was conducted in Lake for a period of two years and recorded the presence of 17 macrophytic species belonging to 14 families. Among various ecological groups, rooted-floating type with 7 species showed qualitative dominance over emergent (04 species), and submerged and free floating species (03 species each). The computation of different diversity indices of macrophytes revealed that the highest values for the Shannon index, Simpson diversity index and Margalef diversity index were exhibited by Kondabal (Site-S2), Gratabal (Site-S1) and Jarokabal (Site-S6) respectively.

Keywords: Diversity indices, Macrophytes, Manasbal Lake, Sites

INTRODUCTION

Macrophytes, in their various forms, are the most important biotic constituents of a lake environment. Because of their ability to integrate environmental changes over a few years and reflect the cumulative impact of multiple disturbances, macrophytes are regarded as effective indicators of the ecological state of water bodies (Tremp 1995). They develop distinctive spatial patterns (Hutchinson, 1975; Spence, 1982; Klosowski, 1992) that frequently serve as a transitional boundary between open water and reed swamp habitats. Macrophytes participate in a number of feedback processes that help to keep the water clean even when nutrient levels are rather high (Moss, 1990). Furthermore, macrophytes have been shown to influence lake nutrient status, bottom material resuspension, and water turbidity (James and Barko, 1990; Sand-Jensen and Borum, 1991; Horppilla and Nurminen, 2001). Aquatic plants and their communities may also be good indicators of changes occurring in lakes as a result of human-caused acidification and eutrophication (Roelofs, 1983; Lehman and Lachavanne, 1999).

Macrophytes are an important component of lake ecosystems that support a variety of food chains in the water body. The macrophytes determine the general physiognomy of the ecosystem, showing the degree of pollution, and are thus responsible for the biogeochemical cycling of nutrients (Wetzel, 1975). Macrophytes contribute a significant portion of primary production in shallow lakes and wetlands, and hence play an important role in shaping the structure and function of these ecosystems. Expanding urbanization and unregulated population are to blame for the deterioration of these water bodies by affecting the limnological profile, which in turn affects the dominating components of the water body- macrophytes. Despite the fact that the wetlands of Kashmir have been studied for limnology and anthropogenic influence (Khan, 2001; Khan and Shah, 2004; Rather and Pandit, 2007; Parray *et al.,* 2008), very little information on the quantitative examination of macrophytes is available. As a result, the current study was done to evaluate the community structure of macrophytes inhabiting Lake Manasbal.

STUDY AREA

The Manasbal lake is Kashmir's deepest lake, located 32 kilometers northwest of Srinagar at an altitude of roughly 1585 meters (amsl) within the geographical coordinates 34°14′40′-34°15′22′N and 74°39′10′-74°41′20′E. The lake has an oblong shape and an area of 2.80 km^2 with a maximum depth of 12.5 m. (Yousuf 1979). The lake has its own water source in the form of underground springs dispersed throughout its basin. During the months of May to September, an irrigation canal (Lar-Kuhl) also feeds water to the lake. The surplus water in the lake is drained into the river Jhelum by an outflow canal named Nunnyar Nalla, which runs from the western side of the lake. The lake is home to a luxuriant growth of rooted floating leaf type macrophytes, particularly *Nelumbo nucifera,* which has an eye-catching appearance in August when its blooms are in full bloom. Six study locations in the lake were chosen based on depth and vegetation to investigate the distributional pattern of the selected macrophytes (Figure 1).

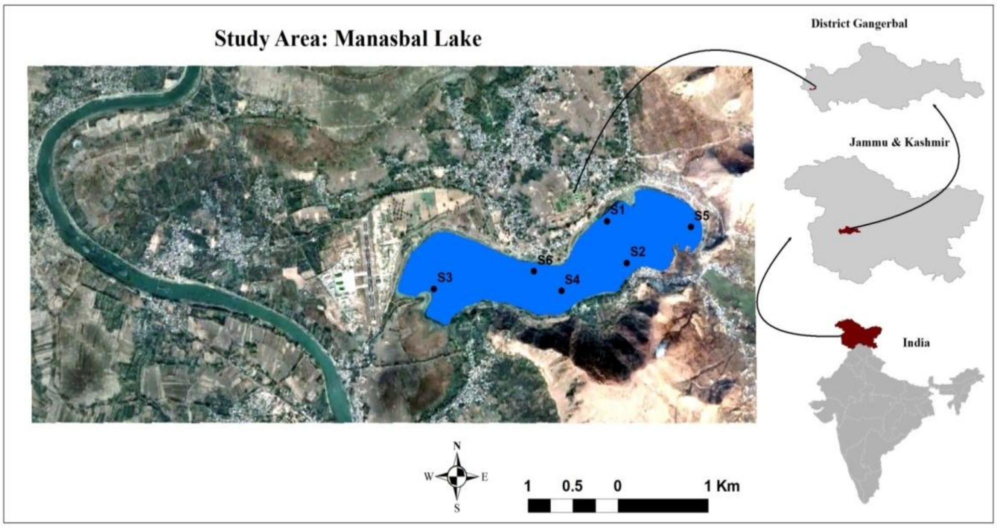

Figure 1: Map depicting different sampling locations in Manasbal lake

MATERIALS AND METHODS

Macrophytic analysis

Several locations were chosen for the current macrophytic investigation because of apparent variations in topography, soil conditions, floral features, and human influences. Using the Random Quadrat Method, the macrophyte community characteristics were calculated on a seasonal basis during a two-year period (Misra, 1968; Gupta, 1999). At each of the selected sites, 1m^2 quadrats were laid out at random. The macrophytes in each quadrat were separated species by species, and the number of individuals in each species was counted to determine various phytosociological characteristics (Misra, 1968). Standard literature (Biswas and Calder, 1954; Ward and Whipple, 1959; Subramanyam, 1974; Adoni *et al.,* 1985; Cook, 1996) and taxonomic expertise were used to identify the macrophytes. The phytosociological parameters such as frequency, density, and dominance were estimated in accordance with Curtis (1956), Philips (1959), and Misra (1960). The Importance Value Index of a species in the community provides an indication of relative importance of the species as comparison to other species (Curtis, 1959) and is calculated by adding the relative density, relative frequency, and relative dominance. The species diversity of aquatic macrophytes was determined using the following formulas:

Shannon and Weiner diversity index (H) calculated using the Shannon and Weiner formula (1949)

$$H' = -\sum_{i=1}^{i=s} \left(\frac{ni}{N}\right) log_e \left(\frac{ni}{N}\right)$$

H'= Index of species diversity

ni= Density of one species

N= Density of all species

e= Base of natural logarithm $log_e \left(\frac{ni}{N}\right) = 2.303 log_{10} \left(\frac{ni}{N}\right)$

$\sum_{i=1}^{i=s} \left(\frac{ni}{N}\right)$ = Addition of the expression for the values of $i = 1$ to $i = s$

Simpson's Diversity Index (D)

It provides higher weightage to dominant species in the sample and decreases as diversity increases and was computed as:

$$D = 1 - \sum_{i=1}^{s} (pi)^2$$

Where, "pi" is the proportion of individuals in the "ith" taxon of the community and "s" is the total number of taxa in the community (Simpson, 1949).

Margalef Diversity Index (1958)

The Margalef diversity index (d) was calculated as:

$$\mathbf{d} = \frac{(S-1)}{lnN}$$

Where d =Margalef diversity index

S = Number of species

N = Total number of individuals in the sample

Evenness

Evenness is a measure of the relative abundance of the various species that contribute to an area's richness. The following formula was used to calculate the evenness:

$$J' = {H'}/{H'max}$$

Where: J' = Evenness index

H' = the observed value of Shannon index

H'max = 1nS

S =Total number of species

RESULTS AND DISCUSSION

During the two-year research period, seventeen macrophytic species from 14 families were identified. Table 1 shows the frequency range, relative frequency, density, relative density, abundance, relative abundance, and important value index.

Table 1: Macrophytic community features of Manasbal Lake

Species name	Density	Freq	Abundance	RD	RF	RA	IVI
Emergents							
Typha angustata	16	27.8	19.2	1.97	6.49	2.16	10.62
Phragmites australis	1.9	27.8	2.5	0.23	6.49	0.28	7
Phragmites communis	0.88	16.7	2.28	0.1	3.9	0.26	4.26
Polygonium barbatum	3.83	22.2	5.75	0.47	5.19	0.64	6.3

Submerged							
Hydrilla verticillata	12.38	22.2	18.58	1.52	5.19	2.09	8.8
Ceretophylum demersum	46.39	22.2	69.58	5.71	5.19	7.84	18.74
Myriophylum spicatum	17.22	22.2	25.83	2.11	5.19	2.91	10.21
Rooted floating leaved type							
Nelumbo nucifera	5.77	27.8	6.93	0.71	6.49	0.78	7.98
Trapa natans	12.22	33.33	12.22	1.5	7.78	1.37	10.65
Nymphaea alba	4	27.8	4.8	0.49	6.49	0.54	7.52
Nymphoides peltatum	18.88	22.2	28.33	2.32	5.19	3.19	10.7
Hydrocharis dubia	34.88	27.8	41.86	4.29	6.49	4.71	15.49
Potomegeton natans	5.5	22.2	8.25	0.67	5.19	0.92	6.78
Euryale ferox	0.16	5.6	3	0.017	1.3	0.33	1.647
Free floating							
Azolla	469.88	33.33	469.88	57.84	7.78	52.96	118.58
Salvinia	30.88	33.33	30.88	3.8	7.78	3.48	15.06
Lemna	137.33	33.33	137.33	16.9	7.78	15.48	40.16

Among the 17 macrophyte species identified during the current investigation,, 07 were rooted floating type, 4 were emergents, 3 each were submerged and free floating (Fig. 1). Poaceae, Hydrocharitaceae, and Nymphaceae showed dominance in the lake (02 species each), followed by Polygonaceae, Menyanthaceae, Nelumbonaceae, Typhaceae, Potamogetonaceae, Salviniaceae, Trapaceae, Azollaceae, Ceratophyllaceae, Haloragaceae, and Lemnaceae (01 species each). An overall macrophytic investigation revealed that the rooted floating leaved type (07 species) was dominant, followed by emergents (04 species), submerged and free floating leaved types (03 species each).

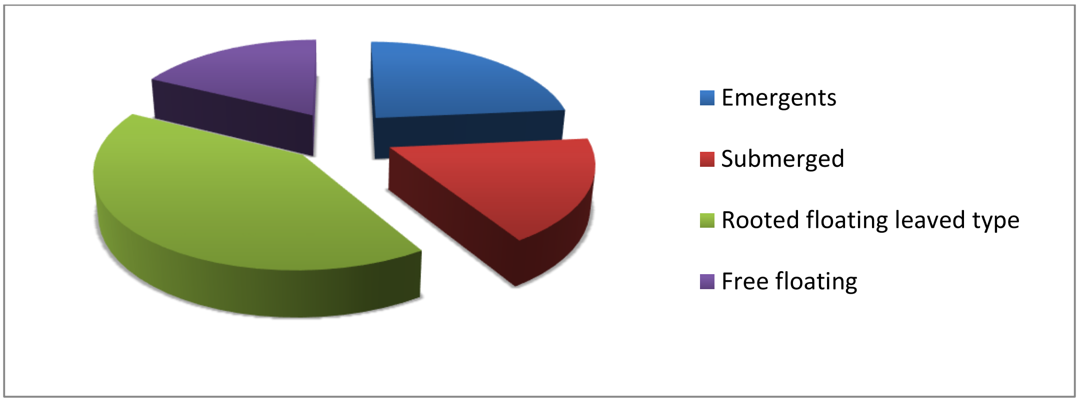

Figure 2: Percentile share of the macrophytes inhabiting Manasbal Lake

The study of Table 1 and Figure 2 demonstrates that the maximum overall frequency was exhibited by *Azolla, Salvinia, Lemna and Trapa natans,* (33.33 % each) and the least was shown by *Euryale ferox* (5.6 %). *Azolla sp.* showed highest overall dominance in terms of density, frequency, abundance and IVI. *Typha angustata* and *Phragmites australis* were the dominant species among emergents in terms of frequency of occurrence recording frequency values of 27.8 each followed by *Polygonium barbatum* with a value of 22.2. *Trapa natans* recorded highest frequency value of 33.33 followed by *Nympheae alba, Nelumbo nucifera* and *Hydrocharis dubia* with a frequency value of 27.8 each among rooted floating-leaf types, while as *Ceratophyllum demersum, Hydrilla verticillata and Myriophyllum spicatum* showed same frequency 0f 22.2 among the submerged. The three free floating species i.e., *Salvinia natans, Azolla sp.* and *Lemna sp*. depicted mean frequency values of 33.33 each.

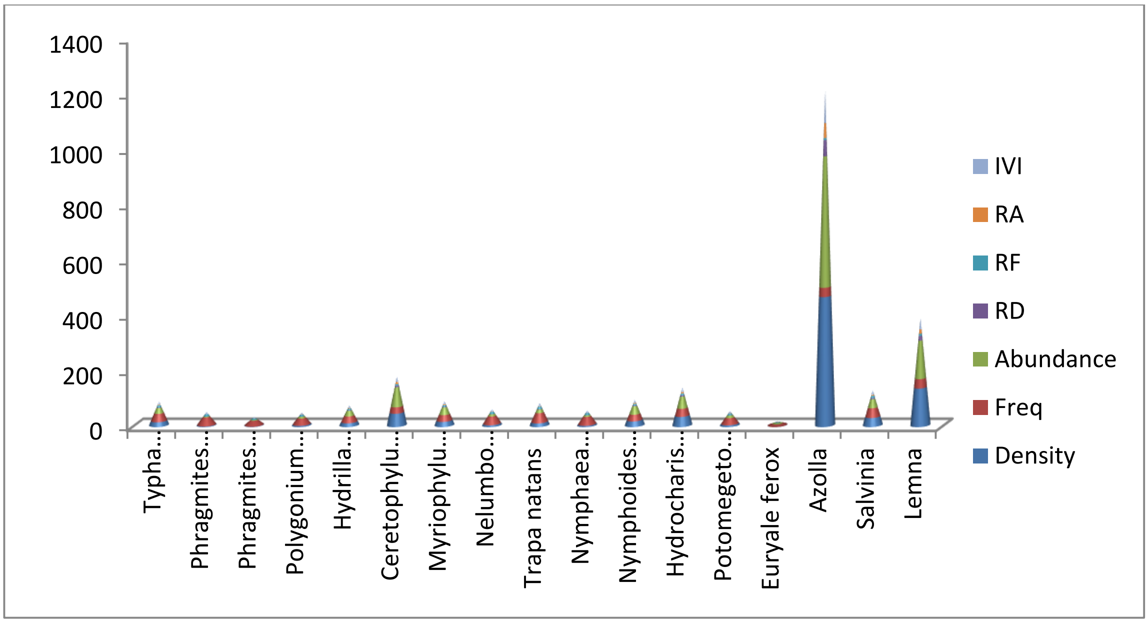

Figure 3: Density, Frequency, Abundance, and IVI of the Macrophytes inhabiting Manasbal Lake

In general, the maximum value for importance value index (IVI) was obtained for *Azolla sp.* (118.58), *Lemna* (40.16) and *Ceretophyllum demersum* (18.74), while as the least was obtained for *Euryale ferox* (1.64) followed by *Phragmites communis* with a value of (4.26). During the present study a total of 17 macrophytic species were recorded from the Manasbal lake. However, Maqbool and Khan (2013) reported 15 macrophytic species belonging to 10 families; Siraj *et al.,* (2018) observed 12 macrophytic species, while as Abubakar and Kundangar (2008) and Khandey *et al.,* (2015) reported 10 and 07 macrophytic species respectively from the Manasbal lake. Thus, increasing macrophyte vegetation shows that lake water is obtaining nutrients, which aids in the abundant growth of macrophytes. The main source of plant nutrients is obviously the sewage, waste water, and animal dung used by the locals for drying on the outskirts of Manasbal lake, as well as detergents used for washing clothing directly within the region. The inflow of animal dung helps to enhance nutrients, which promotes the growth of aquatic vegetation.

The *Azolla sp.* which is an indicator of organic enrichment, was the most dominant species in terms of density, frequency abundance and recorded highest IVI from the Manasbal lake. The present dominance of *Azolla sp.* can be attributed to its invasive tendency as well as its affinity for highly eutrophic and stagnant water.Similar relationship between growth pattern and eutrophication level have been worked out by Gopal and Sharma (1990). *Azolla sp.* is quite effective in appropriating surface and in casting shade, thus making the niche less habitable for other plants to survive (Gopal, 1990; Scheffer, 1998; Rea and Storrs, 1999). High temperature during the summer months also favour the invasive nature of *Azolla sp.* through vegetative fragmentation (Uheda *et al.*, 1999) which further explains its dominance during the warm months of the year.

Ceretophyllum demersum and *Myriophyllum spicatum* were found to be the most dominant submerged species during the research period. The increased growth of *Ceretophyllum* and *Myriophyllum* in the lake might be attributed to shallow depth, increased transparency of the waters, enrichment of lake sediments, and greater calcium levels. The vigorous growth of these plants indicates their ability to adapt in diverse conditions (Burlakoti and Karmacharya, 2010). Many workers (Segal, 1971; Singhal and Singh, 1978; Acharya, 1997; Shrestha, 2000) have attributed the extensive colonization of these species to their high growth potential in sedimentation prone and culturally eutrophicated water bodies, which seems to explain their dominance in the lake.

Among the rooted floating leaved species, *Hydrocharis dubia* showed highest dominance in terms of mean density, abundance and importance value inde*x* and *T. natans s*howed maximum frequency. In general, the dense growth of the rooted floating leaved species may be attributed to better adaptability of these plants to withstand the turbidity of water (Papastergiadou and Babalonas, 1992; Burlakoti and Karmacharya, 2010). *Euryale ferox* showed least dominance in terms of density, frequency and abundance and was recorded only at Site-S6 from the Manasbal lake. The reason for this is that local boatmen destroy this plant species in its initial vegetative stage at shallower depths, fearing that the thorny petioles of the plant at a later stage of growth would make extracting commercially useful rhizomes of *Nelumbo nucifera* hard and may be also due to environmental deterioration of the lake due to accelerated eutrophication. Further, According to Gopal and Sharma (1990), floating leaf macrophytes such as *Nelumbo nucifera* and *T. natans* may thrive well in low-transparency waters once established as mature plants. The emergent, *T. angustata* recorded its highest IVI followed by *Phragmites australis* which can be ascribed to its strong tolerance for water level fluctuations (Vander Valk and Davis, 1976) and the late emergence of its aboveground shoots (Sharma and Pradhan, 1983). The significant coverage of the *Typha angustata* and *P. australis* in the lake are indicative of its highly productive status (Hutchinson, 1975).

The study illustrated that the Manasbal lake is having good coverage of macrophytes, owing to change in water quality, water level fluctuation (Zutshi and Gopal, 1990; Pandit, *et al*., 2010), shallowing of lake by sedimentation (Pandit, 1992) and the presence of pollution in the form of solid waste through inlet tributaries/channels from adjacent areas and from agricultural fields. Nutrient enrichment of waters by domestic sewage or otherwise, cause drastic changes in the biomass of aquatic plants and later their species composition (Pandit, 2010; Phillips *et. al.,* 1978). With eutrophication, macrophyte growth becomes extremely dense (Moss, 1979), and as lake alkalinity rises, floating leaf species are replaced by emergent Macrophytes (Makela *et al.,* 2004). Emergents, the most productive communities of macrophytes (Westlake, 1963; Wetzel, 1973 and Koul *et al.*, 1978), in the studied lake indicated that the lake is evolving at rapid pace, pointing towards increasing productivity of the lake ecosystems. The coverage of macrophytes in the littoral area was greater than in the center of the lake, where the species composition was observed to be lower. According to (Keddy 2000), emergent plant species predominate in shallow water, floating-leaf type macrophytes predominate in deeper water, and submerged aquatics prevail in the deepest water.

The calculation of diversity indices of macrophytes indicated that the maximum values for the Shannon-Weiner's index, Simpson diversity index and Margalef diversity index were exhibited by Kondabal (Site-S2), Gratabal (Site-S1) and Jarokabal (Site-S6) respectively, which may be due to the fact these sites are located near human habitations and receive discharges rich in nutrients from domestic sewage. Maximum species diversity recorded for these sites support the earlier observation that the water bodies influenced by domestic sewage effluents are most conducive to luxuriant growth of macrophytes (Tripathi and Pandey, 1990). The low values at Site-S4 may be due to the fact that this site is least polluted and supported comparatively low diversity and density of macrophytes during both the year of study. The results of evenness index indicated that Manasbal lake has a higher equal representation of species at Site-S4 and has lower representation or highest unequal representation at Kondabal and Gratabal sites.

Table 2:Macrophyte diversity indices

Sites	Shannon_H	Simpson_1-D	Evenness_e^H/S	Margalef
S1	1.638	0.6655	0.3216	2.139
S2	1.689	0.6938	0.3383	2.088
S3	1.01	0.4812	0.305	1.336
S4	0.8692	0.4514	0.5963	0.6487
S5	1.558	0.6096	0.3167	2.098
S6	1.448	0.5782	0.2503	2.266

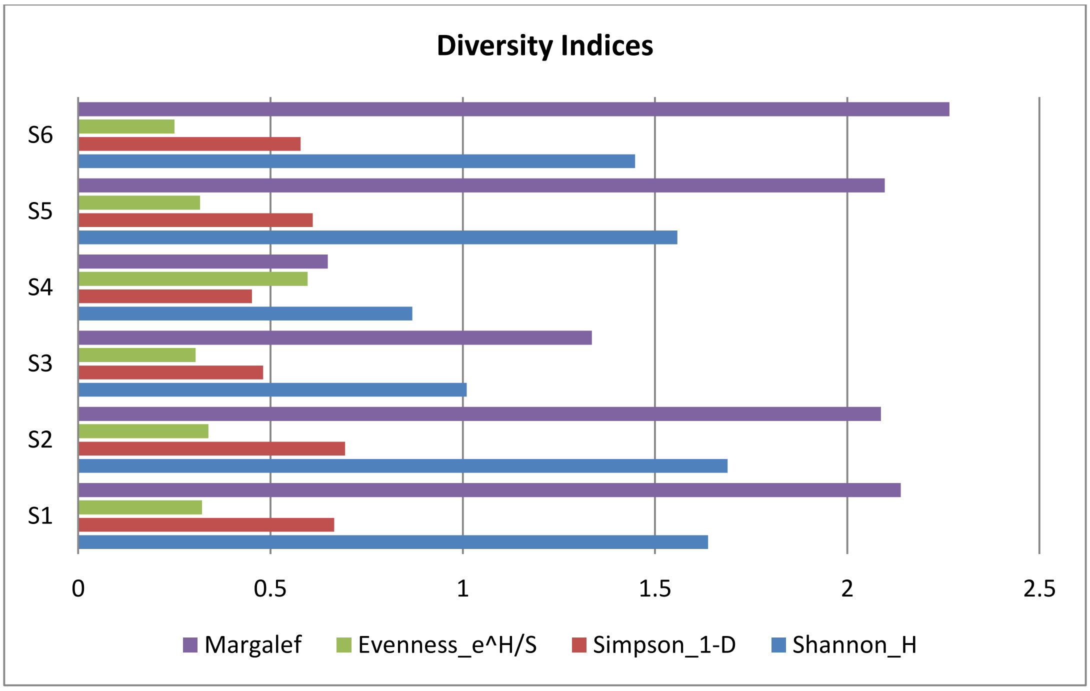

Figure 4: Showing variations in diversity indices of macrophytes in Manasbal lake

CONCLUSION

Based on the foregoing discussion, it is obvious that macrophyte proliferation is accelerating in Manasbal lake. Thus, increasing macrophyte vegetation shows that lake water is receiving nutrients, which aids in the abundant growth of macrophytes. Domestic sewage, animal dung used by the locals for drying in the marginal peripheries of Manasbal lake, and detergents used for washing clothes directly within the region are undoubtedly the main sources of plant nutrients. Besides, the dominance nature of *Azolla sp.* in terms of density, frequency abundance and highest IVI thus poses a serious threat to the lake. *Euryale* ferox was only found at Site-S6, which might be attributed to increasing human interference at the other sites. The highest diversity indices values were exhibited by Kondabal (Site-S2), Gratabal (Site-S1) and Jarokabal (Site-S6) sites respectively. As a result, the study focuses on the immediate need to take effective measures for the conservation and restoration of the lake. Constant monitoring and development of appropriate management strategies are extremely important for lake protection and conservation in future.

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