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Limnology and Rotifer Fauna of Khushalsar Lake, Kashmir

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Abstract

Kashmir traditionally known as heaven on earth for its beauty is gifted with water resources comprising rivers, lakes, streams and springs. Lakes provide a multitude of uses and are prime regions of human settlement and habitat. One such water body is Khushalsar Lake located in the downtown area of Srinagar city. It is noticed that Khushalsar at present has fallen victim to extensive encroachment, garbage dumping and the release of untreated sewage. Taking the pathetic condition of this lake and dynamic nature of water bodies in general into consideration this study was taken up to analyse the different physicochemical parameters and the rotifer abundance of this water body since rotifers are considered to be important indicators of trophic conditions of any aquatic habitat. The data collected was analysed using standard tools, statistical software's SPSS (version 20) and PAST3. Nutrient content of this water body was found to be high and only sixteen species of Rotifera were observed. Statistically different physico-chemical parameters were compared at inlet, middle and outlet of the study lake. Only few parameters showed significant differences. Shannon-Wiener index of rotifer signifies the water body to be moderately diverse as the values lies below 5.00 while as values of Simpson diversity index indicate accelerated eutrophication.

Keywords: Kashmir, Khushalsar Lake, Lakes, Nutrient Content, Rotifera, Shannon-Wiener Index, Statistics

1. Introduction

Water resource of any region has a particular importance. Among all the water bodies' lakes provide a multitude of uses and are prime regions of human settlement and habitat. Uses include drinking water supply, industrial cooling water supply, generation of power, navigation, commercial and recreational fisheries, boating and other aesthetic uses. In addition to this, lake water is also used for agricultural irrigation, canalization and for waste disposal. In Kashmir, lakes too occupy special importance because they serve as a prime attraction that draws tourists to this place. Not only are this they also of great cultural, ecological and socioeconomic importance to the people of this valley.

One such water body is Khushalsar lake located in the downtown area of Srinagar city. This water body is located towards the north west of the city at a distance of about 8.5 km from city centre, at an elevation of 1589 m.a.s.l having an average depth of 3.5 meters. It is a single basined water body. Once known for its crystal clear waters the lake at present is in a highly deteriorated state. It is under immense anthropogenic pressure with surroundings having dense human habitation and vegetable gardens for commercial marketing. At present the lake occupies approximately 647 kanals (main water body), 949 kanals being under marshy area (Recent updates of Lakes and Waterways development authority, 2018). The inlet of lake receives water from Nigeen basin of Dal lake by a channel or nallah dug under the rule of an Afghan governor (Amir Khan) and known by his name even today (Nallah Amir Khan).

There is no known source of underground springs feeding this lake till date. The main outlet is again a channel which drains its water in Anchar Lake. Earlier a small channel (Mar khol) used to connect this lake to

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Brarinambal lagoon but it was filled later on and converted to road which is known today by the name of Nallah Mar road,thus further deteriorating its ecological conditions. Though relatively small it still has got its own importance by providing livelihood, acting as source of groundwater recharge, feeding, nesting and breeding site for many bird species. Taking into account the pathetic condition of this lake and the changing nature of water bodies in general into consideration, this study was taken up to analyse the different physicochemical parameters and the rotifer composition and abundance of this water body.

2. Brief Description of Study Sites

Site 1st(K1): This is the site where water from Nigeen (one of the basins of Dal Lake) enters Khushalsar *via* Gilsar (a small lake where water from Dal Lake accumulates before it enters in Khushalsar). Only few macrophytic associations were found here. On both sides of this site emergent species of macrophytes like *Polygonum, Phragmitesand Typha* spcould be seen.

Site 2nd(K2): This is the open water area of the lake which is mainly used for nadroo (Lotus stems) cultivation by the locals. Floating leaf type macrophytes like *Nelumbo nucifera, Nymphoides peltatum* and submergents like *Potamogeton* species could be observed.

Site 3rd(K3): Through this site water leaves the lake and the depth of this site is least of all the sites with few plants of *Lemna* sp. floating on the surface. On one side proper bunding of the lake is not done and on the other side some area is occupied by salix trees and human habitation is also found (Figure 1-4).

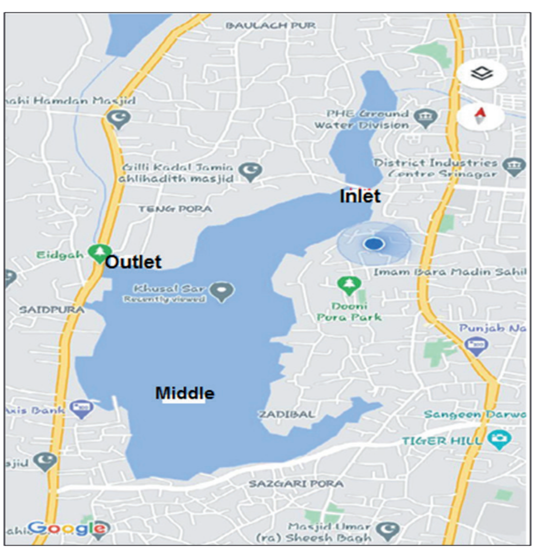

Figure 1. Network of sampling sites in Khushalsar Lake.

Figure 2. Inlet of the Lake.

Figure 3. Middle of the Lake.

Figure 4. Outlet of the Lake.

3. Methodology

For the collection of data for present investigation, the water samples were collected from the sampling sites by dipping one litre polyethylene bottle just below the surface of water. Specially recommended glass bottles (Winklers bottles) were used for the estimation of dissolved oxygen. For estimation of dissolved oxygen, samples were fixed at the sampling site in accordance with modified Winkler method. The analysis of water samples was done by adopting standard and internationally accepted methods[1-5]. The methods employed for the determination of different physico-chemical parameters of water are enumerated as follows.

Table 1. Methodology used for determining various physico-chemical parameters

Sl.No.	Parameters	Method
1.	Air temperature	APHA, 1998
2.	Water Temperature	APHA, 1998
3.	Transparency	Welch, 1948
4.	pH	Digital pH meter (Model 335 Systronics)
5.	Specific conductivity	Digital Conductivity meter (Systronics DB-104)
6.	Dissolved Oxygen	Modified Winkler's method
7.	Free Carbon Dioxide	Titrimetric method (APHA, 1998)
8.	Total Alkalinity	Titrimetric method (APHA, 1998)
9.	Chloride	Argentometric method (APHA, 1998)
10.	Ammonia	Phenate method (APHA, 1998)
11.	Nitrate	Sodium Salicylate method (CSIR, 1974)
12.	Nitrite	Sulphanilamide method (APHA, 1998)
13.	Total Phosphorus	Stannous Chloride Method (APHA, 1998)

3.1 Collection and Preservation of Zooplankton Samples

Zooplankton samples were collected from all sites of the lakes under study, which differ in water depth, vegetation and other characteristics. The samples were collected by sieving 10 litres of the subsurface lake water through nylon cloth conical zooplankton net having 75 meshes/linear cm. The contents collected in the plankton tube attached to lower end of net were transferred to separate polyethylene tubes and after sedimentation a subsample was taken for study. The organisms were preserved in 4% formalin.

3.2 Qualitative Analysis

Preserved Zooplankton samples were identified upto specific level by observing them under a Research Microscope (model- Magnus MLX – Bi). Systematic identification was done by taking the help of Edmondson[6], Penak (1978).

3.3 Quantitative Estimation of Zooplankton

For quantitative zooplankton study, a sedge-wick rafter cell of 1ml capacity was used which is 50mm long, 20mm wide and 1mm deep. The samples were transferred to the cell with a large graduated bore pipette or a dropper. The air bubbles were avoided while transferring the sample to the cell. Before counting the zooplankton, it was ensured that all the organisms have settled down. Every sample was counted for the zooplankton at least three times and an average was taken for the samples of each month. The number of each species or genus was calculated by the following formula 9 and then total zooplanktons were accounted on monthly basis:

$$n=\frac{(a\times c)}{l}$$

Where n= number of individuals per cubic meter of water.

a = no. of individuals in one ml of concentrated sub sample.

c = volume of concentrated sample.

l = vol. of water sieved. (10 L).

3.4 Diversity Indices

In the literature, we come across various diversity indices like Simpson, Shannon-Wiener Index etc. Shannon-Wiener Index is most commonly used index and is given by the following function:

$$H=\Sigma[(pi)\times ln(pi)]$$

where, *pi* = proportion of total sample represented by species *i*.

Divide number of individuals of species i by total number of samples.

S = number of species, = species richness

Hmax=ln(S) = Maximum diversity possible

E = Evenness = *H/Hmax*

4. Results

The data for various physic-chemical parameters and rotifer abundance was collected from December 2012 to September 2014. The readings could not be procured in October and November (2014) due to floods. The data presented in (Table 1) shows the Mean ± S.E of different physico-chemical parameters observed at three different sites of the water body under investigation during two year study period. Air temperature varied in accordance with different seasons. On comparing the mean values of different sites non-significant difference was observed during 2013 as well as in 2014. The overall annual mean value of air temperature of the lake was found to be 17.55 ± 0.08^{0}C in 2013 and 16.88 ± 0.17^{0}C in 2014. Water temperature always followed air temperature. Statistically insignificant differences were found in water temperature as well. The annual mean value of water temperature of the lake was 13.99 ± 0.23^{0}C in 2013 and 12.80 ± 0.13^{0}C in 2014. The lake water was observed to be muddy throughout the investigation period due to which the transparency values were found to be lower. In 2013 the annual value of transparency was calculated as 0.51±0.08 m but the overall mean value was calculated as 0.71± 0.81 m for the second year of study. The mean pH value at different sites during both the years of study was 8 or slightly above it. However, measurable difference was not observed among different sites during both the study years ($p>0.05$). The annual mean value of pH was found to be 8.05 ± 0.12 units for the year 2013 and 8.44 ± 0.15 units for 2014. Specific conductivity or conductance of water sample is considered to be integral part of water quality assessment. It may change with water temperature, total dissolved solids or the ionic content of the water sample. In the present study statistical comparison by ANOVA showed $p>0.05$ for different sites during the two year study period which implied negligible differences. The annual mean value for specific conductivity was obtained as 393.9 ± 4.56 µS/cm for 2013 and 394.9 ± 24.3 µS/cm in 2014. The site-wise comparison of Dissolved Oxygen (DO) showed measurable differences in 2013 while as the three sites had almost similar mean values of dissolved oxygen during 2014. The mean DO content of the lake water for 2013 was obtained to be 7.04 ±1 mg/L. However it was slightly greater 7.42 ± 0.48 mg/L in the following year (2014). Free carbon dioxide (Free CO_2) varied in different seasons but analysis of different sites during the two year study period revealed notable differences ($p<0.05$) in both the study years. The yearly mean value for the first year was obtained as 22.67 ± 1.86 mg/L. But it was slightly higher for the second year (2014) (24.19 ± 2.23 mg/L). Chloride values showed seasonal fluctuations. Moreover the chloride content of the water body showed insubstantial differences among various sites during the two year study period. The overall mean of the lake was calculated as 34.4 ± 6.5 mg/L for 2013 and somewhat lower in 2014 i.e.,31.9 ±1.9 mg/L. The lakes of Kashmir have been considered as alkaline lakes which were again depicted by alkalinity values of this lake. Seasonal difference was well noticeable. However site-wise analysis observed insignificant differences where $p>0.05$ was calculated.The mean value was calculated as 276.48 ± 17.92 mg/L in the first year and 271.30 ± 11.32 mg/L in 2014. Among various nitrogenous compounds in the water body measurable differences were found in nitrates ($p<0.05$) in 2014 among different sites whereas other ions such as ammonia and nitrites were present uniformly at different study sites in 2013 as well as in 2014. Moreover the annual average value of 325.994 ± 10.02 µg/L was observed for ammonical-nitrogen in first year of investigation and 320.48 ± 14.40 µg/L in 2014. Total phosphorous being the most important parameter in assessing the trophic status of water bodies also showed invaluable differences at various sites during both the study years. The annual average value of 521.8 ± 10.5 µg/L was observed for the water body in first year of investigation.

Correlation among various physico-chemical water quality parameters under study at Khushalsar Lake during 2013 is presented in (Table 1). The Table 1 reveals that air temperature has significant positive correlation with water temperature ($r=0.988$, $p<0.01$,). Transparency showed significant positive correlation with DO ($r=-0.372$, $p<0.05$), chloride ($r=0.380$, $p<0.05$) Ammonia ($r=0.464$, $p<0.01$) Total phosphorus ($r=-0.418$, $p<0.05$). pH showed significant positive correlation with CO_2 ($r=-0.540$, $p<0.01$) Chloride l($r=-0.563$, $p<0.01$) Nitrate ($r=-0.546$, $p<0.01$) and Total phosphorus ($r=-0.385$, $p<0.05$). Specific conductivity showed negative relation with Ammonia ($r=-0.438$, $p<0.01$) and Nitrite ($r=-0.394$, $p<0.05$). CO_2 showed significant positive correlation with Chloride ($r=-0.551$, $p<0.01$) nitrate ($r=-0.399$, $p<0.05$), Nitrite ($r=0.401$, $p<0.05$) and Total phosphorus ($r=-0.360$, $p<0.05$). Chloride showed significant positive correlation with Total Alkalinity ($r=-0.521$, $p<0.01$), Ammonia ($r=-0.369$, $p<0.05$) Nitrate ($r=-0.479$, $p<0.01$) and Total phosphorus ($r=-0.679$, $p<0.01$).Total alkalinity showed significant positive correlation with Ammonia ($r=-0.557$, $p<0.01$) Nitrate ($r=-0.416$, $p<0.05$), Nitrite ($r=-0.367$, $p<0.05$ and Total phosphorus ($r=-0.484$, $p<0.01$). Ammonia showed significant positive correlation with Nitrate ($r=0.372$, $p<0.05$), Total phosphorus ($r=0.493$, $p<0.01$). Nitrate showed significant positive correlation with Total phosphorus ($r=0.469$, $p<0.01$). Negative correlation was also found among various water parameters. Water temperature showed negative relation with Transparency ($r=-0.582$, p<0.01), DO (r=-0.463, p<0.01), Chloride (r=-0.379, p<0.05), Total alkalinity (r=-0.564, p<0.01), Ammonia (r=-0.653, p<0.01), Nitrate (r=-0.392, p<0.05) and Total phosphorus (r=-0.519, p<0.01). Specific conductivity showed negative relation with Ammonia (r=-0.438, p<0.01) and Nitrite (r=-0.394, p<0.05). Significant negative correlation was found between Air temperature and Transparency (r=-0.594, p<0.01). Similarly, Correlation among the water quality parameters under study at Khushalsar lake during 2014 is presented in (Table 2). Table 2 reveals that air temperature has significant positive correlation with water temperature (r=0.979, p<0.01),Transparency (r=0.474, p<0.05) and pH (r=0.738, p<0.01). However, it showed negative correlation with DO (r=-0.637, p<0.01), Chloride (r=-0.517, p<0.01) and Total Alkalinity (r=-0.754, p<0.01). Water temperature also showed significant positive correlation with some parameters like Transparency (r=0.487, p<0.01), pH (r=0.686, p<0.01) and negative correlation with DO (r=-0.708, p<0.01) Total alkalinity (r=-0.775, p<0.01) and Chloride (r=-0.449, p<0.01). pH showed significant positive correlation with some parameters like DO (r=-0.434, p<0.05) CO_2 (r=-0.4663, p<0.01), Chloride (r=-0.672, p<0.01), Total alkalinity (r=-0.509, p<0.05) and Nitrate (r=-0.484, p<0.01).

Significant positive correlation was also found between transparency and DO (r=0.467, p<0.01), DO and Total alkalinity (r=0.627, p<0.01) CO_2 and Chloride (r=0.433, p<0.05) and Nitrite and Nitrate (r=0.366, p<0.05) (Table 3-5).

4.1 Rotifer Composition and Abundance

Rotifer composition and population abundance as depicted in Table 6 and 7 shows only sixteen species in 2013 as well as in 2014. Seasonal distribution of different species is also given in the said tables. Genus *Brachionus* was represented by four speciesit thrived well in this water body. Three species i.e., *B. calyciflorus, B. quadridentata and B. bidentata* were well represented in all the seasons except winter when the population density dropped. *Brachionus angularis* had lower population density in all the seasons in both the study periods. *Asplanchna priodonta* showed highest population density in summer and lowest in spring. It followed almost same trend in the following time period. Genus *Keratella* was represented by two species *Keratella cochlearis and Keratella quadrata. Keratella cochlearis* showed low abundance in winter and spring in 2013 and 2014 respectively. It gradually increased its population and reached highest in summer in both the study periods. *Lecane luna* appeared in both the study periods. It disappeared in winter season of both the years and gradually increased its population density and attained its peak in summer season. Same trend was observed for this species in the following year. *Polyarthra vulgaris* attained highest population density in summer in both the years. Winter population was however also well represented in the lake. *Synchaeta* sp. was well represented in cooler period and it disappeared in summer of both the years. *Lepadella* sp. was well represented in summer and was seen in lower population density in other seasons. It showed similar behavior in the next year. Genus *Filinia* was represented by two species *Filinia longiseta* and *Filinia terminalis. Filinia longiseta* attained highest population density in summer months in both the years but *filinia terminalis* had very low population density in both years and acquired higher population density in cooler months. *Pompholyx sulcata,Cephalodella gibba* and *Trichocerca longiseta* showed low population density in winter period but gradually increased in number and attained peak population density in warmer period i.e.,summer and autumn.

On analyzing the data of year 2013 statistically it was revealed that dominance index showed lowest value in spring (0.0819) as depicted in (Table 8) and uppermost dominance value was observed during winter (0.1551). The Simpson index varied from 0.8449 (winter) to 0.9208 (summer), indicating heavy pollution. The Evenness ranged from 0.7586 (winter) to 0.8774 (summer) indicating summer is slightly diverse than other seasons. The Shannon Wiener (H') diversity index was noticed highest during spring (2.619) and least during winter (2.122). This means the water body was moderately diverse as the value of H' was less than 5.00. In the year 2014 diversity values are presented in (Table 9). It revealed that dominance index showed least value during spring (0.09637) and uppermost dominance index during winter (0.1217). The Simpson index varied from 0.8783 (winter) to 0.9036 (spring), indicates water being highly polluted. The Evennes ranges from 0.7958 (winter) to 0.9175 (summer). The Shannon Wiener (H) diversity index was noticed highest during spring (2.456) and least during winter (2.336). It again depicted moderate diversity of the water body and a variety of species appear during spring season.

5. Discussion

Aquatic ecosystems are often dynamic. Their quick response to surrounding environment biotically as well as abiotically makes them a subject of interest besides being naturally important in regulating the microclimate of any area. The faunal communities they hold inturn respond to changing conditions speedily.Morphological and behavioral changes are induced in aquatic communities by alterations in temperature. Not only metabolism but swimming, feeding as well reproductive rate gets changed in a significant way. It affects the biotic components of a water body besides

Table 2. Correlation analysis of physic-chemical parameters under study (2013)

Para-meters	Air temp	Water temp	Tran-spa-rency	pH	S.Cond.	Dis-sol-ved Oxy-gen	Free CO2	Chlo-ride	T.Al-kali--nity	Amm-onia	Nit-rate	Nit-rite	T.Pho-spho-rus
Air temp	1	.988	-.594**	.246	.320	-.434	-.212	-.440	-.582	-.635	-.445	-.312	-.553
Water temp	.988**	1	-.582**	.203	.315	-.463**	-.179	-.379*	-.564**	-.653**	-.392*	-.308	-.519**
Trans-parency	-.594**	-.582**	1	-.209	-.287	.372*	.197	.380*	.057	.464**	.325	.179	.418*
pH	.247	.203	-.209	1	-.129	.026	-.540**	-.563**	-.243	-.145	-.546**	-.270	-.385*
S.Cond.	.320	.315	-.287	-.129	1	-.265	-.091	-.125	-.154	-.438**	-.076	-.394*	-.109
Dis-solved Oxygen	-.434**	-.463**	.372*	.026	-.265	1	-.068	.147	.133	.219	.048	.132	.118
Free CO2	-.212	-.179	.197	-.540**	-.091	-.068	1	.551**	.220	.308	.399*	.401*	.360*
Chloride	-.440**	-.379*	.380*	-.563**	-.125	.147	.551**	1	.521**	.369*	.479**	.295	.671**
T.Alka-linity	-.582**	-.564**	.057	-.243	-.154	.133	.220	.521**	1	.557**	.416*	.367*	.484**
Ammo-nia	-.635**	-.653**	.464**	-.145	-.438**	.219	.308	.369*	.557**	1	.372*	.290	.493**
Nitrate	-.445**	-.392*	.325	-.546**	-.076	.048	.399*	.479**	.416*	.372*	1	.137	.469**
Nitrite	-.312	-.308	.179	-.270	-.394*	.132	.401*	.295	.367*	.290	.137	1	.205
T.Phos-phorus	-.553**	-.519**	.418*	-.385*	-.109	.118	.360*	.671**	.484**	.493**	.469**	.205	1

*= significant at 1% of level of significance and **=significant at 5% level of significant.

Table 3. Correlation analysis of physic-chemical parameters under study (2014)

Para-meters	Air temp	Water temp	Tran-spa-rency	pH	S.Cond.	Dis-sol-ved Oxy-gen	Free CO2	Chlo-ride	T.Al-kali--nity	Amm-onia	Nit-rate	Nit-rite	T.Pho-spho-rus
Air temp	1	.979**	.434*	.738**	-.015	-.637**	-.204	-.517**	-.754**	.014	-.097	-.025	.042
Water temp	.979**	1	.487**	.686**	.016	-.708**	-.115	-.449*	-.775**	-.015	.008	.004	.045
Trans-parency	.434*	.487**	1	.329	-.016	-.467**	.223	-.170	-.694**	.017	-.121	-.075	.100
pH	.738**	.686**	.329	1	.020	-.434*	-.463**	-.672**	-.509**	.002	-.484**	-.163	-.089
S.Cond.	-.015	.016	-.016	.020	1	-.354	.309	-.109	.048	-.051	.150	-.075	.077
Dis-solved Oxygen	-.637**	-.708**	-.467**	-.434*	-.354	1	-.219	.144	.627**	-.077	-.129	-.123	-.371*
Free CO2	-.204	-.115	.223	-.463**	.309	-.219	1	.433*	.006	-.279	.354	.077	.124
Chloride	-.517**	-.449*	-.170	-.672**	-.109	.144	.433*	1	.312	.108	.348	.039	.052
T.Alka-linity	-.754**	-.775**	-.694**	-.509**	.048	.627**	.006	.312	1	-.114	.033	-.058	-.204
Ammo-nia	.014	-.015	.017	.002	-.051	-.077	-.279	.108	-.114	1	.038	.075	.057
Nitrate	-.097	.008	-.121	-.484**	.150	-.129	.354	.348	.033	.038	1	.366*	.146
Nitrite	-.025	.004	-.075	-.163	-.075	-.123	.077	.039	-.058	.075	.366*	1	.256
T.Phos-phorus	.042	.045	.100	-.089	.077	-.371*	.124	.052	-.204	.057	.146	.256	1

*= significant at 1% of level of significance, and **=significant at 5% level of significant.

Table 4. Physico-chemical characteristics of water (Mean ± S.E) at three sites of lake (December 2012-November 2013)

Sl. No.	Site(s)	Parameter(s)	Mean ± S.E,	P-value
1.	K1	Air Temperature (^{0}C)	17.458 ± 2.921	>0.05
	K2		17.575 ± 2.892	
	K3		17.625 ± 2.972	
2.	K1	Water Temperature (^{0}C)	13.800 ± 2.653	>0.05
	K2		14.258 ± 2.716	
	K3		13.925 ± 2.686	
3.	K1	Transparency (m)	0.527 ± 0.065	>0.05
	K2		0.608 ± 0.100	
	K3		0.428 ± 0.049	
4.	K1	pH (Units)	8.058 ± 0.083	>0.05
	K2		8.175 ± 0.121	
	K3		7.933 ± 0.083	
5.	K1	Sp. Cond. (µS/cm)	397.392 ± 9.324	>0.05
	K2		388.767 ± 13.577	
	K3		401.050 ± 12.636	
6.	K1	DO (mg/L)	7.367 ± 0.228	>0.05
	K2		7.383 ± 0.255	
	K3		6.375 ± 0.388	
7.	K1	CO_2 (mg/L)	20.583 ± 1.064	>0.05
	K2		23.283 ± 1.111	
	K3		24.150 ± 0.820	
8.	K1	Chloride (mg/L)	31.817 ± 2.183	>0.05
	K2		34.417 ± 1.904	
	K3		34.433 ± 2.218	
9.	K1	Total Alkalinity (mg/L)	285.625 ± 11.471	>0.05
	K2		255.833 ± 13.130	
	K3		287.975 ± 12.619	
10.	K1	Ammonical-Nitrogen (µg/L)	323.550 ± 21.039	>0.05
	K2		317.375 ± 14.980	
	K3		336.967 ± 7.677	
11.	K1	Nitrate-Nitrogen (µg/L)	400.083 ± 13.480	>0.05
	K2		371.083 ± 13.874	
	K3		394.308 ± 12.368	
12.	K1	Nitrite-nitrogen (µg/L)	34.825 ± 2.484	>0.05
	K2		33.817 ± 2.962	
	K3		39.725 ± 1.584	
13.	K1	Total Phosphorus (µg/L)	510.758 ± 12.925	>0.05
	K2		531.733 ± 13.260	
	K3		522.908 ± 20.262	

Table 5. Physico-chemical characteristics of water (Mean±S.E) at three sites of lake (December 2013-September 2014)

Sl. No.	Site(s)	Parameter(s)	Mean ± S.E,	P-value
1.	K1	Air Temperature (^{0}C)	16.810 ± 3.389	>0.05
	K2		16.760 ± 3.318	
	K3		17.090 ± 3.297	
2.	K1	Water Temperature (^{0}C)	12.810 ± 3.174	>0.05
	K2		12.670 ± 3.140	
	K3		12.930 ± 3.248	
3.	K1	Transparency (m)	0.613 ± 0.084	>0.05
	K2		0.926 ± 0.071	
	K3		0.593 ± 0.071	
4.	K1	pH (Units)	8.320 ± 0.099	>0.05
	K2		8.610 ± 0.141	
	K3		8.390 ± 0.080	
5.	K1	Sp. Cond. (µS/cm)	370.270 ± 12.670	>0.05
	K2		395.200 ± 12.909	
	K3		419.088 ± 15.754	
6.	K1	DO (mg/L)	7.910 ± 0.202	>0.05
	K2		7.380 ± 0.408	
	K3		6.960 ± 0.345	
7.	K1	CO_2 (mg/L)	22.020 ± 1.297	>0.05
	K2		24.060 ± 1.233	
	K3		26.480 ± 0.861	
8.	K1	Chloride (mg/L)	32.510 ± 2.053	>0.05
	K2		29.820 ± 1.961	
	K3		33.620 ± 2.607	
9.	K1	Total Alkalinity (mg/L)	273.990 ± 15.878	>0.05
	K2		258.870 ± 25.540	
	K3		281.030 ± 17.792	
10.	K1	Ammonical-Nitrogen (µg/L)	336.740 ± 7.978	>0.05
	K2		315.410 ± 10.990	
	K3		309.310 ± 15.650	
11.	K1	Nitrate-Nitrogen (µg/L)	433.060 ± 8.577	>0.05
	K2		383.900 ± 13.685	
	K3		421.850 ± 13.551	
12.	K1	Nitrite-nitrogen (µg/L)	38.600 ± 2.626	>0.05
	K2		34.760 ± 2.492	
	K3		35.230 ± 2.053	
13.	K1	Total Phosphorus (µg/L)	524.180 ± 11.998	>0.05
	K2		523.480 ± 12.402	
	K3		545.590 ± 15.538	

Table 6. Seasonal Abundance (Ind/L) of Rotifera in the Khushalsar Lake in 2013

Sl. No.	Species name	Winter	Spring	Summer	Autumn
1.	*Brachionus calyciflorus*	37	203	208	174
2.	*Brachionus quadridentatus*	29	206	316	173
3.	*Brachionus bidentata*	41	128	301	228
4.	*Brachionus angularis*	21	132	74	148
5.	*Asplanchna priodonta*	89	55	363	316
6.	*Keratella cochlearis*	0	34	226	256
7.	*Keratella quadrata*	289	199	0	131
8.	*Lecane luna*	0	40	49	126
9.	*Polyarthra vulgaris*	115	100	132	182
10.	*Synchaeta sp.*	81	57	0	49
11.	*Lepadella sp.*	0	67	183	59
12.	*Filinia longiseta*	112	132	0	34
13.	*Filinia terminalis*	69	44	0	0
14.	*Pompholyx sulcata*	0	64	124	73
15.	*Cephalodella gibba*	0	150	224	225
16.	*Trichocerca longiseta*	52	70	100	157

Table 7. Seasonal Abundance (Ind/L) of Rotifera in the Khushalsar Lake in 2014

Sl. No.	Species name	Winter	Spring	Summer	Autumn
1.	*Brachionus calyciflorus*	83	257	199	73
2.	*Brachionus quadridentatus*	83	162	291	59
3.	*Brachionus bidentata*	56	142	249	74
4.	*Brachionus angularis*	41	71	90	56
5.	*Asplanchna priodonta*	77	0	283	69
6.	*Keratella cochlearis*	73	0	206	92
7.	*Keratella quadrata*	300	126	0	0
8.	*Lecane luna*	0	75	77	32
9.	*Polyarthra vulgaris*	130	127	193	37
10.	*Synchaeta sp.*	77	16	0	2
11.	*Lepadella sp.*	0	70	183	33
12.	*Filinia longiseta*	146	89	0	0
13.	*Filinia terminalis*	31	8	0	0
14.	*Pompholyx sulcata*	0	112	82	20
15.	*Cephalodella gibba*	25	83	154	72
16.	*Trichocerca longiseta*	55	83	115	28

Table 8. Rotifer diversity of Khushalsur during 2013

Diversity indices	Winter	Spring	Summer	Autumn
Taxa	11	16	12	15
Individuals	935	1681	2300	2331
Dominance_D	0.1551	0.0819	0.1041	0.08342
Simpson_1-D	0.8449	0.9181	0.9208	0.9166
Shannon_H	2.122	2.619	2.354	2.573
Evenness_e^H/S	0.7586	0.858	0.8774	0.8737

Table 9. Rotifer Diversity of Khushalsur during 2014

Diversity indices	Winter	Spring	Summer	Autumn
Taxa	13	14	12	13
Individuals	1177	1421	2122	647
Dominance_D	0.1217	0.09637	0.0971	0.09675
Simpson_1-D	0.8783	0.9036	0.9029	0.9032
Shannon_H	2.336	2.456	2.399	2.410
Evenness_e^H/S	0.7958	0.8329	0.9175	0.8565

affecting other physicochemical features of any aquatic ecosystem.

Since the water body is shallow in nature water temperature quickly responded to the change in air temperature. Similar findings were reported by some workers in case of shallow water bodies[7]. Seasonal changes were momentous but the difference among different sites was insignificant. Few workers[8] considered siltation, microscopic organisms and suspended organic matter to affect transparency of water. The water body under study is shallow. It has an average depth of about 3m. Therefore bottom sediments get easily mixed with water column even with the slightest disturbance. Hence overall transparency was low. Statistically differences were significant in 2014 as continuous rains brought much mud and silt from surrounding areas at inlet and outlet of the lake.

High pH value in summer season which may be due to high photosynthetic activity of micro and macro vegetation making the water alkaline, was also marked by a number of workers[9]. The water body under study showed the low annual pH value which may be due to the shallow nature and high organic matter present which is continuously decomposing resulting in high production of Free CO_2. The middle of the lake is well infested with macrophytes and hence free carbon dioxide (Free CO_2) is utilized due to prolonged photoperiod during summer by growing plants and phytoplankton. Therefore the differences between three sites were well marked in both the years. On analyzing the specific conductivity of the water body it was found to be high in 2013 as well as in 2014. Some of the workers[10] attributed the high value of water conductivity mainly with decomposed organic matter.

In spring and winter Dissolved oxygen content goes up in most lakes. Here the values showed slight changes but overall concentration remained low. Low values of dissolved oxygen may be attributed to high organic matter present as in such cases BOD of the water body increases which depletes oxygen content. Low oxygen content due to high organic matter was also observed by few worker[11]. In 2013 statistically significant variations were observed among three sites which may be attributed to flushing of lake from Dal Lake in spring as the dilution with freshwater increases the DO levels. Dissolved oxygen levels go up at inlet and outlet but remain unchanged in the middle site. Inlet and outlet of the lake lie opposite to each other.Whileas in the second year (2014) profound rainfall increased the water level in Dal Lake which subsequently paved the way for entry of excess water into the lake under study (since the two are connected via Gilsar Lake). Dilution with excess water kept the Dissolved oxygen content at all sites almost similar. Since the lake is very shallow and receives higher loads of sewage from the surrounding residential area therefore decomposition of organic matter leads to increase in CO_2 levels too. Shallow lakes often tend to accumulate more materials than deeper lakes therefore concentration of chloride ion was also reported to be high. A number of workers[12] reported similar findings while working on some Kashmir lakes. Moreover in the surroundings there is a dense human habitation.

All the domestic sewage enters into the lake. Pesticides, manures and other fertilizers are often used to increase the yield of the crops which could be another reason for high chloride concentration in this lake. It had highly alkaline water during the whole study period as the alkalinity values were recorded above 200 mg/l in every month therefore it is considered to be strongly alkaline. The ammonical nitrogen recorded was also towards higher scale which may be attributable to the fact that it receives high load of organic matter which decomposes in summer and autumn season. However here as already mentioned, a greater part of this water body is used for growing vegetables on commercial scale which may be the reason for high concentration of this nutrient in this lake where fertilizers are used. Moreover the weed infestation which acts as sink of nutrients is less leading to high concentration of nutrients important for plant growth. Nitrates and total phosphorus were also on higher level and their concentration increased more in winter. This happens when the winters are usually dry.

In this lake a number of drains carrying sewage water from surrounding residential area open directly and release detergent rich waters. Moreover use of fertilizers within and in the water shed of this water bodies can be the main reason for nutrient rich waters.

During a two year study total 16 rotifer taxa were identified. Rotifers are considered as important components of freshwater zooplankton communities. They act as herbivores, predators, or omnivores[13]. They also serve as a major food source for many invertebrates[14]. In India about 95% are reported to inhabit freshwater which is their original habitat while 5% occur in continental oceanic environment? However they do not occur in open sea. Most of them are cosmopolitan while others are restricted in their distribution like *Cephalodella, Synchaeta* and *Notholca*[15]. Genus *Brachionus* was dominant, it was represented by four species viz, *Brachionus bidentata, Brachionus quadridentata, Brachionus calyciflorus, Brachionus angularis*. In this genus *Brachionus quadridentata* showed highest population density during the two year study period and B.angularis had the lowest population density.

Some of the workers[16] are of the opinion that most species of this genus thrive well in warm waters as was found in the present study. Their population density increased mostly in summer. In genus *Keratella, Keratella cochlearis* showed peak population in summer but *Keratella quadrata* was abundantly found in winter season. Many workers[17] also observed its (*Keratella quadrata*) restricted population growth during the period of food availability in central Himalayan lakes. Family *lecanidae* was represented by species *Lecane luna*. The members of this group usually thrive in fresh and saline waters and are found in littoral habitats[18]. Seasonal distribution of *Lecane luna* showed it to be present during warmer period in all the three water bodies. It was absent in colder months. Moreover this genus is a tropic centered genus. *Asplanchna priodonta* is known to effectively control populations of algae and rotifers since it is a predatory rotifer species[19]. It was present throughout the study period making it perennial. A number of investigators from Kashmir[19] however also reported it to be perennial rotifer.

Polyarthra vulgaris and *Synchaeta* sp. were the members that appeared from family *Synchaetidae*. *Synchaeta* sp. has been reported to be cold water genus by number of workers.It was also reported it to be present in oligotrophic and mesotrophic waters[20]. In the present study it showed its abundance in colder months and was present only at site K2 in Khushalsar lake. *Polyarthra vulgaris* attained high population in warmer period and winter population remained low. It was observed to tolerate temperature range from less than 1^{0}C to more than 20^{0}C[21]. It shows similarity with the present findings. *Lepadella ovalis* is a cosmopolitan rotifer. It was reported to be abundant in macrophytes[26] which are in line with the present finding where it was present in low numbers in inlet and outlet of Khushalsar. Genus Filinia was represented by two species *Filinia longiseta* and *Filinia terminalis*. In the present study *Filinia longiseta* was present abundantly at littoral sites and avoided open water zone. It was reported to be omnivorous feeding on any kind of food[27].

Trichocerca is a warm water preffering genus as reported by few workers[28] which is similar to the findings of the present study where it showed peak populations in summer and autumn. This species was reported to be a pelagic form[29]. In the present study *Trichocerca longiseta* was almost uniformly present at all the sites indicating that it can survive equally in littoral and limnetic areas. Family *Notommatidae* was represented by only one species i.e., *Cephalodella gibba*. Some workers reported this genus to have restricted distribution, Jammu and Kashmir being one of the states[15].

6. Conclusion

After observing different physico-chemical characteristics and rotifer species composition and abundance it was observed that nutrient content of this lake is high and very few rotifer species are observed. The rotifer diversity being low also suggests contamination of water body which does not allow the different species to flourish. The water body needs to be monitored continuously for its abiotic and biotic features. Moreover people living in surrounding areas need to be sensitized and various awareness programmes should be organised to make them understand the importance of water bodies. Illegal encroachment needs to be checked by concerned authorities and opening of inlet and outlet channels that used to exist in past should be made functional again. Agricultural practices carried in and around the lake should not exceed threshold levels that could lead to further damage of the water body. Construction should be limited in catchment area. Moreover Government and local people should work in collaboration to protect this asset.

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