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Rotifer community in Manasbal Lake of Kashmir

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Abstract
Species composition and distribution of Rotifera was studied in Manasbal Lake. Thirty three taxa of Rotifera belonging to 17 genera and 7 families were recorded. Rotifer community was characterised by high richness of family Brachionidae. Higher density of the group was recorded at macrophyte infested littoral area. Rotifer richness showed a positive relationship with water temperature, dissolved oxygen, conductivity and negative relation with depth, total phosphorus, nitrate nitrogen, alkalinity, hardness, carbon dioxide and chloride. Rotifer density was lower at outlet zone due to flushing of water.

Keywords: Manasbal Lake; Rotifera; Littoral; limnetic; outlet.

1. Introduction
The great diversity of zooplankton species, including rotifers, appears to reflect the wide range of limnetic and littoral biotopes which differ in morphometry, presence of macrophytes, productivity, trophic state and proximity to pollution sources [1]. The abundance of rotifer plankton is more or less governed by the interaction of a number of physical, chemical and biological properties of lake waters and is related to the suitable conditions for their survival in the lake. Therefore the community structure of the group in a water body would depend on its trophic status of the lake and accordingly individual species may reflect the level of eutrophication [2]. Where macrophytes are abundant in the littoral of lakes zooplankton especially, rotifers are abundant and diverse. Rotifera has been documented from a wide variety of fresh water lakes of Kashmir. The Rotifera community of Manasbal Lake, the deepest natural fresh water lakes of Kashmir valley, has special ecological significance. In the past, there have been some reports on the occurrence and abundance of rotifer plankton of this lake [3-7]. The work reported in most of these papers, was conducted in 1970s. In order to appreciate the changes that might have taken place during the last couple of decades on the community structure of rotifer in the lake, The ecological conditions of the water body have shown significant changes over the last two three decades. In order to find out whether the changes in the limnology of the lake is reflected in the community structure of rotifer, a study was conducted on the composition, and abundance of Rotifera in the lake during December, 2011 to November, 2013. The data collected are described in the present communication.

2. Materials and Methods
Manasbal Lake is situated about 32 km to the north-east of Srinagar at an altitude of 1584 m asl. It is a semi-drainage type water body without a permanent inlet, but having an outlet where through excess water joins the River Jhelum. Three sampling sites (M_1, M_2 and M_3) were selected in the lake for the present study on the basis of depth, vegetation, out flow channels (Fig. 1).

Site **M_1** was located in the littoral zone near village Kondabal ($34^0 39' 7''$N and $74^0 47' 30.4''$E) in the most degraded area, receiving all kinds of domestic sewage from nearby human habitation. The most dominant macrophytes in this area are *Ceratophyllum demersum* and *Myriophyllum spicatum*.

Site **M_2** was located on the western side of the lake near the outlet channel at 34008′21″N and $74^0 47' 37''$E. The macrophyte community in this area is dominated by *Nelumbo nucifera*.

Site **M3** was selected in the central part of the lake, opposite to secondary school at $34^0 08' 38.7''$N – $74^0 47' 22.0''$E. It is the deepest point of the lake with a maximum depth of 13 m. There is scanty growth of vegetation in this area.

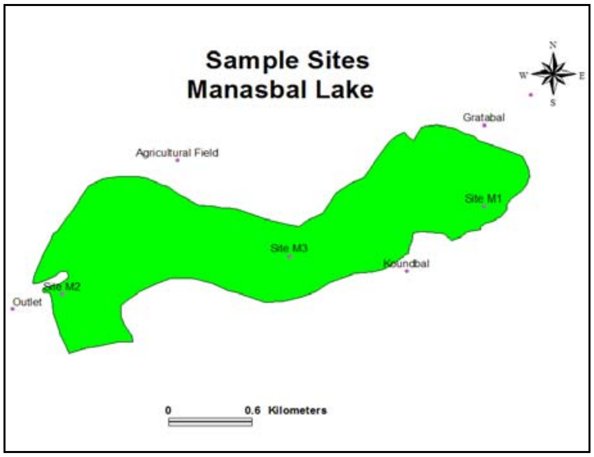

Fig 1: Map of Manasbal Lake showing the study sites.

Sampling at site M_1 and M_2 was restricted to the surface layer, whereas at Site M_3 samples were collected at 0.5 m, 3 m, 6 m, and 9 m depths. Physico-chemical analysis of the water samples was done as per the methods given by [8-10].
For a qualitative analysis collection of the plankton was carried out by hauling plankton net fitted with nylobolt net cloth no. 140T (Nylobolt company, Mumbai) through water in vertical and horizontal directions. Identification of the plankton preserved in 4% formalin was done with the help of standard taxonomic keys [11-12] (Edmondson, 1959; Pennak, 1978; Wallace and Snell, 2001). Quantitative samples were procured with the help of a 2 – litre Ruttner type sampler.

2.1 Data manipulation analysis
2.2 Pearson correlation analysis
For calculation purpose formula for coefficient of correlation (Karl Pearson method) was used as.

$$r = \frac{n\sum dx - dy - \sum dx.\sum dy}{\sqrt{n\sum dx^2 - (\sum dx^2}\sqrt{n\sum dy^2 - (\sum dy)^2}}$$

Where ∑dx= sum of deviation of x series
∑dy= sum of deviation of y series
r = correlation co-efficient
n = no. of observations

2.3 Shannon Weaver index (H')
Shannon Weaver index was calculated for Rotifer diversity using the formula:

$$H' = -\sum \frac{Ni}{N} \log 2 \frac{Ni}{N}$$

Where Ni is the number of individuals of its species. N is the total number of species. Past programme was used to measure diversity for comparison purposes

3. Results
Water temperature ranged from (4–28.4 ^{0}C), Conductivity (160–367 µs/cm), Free carbon dioxide (6–17 mg/l), Dissolved oxygen (4.8–16 mg/l), Alkalinity (90–224 mg /l), Carbonate alkalinity (4-50 mg /l), Hardness (90–372 mg /l), Ammonical nitrogen (23–161 µg/l), Nitrate nitrogen (117–376 µg/l), Total phosphorus (123-310 µg/l), Ortho phosphorus (9-32 µg /l) (Table :- 1)

Table 1: Results of the physico chemicals parameters of the Manasbal Lake.

Parameters	M_1 – Littoral zone	M_2 – 0utlet	M_3- limnetic zone
Water temp 0 ^{0}C	4 – 28.4	4 – 28.3	4 – 28. 2
Conductivity µs/cm	160 – 287	225-367	189-306
Dissolved oxygen mg/l	4.8 – 16	7-14	5.2-13.7
Free carbon dioxide mg /l	6 – 17	7-18	9-22
Alkalinity mg/l	153 – 224	90-200	105 -196
Hardness mg/l	90 – 210	100- 372	98-220
Ammonical nitrogen µg /l	72 – 161	25-132	23-121
Nitrate nitrogen µg/l	184 -376	115 - 376	117 -3765
Total phosphorus µg/l	146 – 286	145 -310	123-291
Ortho phosphorus µg /l	16 -28	9 -32	12-25

3.1 Rotifer Composition and Distribution
Thirty three taxa of Rotifera were recorded which belonged to 2 orders, *viz*., order Ploima and order Bdelloidea. 32 taxa representing 15 genera in 6 families belonged to order Ploima, while order Bdelloidea was represented by only one species. The largest rotifer family in the lake was Family Brachionidae, which was represented by 16 species. The others included Lecanidae (5 species), Lepadellidae (4 species), Notammatidae (3 species), Synchaetidae (2 species) and Trichocercidae (2 species) (Table 2).

Table 2: List of rotifer species recorded from Manasbal Lake during December 2011– November 2013.

Phylum	**Rotifera**						**Bdelloidea**
Class	**Monogonanta**						
Order 1	**Ploima**						
Order 2							
Family	Brachionidae	Lepadellidae	Synchaetidae	Trichocercidae	Notommatidae	Lecanidae	Bdelloidea
Genus	*Brachionus*	*Lepadella*	*Synchaeta*	*Trichocerca*	*Cephalodella*	*Lecane*	*Philodinidae*
	Brachionus angularis (Gosse)	*Lepadella ovalis* (Muller)	*Polyarthra vulgaris* (Carlin)	*Trichocerca longiceta* (Shrank)	*Cephalodella auriculata* (Ehrenberg)	*Monostyla bulla* (Gosse)	*Philodina roseola* (Ehrenberg)
	B. bidentata (Anderson)	*L. patella* (Muller)	*P. dolicohoptera* (Idelson)	*T. porcellus* (Gosse)	*C. exigua* (Gosse)	*M. closterocerca* (Schmards)	
	B calyciflorus (Pallas)	*Colurella obtusa* (Ehrenberg)			*C. gibba* (Ehrenberg)	*M. lunaris* (Ehrenberg)	
	B. plicatilis (Muller)					*M. quadridentata* (Ehrenberg)	
	B. quadridentata (Hermann)					*Lecane luna* (Ehrenberg)	
	Keratella	*Squatinella*					
	Keratella cochlearis (Gossi)	*Squatinella mutica* (Ehrenberg)					
	K. quadrata (Muller)						
	K. valga (Ehrenberg)						
	Mytilina						
	Mytilina mucronata (Muller)						
	M. ventralis (Ehrn)						
	Platiyas						
	Platyias patulus (Muller)						
	P. quadricornis (Ehrenberg)						
	Trichotria						
	Trichotria tetractis (Ehrenberg)						
	Notholca						
	Notholca acuminata (Gosse)						
	Kellicotia						
	Kellicottia longispina (Kellicot)						
	Euchlanis						
	Euchlanis dilatata (Ehrnberg)						

Taking into account the spatial distribution of Rotifer assemblage, species dominance and species diversity index, 3 sites in Manasbal Lake were distinguished. Distribution of Rotifera was independent with the sites. There were significant differences in Rotifer population density regarding months as well as sampling sites. The number of taxa differed from site to site.

On comparing the number of taxa at different sites, highest species diversity was recorded at Brachionidae (14 taxa) contributing to 58% of total Rotifer population density followed by Lepadellidae (2taxa) contributing 14%, Lecanidae (2taxa) with 8%, Notommatidae and Trichocercidae (2taxa) with 4.2% each, Synchaetidae and Philodinidae (1taxa) contributed 3.2%, 2% respectively (Fig 2). Family Brachionidae was dominant both qualitatively and quantitatively. Overall contribution of rotifers at site M_1 was 71.42% with a population density of 4,44,500 indi/m^3. Among the family Brachionidae *Brachionus calyciflorus* was dominant one contributing 16.6% of total rotifer population, *Keratella cochlearis* 15.1%. From family Lepadellidae, *Lepadella ovalis* was dominant 57.1%, in Lecanidae. *Monostyla bulla* was dominant 67%, from family Notommatidae, *Cephalodella auriculata* and *Cephalodella gibba* contributing 47.3% each. Similarly *Trichocerca porcellus* among the family Trichocercidae was dominant taxa; among the family Trichocercidae contributing 84% of total rotifer population contributed 3.5%.

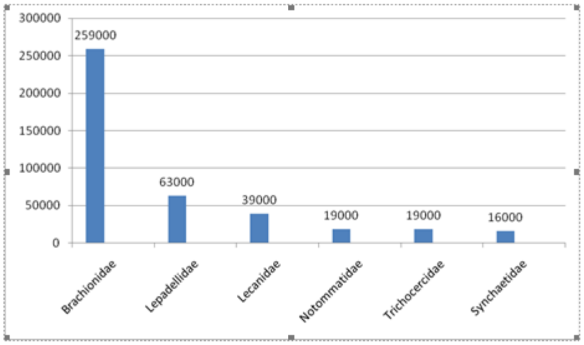

Fig 2: Population density (indi /m^3) of various families at site M_1 of Manasbal Lake

At site M_2 species diversity was (H = 2.626) with 17 taxa of Rotifera of which family Brachionidae was dominant group (7 taxa) contributing 45.2% of rotifer population density followed by family Lecanidae (3 taxa) contributing 19.6%, Lepadellidae (3 taxa) 16.2%, Synchaetidae (2 taxa) 8.8%, Notommatidae (1 taxa) 5.9%, Trichocercidae (1 taxa) 1.2% (Fig 3). Among family Brachionidae, *Brachionus calyciflorus* and *Keratella cochlearis* were dominant species contributing 32% and 9.8% respectively. Among the family Lepadellidae *Colurella obtusa* was dominant contributing 16%% of total rotifer population. *Monostyla bulla* was dominant taxa among the family Lecanidae contributing 9.85%. *Polyarthra vulgaris* contributed 8.1% of total rotifer population among the family Synchaetidae. Overall contribution of rotifers was 51.5% with a population density of 2, 34,000 indi/m^3 (Fig 4).

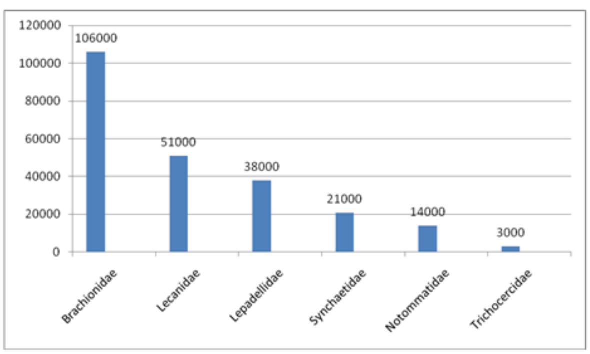

Fig 3: Population density (indi/m^3) of various families at site M_2 of Manasbal Lake

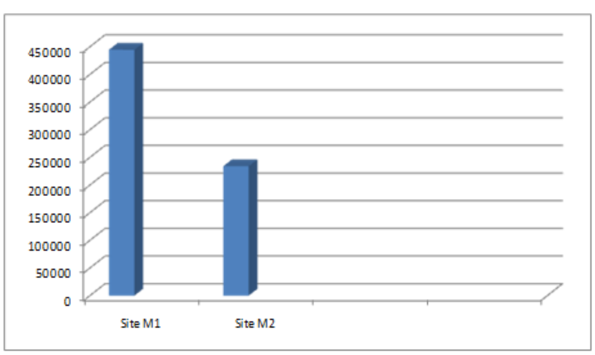

Fig 4. Population density of rotifer at Site M_1 and Site M_2

Limnetic zone of the lake is the best documented area. The site in the deepest section of the lake best represents average conditions of the lake. 26 taxa of rotifer were recorded from limnetic zone. Out of these 13 taxa were recorded from epilimnion surface water - 0.5 m depth (H= 2.409). At the surface water Brachionidae was dominant family (9 taxa) contributing 68.5%, Synchaetidae (2 taxa) contributing 18.8%, Lecanidae (1 taxa) contributing 7.2% and Lepadellidae (1taxa) contributing 5.5% of total rotifer population density (Fig 5a). Among the family Brachionidae contributing to total rotifer population were *Platiyas quadricornis* 22.9 %. *Polyarthra vulgaris* among Synchaetidae family was dominant contributing 11%. Lecanidae was represented by *Lecane luna* contributing 7% of total rotifer contribution. Similarly Lepadellidae was represented by *Squatinella mutica* as a dominant rotifer contributing 5.5%. In early periods of thermal stratification from March to May *Keratella cochlearis* made its appearance contributing 31.1% as summer progressed *Platiyas quadricornis* showed its dominance contributing 27.2%. In autumn (Sep – Nov) *Squatinella mutica* contributed 45.4% of total rotifer population.

At metalimnion from 3m depth to 6m depth (metalimnion) 19 taxa (H= 2.599) were recorded. At both the depths family Brachionidae (9 taxa) was dominant contributing 54%, Lecanidae (4 taxa) with 22.8%, Trichocercidae (1 taxa) contributing 11.3%, Synchaetidae (1 taxa) contributing 7.3%, Lepadellidae (3 taxa) 5.0% and Philodinidae (1 taxa) contributing 2.8% of total rotifer population (Fig 5b). Among the family Brachionidae *Keratella cochlearis* was dominant contributing 16.2% *Brachionus quadridentata* 9.6%. *Monostyla bulla* 10.1%, *Monostyla closterocerca* 4% among Lecanidae. *Lepadella ovalis* 3% among Lepadellidae were dominant. Among Trichocercidae *Trichocerca longiseta* was dominant contributing 6.5% of total rotifer population *Polyarthra vulgaris* among Synchaetidae was dominant contributing 2.5%, *Philodina roseola* contributed 3% among the family Philodinidae.

At hypolimnion 9 m depth 7 taxa (H=1.723) were recorded. Family Brachionidae (6 taxa) was dominant contributing 85% followed by Philodinidae (1 taxa) contributing 15% of total rotifer population (Fig 5c). *Brachionus angularis*, *Brachionus quadridentata* among Brachionidae were dominant contributing 35.4%, 25.8% of total rotifer population respectively.

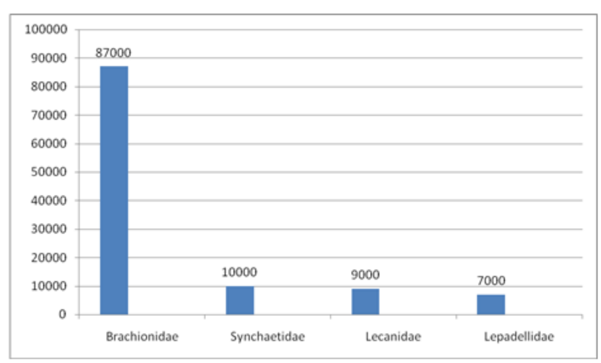

Fig 5a. Population density of various families of rotifer at surface water of site 0.5m depth of site M_3 (Epilimnion)

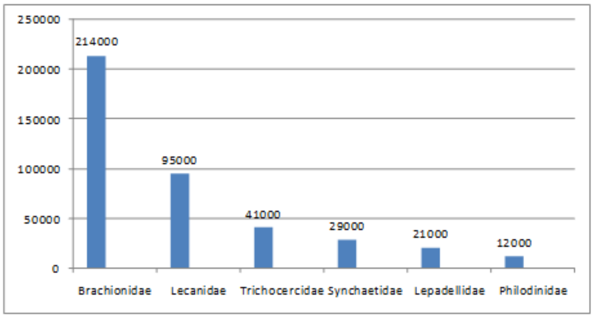

Fig 5b. Population density (indi/m^3) of various families of rotifers at 3m to 6m depth (metalimnion) of site M_3

Rotifera population contributed significantly to temporal variations and followed a cyclical pattern (Table 3) being lowest in winter and then rising through early part of the spring and it varied from site to site. At site M_1 population density fluctuated between 8000 indi/^{3} (January) to 72000 indi/m^3 (April), at site M_2 it fluctuated from 2000 indi/m^3 (January) to 44000 indi/m^3 (April). Similarly at limnetic site from surface water it varied from 1000 indi/m^3 (Oct – Nov) to 19000 indi/m^3 (July), at metalimnion from 3m to 6m depth it varied from 9000 indi/m^3 (November) to 91000 indi/m^3 (June), at 9m (hypolimnion) it fluctuated from 1000 indi/m^3 (November) to 8000 indi/m^3 in March. The seasonal fluctuations of the rotifer plankton in the lake exhibited bimodal pattern of fluctuations.

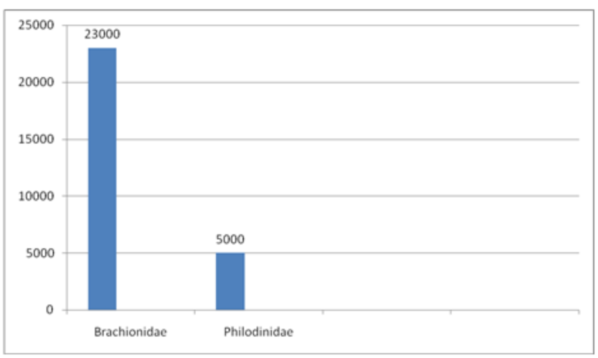

Fig 5c: Population density (indi/m^3) of various families of rotifers at 9m depth (hypolimnion) of site M_3

At littoral sites the rotifer population recorded its first peak in April (mid spring) with a population density of 72000 indi/m^3 and second peak in July (mid-summer) 62000 indi/m^3 From August it showed decreasing trend, at site M_2 first peak was recorded in April (mid spring) with a population density of 44000 indi/m^3 and second peak in July (mid-summer) with a population density of 38000 indi/m$^{3.}$. Overall population density of Rotifera at littoral sites varied from 18,000 indi/m^3 (Nov) to 103,000 indi/m^3 (April) during (Dec 2011 –Nov 2012) and 13,000 indi/m^3 (Jan) to 116500 indi/m^3 (May) during (Dec 2012 –Nov 2013) in Manasbal Lake. It revealed a cyclical pattern, being lowest in December (winter) with the appearance of *Brachionus quadridentata, Notholca acuminate, Platiyas quadricornis, Polyarthra vulgaris, Keratella cochlearis, Monostyla bulla* contributing a population density of 9000 indi/m^3 and then rising through winter and early spring attained first peak in April (mid spring) with the appearance of *Brachionus angularis, B. calyciflorus, B. quadridentata, Lepadella ovalis, Cephalodella auriculata, Cephalodella exigua, Euchlanis dilatata , Keratella cochlearis, K. quadrata, K. longispina, Monostyla bulla, M. quadridentata, M. lunaris, Lecane luna, Lepadella patella, Mytilina mucronata, Platiyas quadricornis, P. patulus, Trichocerca porcellus, Trichotria tetractis, Colurella obtuse*, with a population density of 126,000 indi/m^3. There after the population experienced a short decline in May which continued till June followed by another peak in July (mid-summer) with the appearance of certain species *Brachionus angularis, B. Bidentata; B. Calyciflorus; B. quadridentata, Cephalodella auriculata, C. gibba, Euchlanis dilatata, Lepadella ovalis, L. patella, Keratella quadrata, Platiyas quadricornis, Platiyas patulus, Polyarthra vulgaris, Trichocerca porcellus* attaining a population density of 100,000 indi/m$^{3.}$ From August it showed decreasing trend with the disappearance of some species. This makes it clear that the Rotifera exhibits a typical bimodal pattern in the lake with two distinct population peaks (Fig .6).

In limnetic site population density varied from 8000 indi/m^3 (January) to 110,000 indi/m^3 (June) during (Dec 2011–Nov 2013). It showed a cyclical pattern being lowest in December (winter) with the appearance of *Notholca acuminate, Polyarthra vulgaris* attaining a population density of 8000 indi/m^3 which increased in January showing first minor peak with a population density of 20, 000 indi/m^3. Thereafter the population experienced a short decline in February and then showing an increasing trend attaining a second major peak in June with the appearance of *Mytilina mucronata, M. ventralis, Platiyas quadridentata ,Platiyas patulus, Trichocerca longiseta , Keratella cochlearis, K. valga, K. quadrata, Lepadella patella, L. ovlis, Monostyla quadridentata, M. bulla, Brachionus calyciflorus, B. plicatalis, B. quadridentata, Euchlanis dilatata, Polyarthra vulgaris, Brachionus quadridentata, Philodina roseola*, with a population density of 11,000, indi/m^3. From August it showed a decreasing trend with the appearance and disappearance of certain species. A typical bimodal pattern in the lake at limnetic site with two distinct population peaks were recorded, one in (January) winter during the circulation period and another in June during the stagnation period (Fig 7).

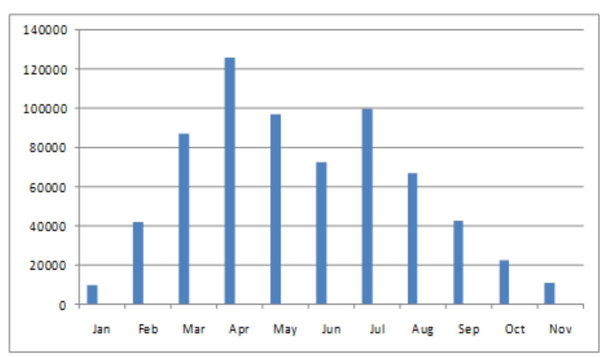

Fig 6: Monthly variations in population density of Rotifera (indi/m3) at littoral sites in Manasbal lake from (Dec. 2011-Nov. 2013)

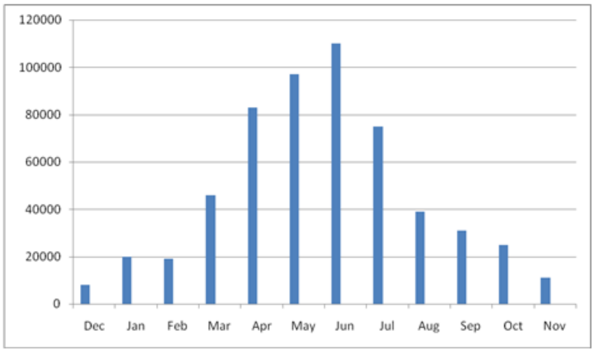

Fig 7: Monthly variations in population density of rotifer (indi/m^3) at limnetic site of Manasbal lake during (Dec 2011–Nov 2013)

Table 3: Correlation between various physico-chemical parameters with Rotifer density

Parameters	Rotifera
Water Temperature	0.094**
Depth	-0.379**
pH	0.115
CO_2	-0.026
Alkalinity	-0.032
Hardness	-0.034
Chloride	-0.153
Conductivity	0.043
Total Phosphorus	-0.332**
Nitrate nitrogen	-0.082
Oxygen	0.392

** Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

4. Discussion

While comparing the different data of different periods the Yale North India expedition, eight species of rotifer from Lake Manasbal reported [13], Akhter S [14] reported ten species however she could not find *Actinurus neptunis* and *Mytilina mucronata*. Yousuf AR [15] recorded 30 species from the same Lake, but *Polyarthra trigla*, *Keratella quadrata*, *K. valga*, *Brachionus angularis* were not found in his study which were reported by Akhter S [14]. Yousuf AR [3] recorded thirty eight species *Keratella quadrata* was reported by the same authors which was not recorded by Yousuf AR [15]. Siraj S [16] reported 28 taxa of rotifers. The author recorded *Synchaeta oblongata*, *S. pectinata*, *Hexarthra*, *Gastropus*, *Asplanchna priodonta*, *Notommata* which were not found in present study. However certain taxa which were recorded in present study *viz*; *Kellicotia longispina*, *Keratella valga*, *Polyarthra dolicohoptera*, *Cephalodella auriculata*, *C. exigua*, *C. gibba*, *Monostyla bulla*, *M. closterocerca*, *M. lunaris* and *M. quadridentata* were not recorded by her. Pandit AK *et al*. [7] reported *Keratella valga*, *Polyarthra dolicohoptera*, *Cephalodella exigua*, *C. gibba*, *Monostyla bulla*, *M. Closterocerca*, *M. lunaris*, and *M. quadridentata* however *Colurella auriculata*, *Kellicotia longispina* were not recorded by them. During the present study a total of 33 different rotifer taxa belonging to seven families were recorded from the lake in the dominance order of Brachionidae> Lecanidae > Lepadellidae > Notommatidae> Synchaetidae > Trichocercidae. Yousuf AR [3] reported 38 taxa belonging to 11 families of rotifera of which family Brachionidae was dominant followed by Lecanidae> Synchaetidae> Trichocercidae. The relative importance of these families broadly corresponds with the results in flood plain lakes of South America [17]. It is evident that some of the species have been disappeared and some have been replaced by other allied ones. This has been confirmed by comparing the data. According to [3] change in the species composition of rotifer in the lake may be attributed to change in physico-chemical characteristics of the lake. The study showed high richness of Family Brachionidae which was contributed by 16 taxa under 8 genus. Genus *Brachionus* was dominant qualitatively being represented at by 5 species namely *Brachionus angularis*, *B. bidentata, B. calyciflorus*, *B. plicatalis* and *B. Quadridentata* [7] reported *Brachionus calyciflorus*, *B. plicatalis* and *B. quadridentata* in both mesotrophic (Manasbal lake) and hyper eutropic lakes (Khushal sar). Presence of these species in present lake reveals that lake is tending towards eutrophication. Various species of this genus are alkaline, cosmopolitan and show a wide variation [18-20] which is in line with the findings of present investigation as Manasbal Lake is alkaline which ranges from 90-224mg/l.

Diversity of Rotifera is often high in the vegetative habitats than (limnetic zone) [21, 22]. Site M_1 is the littoral macrophyte infested. According to [4] littoral macrophyte infested area provide favourable life conditions for rotifers resulting in year round higher diversity of organisms in this region. It is the most diverse part of the zone which has more biodiversity. [4, 6] also reported high number of zooplankton in macrophyte infested area than in waters without vegetation. According to [23] large macrophyte covered areas support a variety of littoral associated species and also provides other zooplanketers with a spatial refuge, enabling pelagic species to gather in this zone. *Brachionus calyciflorus* and *Keratella quadrata* were dominant in this zone among the family Brachionidae and their presence are seems as indicators of eutrophication as this zone is rich in organic matter. According to [24] the species belonging to family Lecanidae mainly remain in the littoral environment although some can frequently be found in the open water zone of the lake. In the present study *Monostyla bulla* of family Lecanidae was found both in littoral and limnetic zone which is in line with present findings. Genus Cephalodella belonging to family Notommatidae consisting of *Cephalodella auriculata*, and *C. gibba* were most often occurring in littoral environment. Genus *Trichocerca* was represented by *Trichocerca porcellus* as dominant in littoral macrophyte infested site. According to [25, 3] the most important factor in the seasonal abundance and vertical distribution of rotifers in the Manasbal lake is thermal stratification. The authors opined that the thermal stratification governs the physico–chemical factors as well as their influence on the abundance of rotifers. Since Manasbal lake remains completely stratified into three layers, epilimnion, metalimnion and hypolimnion for 9 months from March / April to November, the distribution of Rotifers in the limnetic zone of Manasbal lake varies in close association with thermal stratification. During the present study twenty six taxa of rotifers were recorded from the same site. Yousuf AR [6] while studying the vertical distribution of Rotifers in a warm monomictic lake, Manasbal of Kashmir, reported 23 species of Rotifers from the limnetic zone of the lake. With the progression of thermal stratification distribution of rotifers varied from surface to bottom. At the surface water (epilimnion) *Platiyas quadricornis*, *Keratella cochlearis*, *Mytilina ventralis*, *Polyarthra vulgaris*, *Lecane luna*, *Squatinella mutica* were dominant taxa contributing most of rotifer population. Population of rotifers decreased at the surface and abrupt increase was noticed in the metalimnion. *Polyarthra vulgaris* was most dominant in metalimnetic zone. Since *Polyarthra vulgaris* was a perennial rotifer in lake, it disappeared in summer (June–July) when *Brachionus quadridentata* made its appearance in abundance. Yousuf AR [5] reported that abundance of *Polyathra vulgaris* is influenced by certain opportunistic forms like *Anuraeopsis fissa* and *Brachionus quadridentata* and relate such behaviour with competing for the same food. Yousuf AR *et al*. [3-6] also reported dominance of *Polyarthra vulgaris* in metalimnion of the same lake. However the species was recorded at all sites. *Trichocerca longiceta* was recorded as dominant taxa. According to [26] *Trichocerca longiceta* is a typical pelagic form. *Keratella cochlearis* was one of the most dominant rotifer in the metalimnion [6] reported *Keratella cochlearis* as a dominant rotifer. *Brachionus quadridentata*, *Monostyla bulla*, *M. closterocerca*, *Lepadella ovalis, Mytilina ventralis* were also dominant taxa in metalimnion site. *Brachionus angularis* was most dominant at hypolimnion which is rich in organic matter. Pandit AK [27] reported *Brachionus angularis* in Brarinumbal basin which is rich in organic matter. Other species which were present in hypolimnion were *Brachionus quadridentata*, *Keratella cochlearis, Philodina roseola, Euchlanis dilatata, Notholca acuminate*. *Keratella cochlearis* was also reported by Yousuf AR [6] in hypolimnion. Presence of *Notholca acuminate* at hypolimnion seems it prefers cold water. It seems that in the early summer epilimnion is full of life. Phytoplankton can grow quickly because they have plenty of light, nutrients and water temperature is warm. In turn rotifers are also more and feed on phytoplankton. The peak population remained till early summer in the epilimnion. As summer progresses the phytoplankton use up the nutrients in the epilimnion. They begin to die and sink to the bottom of the lake. They are decomposed and converted into nutrients that phytoplankton need to grow. But the thermo cline acts as a barrier between the epilimnion and hypolimnion, these nutrients are unavailable to the phytoplankton in the epilimnion. Phytoplankton cannot grow in the hypolimnion, where there are nutrients but there is no light. All through the period of stratification the Rotifers remained mainly concentrated in the metalimnion due to availability of high temperature and higher quantities of food (detritus). The highest density of the group was present in metalimnion. *Keratella cochlearis* was the dominant rotifer from surface to bottom but its population was highest 64000 indi/l^3 in the metalimnion and it was found throughout the year.

Water arriving in the outlet drives a great quantity of organic and inorganic matters [28], dissolved or in suspension which brings about an expansion of phytoplankton and bacteria. Rotifers feed upon phytoplankton, bacteria and are good competitors of survival. But the present study showed decline in diversity of Rotifers in outlet zone which may be due to shorter residence time of water which do not allow establishment of plankton populations and they get dispersed along with flushing of water. Certain pollution indicators *Brachionus calyciflorus Keratella quadrata* were dominant species at this site. Genus *Keretella* are considered to be generalist rotifers feeding on bacteria and detritus [29]. It is one of the dominant Rotifer at outlet which may also be related to availability of food.

As for as seasonal abundance was concerned, rotifer population showed bimodal pattern with two peaks. In Kashmir lakes bimodal pattern was recorded by Yousuf AR [3, 5, 3, 31]. Different taxa recorded their peak populations at different times of the year. Our data reveal least population density during winter months when rotifers are known to undergo diapauses [32]. Our data showed *Keratella cochlearis*, *K. quadrata, Lepadella patella, Platiyas quadricornis, Polyarthra vulgaris* as perennial, while as *Kellicotia longispina*, *Notholca acuminate* were recorded in winter and are cold stenothermal species. *Notholca acuminate* was recorded as a cold stenothermal species by Sampath [20] .Winter peak(January) in limnetic site correspond with the findings of Yousuf AR [3] who recorded first minor peak in winter (February) *Brachionus bidentata*, *B. calyciflorus*, *B. quadridentata*, *B. plicatals*, *Euchlanis dilatata*, *Keratella valga*, *Monostyla closterocerca, Mytilina mucronata, Mytilina ventralis* were warm stenothermal species.

Yousuf AR, Wolfin BWC [33, 34] pointed out that ecological factors have a prominent role in determining the abundance and seasonal succession of zooplankton. Temperature has been considered as one of the factor to cause the abundance of rotifers in fresh water [35]. When correlation was estimated it showed a significant positive correlation relationship between water temperature and rotifer abundance (r = 0.094). According to [36] most rotifers commonly exhibit maximum densities in early summer in temperate lakes and show wide range of temperature tolerance. The maximum numbers of rotifer population seen during summer indicates the influence of temperature supported by positive correlation between temperature and rotifer density. Dissolved oxygen is the main factor which influences the occurrence and abundance of rotifers [37]. A positive relationship between oxygen and rotifer density (r= 0. 171) reveals that dissolved oxygen favours the abundance of rotifers. Sharma BK [38] reported positive correlation with dissolved oxygen According to [39] water chemistry and hydrology are the major physical factors responsible for the formation of various ecological communities. Pennak RW [40] claims plankton is abundant when water level is low while rise in water brings about a sharp decline in their density. In present study low water level during summer seems to play an important role in concentrating rotifer density as it showed significant relation with rotifer density (r = -0.379). Total phosphorus also seemed to be an important role in regulating the density of rotifers. Esler JJ [41] claims that when phosphorus decreases due to consumption by primary producers namely phytoplankton, the latter triggers an increase in zooplankton especially rotifers. This rise in phytoplankton will eventually lead to increase in rotifers. Total phosphorus showed an inverse relationship with rotifer density (r= -0.322). During the present study total phosphorus concentration was low in summer when compared. During present study significant negative relationship was recorded (r= -0.082) between nitrate nitrogen and rotifer abundance. During the peak population density, concentration of nitrate nitrogen was low (warmer months) which seems low nitrate nitrogen favours the abundance of rotifers. According to [42] when phosphorus and nitrate decreases due to consumption by primary producers, the latter triggers an increase in zooplankton, thus any decline in phytoplankton will naturally lead to a decrease in zooplankton mean while causing an increase in unused inorganic substances. It reveals abundance of rotifers is dependent upon phytoplankton which consumes total phosphorus and nitrogen. Berzins B [43] reported inverse relationship between high pH and rotifer density. [44] claimed certain deaths occur due to stress by high pH which increases with high temperature resulting in synergetic action upon rotifers. However in present study it showed positive relationship with pH (r = 0.115) which seems rotifers tolerate a wide range of pH. High concentration of alkalinity was recorded in winter and autumn where as low in spring and summer. Total alkalinity showed inverse relationship with rotifer density (r=-0 .032). Yousuf AR [3] reported decrease in alkalinity in summer increases the population. This suggested low alkalinity is not related with high yield of rotifers. Low conductivity recorded in summer seems to be good indicator of water quality [45]. Conductivity and rotifer density showed significant correlation (r =0.043). Wanganeo A [46] reported significant positive correlation with chloride and rotifer density in Wular Lake. In Manasbal lake it showed an inverse relationship with chloride (r=-0.153) which seems rotifers avoid sewage ladden water which are rich in salts. Meshram, CB [47] reported that hardness is essential for normal growth and development of aquatic animals. Carbon dioxide and rotifer density showed negative correlation (r =-0.029) .Carbon dioxide was absent in spring and summer when rotifer population was high and it reveals it avoids to survive in the environment of carbon dioxide. Wanganeo A [3] also reported large quantities of carbon dioxide harbours very small population. The present study showed inverse relationship with hardness and rotifer density (r = -0.032) which reveals hardness has no effect on abundance of rotifer density.

5. Conclusion

It may be concluded from the results that diversity of Rotifers is related with suitable habitat, availability of food for their survival. Presence of certain species of *Brachionus* indicates that the lake is tending fast towards eutrophication. The dominance of *Brachionus calyciflorus* at littoral zone indicates eutrophication, as this site is used for many activities like washing, bathing; effluents of organic wastes are discharged into the lake. Occurrence and abundance of the vertical distribution are the thermal stratification which influences not only physical and chemical factors of the water but also availability of food. Individual abiotic factors have a limited influence on rotifer abundance. Some parameters were favourable for rotifer populations, but others showed negative impacts. So the distribution of rotifers may be governed by the combination of these positive and negative aspects.

6. References

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