Checklist of Rotifer Community from Wular lake of Kashmir Himalaya

Javaid Ahmad Shah*[1], Ashok K. Pandit and G. Mustafa Shah[2]

[1]Centre of Research for Development (CORD), University of Kashmir, Srinagar-190006, J & K, India.
[2]Department of Zoology, University of Kashmir, Srinagar 190006, J&K, India
Corresponding author: *javaidshah31@gmail.com

Abstract: The present study scrutinizes the wheel animalcule community of the Wular lake in Kashmir Himalaya. Till date no published literature is available on the rotifer community of the largest freshwater lake of Indian subcontinent. Sampling was carried out during two years of study (Sep.2012- Aug.2014). Twenty six taxa of rotifers were recorded from the nine study sites belonging to by eleven families. Among the recorded families, Brachionidae was the dominant, followed by Lecanidae and Lepadellidae. Among the family Lecanidae majority of the species co- exists with each other suggesting that these species share same niche levels in a given ecosystem. Wheel animalcules had peak abundance in summer when there was high temperature and abundant growth of macrophytes. Bray- Curtis dendrogram showed close resemblance between sites I, II and VI. However, the site III, V and IX showed dissimilar nature as far as distribution of the species is concerned. *Brachionus: Trichocerca* ratio reflects that waterbody under investigation is racing towards eutrophication.
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1. Introduction

Rotifera are pseudocoelomatic soft-bodied animals and are believed to be the oldest groups of invertebrates in nature (Sladecek, 1983; Shah *et al*., 2015). Wheel animalcules are very much important organisms in the aquatic ecosystems due to their short life cycle (Esteves, 1998), their intermediate trophic position (Pandit, 1980; Sanders and Wicham, 1993) and their dominance position in the zooplankton community (Shah *et al.,* 2015). Most of the species are cosmopolitan in nature (Hyman, 1951; Ricci and Melone, 2000). Monogononta, Bdelloidea and Seisonidea are the three major classes of rotifers, former two being entirely fresh watered and the latter as the only marine. They act as connecting link between primary producers and consumers in aquatic ecosystems (Sitre, 2012). They play an important role in energy transfer and recycling (Makarewicz Likens, 1979) and are used as bioindicators of water quality (Sladecek, 1983, Radwan *et al*., 1988; Nogrady *et al*., 1993).

2. Study Area

Valley of Kashmir is positioned in the midst of the Himalayan mountains, experiencing a temperate-cum-Mediterranean climate with four distinct seasons (Kaul *et al*., 1978). The high altitude valley abounds in a vast array of freshwater bodies and amongst these the lakes, ponds and wetlands are of special ecological importance, as they provide food, fodder, aquatic game and tourist recreation, besides being a great repository of flora and fauna. Among the lakes, Wular Lake, the largest freshwater lake in the Indian subcontinent, located 34 km northwest of the city of Srinagar Kashmir, lying between the geographical coordinates 340 16' -340 20' N latitude and 740 33' – 740 44' E longitude. The lake is mono-basined, elliptica l in shape and is of fluviatile origin, formed by the meandering of River Jhelum. It is of shallow nature having well developed macrophytes and lies at an altitude of 1580 m (a.m.s.l.) and its depth is on average 3.6 m, though it reaches 5.8 m at its deepest point (Shah and Pandit, 2012a, 13a, 13b). The lake plays a significant role in the hydrographic system of the Kashmir valley by acting as a huge reservoir, absorbing the high annual flood of River Jhelum (Shah and Pandit, 2012; Shah *et al*., 2014). The largest freshwater shallow lake in 1990 has assumed the status of a Ramsar Site, a Wetland of International Importance. Nine sites differing in various characteristics like water depth, vegetation and other biotic factors were chosen for the present study (Fig.1). Sites I and II were chosen near villages Vantage and Laharwalpora respectively, having high anthropogenic pressures from the catchment. Sites III (near Ashtung), IV and V(near Watlab) have well developed macrophytic vegetation with less human interference, while sites VI and VII were located near the outlet of the lake (near Ningli) and the remaining two sites (VIII and IX) were situated near the inlet i.e., River Jhelum (near Makhdoomyari) of Wular lake.

3. Material and Methods

Plankton samples were collected between Sep.2012 to Aug.2014 from the nine study sites by filtering 100 liters of water through a net from the littoral as well as the limnetic zones of the lake in every month. The samples were collected in clear polyvinyl bottles and preserved in 5% formalin. Identification of the taxa were made by using different keys (Koste, 1978; Edmondson; 1992; Segers, 1995; Sharma and Sharma, 2008). Bray-Curtis analysis was performed by the software Biodiversity Pro to predict the similarity between the sites.

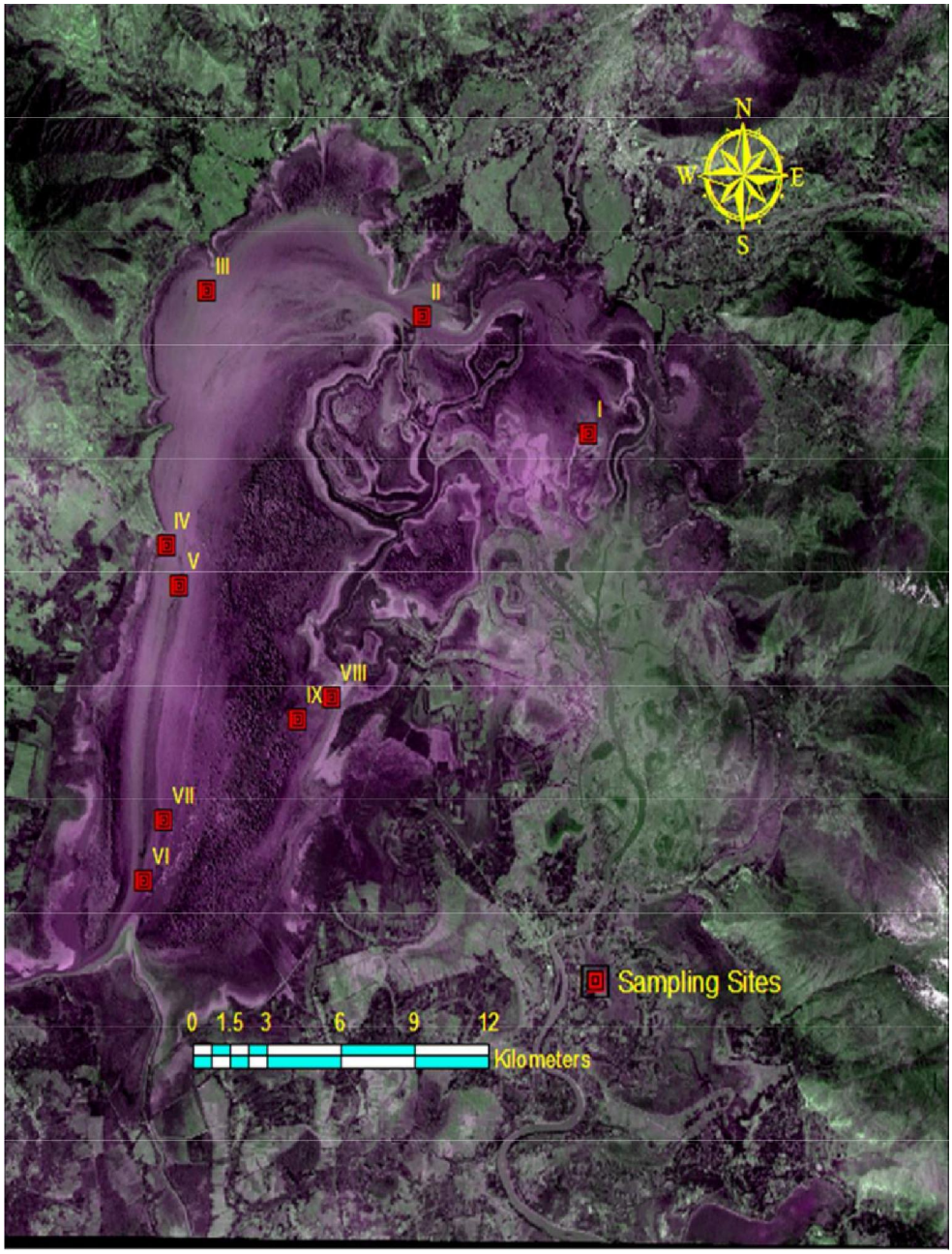

Figure 1. Map of Wular lake with nine sampling sites

4. Results

During the entire study period, 26 rotifers represented by eleven families were recorded (Brachionidae 09, Lecanidae and Lepadellidae with 04 species each, Filiniidae with 02 species, Mytilinidae, Synchaetidae, Asplanchnidae, Notommatidae, Hexarthridae, Scaridiidae and Trichocercidae with 01 species each). Highest number (23) of species were recorded at site II, followed by (18) at site VII, (17) at site VI, (15) at sites IV and VIII, (14) sites V and VIII

and decreasing to lowest (13) at site III (Table 1). Among the recorded species which were absent in winter were: *Anuraeopsis* sp., *B. calyciflorus, B. quadridentata*, *Keratella hiemalis*, *Platyias quadricornis, Platyias patulus*, *Lecene* sp., *Monostyla bulla*, *Monostyla* sp., *Lepadella patella*, *Squatinella* sp., *Colurella obtusa*, *Paracolurella, Polyarthra vulgaris, Cephalodella* sp., *Hexarthra mira, Scardium longicaudum* and *Trichocerca* sp. The species which were abundant in autumn were *B. quadridentata*, *Lepadella patella* and *Squatinella* sp. The species which preferred moderate temperatures of spring were *Keratella hiemalis, Platyias quadricornis*, *Filinia* sp. and *Polyarthra vulgaris* (Table 2). Further, among the family Lecanidae majority of the species co- exists with each other suggesting that these species share same niche levels. Bray- Curtis dendrogram showed close resemblance between sites I, II and VI (95-97%). However, the sites III, V and IX showed dissimilar nature as far as distribution of the species is concerned (Fig.2).

Table 1. Distribution pattern of rotifers at nine study sites of Wular lake

S. No	Rotifera	I	II	III	IV	V	VI	VII	VIII	IX
	Family Brachionidae									
1	*Anuraeopsis* sp.	P	P	A	P	A	P	P	A	P
2	*Brachionus bidentata* (Anderson, 1889)	A	P	P	P	P	P	P	P	P
3	*B. calyciflorus* (Ehrenberg, 1838)	P	P	P	P	P	P	P	P	A
4	*B. quadridentata* (Hermann, 1783)	P	P	A	P	A	A	P	A	A
5	*Brachionus* sp.	P	P	P	P	P	P	P	P	P
6	*Keratella cochlearis* (Gosse, 1851)	P	P	A	A	P	P	P	A	P
7	*Keratella hiemalis* (Carlin, 1943)	P	P	A	A	A	P	P	P	A
8	*Platyias quadricornis* (Ehrenberg, 1834)	P	P	P	A	A	A	A	P	A
9	*Platyias patulus* (O. F. Muller, 1786)	P	P	P	P	P	P	P	P	P
	Family Lecanidae									
10	*Lecene* sp.	P	P	P	P	P	P	P	P	P
11	*Monostyla bulla* (Gosse, 1867)	P	A	A	P	A	A	A	A	P
12	*Monostyla depressa* (Bryce,1891)	P	P	P	P	A	A	A	A	P
13	*Monostyla* sp.	P	P	P	P	P	P	P	P	P
	Family Lepadellidae									
14	*Lepadella patella* (O. F. Muller, 1786)	P	P	A	A	A	A	P	A	A
15	*Squatinella* sp.	A	A	P	A	P	A	A	A	P
16	*Colurella obtusa* (Gosse, 1886)	P	P	P	P	P	P	P	P	P
17	*Paracolurella* (Myers, 1936)	A	P	A	A	A	A	P	P	A
	Family Filiniidae									
18	*Filinia terminalis* (Plate, 1886)	P	P	A	P	P	P	P	P	P
19	*Filinia* sp.	P	P	A	A	A	P	P	P	P
	Family Mytilinidae									
20	*Mytilina* sp.	A	P	P	A	P	P	P	P	A
	Family Synchaetidae									
21	*Polyarthra vulgaris (Carlin, 1943)*	P	P	A	A	P	P	A	A	A
	Family Asplanchnidae									
22	*Asplanchna priodonta (Gosse, 1850)*	P	P	P	P	P	P	P	P	A
	Family Notommatidae									
23	*Cephalodella sp.*	A	P	A	A	P	P	A	A	A
	Family Hexarthridae									
24	*Hexarthra mira (Hudson, 1871)*	A	P	P	A	A	P	P	P	P
	Family Scaridiidae									
25	*Scardium longicaudum (O. F.Muller, 1786)*	P	A	A	P	A	A	A	A	A
	Family Trichocercidae									
26	*Trichocerca sp.*	A	P	A	P	A	A	A	A	A
	Grand Total	**19**	**23**	**13**	**15**	**14**	**17**	**18**	**15**	**14**

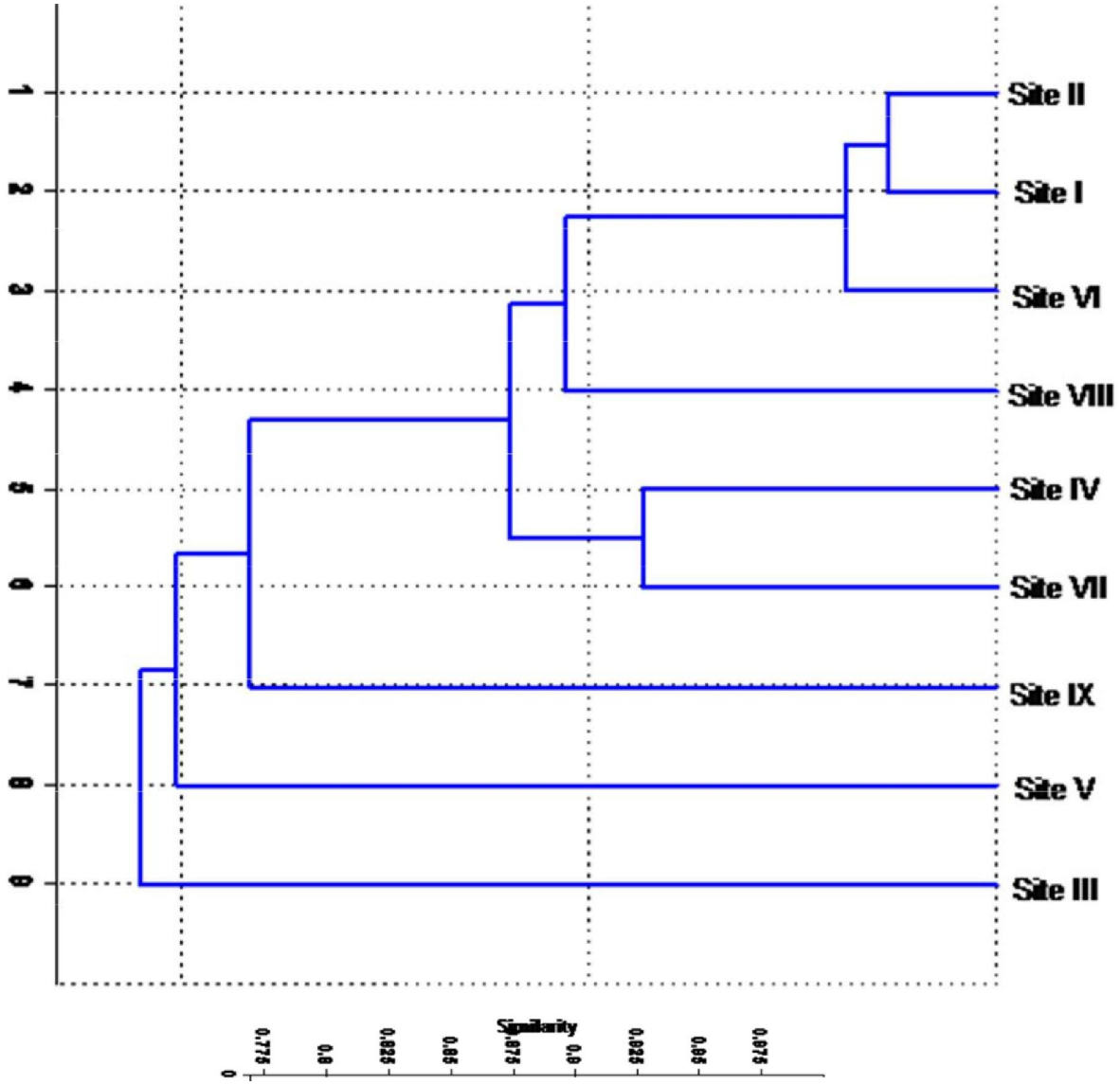

Figure 2. Bray- Curtis cluster analyses of nine study sites of Wular lake

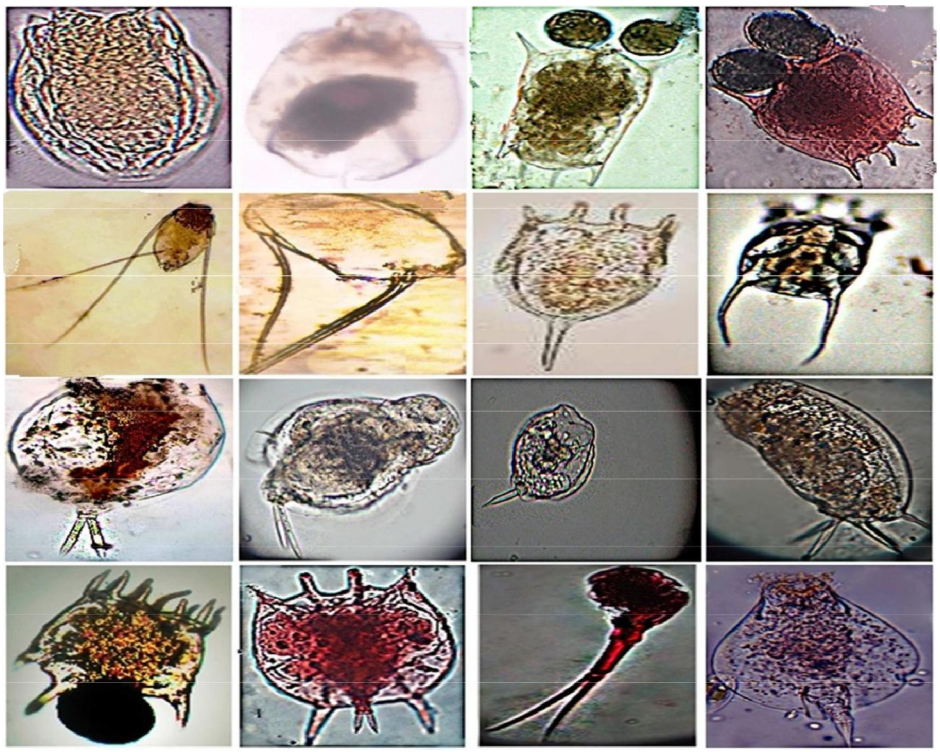

Figure 3. Some rotifers of Wular lake1: *Anuraeopsis* sp.; 2: *Asplanchna priodonta*; 3: B. *calyciflorus*; 4: *B. quadridentata;5: F. terminalis; 6: Filinia sp.;7 : K. cochlearis; 8: Keratella hiemalis; 9: Lecene* sp.*;* 10*: Lepadella patella*; 12*: Mytilina* sp.,13: *P. patulus*; 14: *P. quadricornis;* 15*: Paracolurella* and 16*: Trichocerca* sp

Table 2. Distribution of Rotifera species in different seasons in Wular lake

Rotifera	Autumn	Winter	Spring	Summer
Family Brachionidae				
Anuraeopsis sp.	+	X	++	++++
Brachionus bidentata (Anderson, 1889)	+++	++++	+	++
B. calyciflorus (Ehrenberg, 1838)	++	X	+++	++++
B. quadridentata (Hermann, 1783)	++++	X	++++	++
Brachionus sp.	++	+	++	++++
Keratella cochlearis (Gosse, 1851)	+	+	+	++++
Keratella hiemalis (Carlin, 1943)	+	X	++++	++
Platyias quadricornis (Ehrenberg, 1834)	++	X	++++	++
Platyias patulus (O. F. Muller, 1786)	+	X	++	++++
Family Lecanidae				
Lecene sp.	++++	X	++	++++
Monostyla bulla (Gosse, 1867)	++	X	++	++++
Monostyla depressa (Bryce,1891)	++	X	++	++++
Monostyla sp.	+	X	+	++++
Family Lepadellidae				
Lepadella patella (O. F. Muller, 1786)	++++	X	++	++++
Squatinella sp.	++++	X	++++	++
Colurella obtusa (Gosse, 1886)	+	X	++	++++
Paracolurella (Myers, 1936)	++	X	+++	++++
Family Filiniidae				
Filinia terminalis (Plate, 1886)	++++	+	++++	++
Filinia sp.	+	++	++++	++++
Family Mytilinidae				

Mytilina sp.	+	+	++	++++
Family Synchaetidae				
Polyarthra vulgaris (Carlin, 1943)	+	**X**	++++	++
Family Asplanchnidae				
Asplanchna priodonta (Gosse, 1850)	+	++++	+	++
Family Notommatidae				
Cephalodella sp.	++++	**X**	++	++++
Family Hexarthridae				
Hexarthra mira (Hudson, 1871)	+	**X**	++++	+++
Family Scaridiidae				
Scardium longicaudum (O. F.Muller, 1786)	+	**X**	+	+
Family Trichocercidae				
Trichocerca sp.	+++	**X**	+	++++

X= absent; + =less than 50ind/l; ++= more than 50 ind/l; +++= more than =150ind/l; ++++ above 200ind/l

5. Discussion

During the present study, Brachionidae was the most dominant family followed by Lecanidae because of their adaptability to the diverse and harsh environmental conditions (Pejler 1977; Shiel *et al.* 1998; Nandini *et al.* 2007; George *et al.* 2011). Segers, (1995) opined that Lecanidae is the second largest family among rotifers with about 160 valid species.

Among the recorded species of rotifers there seems to be distinct rotifer communities in different seasons of the year (Sanoamuang, 1992; Duggan *et al*., 1998). Among the Brachionidae *Anuraeopsis* sp. was abundant in summer and absent in winter. Koste (1978) and Sharma (2000) reported it as warm stenothermal species. However, Yousuf and Qadri (1981) reported it a cold stenothermal species. *Brachionus bidentata* was found to be more in winter and autumn at majority of sites.

Lougheed and Fraser (1998) reported its abundance in autumn and summer. However, Erdogan and Guhar (2005) observed its peak populations in summer and winter. Sharma (2005) reported its abundance in flood plain lakes of India. *Brachionus quadridentata* was more in density in summer and less in winter reflecting its thermophilic nature. Our results are broad agreement with the findings of (Balkhi, 1989; Wolska and Piasecki, 2007; Bozkurt and Guven, 2009).

Brachionus calyciflorus was absent in winter and abundant on those sites which were (i) more polluted (ii) shallow nature and (iii) have abundance of macrophytes. Our results are in consonance with the findings of Shiel *et al.,* (1982) they opined that *Brachionus calyciflorus* showed cosmopolitan behavior, eurythermal, alkaline and prefers shallow habitats. Further, Sladecek (1983) and Bohrer (1995) reported that it tolerates high levels of organic pollution, feeds mainly on cyanophyceae blooms (Fulton and Paerl, 1987). Berzins and Pejler (1989) are of the opinion that this species prefers temperature above 20° C and remain associated with macrophytes (Garcia *et al.,*2007).

Keratella cochlearis showed highest population in summer and was present sporadically throughout year. Hutchinson (1967) and Koste (1978) reported its cosmopolitan nature, Balkhi (1987) found it in large numbers in summer and winter, Berzins and Pejler (1989) classified it as warm stenothermal species. Nogueira (2001) and Sampaio *et al.* (2002) reported its presence in oligotrophic systems. Wanganeo and Wanganeo (2006) found its maximum density in summer, Wolkska and Piasecki (2007) reported its abundance in autumn, Spoljar *et al.* (2011) are of the view that the species is trophic indicator being abundent in summer. *Platyias quadricornis* and *P. patulus* were completely absent in winter and showed abundance in summer in vegetated areas. Same was reported by following workers (Jyoti and Sehgal, 1979; Sladecek, 1983; and Pandit, 1998). Further, Sladecek (1983) categorized *Platyias quadricornis* as beta- mesosaprobic rotifer that represents moderate pollution of the water body.

Lecene flexilis was absent in winter and showed pronounced growth in autumn and summer when there is luxuriant growth of macrophytes. Hann (1995) and Green (2003) reported that this species prefers macrophytes to avoid predation. Sakuma *et al.* (2002) opined that this species remained firmly attached to macrophytes even after shaking 50 times. *Lecene* sp. was absent in winter being dominant in autumn and summer. Our observations are in line with Balkhi *et al.* (1984) categorized it as warm stenothermal, Sharma *et al.* (2013) reported it as summer species, Yağcı-(2014) reported its predominance in summer and autumn. *Monostyla bulla* and *M. depressa* was present in abundance in summer and remained absent in winter. Barrabin (2000) reported *Monostyla bulla* as cosmopolitan in nature and inhabits vegetation with pH range of 6.2-8.2. *Monostyla* sp. showed thermophyllic nature, remained absent in winter showed summer population peak. Yousuf *et al.* (1981) reported its perennial nature, Balkhi *et al.* (1984) and Sharma *et al.* (2013) categorized it as warm stenothermal. Further, among the family Lecanidae majority of the species co- exists with each other suggesting that these species share same niche levels. A number of field observations support our observation that many species of Lecane can coexist in a given water body (Ejsmont-Karabin and Kuczynska-Kippen, 2001; Nandini *et al.,* 2005, Soto *et al*., 2011).

Lepadella patella was abundant in autumn and summer at those sites which showed polluted waters. Sladecek (1980) reported its cosmopolitan nature, Balkhi *et al.* (1987) found it in autumn, Balkhi (1987) represented it as eurythermal species and prefers eutrophic waters. *Squatinella* sp. preferred macrophytic zones during present study and was absent in winter. Balkhi (1987) is of the view that this species is poorly represented in valley lakes and constitute an autumnal form. Bruno *et al.* (2005) categorized it as littoral species being associated with macrophytes. *Colurella obtusa* and *Paracolurella* were also absent in winter, being abundant during autumn and summer throughout the study. Balkhi (1983, 1989) and Yousuf *et al.* (1984) categorized it as a summer form in Kashmir lakes. Sladecek (1983) reported abundance of the species among macrophytes and occupies littoral zones of the lake. *Cephalodella* sp. registered its peak population in autumn and summer when there was luxuriant growth of macrophytes. Sarma and Manuel (1998), Kaya and Altındağ (2009) supports our observations that the species remain associated with macrophytes and prefer wider range of environmental conditions. Pandit (1998) also found it abundant in summer and categorized it as warm stenothermal. *Scardium longicaudum* was present in low abundance and showed perennial behavior in the present study. Sladecek (1983) categorized it as oligotrophic; Balkhi (1987) opined that this species prefers stagnant and warm waters. *Filinia terminalis* was present throughout year, prefers moderate temperature, showed peak population in autumn and early spring, poorly represented in summer registering its presence on those sites which have little anthropogenic pressures. Regarding the distribution pattern of this species is concerned; there is difference of opinion regarding its behavior. Some workers observed its peak population in warmer months (Bruno *et al.,* 2005). Our observation is in line with the Pejler (1961) who opined that this species prefers temperature range of 19° C in shallow unstratified lakes. Balkhi (1987) reported its presence in autumn, Wolkska and Piasecki (2007) categorized it as oligothermal species. Our results contradicts with the recent observations of Yagci (2013) who opined that the species is only present in winter and categorized as cold stenothermal. *Filinia* sp. was absent in winter and was fairly present in the remaining seasons. Radwan (1976) and Duggan *et al.,* (2001) characterized it as eutrophic species. Sladecek (1957,83) found its abundance from early May till late August. Besides above workers our results were also supported by Ferrara *et al.* (2002) they reported its abundance in spring and poor population density in winter. *Hexarthra mira* was abundant in spring and summer season in when the transparency of water was low. Sladecek (1983) categorized it as inhabitant of critically pollutes sites. However, Sousa *et al.* (2008) opined that the species preferred turbid environments with temperature range of 20 -28° C.

Asplanchna priodonta was found in Wular lake on those sites where there is more anthropogenic pressure and being dominant in winter. Our results are in line with the Galkovskya *et al.* (2006) they opined that this species prefers temperature below 10 ° C. Balkhi (1987) registered this species abundance in winter and autumn. Radwan (1980) reported it as cosmopolitan species, Matsunura- Tundsi (1999) opined that it prefers eutrophic environment However, Yousuf and Mir (1994) found its abundance in warmer periods. Balkhi (1983) and Balkhi *et al.,* (1984) reported its eurythermal nature also supported by Nogrady and Segers (2002). *Mytilina* sp. showed poor distribution in winter and fair population in spring and summer. Our results contradict with Yousuf (1989) who reported it a winter dominant form. However, our observation is in consonance with Yagci *et al.* (2012) who reported its dominance in spring and summer season.*Polyarthra vulgaris* showed narrow to wider temperature tolerance being sometimes present in abundance in winter and spring, sometime form the dominant form in summer. During our study it was inferred that: (i) it showed low abundance on those sites which have high pollution levels (ii) there is some

trophic relation between *B. bidentata* and *B. quadridentata* especially in summer season with the *Polyarthra vulgaris* (Fig.3). Our results were supported by the works of Nogueira (2000) who reported that it is avoiding polluted sites. Yousuf and Qadri (1986) reported its peak population in winter in Lake Manasbal and contributes highly for shaping the rotifer community. Our results were not supported by the works of Yousuf and Mir (1994) they showed that this species was poorly represented in winter. Yousuf and Qadri (1986) further pondering on the distribution of the same species opined that it is a perennial species preferring a temperature range of 9 - 18° C and avoids warm waters with > pH 8.5 and when temperature exceeds 25° C population greatly decreases. *Trichocerca* sp. was abundant in warm periods during the present study. Rutner Kolisko (1974) is of the view that *Trichocerca* sp. with *Filinia* are found in eutrophic waters. Sladecek (1983) categorized it as oligotrophic species.

As far as Bray- Curtis dendrogram is concerned, sites I and II showed close similarity because both the sites showed anthropogenic pressures from the immediate catchment. Among the sites III and IX recorded dissimilar nature; the former site has a clear water phase throughout year and has least anthropogenic pressure from the catchment area. However, the later site (IX) is located near the entry of River Jhelum therefore supports least diversity of wheal animalcules.

***Brachionus: Trichocerca* ratio** ($Q_{B/T}$)

Brachionus: *Trichocerca* ratio was introduced by Sladecek in 1983. It is also called as Sladecek's $Q_{B/T}$ quotient. As per Sladecek (1983), the genus Brachionus are generally found in eutrophic waters and the genus *Trichocerca* is purely oligotrophic in behavior. This ratio can be used for individual waterbody or even for the individual sample.

***Brachionus: Trichocerca* Ratio**

$$Q_{B/T} = \frac{\text{Number of species of } Brachionus}{\text{Number of species of } Trichocerca}$$

If the value of this quotient is less than 1.0 it means oligotrophic condition, values between 1.0 and 2.0 reflect mesotrophic and values over 2.0 indicate eutrophic conditions. During our study, 04 genera of *Brachionus* and only 1 genera of *Trichocerca* were recorded in both the biotopes therefore; the ratio of the same quotient is 4:1 that reflects the eutrophic condition of the wetland as per Sladecek (1983).

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Competing interests

The authors declare that they have no competing interests.

Authors' contributions

AKP and GMS authors are the research guides of the first author JAS. They have also drafted the sampling design and critically evaluated, coordinated and helped in draft the manuscript. Without their support it was impossible to perform the research. The first author has made collection, identification, systematic position, photography of rotifers, analysis and interpretation of the whole data. All authors read and approved the final manuscript.

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