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Diversity indices of pelagic rotifers in Camp Balloki Water Park, Lahore, Pakistan

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Abstract: This work attempted to evaluate the rotifer species diversity indices of Camp Balloki Water Park and infer the state of the water according to rotifers and physicochemical parameters. The diversity indices, species richness, and evenness were assessed every month. The Shannon–Weaver index indicated that this habitat had great diversity of rotifers throughout the year. These results were supported by the Simpson dominance, diversity, and reciprocal indices. Water and plankton samples were taken monthly from January 2006 to December 2006. In total, 38 rotifer species of 20 genera and 13 families were identified. *Brachionus*, *Lecane*, and *Trichocerca* dominated the locality. Rotifer density was positively correlated with water temperature and conductivity. However, negative correlation was observed with pH, dissolved oxygen, and total hardness. ANOVA expressed statistically significant differences in all of the physicochemical parameters of water from January to December. Hierarchical cluster analysis of variables showed that temporal differences were present in the rotifer community, which may be seasonal in nature.

Key words: Shannon–Weaver index, Simpson index, species richness, species evenness, rotifers, cluster analysis

1. Introduction

Occurrence of rotifers in a pelagic zone depends on several environmental factors (Karabin, 1985). Pelagic rotifers are commonly found in rivers, lakes, or ponds; they may show cyclomorphosis, variations in body form leading to seasonal or nutritional changes (Wallace and Snell, 2010). A few rotifers are very specialized, but most are opportunistic organisms that feed on different types of foods such as bacteria, algae, and ciliates; some species are detritivorous (Allan, 1976; Wallace et al., 2006; Wallace and Snell, 2010). Thus, rotifers are among the most diverse groups in these environments that show high population densities and diversities, as well as high tolerances to environmental conditions (Bozelli, 2000; Neves et al., 2003).

Rotifers of lake ecosystems constitute the main share of zooplankton. Rotifers are main players in causing changes in the trophic structure of water bodies (Radwan, 1973). Some rotifer species are also thought to be indicators of the trophic state of water (Paleolog et al., 1997; Sulehria et al., 2009a).

Seasonal occurrence of pelagic rotifers and their interaction with limnological parameters has been investigated from a few freshwater ecosystems in Pakistan (Mahar et al., 2000; Malik and Sulehria, 2003, 2004; Baloch et al., 2004, 2008; Sulehria et al., 2009a, 2009b; Sulehria and Malik, 2012).

In diversity studies, it is common to focus on selected taxonomic groups. The diversity of the key taxonomic groups expresses the diversity at ecosystem level (Margalef, 1974). In this regard, rotifer assemblages characterize the diversity of the pelagic communities of lakes.

The aims of the study were: 1) to identify dominant rotifer groups; 2) to analyze spatiotemporal distribution of rotifers within the lake; 3) to explore diversity indices of rotifer species; and 4) to determine the correlation between rotifers and limnological parameters of water.

2. Materials and methods

2.1. Sampling site

The Balloki Headworks, having a latitude of 31.22 (31°13′10″N) and a longitude of 73.86 (73°51′35″E), is located on the River Ravi, about 65 km from Lahore to the southwest near Phool Nagar on Multan Road. Camp Balloki Water Park is a lake located between 2 canals (Balloki-Sulemanki Link Canal and Lower Bari Doab Canal) about 0.5 km away from the headworks (Sulehria and Malik, 2012; Figure 1).

2.2. Sampling and bioidentification

The lake in the Camp Balloki Water Park covers an area of about 562.81 m^2 and has a maximum depth of 3 m in the center. Five sampling stations were selected, including

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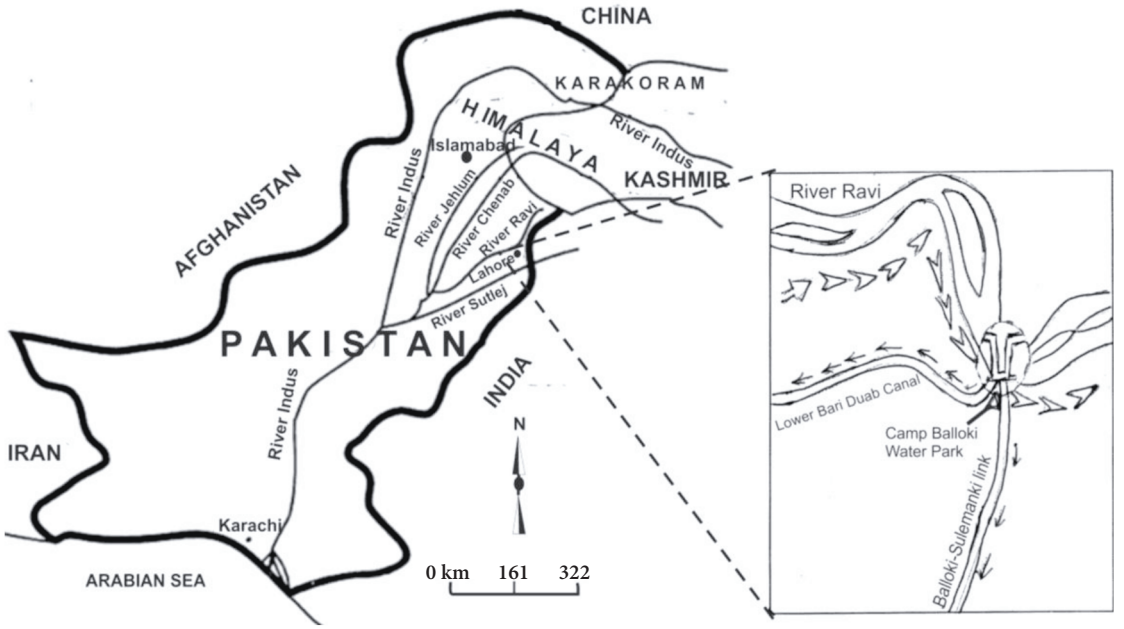

Figure 1. Map of study area.

the eastern side (CB1), southern side (CB2), western side (CB3), northern side (CB4), and central area (CB5).

Rotifer samples were collected by vertical hauls from 2 m above the maximum depth to the surface using 37-µm mesh-size standard plankton net. Three samples were collected from each sampling station. Rotifers were kept alive for accurate identification. Rotifers were first narcotized with grains of magnesium to avoid body contractions and were then preserved in 4% formalin solution. Rotifers were identified according to available standard keys (Ward and Whipple 1959; Koste, 1978; Nogrady et al., 1995). A Sedgewick-Rafter chamber was used to count the rotifers at 40× to 100× magnification with a light microscope (APHA, 2005).

2.3. Physicochemical and hydrological analysis

The hydrophysical, hydrochemical, and hydrological conditions of the lake were monitored simultaneously at each sampling station. Water and air temperature (°C), pH, conductivity (µS/cm), dissolved oxygen (mg/L), and oxygen saturation (%) were measured in the field (in situ) using a WTW Multi 340i.

2.4. Diversity indices analysis

Shannon–Weaver and Simpson indices were chosen to quantify the biodiversity in Camp Balloki Water Park.

The Shannon–Weaver index (H) was calculated by using the Shannon–Weaver equation:

$H = -\Sigma P_i(\ln P_i)$ (Shannon and Weaver, 1949),

where P_i is the proportion of each species in the sample. Pi = ni/N (Omori and Ikeda, 1984), where ni is the number of individuals of a particular species and N is the total number of individuals of all species in the sample.

Simpson's index of dominance (D) was calculated according to Simpson's equation (Simpson, 1949):

$D = \Sigma\, n\,(n-1) / N\,(N-1)$,

where D = Simpson's index of dominance; N = total number of individuals of all species; n = number of individuals of specific species per samples; and Σ = sum.

Simpson's index of diversity (SID) and Simpson's reciprocal index (SRI) were also calculated by the equations SID = 1 – D and SRI = 1 / D, respectively.

Species richness (SR), the number of species recorded from a region, was calculated by Margalef's formula (Margalef, 1951):

$SR = (S-1) / \log_n N$,

where S = total number of species and N = total number of individuals present in the sample.

Species evenness or equitability (E) was calculated according to Pielou's equation (Pielou, 1966):

$E = H / \text{Log}\, S$,

where S is total number of species and H is the Shannon–Weaver diversity index.

2.5. Statistical analysis

Cluster analysis was used to notice and categorize sets of species and to find important physicochemical or environmental conditions linked with underlying trends. Cluster analysis (average linkage method) was performed on the mean densities of rotifer taxa based on the correlation coefficient distance calculated for 5 clusters showing similarity levels (Duggan et al., 2001).

Pearson's correlation test was performed to evaluate the relationships between the rotifer species with various observed environmental parameters that might

be influencing their populations. Analysis of variance (ANOVA) was applied to the data of rotifers obtained in various months in order to find the differences. Cluster analysis, Pearson's correlation, and ANOVA were performed using the software Minitab 13 for Windows (Sulehria and Malik, 2012).

3. Results and discussion

3.1. Diversity patterns

In the present investigation, 38 species of rotifers belonging to 13 families and 20 genera have been identified (Table 1). The family-wise relative quantitative representation (57.9%) of rotifers was Brachionidae > Lecanidae > Trichocercidae (Figure 2). The most prominent genera (44.73%) were *Brachionus* > *Lecane* > *Trichocerca* (Arora and Mehra, 2003; Figure 3). At Camp Balloki Water Park, *Brachionus* comprised 9 species (Table 1). *Brachionus calyciflorus* was a dominant species, with the greatest density during the summer season. This species is thought to be one of the rapidly thriving metazoans and a pioneer species (Ferrari et al., 1989). *Brachionus quadridentata* and *B. calyciflorus* are considered to be representative of eutrophic conditions (Gannon and Stemberger, 1978).

Species diversity exhibited monthly fluctuations that did not differ much, as evident from the Shannon–Weaver index and Simpson index. The Shannon–Weaver diversity index (H) in Camp Balloki Water Park ranged from 3.1464 to 3.5196, being lowest in August and highest in January. This range indicated that this habitat had great diversity of rotifers throughout the year as this range is near the upper limit of the Shannon–Weaver diversity index. These results were supported by the Simpson dominance, diversity, and reciprocal indices. The Simpson index of dominance ranged from 0.3194 in January to 0.4859 in September, showing the greatest diversity in the month of January and the lowest in the month of September. The Simpson index of diversity ranged from 0.9514 in September to 0.96805 in January, while the Simpson reciprocal index ranged from 20.5782 in September to 31.3043 in January, both showing the same results as the Simpson index of dominance. (Figure 4)

The value of species evenness was near 1 from January to December, showing an even distribution of species throughout the year in Camp Balloki Water Park. Species richness ranged from 2.5026 in August to 3.5464 in October. Species richness was higher from October to January, indicating larger food chains, and lower from June to September, which may be due to rain and the relationship of phytoplankton to hydrographic factors. Peet (1974) reported that species diversity causes both richness and evenness in the number of species and equitability for the distribution of individuals among the species.

3.2. Rotifers and physicochemical physiognomies of water

It is obvious from the results that the diversity and the distribution of rotifers were influenced by physicochemical qualities of the water, either positively or negatively, throughout the period of study. Rotifer density was positively correlated with water temperature and conductivity. However, negative correlation was observed with pH, dissolved oxygen, and total hardness (Table 2). ANOVA expressed statistically significant differences in all physicochemical parameters of the water from January to December. These results conform to the findings of Chittapun et al. (2007).

In the present study, temperatures ranged between 33.01 ± 0.32 °C and 13.19 ± 0.12 °C. The mean rotifer population density was highest during hot months (May to July), being highest (48.75 ± 5.83 ind/mL) in the month of June. The lowest mean population density of rotifers was found during cold months, particularly in February (23.75 ± 3.22 ind/mL). Rotifers are able to endure a large range of temperatures. A number of studies are available that indicate a positive relationship between rotifers and

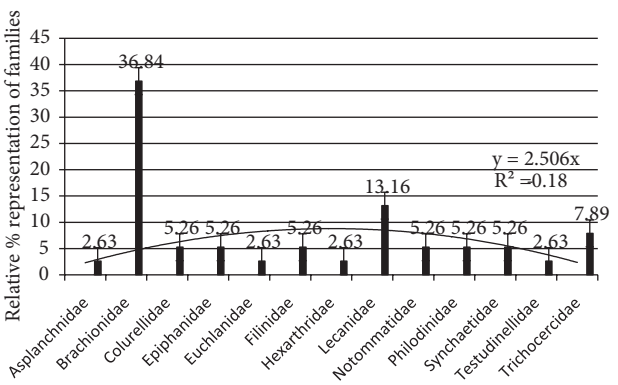

Figure 2. Relative % representation of families with polynomial regression line and standard error bars.

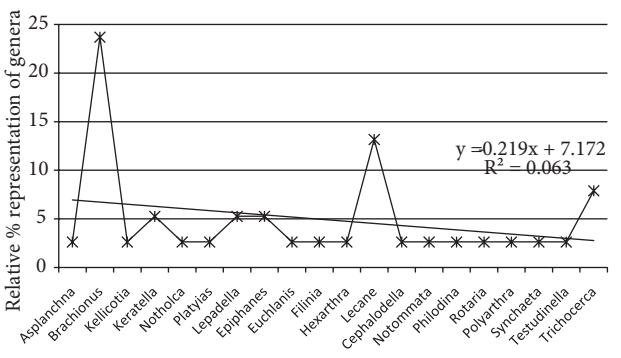

Figure 3. Relative % representation of genera with linear regression line.

Table 1. List of rotifers collected from Camp Balloki Water Park.

Family Asplanchnidae	**Family Filinidae**
Asplanchna priodonta Gosse	*Filinia longiseta* (Ehrenberg)
Family Brachionidae	*Filinia terminalis* (Plate)
Brachionus angularis Gosse	**Family Hexarthridae**
B. bidentata Anderson	*Hexarthra mira* (Hudson)
B. calyciflorus Pallas	**Family Lecanidae**
B. falcatus Zacharias	*Lecane bulla* (Gosse)
B. havanaensis Rousselet	*L. elasma* Harring & Myers
B. leydigii Cohn	*L. luna* (Müller)
B. plicatilis Müller	*L. lunaris* (Ehrenberg)
B. quadridentatus Hermann	*L. quadridentata* (Ehrenberg)
Kellicottia longispina (Kellicott)	**Family Notommatidae**
Keratella cochlearis (Gosse)	*Cephalodella gibba* (Ehrenberg)
K. quadrata (Müller)	*Notommata copeus* Ehrenberg
Notholca acuminata (Ehrenberg)	**Family Philodinidae**
Plationus patulus (Müller)	*Philodina roseola* Ehrenberg
Platyias quadricornis (Ehrenberg)	*Rotaria neptunia* (Ehrenberg)
Family Colurellidae	**Family Synchaetidae**
Lepadella ovalis (Müller)	*Polyarthra vulgaris* Carlin
Lepadella patella (Müller)	*Synchaeta tremula* (Müller)
Family Epiphanidae	**Family Testudinellidae**
Epiphanes macrourus (Barrois & Daday)	*Testudinella patina* (Hermann)
Epiphanes senta (Müller)	**Family Trichocercidae**
Family Euchlanidae	*Trichocerca longiseta* (Schrank)
Euchlanis dilatata Ehrenberg	*Trichocerca porcellus* (Gosse)
	Trichocerca similis (Wierzejski)

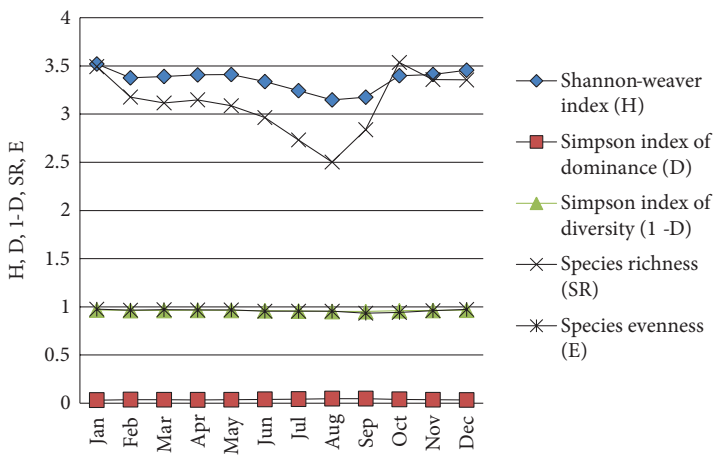

Figure 4. Temporal variations of diversity indices, species richness, and evenness.

Table 2. Correlations (Pearson) of rotifers with physicochemical parameters of water in Camp Balloki Water Park.

Rotifers	WT	pH	DO	OS	C	T.H
WT	0.732					
	0.007					
pH	-0.830	-0.910				
	0.001	0.000				
DO	-0.652	-0.952	0.782			
	0.022	0.000	0.003			
OS	-0.557	-0.674	0.480	0.818		
	0.060	0.016	0.114	0.001		
C	0.858	0.713	-0.864	-0.570	-0.309	
	0.000	0.009	0.000	0.053	0.328	
TH	-0.917	-0.793	0.908	0.640	0.337	-0.893
	0.000	0.002	0.000	0.025	0.285	0.000

Cell contents: Pearson correlation, P-value.
WT = water temperature, DO = dissolved oxygen, OS = oxygen saturation, WF = water flow, C = conductivity, TH = total hardness.

temperature (Schöll and Kiss, 2008; Sulehria et al., 2009a, 2009b; Sulehria and Malik, 2012; Figure 5). This association might possibly indicate that an increase in temperature increases the rate of population growth (Galkovskaya, 1987).

The mean dissolved oxygen (DO) values of water ranged between 15.34 ± 0.16 mg/L in January and 9.20 ± 0.05 mg/L in June. The DO of water expressed a significantly negative correlation with the density and diversity of the majority of rotifer genera (Figure 6). These results agreed with the studies of Saler and Şen (2002) and Sulehria and Malik (2012). However, these findings were entirely different from those of certain earlier surveys carried out in the River Ravi, Jallo Lake, and certain fish ponds (Pakistan) (Malik and Sulehria, 2003, 2004; Sulehria et al., 2009a, 2009b), where rotifers and DO had a positive correlation.

The highest mean pH (8.75 ± 0.05) was observed during the month of December while the lowest mean pH (7.24 ± 0.02) was found during the month of May. The best pH range for rotifers is 6.5 to 8.5 (Neschuk et al., 2002). The pH was negatively correlated to the population density and diversity of rotifers. Similar results were also obtained in certain previous studies such as those of Sulehria et al.

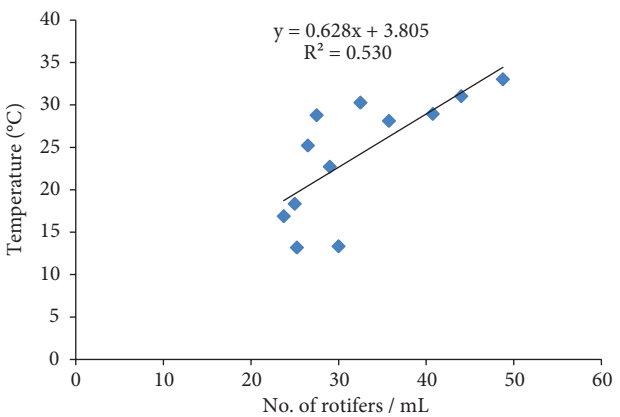

Figure 5. Positive correlation between rotifers and temperature.

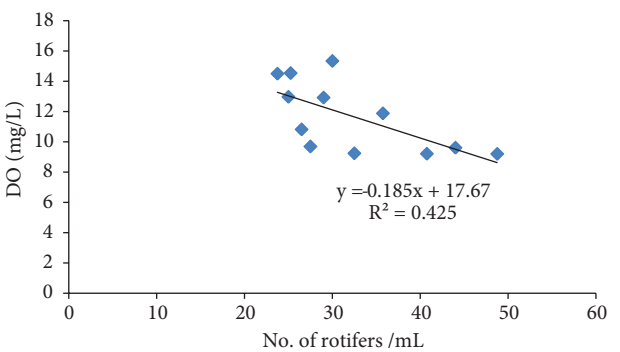

Figure 6. Negative correlation between rotifers and DO.

(2009a) and Sulehria and Malik (2012), but they differed from the findings of Sulehria et al. (2009b). According to Tanner et al. (2005), a pH range between 6.0 and 8.5 shows medium productivity, greater than 8.5 shows high productivity, and lower than 6.0 shows low productivity of a water body.

The highest mean value of conductivity (570.50 ± 7.68 µS/cm) was observed in the month of May and the lowest mean value (390.75 ± 5.85 µS/cm) in December. Conductivity is thought to be a vital sign of trophic conditions. Conductivity was highest in summer, which might be because of high temperature, lower solubility, and high degradation of organic substances. Conductivity showed a positive correlation with rotifer density and diversity. Similar conclusions have also been obtained in certain other studies in Pakistan (Sulehria et al., 2009a, 2009b; Sulehria and Malik, 2012), while these results were different from results from other studies, like those of Malik and Sulehria (2003, 2004).

The mean total hardness values of water ranged between 117.65 ± 0.61 mg/L and 88.17 ± 0.72 mg/L in December and June, respectively. Total hardness was the highest in winter months and lowest in summer months. It had negative correlation with density and diversity of rotifers. However, survival of many rotifer species exhibited that either they were not influenced by different chemicals such as Ca^{+2} and Mg^{+2} (Tamas and Horvarth, 1978) or they had an extensive range of tolerance and the lake is eutrophic (Gannon and Stemberger, 1978). Eutrophication caused genera like *Lecane*, *Epiphanes*, *Lepadella*, *Notholca*, *Synchaeta*, and *Testudinella* to flourish.

These results signify that the population density and diversity of rotifers were strongly affected by the physicochemical parameters of the water body (Ruttner-Kollisko, 1972). Since rotifers are opportunistic organisms, their populations alter with respect to environmental changes (Allan, 1976).

3.3. Cluster analysis

Hierarchical cluster analysis of variables showed that temporal differences were present in the rotifer community, which may be seasonal in nature. Eleven clusters were formed at a 99.27% similarity level. Five clusters were available at 94.21% similarity level. Among the 5 clusters, cluster 1 consists of January only; cluster 2 consists of February, March, and April; cluster 3 comprises May, June, July, August, September, and October; and cluster 4 consists of November and cluster 5 of December only. All were merged into a single cluster at 73.79% similarity level, having a distance level of 0.524 (Figure 7).

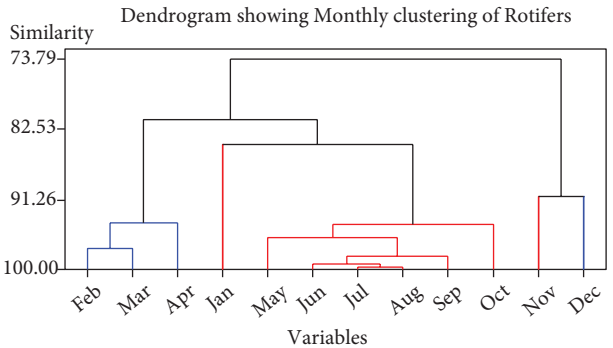

Figure 7. Dendrogram showing monthly similarity of rotifers.

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