Pakistan J. Zool., vol. 44(3), pp. 663-669, 2012.

Population Dynamics of Planktonic Rotifers in Balloki Headworks*

Abdul Qayyum Khan Sulehria and Muhammad Anwar Malik**
Department of Zoology, GC University, Lahore, Pakistan

Abstract.- The population dynamics of rotifers were determined in Balloki Head Works (Pakistan) by tracking monthly variations in diversity and population density. A total of 38 rotifer species belonging to 20 genera and 13 families were identified from the three study areas. Twenty four species were new records for Pakistan. Three families dominated (Brachionidae, Lecanidae and Trichocercidae), with *Brachionus*, *Lecane* and *Trichocerca*, respectively, being the most important genera. The impact of physico-chemical parameters on population dynamics of rotifers were similar for the three study areas. Rotifer density was positively correlated with water temperature, being the highest in summer and the lowest in autumn/winter. Conductivity also had positive correlation with rotifer density. Negative correlation was however observed with pH, dissolved oxygen, and total hardness. Rotifers of the two lotic habitats showed positive correlation with water flow while rotifer diversity was very low as compared to that found in the lentic habitat. Analysis of variance of the three study areas indicated that DO (F=3.80, p=0.033), and conductivity (F=5.23, p=0.011) were statistically significant (α=0.05), while water temperature (F=0.06, p=0.946), pH (F= 0.09, p=0.919) and total hardness (F=0.39, p=0.682) were non-significant..

Key words: water, conductivity, dissolved oxygen, temperature, total hardness

INTRODUCTION

Rotifers are a particularly significant group of the littoral and limnetic micro-invertebrates (Wallace and Snell, 2010). About 95 percent of the known rotifer species are found in freshwaters which are thought to be their original habitat. Rotifers are adapted to many kinds of ecological conditions and pelagic or planktonic forms are common in surface waters (Pejler, 1995; Wallace and Snell, 2010) with a high diversity and population density, as well as high tolerance to environmental conditions, (Bozelli, 2000; Neves *et al*., 2003).

Seasonal occurrence of planktonic rotifers and their relationships with physico-chemical parameters of water and primary productivity have been reported from various water bodies of the world (Pejler and Bērziņš, 1994; Sharma, 2000; Garcia *et al*., 2002) as well as Pakistan (Mahar *et al*., 2000; Malik and Sulehria, 2003, 2004; Baloch *et al*., 2004, 2008).

Rotifers directly use suspended organic substances (Pourriot, 1965) and indirectly consume dissolved organic substances when eating bacteria and protozoa (Arndt, 1993). So, rotifers occupy an important, basal position in aquatic food chains of freshwaters (Wetzel, 2001). This position also is due to their large population density and extraordinary production rates (Wallace, 2002), although they are less important in terms of biomass (Ruttner-Kolisko, 1974).

There have been only few surveys of the rotifer fauna of Pakistan. The purpose of the present work was to collect rotifers from Balloki Headworks (Pakistan) in order to identify them and to determine seasonal variation of density and diversity of rotifers in relation to the physico-chemical properties of water.

MATERIALS AND METHODS

Balloki Headworks, with a latitude of 31.22 (31° 13' 10 N) and a longitude of 73.86 (73° 51' 35 E), on River Ravi is located at a distance of about 65 km (42 miles) from Lahore in the South-West direction near Phool Nagar (previously known as Bhai Phairoo). The study areas included following three sites: (i) Balloki-Sulemanki Link Canal, designated as Study Area 1; (ii) Lower Bari Doab Canal, designated as Study Area 2 and (iii) a lake (Camp Balloki Water Park), designated as Study Area 3, located between two canals, about ½ km away from the Head Works. Both the canals originate from the Balloki Headworks downstream on the River Ravi (Fig. 1).

* Part of Ph.D. thesis of first author.
** Corresponding author: khansulehria@hotmail.com
0030-9923/2012/0003-0663 $ 8.00/0

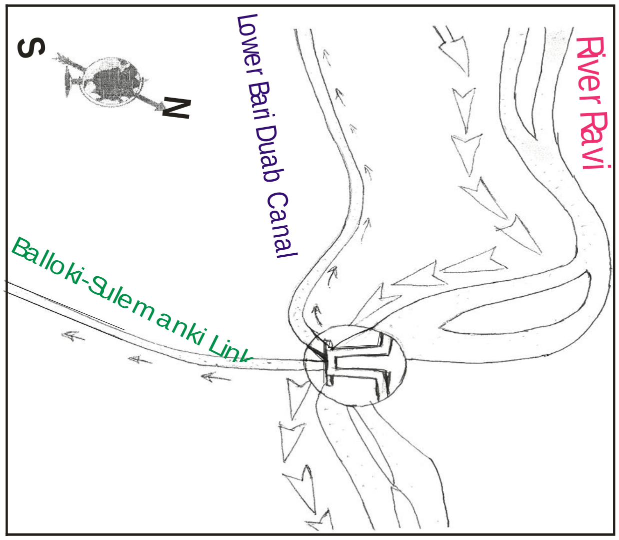

Fig. 1: Map of study area

Water samples for the study of physical-chemical characteristics and planktonic rotifers were collected from these study areas. Sampling was done for 12 months from January 2006 to December 2006 by taking monthly records with a view to assess the present state of water. Samples were collected between 9 A.M. to 1 P.M, usually in the 2nd, but sometimes in the 3rd week of every month.

Water sampling for physico–chemical parameters

Samples were taken from just below the surface water to determine the following physical-chemical parameters: Water temperature, Dissolved Oxygen (DO), pH, Conductivity, Total Hardness, and Oxygen Saturation (%). Flow of water was noted for the canals and atmospheric temperature was also recorded at each site. The procedures adapted to determine these physical-chemical parameters of water were according to APHA (1995).

Sampling and preservation of rotifers

The plankton samples were taken monthly from a maximum depth of 15-25 cm. For plankton analysis 40 litres of water was passed through a sieve of mesh size 341 µm, collecting filtered water in a plastic tub and discarding the material deposited in the sieve. The water of the tub was filtered by another sieve of mesh size 55 µm, the contents of the sieve were washed in a small plastic tub and preserved in 50 ml plastic bottles in 4-5% formalin (Koste, 1978).

Counting and identification of rotifers

Rotifers were counted in a Sedwick-Rafter chamber (APHA, 1995) at 60-100x using an inverted Olympus microscope. Rotifers were identified to species level by observing the body shape, morphological features and behaviour of the rotifers (Ward and Whipple, 1959; Pennak, 1978; Koste, 1978). Live organisms were also observed under the microscope after staining with 1% neutral red in order to study some of the internal features of the organisms.

Statistical analysis

Analysis of Variance (ANOVA) was applied to the data of the three study areas in order to find the differences, and correlation was determined by using MINITAB 13 for Windows.

RESULTS AND DISCUSSION

The three study areas expressed similar trend with respect to impact of physico-chemical parameters on population density and diversity of rotifers. Rotifer density was positively correlated with water temperature, being the highest in summer and the lowest in autumn/winter. Conductivity also had positive correlation with rotifer density. However negative correlation was observed with pH, DO, and total hardness, while positive correlation was observed with water flow (Study area 1 and 2 only). Rotifer diversity was very low in study area 1 and 2 (lotic habitats) as compared to that found in study area 3 (a lentic habitat).

Analysis of variance of the three study areas showed that DO ($F=3.80$, $p=0.033$), and conductivity ($F=5.23$, $p=0.011$) were statistically significant ($\alpha=0.05$) while water temperature ($F=0.06$, $p=0.946$), pH ($F= 0.09$, $p=0.919$) and total hardness ($F=0.39$, $p=0.682$) were non-significant.

These results indicate that the population dynamics of rotifers was strongly influenced by physico-chemical parameters of water throughout the period of observation (Ruttner-Kolisko, 1972). Since rotifers are opportunistic organisms, their populations change in relation to environmental conditions.

Table I.- List of rotifers collected from Balloki Headworks.

Rotifers	Study area 1	Study area 2	Study area 3
Family Asplanchnidae			
Asplanchna priodonta Gosse			+
Family Brachionidae			
Brachionus angularis Gosse	+	+	+
B. bidentata Anderson*			+
B. calicyflorus Pallas	+	+	+
B. falcatus Zacharias			+
B. havanaensis Rousselet*			+
B. ledigi Cohn*			+
B. patulus(Müller* (Now *Plationus patulus*)			+
B. plicatilis Müller	+	+	+
B. quadridentatus Hermann	+	+	+
Kellicottia longispina Kellicot*			+
Keratella cochlearis (Gosse)	+	+	+
K. quadrata (Müller)*			+
Notholca acuminata (Ehrenberg)*			+
Platyias quadricornis (Ehrenberg)*			+
Family Colurellidae			
Lepadella ovalis (Müller)*	+	+	+
Lepadella patella (Müller)*			+
Family Epiphanidae			
Epiphanes macrourus Barrois & Daday*			+
Epiphanes senta (Müller)*			+
Family Euchlanidae			
Euchlanis dilatata Ehrenbreg*			+
Family Filinidae			
Filinia longiseta (Ehrenbreg)	+	+	+
Filinia terminalis (Plate)*			+
Family Hexarthridae			
Hexarthra mira (Hudson)*			+
Family Lecanidae			
Lecane bulla (Gosse)			+
L. elasma Herring & Myers			+
L. luna (Müller)*			+
L. lunaris (Ehrenberg)*			+
L. quadridentata (Ehrenberg)		+	+
Family Notommatidae			
Cephalodella gibba (Ehrenberg)*	+	+	+
Notommata copeus Ehrenberg		+	+
Family Philodinidae			
Philodina roseola (Ehrenberg)		+	+
Rotaria neptunia (Ehrenberg)*			+
Family Synchaetidae			
Polyarthra vulgaris Carlin	+	+	+
Synchaeta tremula (Müller)*			+
Family Testudinellidae			
Testudinella patina (Hermann)*	+	+	+
Family Trichocercidae			
Trichocerca longiseta (Schrank)*			+
Trichocerca porcellus (Gosse)*	+	+	+
Trichocerca similis (Plate)*			+
Total species richness	11	14	38

* *New records for Pakistan: n=24.*

Table II.- Monthly variations and overall population density of rotifers from January to December 2006 in Balloki Headworks

Months	Study area 1		Study area 2		Study area 3	
	Mean	SE	Mean	SE	Mean	SE
Jan.	14.00	0.58	23.67	0.67	30.00	3.67
Feb.	15.67	1.20	24.67	1.45	23.75	3.22
March	19.33	0.88	30.33	1.45	29.00	3.89
April	25.00	0.58	37.00	0.58	35.75	4.31
May	28.00	2.00	40.67	1.45	44.00	4.95
June	30.67	1.76	43.33	1.45	48.75	5.81
July	28.67	1.20	39.33	0.88	40.75	3.28
Aug.	25.00	1.53	35.00	1.00	32.50	2.53
Sept.	21.00	1.15	30.33	0.88	27.50	2.47
Oct.	17.67	2.03	25.33	1.33	26.50	1.66
Nov.	15.00	1.53	22.33	0.33	25.00	3.24
Dec.	11.33	1.20	16.67	0.88	25.25	4.68

Results of ANOVA for rotifers

Source	DF	SS	MS	F	P
Treatments	2	918.0	459.0	7.70	0.002
Error	33	1967.1	59.6		
Total	35	2885.2			

DF, degree of freedom; SS, sum of squares; MS, mean of squares; F, F ratio; P, probability.
Significant

Temperature and rotifer population

Water temperature is very important in controlling the population density and diversity of rotifers. The highest mean rotifer population density was observed during the summer season that is from May to July being the highest in the month of June. It conforms to the work of Schöll and Kiss (2008). The population density started to increase in March, reached its peak in June and was found to be 30.67±1.76/ml, 43.33±1.45/ml and 48.75±5.83/ml in study area 1, 2 and 3, respectively. Then there was a decline in the population density of rotifers from August onward. The lowest mean population density of rotifers was found during the winter/autumn months usually in November, December, January or February (Schöll and Kiss, 2008). The lowest population densities in study 1, 2 and 3 were in the order of 11.32±1.20/ml in December, 16.67±0.88/ml in December and 23.75±3.22/ml in February. The population density of rotifers seemed to be positively dependent on temperature of water and this agrees with the work of Saler and Sen (2002).

The population density and diversity of rotifers increased in spring and summer, but decreased in autumn and winter season. This trend was exhibited by most of the prominent rotifer genera observed in Balloki Headworks *e.g.*, *Brachionus*, *Cephalodella*, *Filinia*, *Philodina*, *Polyarthra*, *Trichocerca* etc., which were abundant in summer and present throughout the year. In study area 3, however, rotifer genera *Lecane*, *Epiphanes*, *Lepadella*, *Synchaeta and Testudinella* exhibited a different dynamic. In these genera, population densities and species diversity increased in cold months and decreased in the warm months, although they had low density and diversity throughout the period of study. In study area 3, *Lecane* was represented by 5 species all of which were present in low temperatures. However, three *Lecane* (*L. elasma*, *L. luna* and *L. lunaris*) were absent in August and September while *L. quardridentata* did not appear from July to September. *Epiphanes* was represented by two species (*E. macrourus* and *E. senta*): these were not present from April to August. *E. macrourus* remained absent even in September. *Synchaeta tremula* was not found from May to September while *Testudinella patina* from June to September and *Notholca acuminata* from April to August. Modenutti (1998) recorded *Notholca acuminata* and *Synchaeta* sp., from Samborombón river basin (Argentina) only during autumn and winter. A strong seasonal variation was observed in rotifer population density and diversity in all the study areas of Balloki Headworks. According to Burger *et al*. (2002) the seasonality of rotifers of the Waikato River, New Zealand was similar to present findings, with high densities in summer and minimum densities over the winter period. However, they observed marked seasonal differences between individual species which was also evident in the present work.

Rotifers have a wide range of tolerance of temperature extremes. Several studies showed a significant positive correlation between zooplankton including rotifers and water temperature (Malik and Sulehria; 2003, 2004; Schöll and Kiss, 2008). This correlation might possibly be due to enhanced rate of population growth at higher temperatures (Galkovskaya, 1987).

Oxygen concentration and rotifer abundance

The population density and biodiversity of most rotifer genera showed significantly negative correlation with DO of water in all the study areas. However, some genera (*Lecane*, *Epiphanes*, *Lepadella*, *Synchaeta*, *Testudinella* and *Notholca*) showed an increase in population densities and biodiversity with increase in DO, but this response may be attributed to low temperature of water instead of high level of DO. The highest mean DO was observed in June and July, while lowest mean values of DO were found in December and January. These results were in accordance with the studies of Saler and Sen (2002) in Cip Dam Lake (Elaziğ-Turkey). However, these results were contrary to some previous studies conducted in The River Ravi and Jallo Lake (Lahore, Pakistan) (Javed and Hayat, 1996; Malik and Sulehria 2003, 2004) where rotifers exhibited positive correlations with DO concentration.

pH and rotifer abundance

The rotifers prefer pH in the range of 6.5 to 8.5 (Neschuk *et al.*, 2002). In this study, pH ranged from 7.21±0.07 to 8.75±0.05, which fall close to the recorded preference. The pH showed negative correlation (Pearson) in relation to the population dynamics (density and diversity), of rotifers in all the three study areas.

Conductivity and rotifer density

Conductivity is considered to be an important indicator of trophic states. Conductivity was high in summer and low in winter, and was positively correlated with rotifer density and diversity in all the three study areas. It conforms to the studies of Neschuk *et al.* (2002) who observed the seasonal samples of zooplankton in the Salado River basin (Argentina) and found that there were differences in number and density of species in relation to conductivity, and those species were common which might tolerate high conductivity.

Total hardness and rotifer population

Total hardness was the highest in December and January but the lowest in May and June. It was negatively correlated with overall population density of rotifers. However, many rotifer species were present in this season, indicating that either they had no effect of various chemicals *e.g.*, Ca^{+2} and Mg^{+2}, (Tamas and Horvarth, 1978) or they had wide tolerance range. Presence of rotifers even in these conditions is an indication of eutrophic conditions (Gannon and Stemberger, 1978), particularly study area 3. In present study, *Lecane, Epiphanes, Lepadella, Notholca, Synchaeta,*and *Testudinella* became more abundant with increase in eutrophication. However, other genera such as *Brachionus*, *Cephalodella*, *Filinia*, *Philodina*, *Polyarthra*, *Trichocerca* were also present, albeit with low density. Unni (1986) reported *Keratella*, *Tropica*, *Filinia* and *Polyarthra* in polluted waters.

Water flow and abundance of rotifer

Water flow is thought to be a major factor controlling the zooplankton seasonal variations in lotic (running) waters (Baranyi *et al*., 2002). Velocity of water was a limiting factor in study area 1 and 2, which resulted in low density and diversity of rotifer population. Richness of rotifer density and diversity in study area 3 might be due to three features of that site: (i) stagnant water; (ii) better light penetration, (iii) high concentration of phytoplankton which is an important source of food for the zooplankton (Chételat and Pick, 2006). Sch□ll and Kiss (2008) made similar observations while studying zooplankton assemblages in the Gemenc floodplain. The stagnant water or slower flow provides better environment for rotifers to reproduce, the water is warmer, and the depth of light penetration also increases, therefore the chances for reproduction of phytoplankton are also better.

Turbidity and rotifer density

The influence of turbidity on biotic factors affecting rotifer densities has been observed in some large rivers (Lair, 2005), but several conditions are responsible for the reduction of rotifer population in areas of high turbidity. These include low phytoplankton concentration and large amount of small aggregates having little organic matter (Zimmermann, 1997). Somewhat similar situation was seen in the present work in study areas 1 and 2 where rotifer densities were limited because of fast flow of water and high turbidity due to the presence of suspended particles and floating plant matter, although other physical-chemical parameters (mentioned above) were also responsible. Therefore, only 11 species of 8 genera and 14 species of 11 genera were collected and identified from study area 1 and 2 respectively, whereas 38 species belonging to 20 genera were observed in study area 3. This shows that there is higher richness of the rotifers in lentic habitats than lotic ones (Arora and Mehra, 2003).

New records of rotifers in Pakistan

Twenty four out of 38 species described in present work are new records from Pakistan. This is for the first time that such a large number of rotifer species have been collected and identified from this region. The family-wise relative qualitative (%) representation of recorded species was Brachionidae > Lecanidae > Trichocercidae in study area 3 where these families comprised 57.9% of the total rotifer species. In study area 1 Brachionidae (45.5%) was the only prominent family that comprised 5 out of 11 species found there. In study area 2 major families were Brachionidae > Notommatidae which comprised 50% of the total species. Most diverse genera were *Brachionus*, *Lecane* and *Trichocerca* (Arora and Mehra, 2003).

In our study all rotifer genera seemed to be cosmopolitan in distribution (Wallace *et al*. 2008). Most prominent genera with respect to the relative (%) representation of species were *Brachionus* > *Lecane* > *Trichocerca*. Seven genera, namely, *Epiphanes, Hexarthra, Kellicotia, Lepadella, Notholca, Rotaria, Synchaeta,* and *Trichocerca* had been reported for the first time from Pakistan. Remaining thirteen genera had already been described in different studies from Pakistan. Javed and Hayat (1996) have mentioned five genera namely *Brachionus, Keratella, Filinia, Philodina,* and *Polyarthra* during their work in the River Ravi. *Asplanchna, Brachionus, Cephalodella, Euchlanis, Filinia, Keratella, Lecane,* were identified from Manchar Lake, Sindh (Mahar *et al*., 2000). Haq *et al*. (2001) had described *Brachionus* and *Platyias* from tanneries near Lahore city. Seven genera of rotifers namely *Brachionus, Keratella, Asplanchna, Notommata, Filinia, Philodina and Lecane* had been represented from Jallo Lake (Malik and Sulehria, 2003) and eight genera namely *Brachionus, Keratella, Filinia, Philodina, Polyarthra, Platyias, Asplanchna* and *Cephalodella* from the River Ravi (Malik and Sulehria, 2004).

At Head Balloki, *Brachionus* was represented by nine species, four of them were new to this region: *B. bidentata, B. havanaensis, B. ledigi* and *B. patulus.* However, their density was very low throughout the study period. *Brachionus calyciflorus* was a dominant species of Head Balloki, which showed the greatest density during the summer. This species is considered to be one of the rapidly flourishing metazoans (Bennet and Boraas, 1989). It is usually mentioned as a pioneer species (Ferrari *et al.*, 1989). In the River Ravi four species of genus *Brachionus* (*B. quadridentata, B. calyciflorus, B. plicatilis* and *B. caudatus*) have been described (Malik and Sulehria, 2004). The same four species of *Brachionus* also have been reported from Manchar Lake, Sindh-Pakistan (Mahar *et al*., 2000). One species *B. rubens* also has been described from tanneries of Lahore city by Haq *et al*. (2001). Both *B. quadridentata,* and *B. calyciflorus* are considered as representative of eutrophicate condition (Gannon and Stemberger, 1978).

REFERENCES

APHA (American Public Health Association), 1995. *Standard methods for the examination of water and wastewater*. 19th ed. Washington, D.C.

ARNDT, H. 1993. Rotifers as predators on components of the microbial web (bacteria, heterotrophic flagellates, ciliates): A review. *Hydrobiologia,* **255**/**256**: 231-246.

ARORA, J. AND MEHRA, N.K., 2003. Species diversity of planktonic and epiphytic rotifers in the backwaters of the Delhi segment of the Yamuna River, with remarks on new records from India. *Zool. Stud.,* **42**: 239-247.

BALOCH, W.A., SOOMRO, A.N. AND BULEDI, G.H., 2008. Zooplankton, especially Rotifer and Cladoceran Communities of the spring and rainwater streams Nai) in Kirthar range, Sindh, Pakistan. *Sindh Univ. Res. J. (Science Series)* **40**(**1**):17-22.

BALOCH, W.A., SOOMRO, A. N. AND JAFRI, S.I.H., 2004. Zooplankton of highly saline water, near Hyderabad. *Sindh Univ. Res. J. (Science Series)* **36**:25-28.

BARANYI, C., HEIN, T., HOLAREK, C., KECKEIS S. AND SCHIEMER, F., 2002. Zooplankton biomass and community structure in a Danube River floodplain system: effects of hydrology. *Freshw. Biol*., **47**: 473-482.

BENNETT, W. N. AND BORAAS, M. E., 1989. A demographic profile of the fastest growing metazoan: a strain of *Brachionus calyciflorus* (Rotifera). *Oikos,* **55:**356–369.

BOZELLI, R. L., 2000. Zooplâncton. In: *Lago Batata*: impactoe recuperação de um ecossistema amazônico (eds. R.L. Bozelli, F.A. Esteves and F. Roland). Rio de Janeiro: IB-UFRJ; SBL. pp. 119-138.

BURGER, D. F. HOGG, D. I. AND GREEN, J. D., 2002. Distribution and abundance of zooplankton in the Waikato River, New Zealand. *Hydrobiologia,* **479:** 31–38.

CHÉTELAT, J. AND PICK, F.R., 2006. Potamoplankton size structure and taxonomic composition: influence of river size and nutrient concentrations. *Limn. Ocean.,* **51**: 681-689.

FERRARI, I., FARABEGOLI, A. AND MAZZONI, R., 1989. Abundance and diversity of planktonic rotifers in the Po River. *Hydrobiologia,* **186/187:** 201–208.

GALKOVSKAYA, G.A., 1987. Planktonic rotifers and temperature. *Hydrobiologia,* **147**:307-317.

GANNON, J. E. AND STEMBERGER, R.S., 1978. Zooplankton (especially crustaceans and rotifers) as indicator of water quality. *Trans. Am. microsc. Soc.*, **97**:16-35.

GARCIA, P.R., NANDINI, S., SARMA, S.S.S., ROBLES-VALDERRAMA, E., CUESTA, I. AND HURTADO, M.D., 2002. Seasonal variations of zooplankton abundance in the freshwater reservoir Valle de Bravo (Mexico). *Hydrobiologia,* **467**: 99–108.

HAQ, R., REHMAN, A. AND SHAKOORI, A. R., 2001. Survival, culturing, adaptation and metal resistance of various rotifers and a gastrotrich (Minor phyla) isolated from heavily polluted industrial effluents. *Pakistan J. Zool.*, **33**:247-253.

JAVED, M. AND HAYAT, S., 1996. Planktonic productivity of river water as a bioindicator of freshwater contamination by metals. *Proc. Pakistan Congr. Zool*., **16**:283-298.

KOSTE, W., 1978. *Rotatoria. Die Rädertiere Mitteleuropas*. Gebrüder Borntraeger. Berlin. Stuttgart. Bd. I & II.

LAIR, N., 2005. Abiotic vs biotic factors: lessons drawn from rotifers in the Middle Loire, a meandering river monitored from 1995 to 2002, during low flow periods. *Hydrobiologia,* **546**:457-472.

MAHAR, M. A., BALOCH, W. A. AND JAFRI, S. I. H., 2000. Diversity and seasonal occurrence of planktonic rotifers in Manchar Lake, Sindh, Pakistan. *Pakistan J. Fish.,* **1**:25-32.

MALIK, M. A. AND SULEHRIA, A. Q. K., 2003. Seasonal variation, density and diversity of planktonic rotifers in Jallo lake. *Biologia* (Pakistan), **49**: 77-88.

MALIK, M. A. AND SULEHRIA, A. Q. K., 2004. Seasonal variation, density and diversity of planktonic rotifers in the River Ravi. *Biologia* (Pakistan), **50**: 5-17.

MODENUTTI, B.E., 1998. Planktonic rotifers of Samborombón river Basin (Argentina). *Hydrobiologia,* **387/388**: 259-265.

NESCHUK N., CLAPS M. AND GABELLONE, N., 2002. Planktonic rotifers of a saline-lowland river: the Salado River (Argentina). *Ann. Limnol.-Int. J. Limnol*., **38**:191-198.

NEVES, I. F., ROCHA, O., ROCHE, K. F. AND PINTO, A. A., 2003. Zooplankton community structure of two marginal lakes of the River Cuiabá (Mato Grosso, Brazil) with analysis of Rotifera and Cladocera diversity. *Braz. J. Biol.,* **63**:329-343.

PACE, M.L., FINDLAY, S.E.G. AND LINTS, D., 1991. Zooplankton in advective environments: The Hudson river community and a comparative analysis. *Can. J. Fish. Aquat. Sci.,* **49**:1060-1069.

PARK, G. S. AND MARSHALL, H. G., 2000a. The trophic contributions of rotifers in tidal freshwater and esturine habitats. *Estu. Coast. Shel. Sci*., **51**:729-742.

PATNAIK, S., AYYAPPAN, S., SAHA, P. K., JENA, S. AND DAS, K. M., 1988. Plankton dynamics in freshwater nursery, rearing and stocking ponds. *The first Indian fisheries forum, Proceedings*. December 4-8, 1987. Mangalore, Karnatka. pp:17-20.

PEJLER, B. AND BĒRZIŅŠ, B., 1994. On the ecology of Lecane (Rotifera). *Hydrobiologia,* **273:** 77-80.

PEJLER, B., 1995. Relation to habitat in rotifers. *Hydrobiologia,* **313**: 267-278.

PENNAK, R. W., 1978. Fresh-Water Invertebrates of the United States. 2nd Ed. Wiley, New York. pp. 803.

POURRIOT, R., 1965. Recherches sur l´ecologie des Rotiferes. *Vie Milieu* (Suppl.)., **21**: 1-224.

RUTTNER-KOLLISKO, A., 1972. III. Rotatoria. Das zooplankton der Binnengewässer. *Die Binnengewässer*. **26**:99-234.

RUTTNER-KOLLISKO, A., 1974. Plankton rotifers: Biology and taxonomy. *Die Binnengewässer*, 26, Suppl., Schweizerbart, Suttgart. pp: 146.

SALER, S. AND SEN, D., 2002. Seasonal variation of Rotifera fauna of Cip Dam Lake (Elaziğ-Turkey). *Pakistan J. biol. Sci.,* **5**: 1274-1276.

SCHÖLL, K. AND KISS, A., 2008 Spatial and temporal distribution patterns of zooplankton assemblages (Rotifera, Cladocera, Copepoda) in the water bodies of the Gemenc floodplain (Duna-Dráva National Park, Hungary). *Opusc. Zool. Budapest*., **39**: 65-76.

SHARMA, B.K., 2000. Rotifers from some tropical flood-plain lakes of Assam (N.E. India). *Trop. Ecol.,* **41**:175-181.

TAMAS, G. AND HORVARTH, L., 1978. Growth of cyprinids under optimal zooplankton conditions. *Bamidgeh,* **28**: 50–56.

UNNI, K. S., 1986. Biological indicators of water pollution. *Abst. Inter*. Workshop on Surf. Water Mang. Bhopal, M.P.

WALLACE, R. L., 2002. Rotifers: exquisite metazoans. *Integr. Comp. Biol.,* **42**: 660-667.

WALLACE, R. L. AND SNELL, T. W., 2010. Rotifera. Chapter 8. In: *Ecology and classification of North American freshwater invertebrates* (eds. Thorp, J.H. and A.P. Covich). Elsevier. Oxford. pp. 173-235.

WALLACE, R. L., WALSH, E. J, SCHRÖDER, T. RICO-MARTINEZ AND RIOS-ARANA, J.V., 2008. Species composition and distribution of rotifers in Chihuahuan Desert waters of Mexico: is everything everywhere? *Verhandl. Int. Vereinin. Limnol.,* **30**: 73-76.

WARD, H. B. AND WHIPPLE, G. C., 1959. W. T. Edmondson 2nd ed. *Freshwater Biology*. John Wiley and Sons. New York.

WETZEL, R.G., 2001. Limnology: Lake and River Ecosystems. 3rd ed. Academic Press. pp: 1006.

ZIMMERMANN, H., 1997. The microbial community on aggregates in the Elbe Estuary. *Aquat. Micro. Eco.* **13**:37-46.

(Received 3 January 2011, revised 6 June 2011)