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Population Dynamics of Rotifers in the Floodplain of River Ravi, Pakistan

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ABSTRACT

The population dynamics of Rotifers of a flood plain ecosystem are supposed to change with mixing of flood water from riverine system, during floods. With respect to biodiversity, floodplain ecosystem remained ignored and no work has been done in Pakistan. With the aim to identify monthly changes in the population of rotifer communities in a flood plain, rotifers were estimated through studying the monthly variations of density and diversity of rotifers, from January to December 2012, in the floodplain of River Ravi near Balloki Headworks, Pakistan. A total of 101 species belonging to 32 genera, 15 families and 3 orders were identified from 15 different sites. Family Brachionidae dominated among all (56%) with the *Brachionus*, *Anuraeopsis* and *Keratella* being the most important genera in family Brachionidae. Rotifer density was highest from April to June 2012. Rotifer density showed a positive correlation with air and water temperature, pH, turbidity and total hardness and strong positive correlation with electrical conductivity, total dissolved solids (TDS) and total alkalinity. Similarly a negative correlation existed between rotifer density and visibility and chlorides and strong negative correlations with dissolved oxygen. Analysis of variance showed a significant difference in rotifers between different months and sites. Shannon diversity index (H) showed high species diversity in August and lowest diversity in November. Simpson index of dominance showed lowest diversity in November. Species richness was highest in August and lowest in April. Species evenness was highest in April and lowest in November. It is summarized that density of Rotifers remain highest during summer, when plenty of food is available where as diversity of Rotifers reaches to its maximum when riverine water, carries variety of Rotifers, mixes with the stagnant and isolated flood plain water.

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Authors' Contributions
AH collected samples, analyzed the data and wrote the article. AM helped in sampling and analysis of data. ME helped in sampling and writing of article. AQKS supervised the work.

Key words
Floodplains, rotifers, River Ravi, population dynamics.

INTRODUCTION

The water characteristics in aquatic environments are important to understand the different biochemical processes taking place in aquatic environment and population dynamics of zooplanktons. Relationship between physicochemical parameters of water and seasonal abundance of rotifers have been studied by Edward and Ugwumba (2010) and Saron and Meitei (2013). Mahar *et al*. (2000), Baloch *et al.* (2008), Sulehria and Malik (2012, 2013) and Lashari *et al*. (2014) have made valuable contributions in studying the relationship of physicochemical parameters of water with zooplankton concentrations in irrigated lake. Zooplankton are good indicators for the assessment of trophic state of water (Imoobe and Adekinka, 2010). Physico-chemical conditions of water body are supposed to determine the density and diversity of fauna and flora (Ayodele and Adeniyi, 2006; Abdul Razak *et al*., 2009).

Zooplanktons invariably form an integral component of freshwater communities and contribute significantly to biological productivity. Zooplanktons can also play an important role in food chain, indicating the presence or absence or in determining the population densities of certain fishes (Shinde *et al*., 2012). Population dynamics of zooplankton in fresh water reservoirs depend on a variety of factors. Bozkurt and Guven (2009) reported that abiotic factors such as dissolved oxygen, temperature and light influence the distribution of species. Shashikanth *et al.* (2008) focused on biotic factors (predation and competition) that can play a major role in seasonal variation of zooplankton species. Sellami *et al.* (2011) claimed that local factors *i.e*., predation and competition had a significant role on for change in community structure and species richness of zooplankton. Mustapha (2010) studied that concentration of nutrients, grazing pressure and reservoir hydrology were responsible for fluctuations in the density of plankton.

Imoobe (2012) held responsible flood during the rainy season for increased population density of zooplanktons. Nkwuda *et al.* (2013) hypothesized that floods could increase zooplankton species richness and reduce density. Neiff and Neiff (2003) observed that alterations of flood pulses were responsible for changing the structure and dynamics of the aquatic communities. Ward and Tockner (2001) concluded that flood change the water quality of lakes by mixing cool, nutrient and oxygen rich water. Okogwu and Ugwumba (2012)

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suggest that flood mixes the autochthonous materials in lake and extends its width and affected zooplankton community in floodplain. Lansac-Tôha *et al.* (2004) and Bonecker *et al*. (2005) argued the influence of the water level on the structure and dynamics of zooplanktons in the floodplains.

Gorski *et al*. (2013) observed that connectivity of floodplain habitats govern population dynamics of zooplanktons. Ward and Stanford (1995) observed that connectivity among the different floodplain environments affected the aquatic community structure, through allowing the exchange of fauna that increases productivity. They argued the interchange of micro-fauna between different environments responsible for increasing the productivity of the interconnected floodplains. Aoyagui and Bonecker (2004) argued that the connectivity favoured species richness than abundance. Loverde-Oliveira *et al.* (2009) and Fantin-Cruz *et al*. (2010, 2011) submitted that fluctuations in water level and temporary connectivity of the river channel with adjacent floodplain resulted in changing the spatial and temporal patterns of present communities.

Planktons are supposed to be a reliable tool to assess the pollution status of aquatic bodies. Any slight change in environmental conditions can lead to the change in plankton communities. Zooplanktons have long been used as pollution indicators (Webber *et al*., 2005), played an important role and served as bioindicators for understanding water pollution status (Contreras *et al*., 2009; Davies and Otene, 2009).

Pakistan floodplain ecosystems are poorly studied with respect to abundance and distribution of rotifers. These ecosystems, being situated in the tropics constitute a favourable habitat for species-rich communities. Only routine limnological surveys of rivers, lakes and in some fish ponds had been conducted and not from floodplains. The aims of this study were: i) to analyze the physicochemical parameters of water of a floodplain lake of river Ravi located in District Kasur, Pakistan; ii) to determine abundance and distribution of Rotifers community; iii) to investigate any correlation between physical and chemical parameters of water and rotifers abundance.

MATERIALS AND METHODS

Study area

The floodplain under study is situated on the River Ravi near Balloki Headworks in District Kasur, Pakistan. It is about 65 Km (42 miles) away from Lahore in south-west direction at Latitude: 31° 11' 25" North and Longitude: 73° 52' 40" East (Fig.1). The floodplain covers an area of about 8.6 square Km. The climate is tropical with a marked monsoonal season. Average atmospheric temperature ranges from a minimum of 5ºC in winter to a maximum of 50ºC in summer (Hussain *et al*., 2013). Average monthly mean rainfall ranges from 6.7mm to 199.6 mm (mean 52.01mm) with minimum in November and maximum in July, 2012 and humidity 70.40%. Water level varies in different months of the year, being lowest in winter (October to April) and highest in summer (July to August) every year.

Water sampling for physicochemical parameters

Monthly variations of physicochemical characteristics of water were studied from January to December, 2012. Samples were taken from surface, from 15 different sites between 9.0 A.M. to 5.0 P.M., usually, in 2nd but sometimes in the 3rd week of every month (Fig. 2). Three samples were collected from each sampling site (taking 45 samples in total). Atmospheric and water temperature (°C), pH, dissolved oxygen (mg/l), electrical conductivity (µS/cm), total dissolved solids (mg/l), turbidity (NTU) and transparency (cm) were measured on the spot with their respective meters. Secchi disc was used to measure transparency. For the determination of total alkalinity (mg/l), total hardness (mg/l), and chlorides (mg/l), water samples were taken in one litre sampling bottles and transported in ice container to the Laboratories at Govt. College University, Lahore, for further processing (APHA, 2005; Hach, 2003).

Plankton sampling

Plankton samples were taken on monthly basis using standard plankton net of mesh size 37µ (Wisconsin net). Three samples were collected from each sampling site (taking 45 samples in total). Sampling for zooplankton was carried out by horizontal towing of the net on a boat for about two meters, holding the net firmly in hand while sitting on boat. Sampled volume was calculated after Perry (2003). Samples were kept in 50 m1 plastic bottle and preserved in 4-5% formaldehyde solution (Koste, 1978).

Counting and identification of rotifers

Rotifers were counted in Sedgwick-Rafter counting chamber (AHPA, 1995) at 60-100x using an inverted Olympus microscope. Rotifers were identified on the basis of different morphological characters, size, shape and behavior of rotifers (Ward and Whipple, 1959; Koste, 1978, Pennak, 1978). Live organisms were also observed under the microscope, after staining with vital stain (1% neutral red), in order to study some of the internal features of the organisms. Photographs of specimens were taken with the help of microscope LEICA HC 50/50 microscope with 5 megapixel camera fitted on it, for identification of Rotifers.

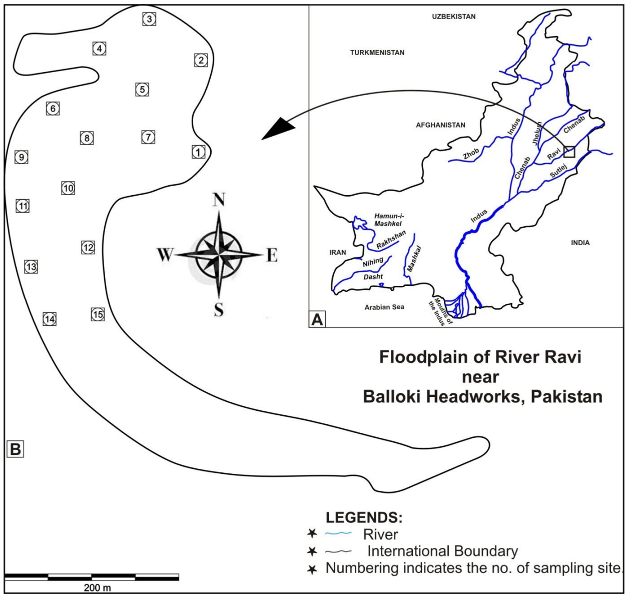

Fig. 1. Map of the study area; map of Pakistan (A), and map of floodplain under study (B).

Diversity indices

Shannon and Simpson diversity indices were calculated, (Shannon and Weaver, 1949, Simpson, 1949), Species richness (SR) was calculated after Margalef (1951) and Species evenness or equitability (E) was calculated after Pielou (1966), to study the abundance and distribution of species in the floodplain of river Ravi near Balloki Headwork's in Pakistan.

Statistical analysis

Different statistical techniques such as Analysis of variance (ANOVA) and Correlation matrix (Pearson's correlation), were used to investigate the significance level of Rotifer density and to find the relationship between rotifers and physicochemical parameters. Samples were collected from 15 different sites in each month. Three samples were taken from each sampling site so that ANOVA be applied. MINITAB 2013 and SPSS 16 (statistical package) programs were used to analyze the data.

RESULTS AND DISCUSSION

Seasonal variations of different physicochemical parameters observed during the whole period of study are shown in (Fig. 2). According to this atmospheric temperature was found maximum in April (40.32ºC) and minimum in January (16.62ºC). Water temperature was recorded maximum in July (33.8ºC) and minimum in December (14.15ºC). Present investigation revealed that air and water temperature followed almost similar pattern. It was mainly due to the seasonal and climatic variations in the region. Similar trend was studied by Caldwril (2003) and Kolo and Oladimeji (2004).

pH was found maximum in July (8.5) and minimum in December (6.8). The increase in pH in warm months might be due to the increase of carbonates, nitrates and phosphates ultimately resulting in eutrophication in summer. Similar findings had also been reported by Kamble *et al.* (2009). Sudden decrease in pH in August might be due to diluting effect of incoming colder water into the stagnant comparatively warmer water of flood plain. In the result of lowering of water temperature, production of $CaCO_3$ is decreased, resulting into lowering of pH. Where as in September, influx of flood water into stagnant floodplain water is reduced, which results in increase in pH in these months again. Araoye (2009) and Mustapha (2009) had also reported similar findings.

Dissolved oxygen was maximum in January (9.46 mg/L) and minimum in June (5.0 mg/L). Increase in oxygen concentration in July might be due to the stirring effect of rain influx of rain and flood water. Low concentration of oxygen in summer (from March to June) was due to the decreased solubility of oxygen during warmer months, Oxygen concentration increased in August due to stirring effect of incoming colder flood water. Similarly, higher concentration of oxygen during winter was due to increased solubility of oxygen during colder months, along with the stirring effect of rain and flood water in July and August. Similar observations, regarding increase or decrease of oxygen, in the result of rain or flood water and decrease or increase of water temperature during winter or summer, were recorded by Morrison *et al.* (2001) and Hussain *et al.* (2013).

Electrical conductivity and total dissolved solids were the highest in June (330 µS/cm) and the lowest in January (232.76 µS/cm). Increase in their values in summer was due to the evaporation factor resulting in decrease in total quantity of water (minimum water level in June *i.e*., 11 feet) and increased water level in August and September (maximum water level *i.e.*, 15 feet) was due to the dilution factor. These observations were in agreement with the findings of Mustapha (2009), Singh *et al*. (2010), Samal (2011) and Mirza *et al.* (2013).

Total dissolved solids were maximum in June (211.2 mg/L) and minimum in January (148.97 mg/L). Turbidity ranges from monthly mean values of 4.62 NTU to 63.7 NTU, being highest in July and the lowest in February. Visibility was the highest in December (150 cm) and the lowest in July (30.48 cm). Inverse relationship was observed between turbidity and

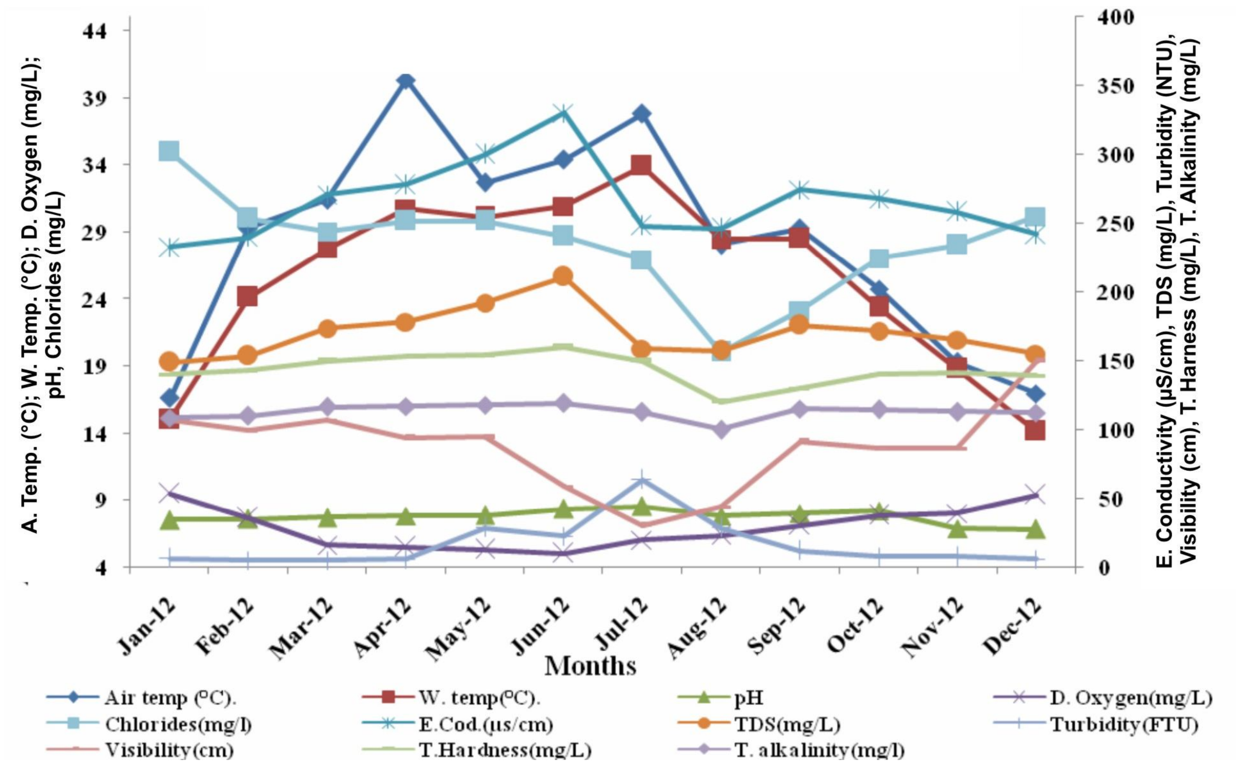

Fig. 2. Seasonal variations of different physicochemical parameters of water (atmospheric temperature (°C), water temperature (°C), pH, dissolved oxygen (mg/L), electrical conductivity (µS/cm), total dissolved solids (mg/L), turbidity (NTU), visibility (cm), total hardness (mg/L), total alkalinity (mg/L), chlorides (mg/L)), in floodplain of river Ravi, Pakistan, from January, 2012 to December, 2012.

visibility. Temporal behavior of turbidity and visibility was not noted. Mirza *et al.* (2013) and Khan and Chaudhury (1994) also recorded similar observations. Total hardness was recorded maximum in June (160 mg/L) and minimum in August (120 mg/L). Total alkalinity was found maximum in June (119 mg/L) and minimum in August (100 mg/L). Total hardness and total alkalinity also followed the same pattern and expresses no casual relationship. Concordant observations were also showed by Ratushnyak *et al.* (2006) and Park and Shin (2007). The values of chloride contents were the highest in January (34.93 mg/L) and the lowest in August (20 mg/L).

Monthly fluviometric level, measured during the period of studies and rainfall (mm), reported by Pakistan Metrological Department (PMD), are presented in Figure 3. Fluviometric level was recorded highest in August and September (15.0 feet) and minimum in June (11.0 feet). Similarly monthly rainfall was recorded highest in July (199.6 mm) and minimum in November (6.6 mm).

In the present study a total of 101 species of rotifers belonging to 32 genera and 15 families were identified (from January 2012 to December 2012) (Table I). Seasonal variations of rotifer density (Fig. 4) showed higher values from April to June, being maximum in June (1300 Ind./L). Rotifer density was the lowest in December and January (570 and 572). Similar results have been reported by Anderson *et al.* (2004), Mageed and Heikal (2006), Scholl and Kiss (2008), Sulehria *et al.* (2009a, 2009b, 2013), Sharma (2011), Nkwuda *et al.* (2013), Sulehria and Malik (2013) and Manckam *et al.* (2014).

Rotifer diversity also showed seasonal variation. Higher values occurred in August (40.0 species) and lower values from December to April (34.0 species) (Fig.5). Species diversity was higher from May to August anzd decreased from September to April. Higher diversity of rotifers from May to August might be attributed to the production of new species in summer and inflow of large amount of river water into the flood plain water during monsoon, which brought different types of riverine species. into the floodplain. An interesting observation was made between density and diversity of rotifers with respect to fluviometric level *i.e.*, higher diversity of

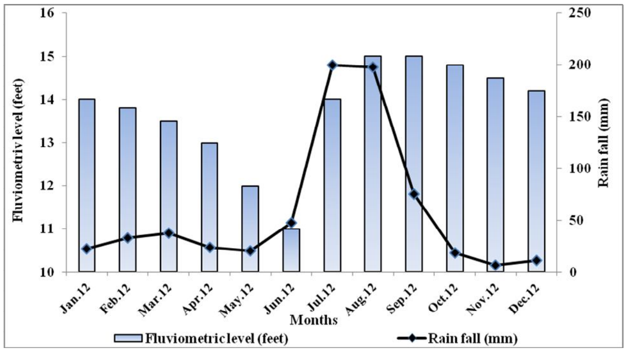

Fig. 3. Monthly variations of rain fall (mm) and fluviometric level (feet) in floodplains of River Ravi near Balloki Headworks, during January, 2012 to December, 2012.

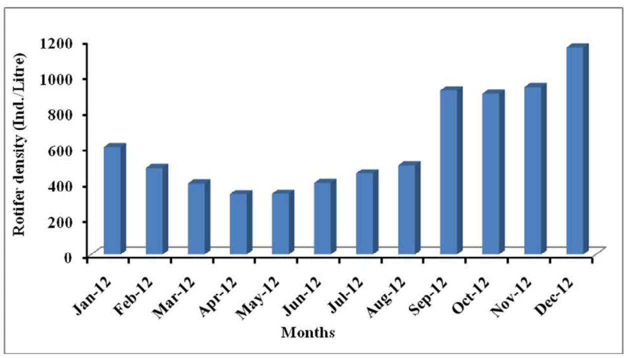

Fig. 4. Seasonal variation of rotifer density in floodplain of River Ravi, Pakistan, from January, 2012 to December, 2012.

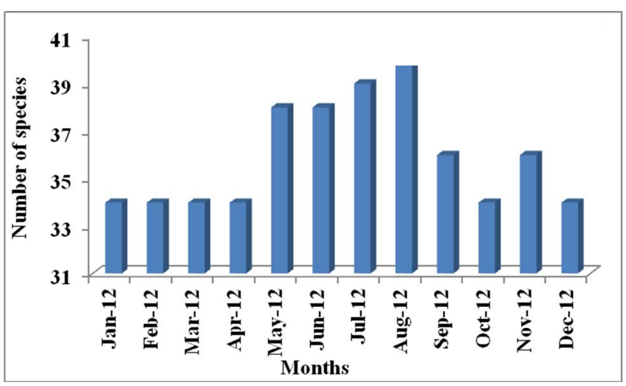

Fig. 5. Seasonal variation of species diversity of rotifers in floodplain of River Ravi, Pakistan, from January, 2012 to December, 2012.

rotifers was recorded during maximum floviometric level and vice versa. It could be due to the fine niche partitioning among zooplankton species in combination with the micro- and macro-habitat heterogeniceity as hypothesized by Segers (2008). Highest richness and diversity values at maximum fluviometric level were also observed by Hoberg *et al.* (2002); Lansac-Tôha *et al.* (2004): Aoyogui and Bonecker, (2004b) and Borges and Pedrozo (2009). Thomaz *et al.* (2007) had also justified the increasing rotifer diversity during increased river water level due to increased connectivity of the floodplain with river which increased the exchange of propaguules, nutrients and organisms among the habitats alongwith the decreased competition among species.

Pearson's Correlation matrix (Table II) was used to find correlation between rotifer density and different physicochemical parameters. According to this rotifer density was showed positive correlated with air temeperature (0.5539°C), water temperature (0.5759°C), pH (0.4277), electrical conductivity (0.9137 µS/cm), total dissolved solids (0.9137 mg/L), turbidity (0.1889 NTU), total hardness (0.5599 mg/L) and totall alkalinity (0.6648 mg/L) where as rotifers negatively correlated with dissolved oxygen (0.6893 mg/L), visibility (0.3301 cm) and chlorides (0.0921 mg/L).

According to ANOVA (Tables III, IV) there was a statistically (highly) significant difference (P=0.00) in number of rotifers among different groups *i.e*., months. Similarly there was a non-significant difference (P=0.00) in number of rotifers between different sites, (F=10.170 and different months (F=7.884).

Shannon diversity index (H) of the floodplain (mean calculated using all samples) ranged from 2.21 to 3.14 being lowest in November and highest in August respectively. Simpson index of dominance was lowest in April (0.06) and highest in November (0.17). Highest species diversity recorded in floodplain in August (40 species) is due to the mixing of river water with the floodplain water. River water brings with it the different species present in river, increasing the diversity of Rotifers in flood plain habitats. Similar observations have been recorded by Lansac-Tôha *et al*. (2004), Aoyogui and Bonecker, (2004b) and Borges and Pedrozo, (2009). The mean value of species richeness of all samples was highest in August (7.50) and lowest in April (6.00). High value of richness in August showed the highest food chain during August because in August connectivity of flood plain with river increases the exchange of water, minerals, sediments and other organisms between the two habitats. Similarly diluting effect in floodplain habitat reduces competition among different species, which ultimately improves the species diversity in that specific habitat. Species evenness was the highest in April (0.9) and the lowest in November (0.6) showing the even distribution of species in April (Fig.6).

Table I.- **List of Rotifer species collected from floodplains of River Ravi near Balloki Headwork's, Pakistan, from January, 2012 to December, 2012.**

Family / Genus	Species
1. Philodinidae	
1. *Philodina*	1. *Philodina roseola* Ehrenberg
	2. *Philodina megalotrocha* Ehrenberg
2. *Rotaria*	3. *Rotaria tridens* (Montet)
	4. *Rotaria neptunia* (Ehrenberg)
	5. *Rotaria rotatoria* (Pallas)
	6. *Rotaria haptica* (Gosse)
2. Branchionidae	
1. *Anuraeopsis*	7. *Anuraeopsis fissa* (Gosse)
	8. *Anuraeopsis navicula* Rousselet
	9. *Anuraeopsis coelata* (De Beauchamp)
2. *Brachionus*	10. *Brachionus bidentatus* Anderson
	11. *Brachionus leydigi* Cohn
	12. *Brachionus quadridentatus* Hermann
	13. *Brachionus falcatus* Zacharias
	14. *Brachionus plicatilis* (Muller)
	15. *Brachionus variabilis* (Hampel)
	16. *Brachionus calciflorus* Palls
	17. *Brachionus diversicornis* (Daday)
	18. *Brachionus forficula* Wierzejski
	19. *Brachionus angularis* Gosse
	20. *Brachionus dichotomus* Shephard
	21. *Brachionus caudatus* Barrois & Daday
3. *Euchlanis*	22. *Euchlanis dilatata* Ehrenberg
4. *Keratella*	23. *Keratella tropica* (Apstein)
	24. *Keratella valga* (Ehrenberg)
	25. *Keratella lenzi* Hauer
	26. *Keratella cochlearis* (Gosse)
	27. *Keratella tecta* (Lauterborn)
5. *Mytilina*	28. *Mytilina mucronata* (Muller)
6. *Notholca*	29. *Notholca acuminata* (Ehrenberg)
7. *Platyias*	30. *Platyias patulus* (Muller)
8. *Proalides*	31. *Proalides tentaculatus* de Beauchamp
9. *Colurella*	32. *Colurella uncinata* (Muller)
	33. *Colurella adriatica* Ehrenberg
10. *Lepadella*	34. *Lepadella patella* (Muller)
	35. *Lepadella triba* Myers
	36. *Lepadella latusinus* (Hilgendorf)
	37. *Lepadella vitrea* (Shephard)
	38. *Lepadella acuminata* Ehrenberg)
11. *Squatinella*	39. *Squatinella rostrum* (Schmarda)
3. Lecanidae	
1. *Lecane*	40. *Lecane pertica* Harring & Myres
	41. *Lecane luna* (Muller)
	42. *Lecane crepida* (Harring)
	43. *Lecane ungulata* (Gosse)
2. *Monostyla*	44. *Monostyla obtusa* Murray
	45. *Monostyla tethis* Harring & Myers
	46. *Monostyla elachis* Harring & Myers
	47. *Monostyla subulata* Harring & Myers
	48. *Monostyla cornuta* (Muller)
	49. *Monostyla bulla* Gosse
	50. *Monostyla lunaris* (Ehrenberg)
	52. *Monostyla closterocerca* Schmarda
	53. *Monostyla hamata* Stokes
4. Proalidae	
1. *Proales*	54. *Proales sordida* Gosse
5. Notommatidae	
1. *Cephalodella*	55. *Cephalodella gibba* (Ehrenberg)
	56. *Cephalodella steria* (Gosse)
	57. *Cephalodella auriculata* (Muller)
2. *Eosphora*	58. *Eosphora najas* Ehrenberg
3. *Monommata*	59. *Monommata grandis / Tessin* (Matchc shap?)
6. Lindiidae	
1. *Lindia*	60. *Lindia deridderi* koste
7. Trichocercidae	
1. *Trichocerca*	61. *Trichocerca vernalis* Hauer
	62. *Trichocerca collaris* (Rousselet)
	63. *Trichocerca rousseletti* (Voigt)
	64. *Trichocerca ruttneri* (Dnner)
	65. *Trichocerca branchyura* (Gosse)
	66. *Trichocerca cavia* (Gosse)
	67. *Trichocerca porcellus* (Gosse)
	68. *Trichocerca cylindrica* (Imhof)
	69. *Trichocerca bicristata* (Gosse)
	70. *Trichocerca similis* (Wierzejski)
	71. *Trichocerca elongata* (Gosse)
	72. *Trichocerca stylata* (Gosse)
	73. *Trichocerca pusilla* (Jennings)
8. Gastropidae	
1. *Ascomorpha*	74. *Ascomorpha ecaudis* Perty
	75. *Ascomorpha saltans* Bartsch
9. Asplanchnidae	
1. *Asplanchna*	76. *Asplanchna priodonta* Gosse
	77. *Asplanchna herricki* (De Guerne)
	78. *Asplanchna girodi* De Guerne
	79. *Asplanchna brightwelli* (Gosse)
10. Synchaetidae	
1. *Polyarthra*	80. *Polyarthra dolichoptera* Idelson
	81. *Polyarthra vulgaris* Carlin
	82. *Polyarthra minor* Voigt
	83. *Polyarthra remata* (Shorikov)
2. *Synchaeta*	84. *Synchaeta tremula* (Muller)
	85. *Synchaeta lakowitziana* Lucks
	86. *Synchaeta tavina* Hood
	87. *Synchaeta oblonga* Ehrenberg
	88. *Synchaeta litoralis* Rousselet
	89. *Synchaeta stylata* Wierzejski
	90. *Synchaeta longipes* gosse
	Synchaeta jollyi Shiel & Koste
11. Microcodonidae	
1. *Microcodon*	91. Microcodon sp.
12. Testudinellidae	
1. *Filinia*	92. *Filinia opoliensis* (Zacharias)
	93. *Filinia pejleri* Hutchinson
	94. *Filinia terminalis* Plate
	95. *Filinia passa* (Muller)
	96. *Filinia longiseta* (Ehrenberg)
2. *Testudinella*	97. *Testudinella patina* (Hermann 1783)
13. Hexarthridae	
1. *Hexarthra*	98. Hexarthra sp.
14. Floscülariidae	
1. *Beauchampia*	99. Beauchampia sp.
15. Colothecidae	
1. *Atrochus*	100. *Atrochus tentaculatus* Wierzejski
2. *Collotheca*	101. *Colotheca coronetta* Cubitt

Table II.- Pearson's correlation matrix of rotifer density and different physicochemical parameters in floodplain of river Ravi, Pakistan, from January, 2012 to December, 2012.

Variables	Rotifer density (Ind./L)	Air Temp. (°C).	Water Temp. (°C).	pH	Dissolved oxygen (mg/L)	Electrical Cod. (μS/cm)	TDS (mg/L)	Turbidity (NTU)	Visibility (cm)	Total hardness (mg/L)	Total alkalinity (mg/l)	Chlorides (mg/l)
Rotifer density (Ind./L)	**1**	0.55	0.58	0.43	**-0.69**	**0.91**	**0.91**	0.19	-0.33	0.56	**0.66**	-0.09
Air temperature (°C).	0.55	**1**	**0.95**	**0.71**	**-0.89**	0.52	0.51	0.47	-0.54	0.49	0.39	-0.24
Water temp. (°C).	0.57	**0.95**	**1**	**0.79**	**-0.92**	0.55	0.55	**0.60**	**-0.69**	0.33	0.29	-0.46
pH	0.43	**0.71**	**0.79**	**1**	**-0.62**	0.44	0.44	**0.59**	**-0.70**	0.26	0.23	-0.30
Dissolved oxygen (mg/L)	**-0.69**	**-0.89**	**-0.92**	**-0.63**	**1**	**-0.71**	**-0.71**	-0.44	0.56	-0.48	-0.41	0.32
Electrical Cod. (μS/cm)	**0.91**	0.52	0.55	0.44	**-0.71**	**1**	**1.00**	0.08	-0.20	**0.60**	**0.72**	-0.06
TDS (mg/L)	**0.91**	0.52	0.55	0.44	**-0.71**	**1.00**	**1**	0.08	-0.20	**0.60**	**0.72**	-0.06
Turbidity (NTU)	0.19	0.48	**0.60**	**0.59**	-0.44	0.08	0.078	**1**	**-0.76**	0.13	-0.08	-0.33
Visibility (cm)	-0.33	-0.54	**-0.69**	**-0.70**	0.56	-0.20	-0.20	**-0.76**	**1**	0.01	0.19	0.55
Total hardness (mg/L)	0.56	0.49	0.33	0.26	-0.48	**0.60**	**0.60**	0.13	0.01	**1**	**0.81**	**0.59**
Total alkalinity (mg/l)	**0.66**	0.39	0.29	0.23	-0.41	**0.72**	**0.72**	-0.08	0.19	**0.81**	**1**	0.36
Chlorides (mg/l)	-0.09	-0.24	-0.46	-0.30	0.32	-0.056	-0.06	-0.33	0.55	**0.59**	0.36	**1**

Values in bold are different from 0 with a significance level alpha=0.05

Table III.- Analysis of Variance of rotifers between different months in floodplain of river Ravi, Pakistan , from January 2012 to December 2012.

No.of rotifers	ANOVA				
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups (Months)	693142.515	11	63012.956	7.884	.000
Within Groups	1342779.062	168	7992.733		
Total	2035921.577	179			

Table IV.- Analysis of Variance of rotifers between different Sites in floodplain of river Ravi, Pakistan, from January, 2012 to December, 2012.

No.of rotifers	ANOVA				
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups (Months)	943046.406	14	67360.458	10.170	.000
Within Groups	1092875.170	165	6623.486		
Total	2035921.577	179			

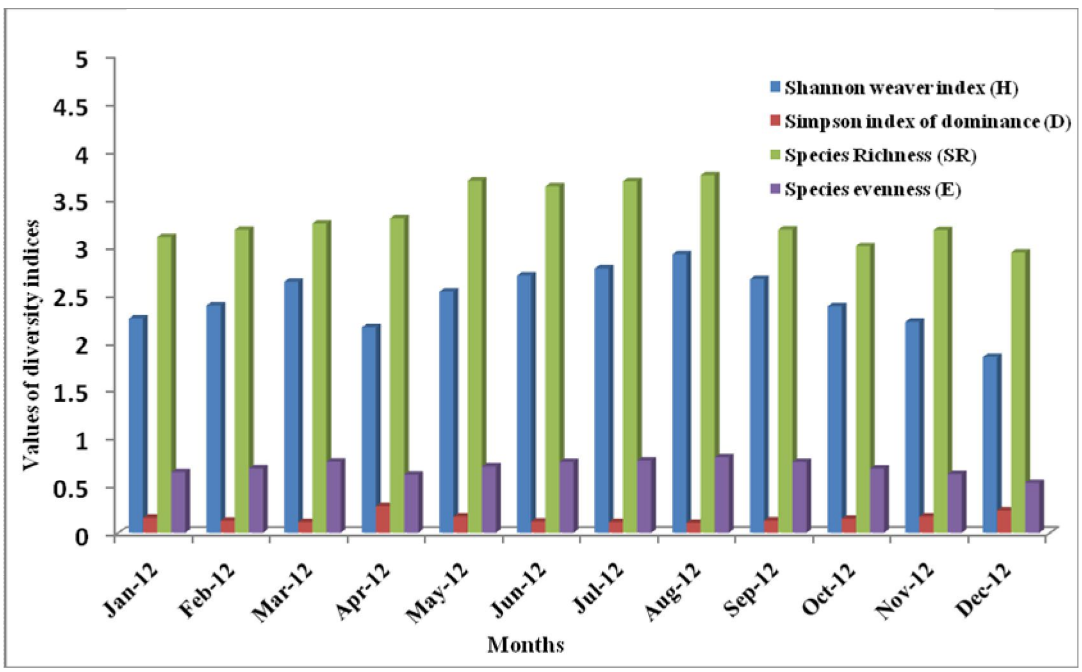

Fig. 6. Seasonal variation of diversity indices of rotifers in floodplain of River Ravi, Pakistan, from January, 2012 to December, 2012.

CONCLUSIONS

The greatest species density and diversity of rotifers was observed during warm months of the year *i.e.*, from May to August. It may be attributed to food availability, rapid reproduction rates and suitability of the physicochemical parameters of water such as water temperature, pH, turbidity, total hardness, electrical conductivity, total dissolved solids (TDS) and total alkalinity which were positively correlated with rotifer's abundance. High rotifer diversity during high fluviometric level, suggests the connectivity of the two habitats during flood seasons that favors the exchange of materials and organisms between two habitats which ultimately improves the food chain. A significant difference in rotifer density and diversity was found among different months and sites. Shannon diversity index (H) showed presence of high species diversity in the floodplain in August. Simpson index of dominance also supported this fact. Species richness was highest in August and lowest in April. Species evenness was highest in April and lowest in November. A more comprehensive study of floodplain is recommended as floodplains are rich in zooplanktons and are potential source of fish.

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Conflict of interest statement

Authors have declared no conflict of interest.

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