

## Diversity of rotifers (Rotifera, Eurotatoria) of Loktak lake, Manipur, North-eastern India

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**Abstract:** The rotifer communities of Loktak lake (a Ramsar site), Manipur, N.E. India, contain 120 species belonging to 36 genera and 19 families and represent the richest biodiversity of Phylum Rotifera known from any aquatic ecosystem of the Indian subcontinent. Biogeographically interesting elements include one Australasian, three Oriental and seven Palaeotropical species. Cosmopolitan species (69.2%) show higher richness while Cosmotropical > Pantropical species are well represented. The rotifer fauna is characterized by notable richness of Lecanidae > Lepadellidae > Trichocercidae > Brachionidae, general 'tropical character', occurrence of several acidophilic species, and a paucity of *Brachionus* spp. The richness (47-79; mean  $\pm$  SD 57 $\pm$ 10 species) follows multimodal pattern of monthly variations with a peak during winter. The rotifer communities have 52.3-80.6% temporal similarity, and show lack of seasonal periodicity of occurrence of different families. The Rotifera form an important quantitative component of zooplankton (45.8  $\pm$  8.1%), and have higher species diversity, lower dominance and higher evenness. Richness and density are inversely correlated with water, temperature, rainfall, hardness, nitrate, chloride and total dissolved solids and positively correlated with dissolved oxygen. In addition, richness is inversely correlated with pH.

**Resumen:** Las comunidades de rotíferos del lago Loktak (un sitio Ramsar), Manipur, NE de la India, contienen 120 especies pertenecientes a 36 géneros y 19 familias, y representan la biodiversidad más rica del Phylum Rotifera conocida de cualquier ecosistema acuático del subcontinente indio. Los elementos biogeográficamente interesantes incluyen una especie australasiática, tres orientales y siete paleotropicales. Las especies cosmopolitas (69.2%) mostraron un mayor riqueza, mientras que las especies cosmotropicales > pantropicales están bien representadas. La fauna de rotíferos está caracterizada por una riqueza notable de Lecanidae > Lepadellidae > Trichocercidae > Brachionidae, un 'carácter tropical' general, la presencia de varias especies acidófilas, y una escasez de *Brachionus* spp. La riqueza (47-79; media  $\pm$  DE 57  $\pm$  10 especies) sigue un patrón multimodal de variaciones mensuales con un pico durante el invierno. Las comunidades de rotíferos tienen una similitud temporal de 52.3 a 80.6 % y no muestran una periodicidad estacional en la presencia de diferentes familias. Los Rotifera forman un componente cuantitativo importante del zooplancton (45.8  $\pm$  8.1%) y tienen una diversidad de especies mayor, una dominancia menor y una mayor equitatividad. La riqueza y la densidad están inversamente correlacionadas con la temperatura del agua, la precipitación, la dureza, el nitrato, el cloruro y el total de sólidos disueltos, y correlacionadas positivamente con el oxígeno disuelto. Además, la riqueza está correlacionada inversamente con el pH.

**Resumo:** A comunidade de rotíferos do lago Loktak (uma estação Ramsar), Manipur, N.E. da Índia, contém 120 espécies pertencentes a 36 géneros e 19 famílias e representam a mais rica biodiversidade do filo Rotifera conhecida em qualquer ecossistema aquático no subcontinente indiano. Os elementos biogeograficamente interessantes incluem uma espécie da

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Australásia, três Orientais e sete Paleotropicals. As espécies cosmopolitas (69,2%) mostraram a riqueza mais elevada, enquanto as espécies Cosmotropicals > Pantropicals estão bem representadas. A fauna rotífera está caracterizada por uma riqueza notável de *Lecanidae* > *Lepadellidae* > *Trichocercidae* > *Brachionidae*, espécies tropicais de carácter geral, ocorrência de várias espécies acidófilas, e uma pobreza de *Brachionus* spp. A riqueza específica (47-79; média  $\pm$  SD 57 $\pm$ 10) segue um padrão multimodal de variação mensal com um pico durante o inverno. As comunidades de rotíferos têm uma semelhança temporal de 52,3-80,6%, e mostram uma falta de periodicidade sazonal quanto à ocorrência das diferentes famílias. Os rotíferos formam uma importante componente quantitativa do zooplâncton (45,8 $\pm$ 8,1%), e têm a mais alta diversidade específica, mais baixa dominância e maior equitabilidade. Riqueza e densidade estão inversamente correlacionadas com a temperatura da água, queda pluviométrica, dureza, nitratos, cloretos e sólidos totais dissolvidos e positivamente correlacionados com o oxigénio dissolvido. Adicionalmente, a riqueza está inversamente correlacionada com o pH.

**Key words:** Abundance, biodiversity, dominance, ecology, evenness, Ramsar site, Rotifera, species diversity.

## Introduction

Rotifera, an integral and important component of aquatic food-webs, have been documented from a wide variety of inland aquatic biotopes of India for more than a century, but there is currently limited information on their diversity in the Indian floodplain lakes in general (Sharma & Sharma 2005a, 2008). The studies on their diversity in “Ramsar sites”, or wetlands of international importance for conservation under the Ramsar convention, of this country are restricted to Deepor beel (Sharma & Sharma 2005b), one of the largest floodplain wetlands in the Brahmaputra basin of lower Assam (N. E. India).

The rotifer communities of Loktak Lake - a Ramsar site, an important floodplain wetland of South Asia, and one of the largest natural freshwater lakes of eastern India, therefore, has special biodiversity and ecological significance. This interesting floodplain lake has great biogenic, ecological and socio-economic importance and is under severe environmental stress (Tombi Singh & Shyamananda Singh 1994) because of human encroachment for agriculture and settlement, influx of waste waters, and serious habitat degradation. Attempts are being initiated for its management and biodiversity conservation. Ironically, so far very little is known about the micro-faunal diversity and ecology of this biodiversity ‘hot-spot’ in general and that of

Phylum Rotifera, an important group of the littoral and limnetic micro-invertebrates, in particular.

I conducted an investigation of the biodiversity of Rotifera of Loktak Lake with special reference to their nature and composition and biogeographically interesting elements. In addition, observations were made on temporal variations in species richness and abundance of the rotifers at a selected sampling site.

## Material and methods

The present study is a part of limnological survey undertaken (during November, 2002 - October, 2003) in Loktak Lake (Longitude: 93° 46' - 93° 55' E, latitude: 24° 25' - 24° 42' N; area: 286 km<sup>2</sup>; max. depth: 4.58 m, mean depth: 2.07 m; altitude: 768.5 m ASL) located in Bishnupur / Imphal districts of Manipur (N. E. India). This wetland is characterized by floating mats of vegetation called “Phumdi” which are inhabited by an endangered brow-antlered deer (*Cervus eldi eldi*). The common aquatic plants of this floodplain lake include *Eichhornia crassipes*, *Hydrilla verticellata*, *Euryale ferox*, *Vallisneria spiralis*, *Utricularia flexuosa*, *Trapa natans*, *Lemna trisula*, *Pistia striates*, *Salvinia* sp. *Nymphaea* spp., *Nymphoides* spp., *Nelumbo nucifera*, *Potamogeton* spp. and *Azolla pinnata*.

Qualitative plankton samples were collected seasonally from different parts of Loktak basin

(during November, 2002 - October, 2003) by towing a nylobolt plankton net (Mesh size: 50  $\mu\text{m}$ ). In addition, water samples and qualitative (by towing) and quantitative (by filtering 25 l of water) plankton samples were collected at regular monthly intervals, during the stated study period, at one sampling site at Sendra (Longitude: 93° 47' 45.61" E, latitude: 24° 30' 56.75" N). All the plankton samples were preserved in 5% formalin.

Water samples were analyzed for various abiotic factors following standard methods (APHA 1992) while water temperature, specific conductivity, pH and dissolved oxygen (DO) were recorded with field probes. Qualitative plankton samples were screened for rotifer species and quantitative collections were analyzed for their abundance. Species were identified following Kutikova (1970), Koste (1978), Segers (1995), Sharma (1998) and Sharma & Sharma (1999, 2000). Segers (2002) is followed for the recent system of nomenclature of Rotifera and remarks on the distribution are made using Segers (2007). Community similarities (Sorensen's index), species diversity (Shannon's index), dominance (Berger-Parker's index) and evenness (Pileou's index) were calculated following Ludwig & Reynolds (1988) and Magurran (1988).

## Results and discussion

### *Abiotic parameters*

Specific conductivity indicates low ionic concentration of Loktak (Table 1). Mean water temperature affirms sub-tropical range. Slightly acidic and soft waters of this floodplain wetland indicate moderate dissolved oxygen, low free CO<sub>2</sub>, low concentration of micro-nutrients (Table 1). In general, the ranges of the recorded abiotic factors are broadly similar with the results of Sharma & Sharma (2001) and Sharma (2005).

### *Rotifera composition and distribution*

One hundred twenty species of Rotifera belonging to 36 genera and 19 families (Table 2) recorded here from Loktak lake is the richest biodiversity of this Phylum known from any aquatic environment of the Indian subcontinent. The present results support the hypothesis of Segers *et al.* (1993) indicating (sub)tropical floodplains to be the world's richest habitats for rotifers. The rotifer richness of Loktak concurs reasonably with the reports of 124 species (Oguta lake) and 136 species

(Iyi-Efi lake) in the Niger delta (Segers *et al.* 1993) and, 130 species from Lake Guarana, Brazil (Bonecker *et al.* 1994). It also compares well with 114 taxa examined from Rio Pilcomayo National park (a Ramsar site), Formosa, Argentina (Jose de Paggi 2001).

**Table 1.** Results of the abiotic factors of Loktak lake (Nov. 2002 – Oct. 2003).

Abiotic factors	Range	Mean $\pm$ SD
Air temperature ( $^{\circ}\text{C}$ )	16.4-30.8	23.4 $\pm$ 4.1
Water temperature ( $^{\circ}\text{C}$ )	14.5-28.5	21.4 $\pm$ 4.0
Rainfall (mm)	0-370.4	112.1 $\pm$ 16.8
pH	6.01-6.74	6.38 $\pm$ 0.23
Specific conductivity ( $\mu\text{s cm}^{-1}$ )	75.0-132.0	98.9 $\pm$ 19.7
Dissolved Oxygen ( $\text{mg l}^{-1}$ )	4.6-9.0	6.2 $\pm$ 1.1
Free CO <sub>2</sub> ( $\text{mg l}^{-1}$ )	6.0-13.0	9.5 $\pm$ 2.1
Alkalinity ( $\text{mg l}^{-1}$ )	10.0-25.0	16.0 $\pm$ 4.4
Hardness ( $\text{mg l}^{-1}$ )	24.0-54.0	38.1 $\pm$ 8.2
Calcium ( $\text{mg l}^{-1}$ )	5.4-15.7	8.9 $\pm$ 3.0
Magnesium ( $\text{mg l}^{-1}$ )	2.0-6.4	4.3 $\pm$ 1.9
Sodium ( $\text{mg l}^{-1}$ )	0.6-7.4	4.7 $\pm$ 2.3
Potassium ( $\text{mg l}^{-1}$ )	2.0-9.2	5.8 $\pm$ 2.1
Phosphate ( $\text{mg l}^{-1}$ )	0.12-0.32	0.23 $\pm$ 0.12
Nitrate ( $\text{mg l}^{-1}$ )	0.27-0.42	0.34 $\pm$ 0.04
Sulphate ( $\text{mg l}^{-1}$ )	0.54-0.99	0.86 $\pm$ 0.12
Silicate ( $\text{mg l}^{-1}$ )	8.40-12.70	10.4 $\pm$ 1.2
Chloride ( $\text{mg l}^{-1}$ )	10.0-20.1	14.9 $\pm$ 3.1
Dissolved organic matter ( $\text{mg l}^{-1}$ )	0.91-2.1	1.38 $\pm$ 0.40
Total dissolved solids ( $\text{mg l}^{-1}$ )	0.20-0.81	0.46 $\pm$ 0.22

Biogeographically interesting elements (refer to Segers 2007) include the Australasian *Macrochaetus danneeli*, the Oriental *Lecane acanthinula*, *L. blachei* and *L. solfatara* and Palaeotropical species namely *Euchlanis semicarinata*, *Lecane lateralis*, *L. simonneae*, *L. unguitata*, *Lepadella bicornis*, *Testudinella brevicaudata* and *Trichocerca abiloi*. In addition, *Filinia camasecla*, an Oriental endemic, is now known for its single Neotropical report from Panama; the later is believed to be an example of its possible introduction (Segers *loc cit.*).

My collections include one new record from the Oriental region, six species new to India and three new to N. E. region of India; the systematic notes on these species are made separately by Sharma (2007). Among these, the report of *Euchlanis semicarinata* deserves special interest; this euchlanid is described originally from Africa and its distribution is now extended to the Oriental region (Sharma *loc cit.*). Besides, the present study extends the distributional ranges of *Lecane elegans*, *L. tenuiseta*, *Lepadella benjamini*, *Rotaria tardigrada*,

*Trichocerca insignis* and *T. tenuior* to the Indian subcontinent while *Ascomorpha ecaudis*, *Lepadella bicornis*, *Rotaria macroceros* and *Testudinella tridentata* are examples of regional distributional interest because of their restricted occurrence in India (Sharma *loc cit.*).

**Table 2.** Systematic list of Rotifera community of Loktak lake (India).

	Phylum	:	Rotifera	
	Super Class	:	Eurotatoria	
	Class	:	Monogononta	
	Order	:	Ploima	
Family : Brachionidae			<i>Squatinella mutica</i> (Ehrenberg 1832)	R
<i>Anuraeopsis fissa</i> Gosse 1851			Family : Lecanidae	
<i>Brachionus angularis</i> Gosse 1851			<i>Lecane acanthinula</i> (Hauer 1938)	R
<i>B. calyciflorus</i> Pallas 1766	P		<i>L. aculeata</i> (Jakubski 1912)	
<i>B. falcatus</i> Zacharias 1898			<i>L. blachei</i> Berzins 1973	
<i>B. mirabilis</i> Daday 1897	R		<i>L. bulla</i> (Gosse 1851)	P, C
<i>B. quadridentatus</i> Hermann 1783	C		<i>L. closteroerca</i> (Schmarda 1859)	
<i>Keratella cochlearis</i> (Gosse 1851)			<i>L. crepida</i> Harring 1914	
<i>K. tropica</i> (Apstein 1907)			<i>L. curvicornis</i> (Murray 1913)	C
<i>Platylabus quadricornis</i> (Ehrenberg 1832)	C		<i>L. doryssa</i> Harring 1914	Ac, R
<i>Platylabus patulus</i> (O.F. Müller 1786)	P, C		<i>L. elegans</i> Harring 1914	R
<i>P. patulus macracanthus</i> (Daday 1905)	Ac		<i>L. flexilis</i> (Gosse 1886)	
Family : Euchlanidae			<i>L. furcata</i> (Murray 1913)	
<i>Euchlanis dilatata</i> Ehrenberg 1832			<i>L. hamata</i> (Stokes 1896)	C
<i>E. semicarinata</i> Segers 1993	R		<i>L. hornemanni</i> (Ehrenberg 1834)	
<i>E. triquetra</i> Ehrenberg 1838	Ac		<i>L. inermis</i> (Bryce 1892)	
<i>Dipleuchlanis. propatula</i> (Gosse 1886)	Ac		<i>L. inopinata</i> Harring & Myers 1926	
<i>Beauchampiella eudactylota</i> (Gosse 1886)			<i>L. lateralis</i> Sharma 1978	
Family : Mytilinidae			<i>L. leontina</i> (Turner 1892)	P, C
<i>Lophocharis salpina</i> (Ehrenberg 1834)	R		<i>L. ludwigii</i> (Eckstein 1883)	
<i>Mytilina bisulcata</i> (Lucks 1912)	Ac		<i>L. luna</i> (O.F. Müller 1776)	C
<i>M. ventralis</i> (Ehrenberg 1830)	C		<i>L. lunaris</i> (Ehrenberg 1832)	P, C
Family : Trichotriidae			<i>L. monostyla</i> (Daday 1897)	R
<i>Macrochaetus danneeli</i> Koste & Shiel 1983	R		<i>L. obtusa</i> (Murray 1913)	R
<i>M. longipes</i> Myers 1934			<i>L. ohioensis</i> (Herrick 1885)	
<i>M. sericus</i> (Thorpe 1893)	P		<i>L. papuana</i> (Murray 1913)	C
<i>Trichotria tetractis</i> (Ehrenberg 1830)	P, C		<i>L. ploenensis</i> (Voigt 1902)	
Family : Lepadellidae			<i>L. quadridentata</i> (Ehrenberg 1830)	C
<i>Colurella obtusa</i> (Gosse 1886)			<i>L. ruttneri</i> Hauer 1938	R
<i>C. sulcata</i> (Stenroos 1898)	Ac		<i>L. signifera</i> (Jennings 1896)	Ac
<i>C. uncinata</i> (O. F. Müller 1773)	C		<i>L. simonneae</i> Segers 1993	R
<i>Lepadella acuminata</i> (Ehrenberg 1834)	Ac		<i>L. solfatara</i> (Hauer 1938)	R
<i>L. apsicora</i> Myers 1934			<i>L. stenroosi</i> (Meissner 1908)	
<i>L. apsidea</i> Harring 1916			<i>L. tenuiseta</i> Harring 1914	R
<i>L. benjamini</i> Harring 1916			<i>L. unguiseta</i> (Fadeev 1925)	P, C
<i>L. bicornis</i> Vasisht & Battish 1971	R		<i>L. unguiseta</i> (Gosse 1887)	C
<i>L. costatooides</i> Segers 1992	R		Family : Notommatidae	
<i>L. dactyliseta</i> (Stenroos 1898)	R		<i>Cephalodella forficula</i> (Ehrenberg 1830)	
<i>L. eurysterma</i> Myers 1942			<i>C. gibba</i> (Ehrenberg 1830)	
<i>L. ehrenbergi</i> (Perty 1850)			<i>C. mucronata</i> Myers 1924	R
<i>L. heterostyla</i> (Murray 1913)			<i>Monommata longiseta</i> (O.F. Müller 1786)	Ac
<i>L. lindau</i> Koste 1981	R		<i>M. maculata</i> Harring & Myers 1930	Ac
<i>L. ovalis</i> (O.F. Müller 1786)	P, C		<i>Monommata</i> sp.	
<i>L. patella</i> (O.F. Müller 1773)	P, C		<i>Notommata spinata</i> Koste & Shiel 1991	R
<i>L. rhomboides</i> (Gosse 1886)				
<i>L. triptera</i> Ehrenberg 1832				

Contd...

Table 2. Continued

Family: Scaridiidae		<i>Floscularia ringens</i> (Linnaeus 1758)	
<i>Scaridium longicaudum</i> (O.F. Müller 1786)		<i>Sinantherina spinosa</i> (Thorpe 1893)	
Family : Gastropodidae		<i>S. socialis</i> (Linnaeus 1758)	
<i>Ascomorpha ecaudis</i> Perty 1850	R	Family : Conochilidae	
Family : Trichocercidae		<i>Conochilus unicornis</i> Rousselet 1892	R
<i>Trichocerca abilioi</i> Segers & Sarma 1993	R	Family : Trochosphaeridae	
<i>T. bicristata</i> (Gosse 1887)		<i>Filinia brachiata</i> (Rousselet 1901)	R
<i>T. cylindrica</i> (Imhof 1891)		<i>F. camasecla</i> Myers 1938	
<i>T. elongata</i> (Schrank 1802)		<i>F. longiseta</i> (Ehrenberg 1834)	
<i>T. flagellata</i> Hauer 1938	R	<i>F. opoliensis</i> (Zacharias 1898)	R
<i>T. insignis</i> (Herrick 1885)		<i>F. saltator</i> (Gosse 1886)	R
<i>T. jenningsi</i> Voigt 1957		Family : Testudinellidae	
<i>T. longiseta</i> (Schrank 1802)		<i>Testudinella brevicaudata</i> Yamamoto 1951	
<i>T. rattus</i> (O.F. Müller 1776)	P, C	<i>T. emarginula</i> (Stenroos 1898)	Ac
<i>T. similis</i> (Wierzejski 1893)	C	<i>T. parva</i> (Ternetz 1892)	
<i>T. tenuior</i> (Gosse 1886)		<i>T. patina</i> (Hermann 1783)	P, C
Family : Asplanchnidae		<i>T. tridentata</i> Smirnov 1931	R
<i>Asplanchna priodonta</i> Gosse 1850	P, C	Class : Bdelloidea	
Family : Synchaetidae		Order : Philodinida	
<i>Pleosomea lenticulare</i> Herrick 1855	R	Family : Habrotrochidae	
<i>Polyarthra vulgaris</i> Carlin 1943	P, C	<i>Habrotrocha angusticollis</i> (Murray 1905)	R
<i>Synchaeta pectinata</i> Ehrenberg 1832	R	Family : Philodinidae	
Family : Dicranophoridae		<i>Philodina citrina</i> Ehrenberg 1832	
<i>Dicranophoroides caudatus</i> (Ehrenberg 1834)		<i>Rotaria macroceros</i> (Gosse, 1851)	
<i>Dicranophorus forcipatus</i> (O.F. Müller 1786)		<i>R. neptunia</i> (Ehrenberg 1830)	
Order : Flosculariaceae		<i>R. tardigrada</i> (Ehrenberg 1832)	R
Family : Flosculariidae			

Ac - Acidophilic species; P - Perennial species; C - Common species; R - Rare species

The species known from Loktak lake comprise a notable fraction of the rotifer fauna of Northeastern India (58.8%) and form 31.7% of the Indian Rotifera. The rotifers (120 species) comprise the most important group of the zooplankton composition (212 total species) and present a significant departure of only 14 species (including some doubtful taxa) listed in an unpublished earlier report from this wetland (Shyamananda Singh 1991). The present study even exceeds the earlier highest Indian report of 110 species (Sharma & Sharma 2005b) from Deepor beel, a Ramsar site and another important floodplain lake of Northeastern India as well as the record of 103 species (Sharma 2005) from the Dighali beel, Assam (N.E. India). The rotifer richness of Loktak is significantly higher than the reports of 29 species from four beels (Goswami 1997), 48 species from 33 beels (Sarma 2000) and 54 species from five beels (Sharma 2000b) of Assam state. Besides, it is contrastingly higher than the reports of only 11 species from two floodplain lakes of Kashmir (Khan

1987) as well as 37 species from two Ox-bow lakes (Khan 2002) and, 38 species from nine floodplain lakes (Khan 2003) of South-eastern West Bengal.

Lecanidae (34 species) > Lepadellidae (19 species) > Trichocercidae (11 species) > Brachionidae (10 species) form notable fractions (61.6%) of the Rotifera at Loktak lake. The relative importance of these families broadly corresponds with the results in floodplain lakes of South America (Bonecker *et al.* 1994, 1998; Lansac-Toha *et al.* 1997), Argentina (Jose de Paggi 1993, 2001), Africa (Segers *et al.* 1993), Bolivia (Segers *et al.* 1998) and Thailand (Sanoamuang 1998). The rotifer communities of Loktak lake are, however, characterized by notably low richness of the Brachionidae and that of *Brachionus* in particular, restricted occurrence of *Filinia* spp. and *Conochilus* and, lack of individuals of *Pompholyx*, *Hexarthra* and *Trochosphaera*. These salient features are in contrast to the composition of Rotifera of Deepor beel (another Ramsar site) as well as of other floodplain lakes of Assam state of

Northeastern India (Sharma & Sharma 2008). In addition, Notommatidae > Euchlanidae = Trochosphaeridae = Testudinellidae form a notable component (18.3%) of the species recorded in this study.

Cosmopolitan species (69.2%) show higher richness while Cosmotropical (11.7%) > Pantropical (10.0%) together form an important component. The stated features along with dominance of 'tropic-centered' genus *Lecane* (28.3%, 34 species) impart a general 'tropical character' to the rotifer fauna of Loktak; this generalization concurs with the composition of the tropical faunas from different parts of the globe (Dussart *et al.* 1984; Fernando 1980; Green 1972; Pejler 1977; Segers 1996, 2001). The notable paucity and restricted occurrence of species of another important 'tropic-centered' genus *Brachionus* (4.2%, 5 species), in turn, may be attributed to slightly acidic nature of Loktak waters. This possibility is well supported by occurrence of eleven acidophilic species (Koste 1978; Sharma 2005) in Loktak (Table 2). Besides, fourteen species (11.7%) can be termed as perennial species (Table 2) in the examined collections, twenty-three species (19.2%) indicate common occurrence while thirty-two species (26.7%) show rare occurrence.

A distinct dominance of the periphytic rotifers (90.0%) and occurrence of fewer planktonic species in Loktak lake certainly indicates lack of definite pelagic habitats (De Manuel 1994) due to excessive growth of aquatic macrophytes and shallow nature of this wetland. In addition, frequent occurrence of both planktonic and non-planktonic species in the littoral zone of the sampled wetland with marginal vegetation affirms occupation of different niches as hypothesized by Bonecker *et al.* (1998). Loktak Rotifera are characterized by occurrence of large number of small-sized species which may be attributed to conditions of low concentrations of food (Papinski 1990) and predation by juvenile fish and invertebrates (Baumgartner *et al.* 1997) though specific observations are desired to confirm these hypotheses.

#### *Rotifer community similarities*

The rotifer communities of Loktak exhibit 52.3-80.6% temporal similarity. The majority of the instances (53.0%) included in the matrix (Table 3) exhibit similarity between > 60-70%. Peak similarity is noted between the samples collected in autumn (November) and late-monsoon (September) while a minima is noticed between winter (December) *vs.* spring (March). The greater

differences in Rotifera composition between February-May and again between June-July are apparently due to fewer species of Lecanidae and Trichocercidae.

#### *Rotifera richness*

The rotifers comprise an important component of the zooplankton in Loktak lake throughout the study period (Fig. 1) and contribute significantly to temporal variations of zooplanktonic richness ( $r=0.989$ ). The richness records notable monthly variations (47-79,  $57 \pm 10$  species) and follows a multimodal pattern (Fig. 1) with peak during winter (December), minima during monsoon (July) and higher values during October-December. Lecanidae, Lepadellidae, Trichocercidae and Brachionidae contribute (Fig. 2) primarily to (59.4-76.4,  $66.9 \pm 5.0\%$ ) to monthly variations of the rotifer richness and show multimodal periodicity while Lecanidae (14-26,  $19 \pm 4$  species) strongly influence (Fig. 2) the pattern of temporal variations in richness. In general, the rotifer communities of Loktak lack seasonal periodicity of occurrence of different families.

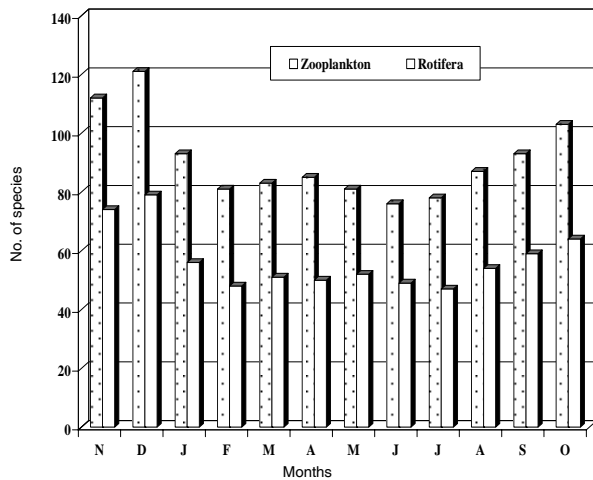
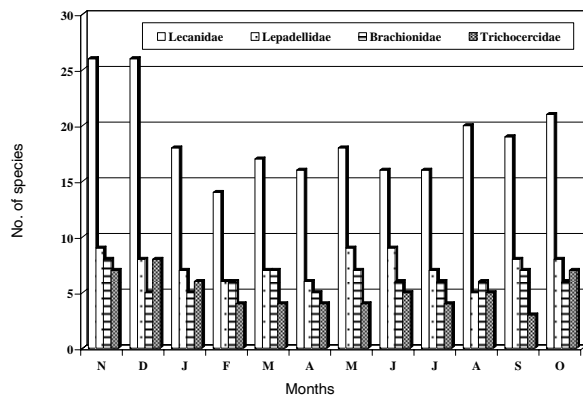
Higher rotifer richness observed during October-December is supported by a significant inverse correlation with water temperature ( $r = -0.434$ ). The richness is also inversely correlated with rainfall ( $r = -0.539$ ), pH ( $r = -0.549$ ), hardness ( $r = -0.620$ ), nitrate ( $r = -0.611$ ), chloride ( $r = -0.713$ ) and total dissolved solids  $r = (-0.553)$  and is positively correlated with dissolved oxygen ( $r = 0.571$ ).

#### *Rotifera abundance, dominance and species diversity*

The rotifer abundance ranges between 84-157 ( $113 \pm 23$ ) n/l during the study period. This group forms an important quantitative component (45.8  $\pm$  8.1%) of zooplankton ( $246 \pm 35$  n/l) and contributes significantly ( $r = 0.924$ ) to their temporal variations; the observed features broadly concur with the results from floodplain lakes of Assam (Sharma 2000a, 2005; Sharma & Sharma 2008). The rotifer density follows multimodal periodicity but exhibits maxima during November-December and minima during June; the former aspect is supported by a significant inverse correlation with water temperature ( $r = -0.483$ ). Further, the density is inversely correlated with rainfall ( $r = -0.566$ ), hardness ( $r = -0.824$ ), nitrate ( $r = -0.617$ ), chloride ( $r = -0.810$ ) and total dissolved solids ( $r = -0.740$ ) and registers positive correlation with dissolved oxygen ( $r = 0.463$ ).

**Table 3.** Percentage similarities (Sorenson's index) between Rotifer communities.

Months	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct
November	–	71.9	69.2	59.6	64.0	61.3	69.8	68.3	62.8	75.0	80.6	73.9
December		–	71.1	59.8	52.3	57.4	61.1	59.4	60.3	64.7	66.7	70.7
January			–	73.1	57.9	56.7	65.4	68.6	75.7	67.3	66.1	73.3
February				–	72.7	59.2	60.0	63.9	61.0	68.6	61.7	67.9
March					–	67.3	58.2	58.0	63.3	67.9	61.8	62.6
April						–	74.5	52.5	55.7	55.8	62.4	64.9
May							–	67.3	54.5	58.5	63.1	72.2
June								–	66.7	62.1	59.3	67.3
July									–	65.3	54.7	61.3
August										–	74.3	69.5
September											–	65.0
October												–

**Fig. 1.** Species richness of Zooplankton and Rotifera in Loktak lake.**Fig. 2.** Species richness of dominant families of Rotifera in Loktak lake.

The rotifer communities of Loktak are characterized by high species diversity (3.372-

4.257,  $3.766 \pm 0.263$ ) compared to other regional floodplain lakes (Sharma 2000a, 2005; Sharma & Sharma 2008). The peak diversity observed during December corresponds with peak richness and density while lowest diversity noticed during May shows no such clear trend. In general, the species diversity records direct correlation with richness ( $r = 0.666$ ) and abundance ( $r = 0.490$ ). The notable feature of higher species diversity with relatively lower numbers (density) of a large number of species noticed in the present study may be ascribed to fine niche partitioning amongst rotifers species in combination with high micro- and macro-scale habitat heterogeneity, especially in littoral environments as suggested by Segers (2008). Specific observations are, however, desired to support this hypothesis.

The present results record higher evenness (0.858-0.990,  $0.940 \pm 0.043$ ), lower dominance (0.093-0.189,  $0.137 \pm 0.019$ ) of Rotifera and show an inverse correlation between the two parameters. The generalizations on higher evenness and lower dominance concur with the results of Sharma (2005) and Sharma & Sharma (2008), and appear to be salient features of the rotifer communities of the lentic ecosystems of Northeastern India.

## Conclusions

Loktak Lake exhibits rich and diversified Rotifera taxocoenosis dominated by littoral-periphytonic monogonont species. The occurrence of various biogeographically interesting elements, acidophilic species and paucity of *Brachionus* spp. are noteworthy. The rotifers form an important qualitative and quantitative component of zooplankton and, are characterized by higher species diversity, higher evenness and lower

dominance than in other regional flood plain lakes. Studies on the rotifer associations with diverse aquatic macrophytes present in this Ramsar site merit special future interest. The impact of invertebrate and vertebrate predation on the nature and composition, community structure and abundance of the rotifers as well as their role in aquatic productivity requires investigations in this unique and interesting wetland.

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