Rotifera diversity of a floodplain lake of the Brahmaputra river basin of lower Assam, Northeast India

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Abstract. This study analyzed diversity and ecology of planktonic Rotifera of Ghorajan beel, a floodplain lake of the Brahmaputra river basin of lower Assam region of Northeast India. Plankton samples collected (January–December, 2010) from littoral (station 1) and semi-limnetic regions (station 2) of this tropical wetland revealed a fairly rich rotifer fauna (84 and 80 species) with distinct variations (range, average ± SD) in monthly richness (35–55, 46±6 and 24–54, 36±5 species) and community similarities (46.6–80.4 and 37.0–95.9 %) at both sampling stations. The richness followed unclear annual patterns. The rotifers mainly contributed (53.3±5.1 and 55.6± 3.6 %) to zooplankton abundance variations and showed high abundance from June through November at both stations. Brachionidae > Lecanidae exhibited high number of individuals; Asplanchnidae and Flosculariidae were also quantitatively important families; specifically, *Asplanchna priodonta, Sinantherina socialis, Brachionus falcatus* and *Lecane bulla* were important species for their abundance. Single abiotic factors exerted a more limited influence on richness than on abundance. Canonical correspondence analysis (CCA) explained 55.6 % and 59.5 % cumulative variance of the rotifer assemblages along axis 1 and 2, respectively; the CCA indicated the importance of transparency and rainfall at station 1, and of transparency, dissolved oxygen and rainfall at station 2. Consequently, the littoral and semi-limnetic stations are characterized by micro-environmental differences.

Keywords. Abundance, Assam, diversity indices, ecology, richness, tropical wetland.

INTRODUCTION

Rotifera, an important component of the littoral and limnetic invertebrate communities and an integral link of aquatic food-webs, have been studied from varied freshwater environments in different parts of India since more than one century. Ironically, few noteworthy investigations exist up to date on freshwater ecology in the Indian floodplain lakes in general and on diversity and ecology rotifers of these ecotones in particular (Sharma & Sharma, 2008). The related studies on the floodplain lakes ('beels' or 'pats') of northeast India concern rotifer diversity of two beels of Assam (Sharma, 2000, 2010) while Sharma (2009) deals with their ecology in Loktak Pat of Manipur.

The present study on Rotifera diversity of Ghorajan Beel, a floodplain lake of the Brahmaputra river basin of lower Assam, assumes interest in light of paucity of studies from India. The rotifer communities were sampled qualitatively and quantitatively at two sampling stations to observe spatial and temporal variations in species richness, community similarities, abundance, species diversity, dominance and evenness during the study period. In addition, the influence of various abiotic parameters on richness and abundance of Rotifera was investigated to examine ecological relationships.

MATERIALS AND METHODS

This study was undertaken during January–December 2010 in Ghorajan Beel (91° 41' 25" E, 26° 09'26" N; area: 117 ha) located along NH 31 in the Kamrup district of lower Assam (Northeast India). Various aquatic macrophytes of this floodplain lake included *Azolla pinnata, Eichhornia crassipes, Hydrilla verticillata, Hygrorhiza aristata, Ipomea fistulosa, Lemna* sp., *Najas indica, Polygonum hydropiper, Vallisneria spiralis* and *Utricularia flexuosa.*

Water samples were collected monthly at two study sites i.e., station 1 (littoral) and station 2 (semi-limnetic), and analyzed for nineteen abiotic factors (Table 1). Water temperature, specific conductivity and pH were recorded by field probes,

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transparency was noted with Secchi disc, dissolved oxygen was estimated by the Winkler's method and other parameters were analyzed following APHA (1992). The qualitative (by towing) and quantitative (by filtering 25 L water each) plankton samples were collected monthly from both the sampling stations by nylobolt plankton net (mesh size 50 μm) and preserved in 5% formalin. The former were screened for the rotifer species and the latter were analyzed for their abundance (ind. L^{-1}). Rotifera species were identified following Koste (1978), Segers (1995), Sharma (1998) and Sharma & Sharma (1999, 2000, 2008).

The diversity indices, namely community similarities (Sørensen index), species diversity (Shannon index), dominance (Berger-Parker index) and evenness (Pielou index) were calculated following Ludwig & Reynolds (1988) and Magurran (1988). The significance of differences in variations of biotic parameters was ascertained by two-way ANOVA. The hierarchical cluster analysis, based on Sørensen similarities, was done using SPSS (version 11.0) to examine the monthly rotifer community groupings. Ecological relationships between abiotic and biotic parameters were determined by simple correlation coefficients (Pearson r_1 and r_2, respectively) for each sampling station; their P values were calculated *vide* http://faculty.vassar.edu/lowry/tabs.html and significance was ascertained after use of Bonferroni correction. Canonical correspondence analysis (CCA) (ECOM II: version 2.1.3.137, PISCES Conservation Ltd. 2007) was used to elucidate the relationships between the rotifer assemblages and their abiotic environment.

Table 1. Temporal variations in abiotic parameters

	Station 1		**Station 2**	
Factors	Range	Average ± SD	Range	Average ± SD
Water temperature ^{0}C	19.7 – 33.2	27.8 ± 4.0	20.2 – 32.7	27.9 ± 3.7
Rainfall mm	4.8 – 365.0	150.4. ± 145.7	4.8 – 365.0	150.4 ± 145.7
Transparency cm	16.0 – 76.0	52.7 ± 20.5	17.0 – 79.0	55.4 ± 21.2
pH	6.72 – 7.16	6.95 ± 0.12	6.75 – 7.12	6.94 ± 0.11
Specific conductivity μS cm^{-1}	99.0 – 193.0	137.8 ± 30.0	108.0 – 190.0	136.9 ± 27.8
Dissolved oxygen mg L^{-1}	4.0 – 8.0	6.5 ± 1.2	4.0 – 8.2	6.1 ± 1.4
Free carbon dioxide mg L^{-1}	4.0 – 30.0	11.3 ± 7.0	2.0 – 28.9	10.9 ± 6.8
Alkalinity mg L^{-1}	50.0 – 84.0	64.8 ±10.0	52.0 – 81.0	66.3 ± 9.4
Hardness mg L^{-1}	48.0 – 68.0	56.8 ± 75.1	46.0 – 70.0	57.3 ± 7.8
Calcium mg L^{-1}	24.1 – 42.4	35.1 ± 5.9	25.7 – 47.3	34.5 ± 5.8
Magnesium mg L^{-1}	0.9 – 7.5	4.9 ± 2.2	0.8 – 7.5	5.3 ± 2.1
Chloride mg L^{-1}	18.9 – 42.9	28.5 ± 6.4	16.9 – 43.9	27.5 ± 6.8
Dissolved organic matter mg L^{-1}	0.9 – 3.8	2.66 ± 0.87	0.8 – 3.8	2.38 ± 0.80
Total dissolved solids mg L^{-1}	1.1 – 2.9	1.97 ± 0.52	1.1 – 2.9	2.01 ± 0.50
Phosphate mg L^{-1}	0.095 – 0.351	0.171 ± 0.083	0.099 – 0.341	0.170 ± 0.077
Sulphate mg L^{-1}	6.3 – 30.3	15.52 ± 7.41	6.8 – 26.3	14.43 ± 6.23
Nitrate mg L^{-1}	0.272 – 1.548	1.011 ± 0.375	0.268 – 1.521	1.016 ± 0.373
Silicate mg L^{-1}	0.599 – 2.657	1.687 ± 0.692	0.543 – 2.704	1.710 ± 0.700
$B.O.D_5$ mg L^{-1}	1.6 – 4.4	2.72 ± 0.70	1.4 – 4.8	2.63 ± 0.86

RESULTS

The variations observed in abiotic parameters in littoral (station 1) and semi-limnetic (station 2) regions of Ghorajan Beel are indicated in Table 1. Water temperature ranged between 19.7–33.2 °C, rainfall between 4.8–365.0 mm, transparency between 16.0–79.0 cm, pH between 6.72–7.15, specific conductivity between 99.0–193.0 µS cm^{-1}, dissolved oxygen between 4.0–8.2 mg L^{-1}, free CO_2 between 2.0-30.0 mg L^{-1}, alkalinity 50.0–84.0 mg L^{-1}, hardness between 46.0–70.0 mg L^{-1}, calcium between 24.1–47.3 mg L^{-1} and magnesium between 0.8–7.5 mg L^{-1}. Chloride content varied between 16.9–43.9 mg L^{-1}, dissolved organic matter varied between 0.8-3.8 mg L^{-1}, total dissolved solids ranged between 1.1–2.9 mg L^{-1}, BOD_5 varied between 1.4–4.8 mg L^{-1}, while concentrations of phosphate, sulphate, nitrate and silicate ranged between 0.095–0.351 mg L^{-1}, 6.3–30.3 mg L^{-1}, 0.268–1.548 mg L^{-1} and 0.543–2.704 mg L^{-1}, respectively during the study period (Table 1).

The occurrence and abundance of Rotifera species observed are indicated in Appendices I and II while their variations (annual ranges and average ± SD) are summarized in Table 2. This study revealed a total of 85 Rotifera species (Table 2) with 46 ± 6 and 36 ± 5 species, and 46.6–80.4% and 37.0–95.9% community similarities (Sørensen index) at station 1 and station 2 respectively (Tables 3–4). The monthly variations in species richness are shown in Fig. 1. Annual variations in the hierarchical cluster analysis of zooplankton, based on their community similarity values (*vide* Sørensen index) are indicated in Figs. 2–3. The rotifers (185 ± 45 ind. L^{-1}, 180 ± 58 ind. L^{-1}) comprised 53.3 ± 5.1 % and 55.6 ± 3.6 %) of total zooplankton abundance in littoral (station 1) and semi-limnetic (station 2) regions respectively (Table 2). Brachionidae (53 ± 10 ind. L^{-1}, 45 ± 13 ind. L^{-1}), Lecanidae (39 ± 13 ind. L^{-1}, 39 ± 14 ind. L^{-1}), Asplanchnidae (20 ± 11 ind. L^{-1}, 18 ± 10 ind. L^{-1}) and Synchaetidae (16 ± 10 ind. L^{-1}, 18± 11 ind. L^{-1}) were important families of Rotifera at the two sampling stations; these were followed by Synchaetidae and Trichocercidae. In addition, quantitatively important genera and species are indicated in Table 2. The monthly variations in abundance of Rotifera and that of two important families namely Lecanidae and Brachionidae are shown in Figs. 4–5. The species diversity of rotifers (Table 2) ranged between 3.442 ± 0.115 and 3.491 ± 0.131 and its monthly variations are shown in Fig. 6. In addition, their dominance ranged between 0.110 ± 0.026 and 0.110 ± 0.032 while evenness varied between 0.901 ± 0.033 and 0.957 ± 0.067 in littoral (station 1) and semi-limnetic (station2) regions respectively (Table 2). Canonical correspondence analysis (CCA) explained 55.6 % and 59.5 % cumulative variance of the rotifer assemblages along axis 1 and 2 at stations 1 and 2, respectively (Table 5). The CCA indicated the importance of transparency and rainfall at station 1 (Fig. 7), and of transparency, dissolved oxygen and rainfall at station 2 (Fig. 8).

DISCUSSION

Abiotic parameters

The circum-neutral and marginally hard waters of Ghorajan Beel showed concentrations of Ca > Mg and are characterized by low ionic concentrations; this last feature warranted its inclusion under 'Class I' category of trophic classification *vide* Talling & Talling (1965). Mean water temperature affirmed the tropical range concurrent with the geographical location of this wetland. Concomitantly, moderate concentrations of dissolved oxygen, low free CO_2; low chloride content and low concentrations of micro-nutrients and other parameters are recorded throughout. The annual ranges of various abiotic factors showed small insignificant differences between stations 1 and 2.

Species richness, community similarities and abundance

The present report of a total of 85 species, belonging to 18 families and 28 genera, indicates a fairly high faunal diversity of Rotifera and reflects

Table 2. Temporal variations of Rotifera (range, average ± SD)

Parameters ↓ Stations →	Station 1		Station 2	
Species richness				
Zooplankton 145 species	143 species		138 species	
Monthly richness	57 - 97	81 ± 11	48 - 89	72 ± 11
Rotifera 85 species	84 species		80 species	
Monthly richness	35- 55	46 ± 6	24 - 52	36 ± 5
Community similarity %	46.6-80.4		37.0-95.9	
Quantitative				
Zooplankton ind. L^{-1}	188 - 496	354 ± 103	154 - 456	342 ± 111
Rotifera ind. L^{-1}	111 - 242	185 ± 45	92 - 245	180 ± 58
% composition	42.8 – 62.2	53.3 ± 5.1	49.2 – 60.5	55.6 ± 3.6
Species Diversity	3.222 – 3.583	3.442 ± 0.115	3.275 – 3.712	3.491 ± 0.131
Dominance	0.061 – 0.151	0.110 ± 0.026	0.049 – 0.137	0.110 ± 0.032
Evenness	0.865 – 0.968	0.901 ± 0.033	0.834 – 1.084	0.957 ± 0.067
Important Families				
Brachionidae ind. L^{-1}	40-70	53 ± 10	22-60	45 ± 13
Lecanidae ind. L^{-1}	22-61	39 ± 13	22-61	39 ± 14
Asplanchnidae ind. L^{-1}	2-40	20 ± 11	0-34	18 ± 10
Flosculariidae ind. L^{-1}	1-39	16 ± 10	2-42	18± 11
Synchaetidae ind. L^{-1}	4-20	11 ± 4	2-18	9 ± 4
Trichocercidae ind. L^{-1}	3-16	10 ± 3	2-14	9± 3
Important genera				
Lecane ind. L^{-1}	22-61	39 ± 12	22-61	39 ± 14
Brachionus ind. L^{-1}	15-31	26 ± 5	7-35	22 ± 7
Sinantherina ind. L^{-1}	1-39	16 ± 10	2-42	18± 11
Keratella ind. L^{-1}	5-27	15 ± 6	7-21	10 ± 4
Trichocerca ind. L^{-1}	3-16	10 ± 3	2-13	8 ± 3
Important species				
Asplanchna priodonta ind. L^{-1}	0-32	22 ± 6	0-30	19 ± 10
Sinantherina socialis ind. L^{-1}	0-20	11 ± 7	0-20	10 ± 9
Brachionus falcatus ind. L^{-1}	5-25	14 ± 7	0-19	8 ± 7
Polyarthra vulgaris ind. L^{-1}	4-20	11 ± 4	2-18	9 ± 4
Lecane bulla ind. L^{-1}	1- 23	11 ± 6	0-23	8 ± 6

Table 3. Percentage Rotifera community similarity after Sørensen's index between months (Station 1)

Months	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Jan.	-	67.4	63.3	50.0	64.1	60.7	73.8	70.3	61.2	66.0	64.0	74.7
Feb.		-	63.4	60.2	61.7	65.2	75.9	63.8	67.3	80.4	62.4	77.1
March			-	52.2	57.8	59.4	58.3	64.1	60.0	64.1	60.8	62.9
April				-	63.9	50.6	69.2	64.1	67.4	63.6	66.7	69.0
May					-	61.7	68.4	67.5	55.6	74.4	48.8	70.9
June						-	66.7	57.4	61.4	63.9	68.8	64.6
July							-	69.7	58.3	69.6	54.5	70.3
Aug.								-	46.6	68.7	61.0	69.4
Sept.									-	52.8	62.7	66.7
Oct.										-	55.1	71.3
Nov.											-	59.8
Dec												-

Table 4. Percentage Rotifera community similarity after Sørensen's index between months (Station 2)

Months	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Jan.	-	70.0	95.9	59.3	38.5	67.6	53.7	81.7	77.5	74.3	92.1	70.1
Feb.		-	87.7	70.4	48.1	67.6	76.6	81.7	82.5	88.6	69.8	80.5
March			-	68.7	41.8	76.2	67.4	88.1	90.3	81.9	76.3	77.8
April				-	52.8	40.0	63.1	64.6	75.7	75.0	73.7	70.4
May					-	42.7	40.0	47.2	40.8	51.0	37.0	62.6
June						-	53.8	63.4	65.9	74.1	75.1	59.1
July							-	62.4	56.9	63.0	51.8	62.6
Aug.								-	54.9	74.1	78.4	72.7
Sept.									-	57.8	67.5	78.3
Oct.										-	57.5	78.2
Nov.											-	57.5
Dec												-

the general environmental heterogeneity of Ghorajan Beel. Rotifers are the main component of total zooplankton richness (145 species) and signifycantly influence its temporal variations ($r_1 = 0.922$, P <0.001; r_2 = 0.938, P <0.001, respectively). High rotifer richness concurs with the reports of Sharma (2000, 2005, 2009, 2010), Sharma & Sharma (2001, 2008) and Khan (2002). The rotifer richness of Ghorajan Beel is similar to the range of 69-93 species recorded from 15 beels of Assam (Sharma & Sharma, 2008) while it is relatively lower than that of Deepor Beel (110 species; Sharma & Sharma, 2005) and Loktak Lake (120 species; Sharma, 2009), two Ramsar sites and important floodplain lakes of Northeast India. Nevertheless, the richness is notably higher than the reports of 48 species from 37 beels (Sharma, 2000), 64 species from twelve beels of the Pobitora Wildlife Sanctuary (Sharma, 2006) of Assam and it presented a distinct contrast to the reports of only 27 species from two floodplain lakes of Kashmir (Khan 1987) and 38 species from four ox-bow lakes and nine floodplain lakes of South-eastern West Bengal (Khan, 2003). We caution against over-emphasis of such comparisons in view of inadequate sampling or incomplete species inventories of several previous Indian works. The rotifer richness of Ghorajan Beel is, however, lower that the reports of 124 species (Oguta Lake) and 136 species (Iyi-Efi Lake) in the Niger delta (Segers et al., 1993); the 130 species from Lake Guarana, Brazil (Bonecker et al*.*, 1994) and the 114 taxa reported from Rio Pilcomayo National park, Formosa, Argentina (Jose de Paggi, 2001). The differences can probably be attributed to the planktonic nature of our collections.

We observe 84 Rotifera species at station 1 and 80 species at station 2; rotifer communities of both sampling stations showed a high similarity (96.3%). In contrast, five species namely *Anuraeopsis coelata, Euchlanis triquetra, Lecane furcata, L. inermis* and *L. lateralis* occurred only at station 1,while only *Dicranophorus forcipatus* is reported at station 2. The monthly rotifer richness varies between 35-55 (46 ± 6) and 24-52 (36 ± 5) species, and shows irregular annual patterns with peaks during March and July and minima during summer (May and April) at both stations respectively, with significant temporal variations between stations ($F_{1, 23}$ = 5.239, P = 0.043). Mean annual rotifer richness of Ghorajan Beel is lower than that of Loktak Pat (Sharma, 2009) and Deepor Beel (Sharma, 2010) while monthly trends differ distinctly from the latter two sites in the periods of peak richness and patterns of variations.

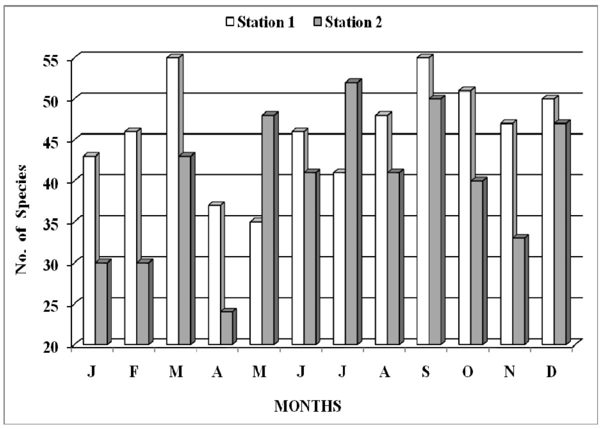

Figure 1. Monthly variations in species richness of Rotifera

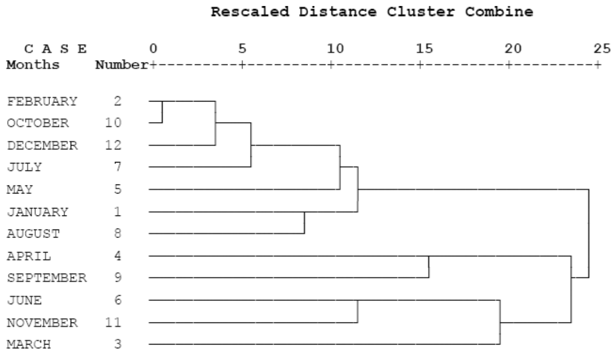

Figure 2. Hierarchical cluster analysis for Rotifera (Station 1)

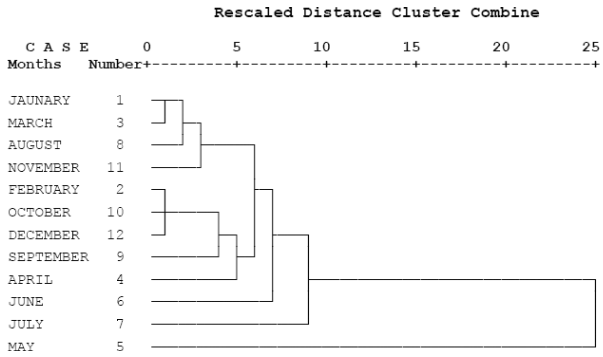

Figure 3. Hierarchical cluster analysis for Rotifera (Station 2)

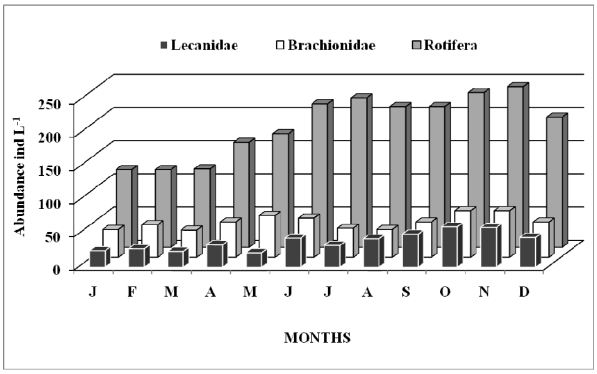

Figure 4. Monthly variations in abundance (ind. L^{-1}) of Rotifera and dominant families (Station 1)

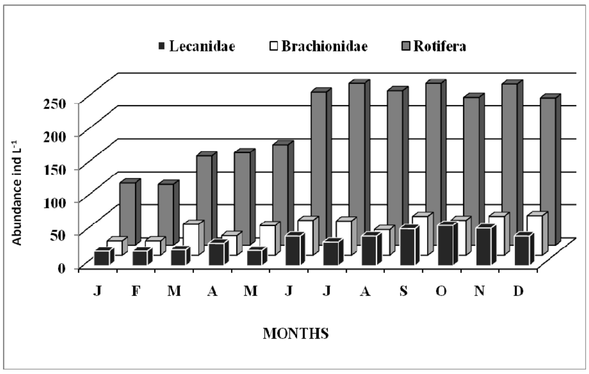

Figure 5. Monthly variations in abundance (ind. L^{-1}) of Rotifera and dominant families (Station 2)

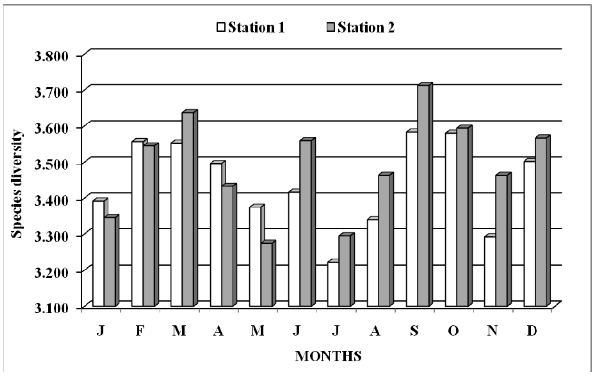

Figure 6. Monthly variations in species diversity of Rotifera

According to the Sørensen index, rotifer communities showed 46.6–80.4 % similarity between months at Station 1 but record a wider range (37.0–95.9 %) at Station 2 and moreover indicated wide variations in the monthly rotifer community composition. Furthermore at station 1 and station 2, community similarity between months in the range of 50–70 % and 50–80 %, respectively, occurred in the majority of instances (80.3% and 84.8%, respectively). At both stations, highest rotifer similarities are recorded between February–October and January–March. Cluster analysis indicates more heterogeneity of the monthly groupings at station 1 in general than at station 2. Our results at station 1 show a higher affinity between February–October while the April, September, June, November and March communities differ distinctly from the rest of the months, with maximum divergence in the June and March samplings. On the other hand, high affinities at station 2 are noticed between January–March and again between February–October–December samples while May and July communities exhibit the greatest divergence in their composition.

Rotifera abundance (annual ranges and average ± SD) exhibits less difference (111–242, 185±45 ind. L^{-1} at station 1 and 92–245, 180±58 ind. L^{-1} at station 2); this is supported by insignificant temporal variations between stations while abundance varied significantly between months ($F_{11, 23}$ = 24.927, P < 0.001). The rotifers represent more than 50% of the total number of individuals in the zooplankton and contribute significantly to variations in zooplankton abundance at both stations. This finding concurs with the results of Khan (1987), Sanjer & Sharma (1995), Sharma & Sharma (2001, 2008) and Sharma (2005, 2006) but differs from the findings of Baruah *et al*. (1993), Sharma (2000) and Khan (2002) who noted higher abundances for Copepoda. In general, rotifer abundance in Ghorajan beel is higher than that of Loktak Pat (Sharma, 2009) and other wetlands (Yadava *et al.* 1987; Baruah *et al.* 1993; Sharma 2000, 2005; Sharma & Sharma 2008), while it is lower than that of Deepor Beel (Sharma, 2010).

Our results show broadly concurrent annual rotifer density variations at both sampling stations and high abundances (< 200 ind. L^{-1}) from June through November, lacking any distinct maximum. This is in contrast to annual patterns with winter maxima observed in Deepor Beel (Sharma 2010) and Loktak Pat (Sharma, 2009). Our results are also in contrast to summer maxima reported from the beels of Assam (Yadava *et al.*, 1987), Bihar (Baruah *et al.,* 1993, Sanjer & Sharma, 1995). The present study shows a lack of any definite pattern of quantitative variations of the loricate or illoricate rotifers and thus corroborates the results of Sharma (1992, 2009, 2010).

Species diversity, dominance and evenness

Our results are characterized by a high species diversity (3.442±0.115 and 3.491±0.131) and, hence, reflecting high rotifer heterogeneity. The species diversity recorded limited differences between both stations and showed an irregular annual pattern with maxima during September and minima during July at both sampling stations. The present findings are broadly in accord with mean diversity values and multimodal annual patterns reported from Loktak Lake (Sharma, 2009) and Deepor Beel (Sharma, 2010) but differ from these wetlands in the periods of maxima and minima. The higher diversities observed in this study with respect to the reports of Sharma (2000, 2005, 2006) can be attributed to a higher species richness and abundance. In general, the salient feature of high species diversity with relatively low densities for the majority of species in our samplings can be ascribed to fine niche partitioning amongst species, in combination with high micro- and macro-scale habitat heterogeneity as hypothesized by Segers (2008) and affirmed by Sharma (2009, 2010).

The high rotifer evenness (0.867 ± 0.046 and 0.872 ± 0.035), another salient feature of this study, affirms the equitable abundance of various species and, in turn, concurs with our findings for the floodplain lakes of Assam (Sharma, 2005, 2010; Sharma & Sharma, 2008) and Manipur (Sharma, 2009). The evenness follows multimodal but different annual patterns at the two sampling stations and is inversely correlated with rotifer richness (r_2 = -0.870, P = 0.0002) only at station 2. The rotifer communities exhibit low dominance (0.125 ± 0.037 and 0.133 ± 0.039). This feature concurs with our reports from certain beels of Assam (Sharma, 2005, 2006, 2010) and from Loktak Pat (Sharma, 2009). The dominance follows indefinite but broadly concurrent annual patterns with peaks during January and February at Stations 1 and 2 respectively. Only at station 2, species dominance correlates negatively with species diversity (r_2 = -0.633, P < 0.02).

Important taxa

Of the eighteen families of Eurotatoria represented in our samples, the members of six families collectively contribute notably (station 1: 149±37 ind. L^{-1} and station 2: 137±43 ind. L^{-1}) to the rotifer abundance at both sampling stations. These families determined patterns of total Rotifera with low mean abundance from January–May. Abundance of Brachionidae (station 1: 53±10 ind. L^{-1} and station 2: 45±12 ind. L^{-1}) is higher than that of Lecanidae (station 1: 39±12 ind. L^{-1} and station 2: 39±14 ind. L^{-1}) and notably influenced rotifer abundance during the study period; this result is in contrast to the reports of Sharma (2000, 2006, 2010). Besides, Asplanchnidae (18±10 ind. L^{-1}) and Floscularidae (18 ±10 ind. L^{-1}) show certain quantitative importance while Synchaetidae and Trichocercidae also deserve mention. Of the stated families, ANOVA recorded significant density variations of Brachionidae ($F_{1, 23}$ = 4.833, P = 0.050), Asplanchnidae ($F_{1, 23}$ = 9.512, P = 0.010) and Synchaetidae ($F_{1, 23}$ = 8.693, P = 0.013) between the sampling stations.

Abundance of two 'tropic-centered' genera, *Lecane* (39±12 ind. L^{-1} and 39±14 ind. L^{-1}) > *Brachionus* (26±5 ind. L^{-1} and 22±7 ind. L^{-1}) is observed; this feature agrees broadly with results of Sharma (2006, 2009) and Sharma & Sharma (2008) while it is in contrast to dominance of *Brachionus* reported by Sharma (2010). In spite of the report of 85 rotifer species from Ghorajan Beel, only five species, namely *Asplanchna priodonta* > *Sinantherina socialis* > *Brachionus falcatus* > *Polyarthra vulgaris* and *Lecane bulla,* are relatively important. Our samples show low abundance of majority of species and lack of definite quantitative periodicity of any family, genera or species. This salient feature concurs with the results of Sharma (2009, 2010).

Ecological relationships

Our results indicate a more limiting influence of individual abiotic parameters on rotifer richness than on abundance; the former correlated positively only with nitrate (r_2 = 0.645, P = 0.023) at station 2. Rotifer abundance correlated positively with sulphate (r_1 = 647, P = 0.023, r_2 = 0.847, P = 0.0005), nitrate (r_1 = 0.795, P = 0.002; r_2 = 0.858, P = 0.0004) and silicate (r_1 = 0.778, P = 0.003; r_2 = 0.679, P = 0.003) at both stations; and only with alkalinity (r_2 = 0.663, P = 0.019) at station 2. CCA explained high (55.6 % and 59.5 %) cumulative variance of the rotifer assemblages along axis 1 and 2 respectively. Furthermore, CCA showed (Fig. 7) the importance of transparency, rainfall, CO_2 and conductivity at station 1 (littoral region) for higher abundances of rotifer taxa. Rotifer richness, species diversity and evenness, and the abundance of Brachionidae, *Brachionus* and *Keratella* are influenced by higher transparency; abundance of Rotifera, Lecanidae and Brachionidae and to a certain extend of Filiniidae and *Polyarthra vulgaris* are influenced by lower DO and transparency; *Brachionus falcatus* and rotifer dominance are influenced by water temperature and conductivity while the abundance of Synchaetidae and Asplanchnidae is influenced by lower rainfall and lower free CO_2 at station 1. Transparency, DO, rainfall, conductivity and free CO_2 are important at station 2. Abundance of Rotifera, Lecanidae, Floscularidae and *Keratella* is influenced by higher dissolved oxygen; richness and species diversity of Rotifera, abundance of Brachionidae and *Brachionus* are influenced by higher conductivity; and richness, species diversity and evenness is influenced by rainfall and conductivity at station 2. In addition, abundance of Synchaetidae is influenced by lower alkalinity at station 2. The stated differences reflect micro-environmental differences amongst the sampling stations.

CONCLUSIONS

The fairly species rich planktonic Rotifera of Ghorajan Beel formed important qualitative and quantitative components of zooplankton. Our observations reveal a relative quantitative importance of fewer species, low abundance of majority of species, high species diversity, high evenness and low dominance. The results suggest a more limited influence of individual abiotic factors on rotifer richness than on their abundance. CCA with ten abiotic factors explained 55.6 % and 59.5 % cumulative variance of the rotifer assemblages along axis 1 and 2. This study is a useful contribution to diversity and ecology of Rotifera in tropical floodplains in general the Indian floodplain lakes in particular.

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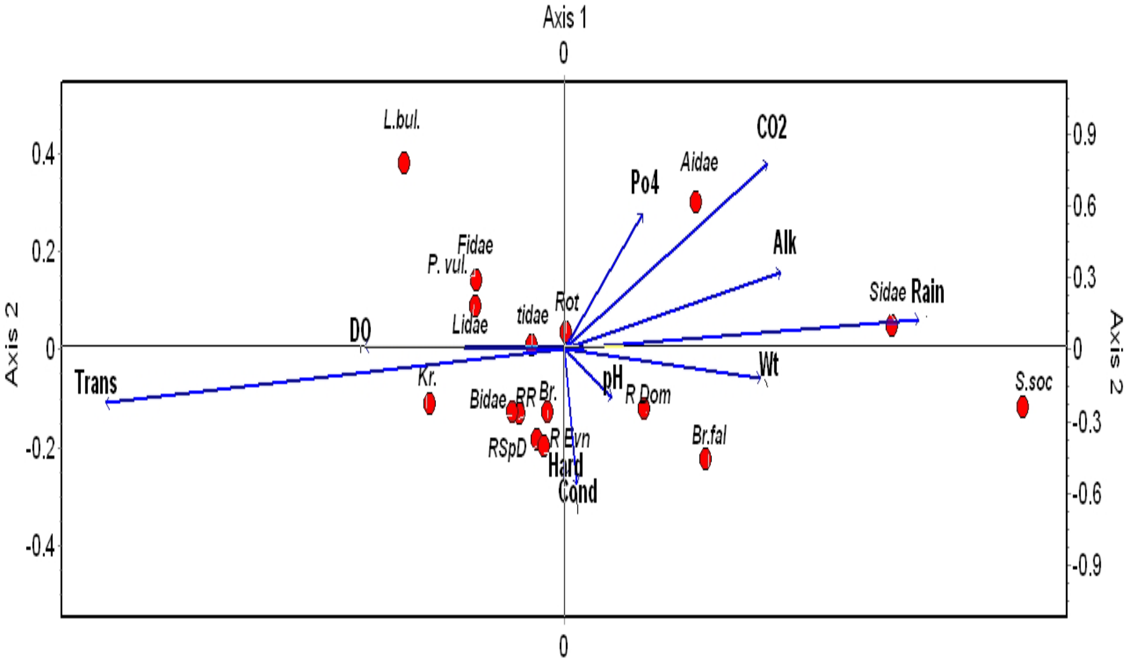

Figure 7. CCA ordination biplot of Rotifera assemblages and environmental variables (Station 1)

Abbreviations. Biotic - Aidae (Asplanchnidae), Bidae (Brachionidae), Fidae (Floscularidae) Sidae (Synchaetidae), tidae (Trichocercidae), Br. (*Brachionus*), Kr. (*Keratella*), Br.fal (*Brachionus falcatus*), L.bul.(*Lecane bulla*), P.vul (*Polyarthra vulgaris*), S. soc (*Sinantherina socialis*), RR (rotifer richness), Rot (rotifer abundance), R SpD (rotifer species diversity), R Dom (rotifer dominance), R Evn (evenness). **Abiotic.** Alk (alkalinity), CO_2 (free carbon dioxide), Cond (conductivity), DO (dissolved oxygen), Hard (hardness), pH (hydrogen-ion concentration), PO4 (phosphate), Rain (rainfall), Trans (transparency), Wt (water temperature).

Table 5. Variance explained in the Canonical Correspondence Analysis (CCA) by the first two axes

Sampling Stations ↓ Canonical Axis →		**Axis 1**	**Axis 2**
Station 1			
Total variance in species data	0.069844		
Sum of canonical eigen values	0.063459		
Sum of non-canonical eigen values	0.006386		
Canonical eigen value		0.0236544	0.0151901
% variance explained		33.9	21.7
Cumulative % variance		33.9	55.6
Station 2			
Total variance in species data	0.083148		
Sum of canonical eigen values	0.078786		
Sum of non-canonical eigen values	0.004362		
Canonical eigen value		0.0294438	0.0200042
% variance explained		35.4	24.1
Cumulative % variance		35.4	59.5

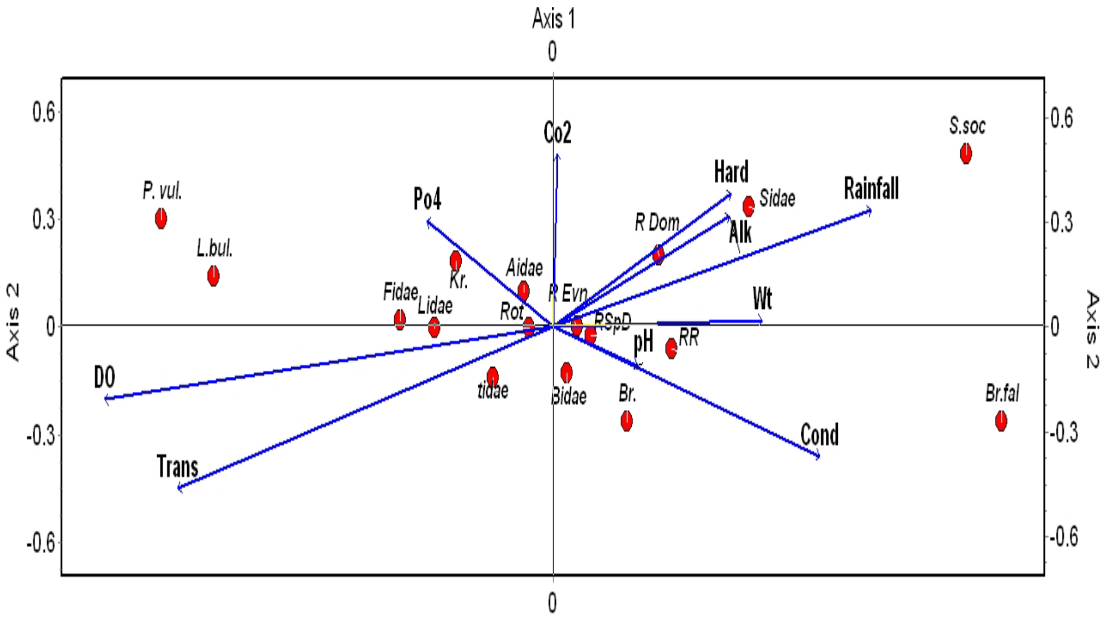

Figure 8. CCA ordination biplot of Rotifera assemblages and environmental variables (Station 2)

Abbreviations. **Biotic** - Aidae (Asplanchnidae), Bidae (Brachionidae), Fidae (Flosculariidae) Sidae (Synchaetidae), tidae (Trichocercidae), Br. (*Brachionus*), Kr. (*Keratella*), Br.fal (*Brachionus falcatus*), L.bul.(*Lecane bulla*), P.vul (*Polyarthra vulgaris*), S. soc (*Sinantherina socialis*), RR (rotifer richness), Rot (rotifer abundance), R SpD (rotifer species diversity), R Dom (rotifer dominance), R Evn (evenness). **Abiotic:** Alk (alkalinity), CO_2 (free carbon dioxide), Cond (conductivity), DO (dissolved oxygen), Hard (hardness), pH (hydrogen-ion concentration), PO4 (phosphate), Rain (rainfall), Trans (transparency), Wt (water temperature).

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Supporting online material: Appendix 1 (http://opuscula.elte.hu/PDF/Tomus43_1/Sharma_App1.pdf)