

Diversity of zooplankton in a tropical floodplain lake of the Brahmaputra river basin, Assam (Northeast India)

B. K. SHARMA¹ and S. SHARMA²

Abstract. The zooplankton diversity of a floodplain lake of the Brahmaputra river basin of lower Assam is analyzed on the bases of net plankton samples collected from the littoral (station 1) and semi-limnetic (station 2) regions during January–December 2010. The species-rich zooplankton (143 species) hypothesized environmental heterogeneity of this wetland. They showed high monthly richness (81 ± 11 and 72 ± 11 species) and recorded 44.7–79.3% and 46.7–89.7% community similarities at two sampling stations, respectively. Zooplankton formed 55.5 ± 10.9 % and 63.9 ± 9.6 % of net plankton abundance. Rotifera > Cladocera mainly influenced their richness and density variations. Copepoda is a sub-dominant quantitative group while *Mesocyclops* spp., *Asplanchna priodonta*, *Chydorus sphaericus*, *Bosmina longirostris* and *Sinantherina socialis* are relatively important taxa. High species diversity and low densities of majority of species are hypothesized to fine niche portioning amongst different species in combination with high micro- and macro-scale habitat heterogeneity. The zooplankton is characterized by high equitability and low dominance. Individual abiotic factors recorded limited influence on richness and abundance. Canonical correspondence analysis with ten abiotic factors explained 56.0 % and 55.8 % cumulative variance of zooplankton assemblages along axis 1 and 2. The CCA affirmed micro-environmental differences between the sampling stations.

Keywords. Abundance, diversity, species richness, tropical wetland, zooplankton.

INTRODUCTION

The floodplain lakes, an important component of inland aquatic resources of India, are hypothesized to be rich habitats for zooplankton diversity (Sharma & Sharma 2008). Ironically, several routine limnological reports from the floodplains of this country invariably provide poor data on diversity of these important fish-food organisms because of incomplete species inventories or unidentified species. This generalization also holds true to the floodplain lakes (commonly called 'beels' or 'pats') of northeast India. The detailed studies on zooplankton from this region are restricted to selected beels of Assam (Sharma 2011a, Sharma & Sharma 2008), and pats of Manipur (Sharma 2011b, Sharma & Sharma 2011). The works of Sharma (2009, 2010) and Sharma & Sharma (2012) are, however, limited to the rotifer diversity.

This study deals with zooplankton communities of Ghorajan Beel, a floodplain lake of the Brahmaputra river basin of lower Assam, with special reference to monthly variations in their richness and abundance, community similarities,

species diversity, dominance and evenness. In addition, the influence of abiotic parameters on qualitative and quantitative variations of zooplankton is analyzed. The results assume biodiversity and limnological value in view of the paucity of works from India in general and fewer works from its northeast region in particular.

MATERIALS AND METHODS

The observations were undertaken during January–December, 2010 in Ghorajan Beel (Long. $91^{\circ} 41' 25''$ E; Lat. $26^{\circ} 09' 26''$ N; area: 117 ha) located in the Kamrup district of lower Assam (Northeast India). Various aquatic macrophytes of this wetland included *Azolla pinnata*, *Eichhornia crassipes*, *Hydrilla verticillata*, *Ipomea fistulosa*, *Lemna* sp., *Najas indica*, *Vallisneria spiralis* and *Utricularia flexuosa*.

Water samples, collected monthly from the littoral (station 1) and station 2 (semi-limnetic (station 2) regions of Ghorajan Beel, were analyzed for nineteen abiotic factors. Water temperature, specific conductivity and pH were recorded by field probes, transparency was noted with Secchi

Prof. B. K. Sharma and Dr. Sumita Sharma, Freshwater Biology Laboratory, Department of Zoology, North-Eastern Hill University, Permanent Campus, Umshing, Shillong – 793 022, Meghalaya, India. E-mail: ¹profbksharma@gmail.com (corresponding author), ²sumitasharma.nehu@gmail.com

disc, dissolved oxygen was estimated by Winkler's method and other parameters were analyzed following APHA (1992). The qualitative (by towing) and quantitative (by filtering 25 l water each) net plankton samples were collected monthly, from both sampling stations, by nylobolt plankton net (No. 25) and were preserved in 5% formalin. The zooplankton was identified following the works of Koste (1978), Michael & Sharma (1988), Sharma (1998) and Sharma & Sharma (1999a, 1999b, 2000, 2008). Quantitative enumeration of zooplankton (ind. L⁻¹) was done with a Sedgewick-Rafter counting cell. The community similarities (Sørensen'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). Hierarchical cluster ana-

lysis, based on Sørensen's similarities, was done using SPSS (version 11.0). The significance of variations of richness and abundance of zooplankton between sampling stations and months was ascertained by ANOVA (two-way). The linear relationships between abiotic parameters and zooplankton were examined by correlation coefficients (r₁ and r₂ respectively) for each sampling station; their P values were calculated and significance was ascertained after use of Bonferroni corrections. Canonical correspondence analysis (ECOM II: version 2.1.3.137, PISCES Conservation Ltd. 2007) was used to elucidate the relationships between zooplankton assemblages and ten abiotic parameters namely water temperature, rainfall, transparency, pH, specific conductivity, dissolved oxygen, free carbon dioxide, alkalinity, hardness and phosphate.

Table 1. Temporal variations (range, average ± SD) of zooplankton

Parameters↓ Stations→	Station 1		Station 2	
RICHNESS				
Zooplankton	138 species 57 – 97 81 ± 11		143 species 48 – 89 72 ± 11	
Rotifera	35 – 55	46 ± 6	24 – 52	36 ± 5
Cladocera	14 – 31	25 ± 4	19 – 27	23 ± 2
Rotifera (84 species) > Cladocera (42 species) > Rhizopoda (12 species)				
QUANTITATIVE				
Net Plankton ind. L⁻¹	432 – 727	631 ± 112	324 – 671	528 ± 123
Zooplankton ind. L⁻¹	188 – 496	354 ± 103	154 – 456	342 ± 111
% composition	33.0 – 69.0	55.5 ± 10.9	44.8 – 76.5	63.3 ± 9.6
Species Diversity	3.799 – 4.223	4.009 ± 0.129	3.905 – 4.213	3.981 ± 0.138
Dominance	0.040 – 0.120	0.079 ± 0.025	0.048 – 0.137	0.091 ± 0.030
Evenness	0.885 – 0.964	0.915 ± 0.026	0.865 – 0.994	0.932 ± 0.042
Different Groups Rotifera > Cladocera > Copepoda > Rhizopoda				
Rotifera ind. L ⁻¹	111 – 242	185 ± 45	92 – 245	188 ± 58
% composition	42.8 – 62.2	53.3 ± 5.1	49.2 – 60.5	55.6 ± 3.6
Cladocera ind. L ⁻¹	50 – 156	106 ± 36	45 – 120	85 ± 23
% composition	21.3 – 36.1	29.7 ± 4.1	19.9 – 32.1	25.7 ± 4.0
Copepoda ind. L ⁻¹	9 – 81	40 ± 24	9 – 93	45 ± 27
% composition	4.8 – 17.7	10.6 ± 4.3	5.8 – 20.5	12.0 ± 4.6
Rhizopoda ind. L ⁻¹	5 – 23	12 ± 5	6 – 35	17 ± 11
Ostracoda ind. L ⁻¹	0 – 20	9 ± 5	1 – 8	5 ± 2
Conchostraca ind. L ⁻¹	0 – 6	2 ± 2	0 – 4	2 ± 1
Important species (ind. L⁻¹)				
<i>Mesocyclops</i> spp.	7 – 59	37 ± 15	8 – 59	39 ± 17
<i>Asplanchna priodonta</i>	0 – 32	22 ± 6	0 – 32	16 ± 10
<i>Chydorus sphaericus</i>	3 – 32	16 ± 8	3 – 20	10 ± 4
<i>Bosmina longirostris</i>	0 – 24	11 ± 9	4 – 20	11 ± 7
<i>Sintherina socialis</i>	0 – 20	11 ± 7	0 – 20	10 ± 9

RESULTS

The temporal variations in abiotic parameters of the littoral (station 1) and semi-limnetic (station 2) regions of Ghorajan Beel are indicated in Appendix I. The details of occurrence and abundance of zooplankton are included in Appendices II and III and their variations (annual ranges and average \pm SD) are summarized in Table 1. A total of 143 species of zooplankton are recorded in this study; of these 138 species are observed in our collections from the littoral region (station 1) while all of them occurred at station 2 (semi-limnetic region). Their monthly richness ranged between 57–97 and 48–89 species, community similarities (Sørensen's index) varied between 46.6–80.4% and 37.0–95.9% (Tables 2–3) while annual variations in the hierarchical cluster analysis, based on Sørensen's community similarity values at station 1 and station 2, are indicated in Figs. 1–2, respectively. ANOVA indicated significant richness variations between months ($F_{11, 23} = 2.536, P = 0.023$) and between the sampling stations ($F_{1, 23} = 7.122, P = 0.022$).

The monthly variations in abundance of zooplankton and their constituent groups are shown in Figs. 3–4. The zooplankton ($354 \pm 103 \text{ ind. L}^{-1}$, $342 \pm 111 \text{ ind. L}^{-1}$) comprised $55.5 \pm 10.9 \%$ and $63.3 \pm 9.6 \%$ of net plankton abundance in littoral (station 1) and semi-limnetic (station 2) regions, respectively (Table 2). Their abundance varied significantly between months ($F_{11, 23} = 141.659, P = 3.3E-10$). Rotifera ($185 \pm 45 \text{ ind. L}^{-1}$, $188 \pm 58 \text{ ind. L}^{-1}$) > Cladocera ($106 \pm 36 \text{ ind. L}^{-1}$, $85 \pm 23 \text{ ind. L}^{-1}$), main quantitative groups are followed by Copepoda ($40 \pm 24 \text{ ind. L}^{-1}$, $45 \pm 27 \text{ ind. L}^{-1}$); Rhizopoda ($12 \pm 5 \text{ ind. L}^{-1}$, $17 \pm 11 \text{ ind. L}^{-1}$) abundance is low while Ostracoda ($9 \pm 5 \text{ ind. L}^{-1}$, $5 \pm 111 \text{ ind. L}^{-1}$) and Conchostraca ($2 \pm 2 \text{ ind. L}^{-1}$, $2 \pm 1 \text{ ind. L}^{-1}$) showed poor abundance. Rotifera abundance showed insignificant temporal variations between stations while it varied significantly between months ($F_{11, 23} = 24.927, P < 0.001$). Cladocera abundance varied significantly between months ($F_{11, 23} = 8.619, P = 0.0006$) and sampling stations ($F_{1, 23} = 13.224, P = 0.004$). Copepoda abundance varied significantly between months ($F_{11, 23} = 8.302, P = 0.0007$).

Table 2. Percentage similarities of Zooplankton (Station 1)

Months	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Jan.	-	64.5	61.7	51.8	62.0	70.1	73.1	68.3	62.0	67.5	69.1	69.1
Feb.		-	60.8	61.1	59.4	60.0	71.0	66.2	67.5	71.6	60.9	73.3
March			-	50.6	59.6	66.7	68.6	63.3	67.4	68.1	68.5	67.4
April				-	61.1	44.7	63.7	52.9	62.3	56.5	61.1	65.3
May					-	62.7	70.4	63.9	54.8	68.4	59.6	72.8
June						-	67.0	63.9	60.3	69.0	70.5	69.4
July							-	71.2	63.1	69.9	64.2	79.3
Aug.								-	55.7	70.2	62.3	71.8
Sept.									-	58.6	66.7	68.9
Oct.										-	59.4	70.9
Nov.											-	65.5

Table 3. Percentage similarities of Zooplankton (Station 2)

Months	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Jan.	-	55.3	89.9	60.2	58.6	73.0	61.0	79.7	74.5	72.7	86.9	68.9
Feb.		-	74.8	67.9	52.6	61.5	72.1	80.9	72.6	72.2	68.7	72.5
March			-	67.7	58.1	77.2	74.1	84.9	79.5	78.4	81.1	78.4
April				-	62.3	46.7	64.2	66.1	69.1	65.0	72.9	67.2
May					-	55.8	51.1	55.4	51.5	53.3	52.4	60.6
June						-	56.4	70.3	68.7	81.7	74.6	68.4
July							-	69.1	65.5	76.6	64.1	71.0
Aug.								-	64.6	74.3	75.5	77.1
Sept.									-	65.8	72.1	77.4
Oct.										-	64.8	78.7
Nov.											-	66.7

The zooplankton species diversity (Table 1) ranged between 4.009 ± 0.129 and 3.981 ± 0.138 and its monthly variations are shown in Fig. 5; their dominance varied between dominance 0.079 ± 0.025 and 0.091 ± 0.030 while evenness ranged between 0.915 ± 0.026 and 0.932 ± 0.042 at two sampling stations, respectively (Table 1). Our results showed no significant linear relationship of

abiotic factors on zooplankton richness while their abundance is positively correlated with sulphate ($r_1=0.859$, $P=0.001$, $r_2=0.844$, $P = 0.002$). The results of canonical correspondence analysis (CCA) with ten abiotic parameters on cumulative variance of zooplankton assemblages at stations 1 and 2 are presented in Figs.6–7, respectively; their important features are summarized in Appendix IV.

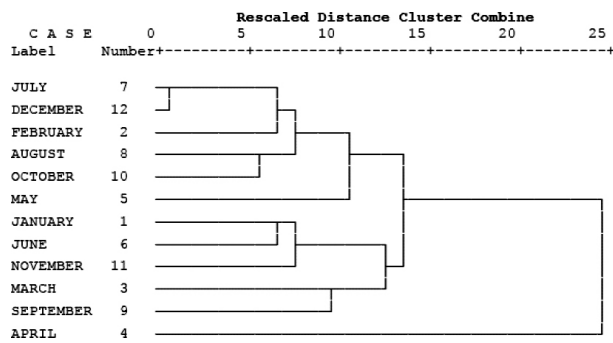


Figure 1. Hierarchical cluster analysis for zooplankton (Station 1).

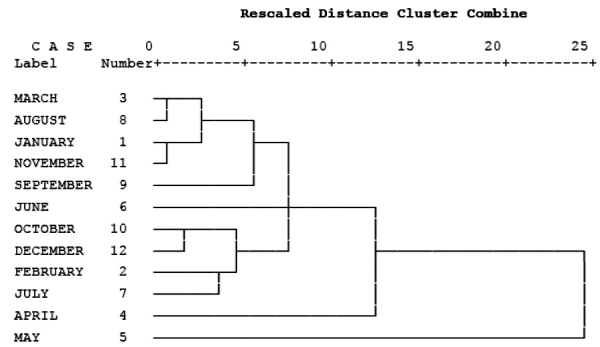


Figure 2. Hierarchical cluster analysis for zooplankton (Station 2).

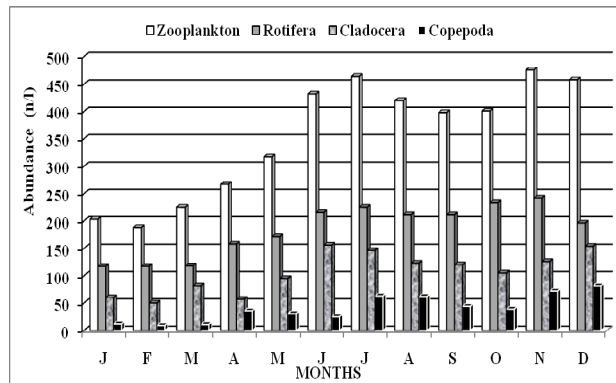


Figure 3. Monthly variations in Abundance (n/l) of zooplankton and important groups (Station 1).

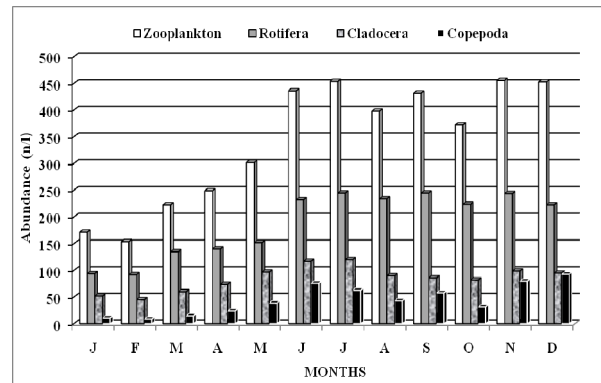


Figure 4. Monthly variations in Abundance (n/l) of zooplankton and important groups (Station 2).

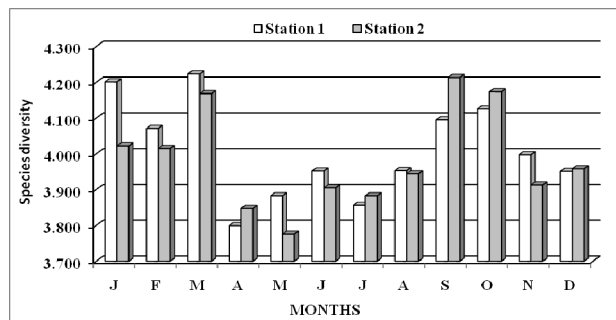


Figure 5. Monthly variations in Species diversity of zooplankton.

DISCUSSION

Abiotic parameters

The circum-neutral and marginally hard waters of sub-tropical Ghorajan Beel recorded low ionic concentrations, moderate dissolved oxygen, low free CO₂, low chloride content and low concentrations of nutrients and other parameters. Annual ranges of abiotic factors differed marginally between the sampling stations (Sharma & Sharma 2012).

Richness and community similarities

The species-rich (143 species) and diverse (six groups) character of zooplankton hypothesized general environmental heterogeneity and habitat diversity of Ghorajan Beel. This wetland is qualitatively more diverse than the 102–118 species reported various *beels* of Assam (Sharma & Sharma 2008) as well as 110 and 103 species observed two '*pats*' of Manipur (Sharma 2011b). Further, Ghorajan zooplankton is distinctly diverse than the reports from other Indian floodplain lakes i.e., 51 species (Khan 1987) and 26 species (Yousuf *et al.* 1986) from Kashmir; 19 species (Baruah *et al.* 1993) and 31 species (Sanjer & Sharma 1995) from Bihar, and 71 species (Khan 2003) from West Bengal. The stated comparisons affirm our remarks on environmental heterogeneity of Ghorajan vis-à-vis other floodplain lakes of this country. The richness is, however, relatively lower than the reports of 189 species from Deepor *beel* (Sharma 2011a) and 171 species from Loktak Lake (Sharma & Sharma 2011) - two biodiversity 'hot-spots' (Ramsar sites) and important floodplain lakes of northeast India.

The occurrence of all the species at station 2 and 138 species at station 1 showed homogeneity in zooplankton composition between the sampling stations. They mainly contributed to richness of net plankton (194 species) of Ghorajan. The zooplankton biocoenosis exhibited 'tropical character' with distinct richness of cosmopolitan species and occurrence of various cosmopolitan, circum-tropical and pantropical species. This generalization affirmed earlier remarks of Sharma & Sharma (2008).

The occurrence of > 70 species at station 1, except during April and May, and > 60 species at station 2, except during February and April affirmed zooplankton speciose composition and hence affirmed environmental heterogeneity of this *beel* practically throughout the study period. They showed high monthly richness at both sampling stations and followed oscillating patterns concurrent with the reports of Sharma & Sharma (2010) and Sharma (2011a, 2011b). Their compo-

sition is mainly influenced by the species-rich Rotifera > Cladocera. The diverse nature of the rotifer communities concurred with the reports from the floodplain lakes of Argentina (Jose De Paggi 1993, 2001), Africa (Segers *et al.* 1993), Brazil (Bonecker *et al.* 1998), Thailand (Sanoamuang 1998) and Australia (Shiel *et al.* 1998).

The community similarities (*vide* Sørensen's index) reflected notable monthly variations in zooplankton species composition in general and in the limnetic region (station 2) in particular. The matrices indicated similarity between > 60–70 percent in maximum instances at station 1 while it ranged between > 60–80 percent in maximum instances at station 2. These features are attributed to common occurrence of cosmopolitan, tropicopolitan and pantropical species. At both stations, highest similarities are recorded between July–December and January–March respectively. The cluster analysis indicated more heterogeneity of the monthly groupings in the littoral region (station 1) in general than at station 2 (limnetic region); this generalization affirmed the authors earlier remarks based on Rotifera (Sharma & Sharma 2012) - the most speciose group. Our results at station 1 showed high affinity between July–December while the April, September and May communities differed distinctly from the rest of the months and April collections exhibited maximum divergence. On the other hand, high affinities at station 2 are noticed between March–August and again between January–November samples while May and April communities exhibited distinct divergence in their composition.

Abundance

The zooplankton formed an important component of net plankton abundance with relatively high percentage composition at station 2. Their quantitative significance concurred with the reports from certain floodplain lakes of northeast India (Sharma & Hussain 2001, Sharma 2011a, 2011b, Sharma & Sharma 2011). This feature differed from higher phytoplankton abundance reported from the floodplain lakes and wetlands of Kashmir (Kaul & Pandit 1982), Bihar (Baruah *et al.*

1993, Sanjer & Sharma 1995), Assam (Yadava et al. 1987) and West Bengal (Sugunan 1989). The zooplankton abundance in Ghorajan *beel* is, however, higher than the reports of Yadava et al. (1987), Baruah et al. (1993) and Sharma & Sharma (2011) while it is lower than that of Sharma (2011) as well as the results of Khan (1987), Vaas (1989), Sanjer & Sharma (1995), Khan (2002) and Sharma (2011b). This study indicated marginal differences of zooplankton abundance between two sampling stations, respectively. It followed nearly concurrent oscillating quantitative monthly variations with relatively high densities ($> 350 \text{ ind. L}^{-1}$) from June through December and lowest abundance during February at both stations but showed maxima during July and November at stations 1 and 2 respectively. This is in contrast to winter maxima observed by Sharma (2011a, 2011b) and Sharma & Sharma (2011) as well as bimodal patterns noted by Yadava et al. (1987) and Sanjer and Sharma (1995).

Rotifera, main quantitative component of zooplankton, followed broadly concurrent quantitative annual variations at both sampling stations with higher abundance ($> 200 \text{ ind. L}^{-1}$) from June through November. Brachionidae $>$ Lecanidae influenced the rotifer abundance while *Asplanchna priodonta* $>$ *Sinantherina socialis* are important species. A detailed account of the rotifer diversity of this wetland is dealt with separately (Sharma & Sharma 2012). Cladocera, second quantitative group, followed oscillating annual patterns with high densities from May through December and peaks during June and July respectively while their lowest densities are noticed during February at both the stations. The quantitative importance of the Chydoridae concurred with the results of Sharma (2011a, 2011b) and Sharma & Sharma (2011) but differed from lack of any such trend as reported by Khan (1987), Sanjer & Sharma (1995), Sharma & Hussain (2001) and Khan (2003). *Chydorus sphaericus* and *Bosmina longirostris* are notable cladoceran species in our study.

Copepoda quantitative sub-dominance in Ghorajan *beel* is in contrast to their dominant role

reported by Yadava et al. (1987), Baruah et al. (1993), Sharma & Hussain (2001) and Khan (2003). The copepods exhibited broadly bimodal patterns with maxima during June and December (peaks) and minima during February in both stations. The cyclopoids (*Mesocyclops* spp.) mainly influenced abundance of this group and concurred with the reports of Khan (1987), Sanjer & Sharma (1995), Sharma & Hussain (2001), Sharma (2011a, 2011b) and Sharma & Sharma (2011). The occurrence of nauplii throughout the study period showed an active continuous reproductive phase of the cyclopoids concurrent with the reports of Sharma (2011a, 2011b) and Sharma & Sharma (2011). Amongst other groups of zooplankton, Rhizopoda recorded low abundance while Ostracoda and Conchostraca showed very poor densities.

Diversity indices

Our results are characterized by high zooplankton species diversity at two stations, respectively with relatively high values (> 4.000) during January–March and again during September–October at both the sites. In fact, the mean diversity at Station 1 is the second highest known till date from any freshwater ecosystem of India and followed that of Loktak Lake (Sharma & Sharma 2010). This interesting feature re-affirmed general environmental heterogeneity of Ghorajan *beel*. The salient features of high species diversity with relatively lower densities of majority of species of our study may be ascribed to fine niche portioning amongst zooplankton species in combination with high micro- and macro-scale habitat heterogeneity as hypothesized by Segers (2008) and affirmed by Sharma (2011a, 2011b) and Sharma & Sharma (2011, 2012). The diversity followed oscillating but different annual patterns at both sampling stations with low values during summer. High evenness of zooplankton observed in our results affirmed equitable abundance of various species and it is endorsed by lower dominance. In general, high evenness and low dominance concurred with the results from floodplain lakes of northeast India (Sharma 2011a, 2011b; Sharma & Sharma 2008, 2011).

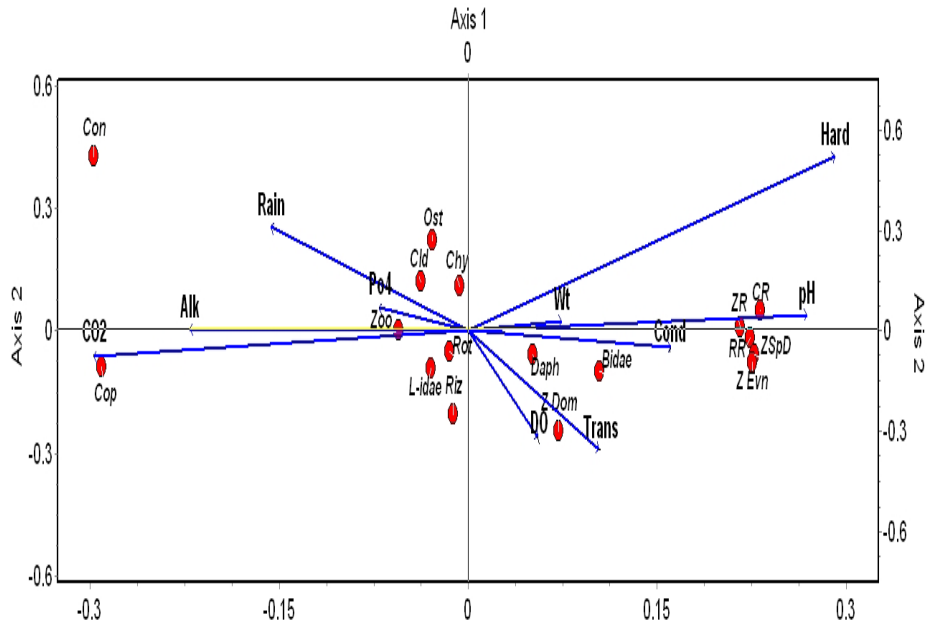


Figure 6. CCA ordination biplot of zooplankton assemblages and environmental variables (Station 1).

Abbreviations. *Biotic.* Bidae (Brachionidae), CR (Cladocera richness), Cld (Cladocera), Chy (Chydoridae), Con (Conchostraca), Cop (Copepoda), Dap (Daphniidae), L-idae (Lecanidae), Ost (Ostracoda), Riz (Rhizopoda), RR (rotifer richness), Rot (Rotifera), Zoo (zooplankton), Z SpD (zooplankton species diversity), Z Dom (zooplankton dominance), Z Evn (zooplankton evenness); *Abiotic.* Alk (alkalinity), CO₂ (free carbon dioxide), Cond (conductivity), DO (dissolved oxygen), Hard (hardness), pH (hydrogen-ion concentration), Po₄ (phosphate), Rain (rainfall), Trans (transparency), Wt (water temperature)

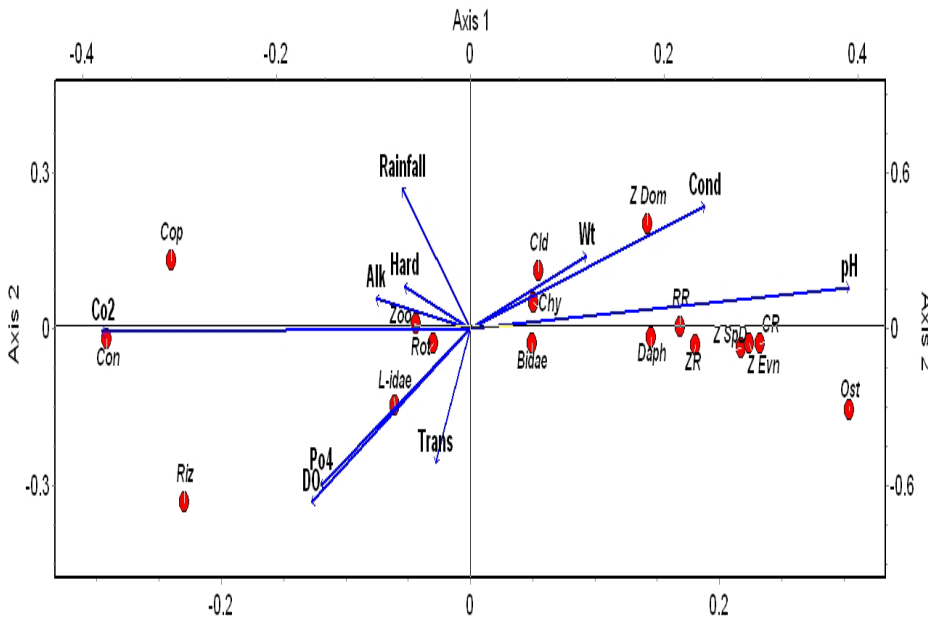


Figure 7. CCA ordination biplot of zooplankton assemblages and environmental variables (Station 2)

Abbreviations. *Biotic.* Bidae (Brachionidae), CR (Cladocera richness), Cld (Cladocera), Chy (Chydoridae), Con (Conchostraca), Cop (Copepoda), Dap (Daphniidae), L-idae (Lecanidae), Ost (Ostracoda), Riz (Rhizopoda), RR (rotifer richness), Rot (Rotifera), Zoo (zooplankton), Z SpD (zooplankton species diversity), Z Dom (zooplankton dominance), Z Evn (zooplankton evenness); *Abiotic.* Alk (alkalinity), CO₂ (free carbon dioxide), Cond (conductivity), DO (dissolved oxygen), Hard (hardness), pH (hydrogen-ion concentration), Po₄ (phosphate), Rain (rainfall), Trans (transparency), Wt (water temperature)

Ecological relationships

Interestingly this study showed lack of influence individual abiotic factors on zooplankton richness and also much limited influence on their abundance. The canonical correspondence analysis (CCA) with ten abiotic parameters, however, explained nearly equal cumulative variance (56.0 % and 55.8 %) of zooplankton assemblages along axis 1 and 2 with importance of free carbon dioxide, hardness and pH, and free carbon dioxide, pH, dissolved oxygen and conductivity at stations 1 and 2, respectively. At station 1, richness of zooplankton, Rotifera and Cladocera; Brachionidae and Daphniidae abundance, species diversity and evenness are influenced by pH; zooplankton, Rotifera, Rhizopoda and Lecanidae abundance are influenced by high values of free carbon dioxide. Low free carbon dioxide influenced Copepoda abundance. Cladocera, Chydoridae and Ostracoda densities are influenced by high rainfall and zooplankton dominance is influenced by low transparency and dissolved oxygen. On the other hand, Rotifera richness, Cladocera richness, zooplankton richness, Brachionidae, Daphniidae, species diversity and evenness are influenced by pH; zooplankton, Rotifera and Lecanidae abundance is influenced by dissolved oxygen and phosphate; Cladocera, Chydoridae and Ostracoda densities are influenced by high conductivity and zooplankton dominance is influenced by low conductivity. Consequently, the littoral and semi-limnetic stations are characterized by micro-environmental differences.

CONCLUSION

The zooplankton mainly contributed to richness and abundance net plankton, showed species-rich and diverse character with rich diversity and quantitative importance of Rotifera > Cladocera. This study exhibited no definite monthly pattern of richness variations while abundance is relatively high from July through December. Our results showed high species diversity, high evenness, low dominance, and low densities of majority of zooplankton. The results indicated no significant relationship of individual abiotic factors

on richness and also showed much limited influence on abundance. CCA with ten abiotic parameters explained 56.0 % and 55.8 % cumulative variance of zooplankton assemblages along axis 1 and 2 at stations 1 and 2, respectively. The importance of different abiotic factors in CCA analysis consequently reflected micro-environmental differences between the sampling stations.

Acknowledgements – This study was undertaken under the “Potential for Excellence Program (Focused Area: Biosciences) of North-Eastern Hill University, Shillong. The senior author is thankful to the Coordinator, UPE-Biosciences, NEHU and the Head, Department of Zoology, North-Eastern Hill University, Shillong for necessary facilities. The senior author also wishes to thank Prof. S. K. Barik, Department of Botany, NEHU, Shillong for help in CCA analysis. Finally, we are thankful to Messer’s G. Thangjam and M. K. Hatimuria for help in several field trips.

REFERENCES

- A. P. H. A. (1992): *Standard Methods for the Examination of Water and Wastewater* (18th Ed.). American Public Health Association, Washington D. C.
- BARUAH, A., SINHA, A. K. & SHARMA, U. P. (1993): Plankton variability of a tropical wetland, Kawar (Begusarai), Bihar. *Journal of Freshwater Biology*, 5: 27–32.
- BONECKER, C. C., LANSAC-TÔHA, F. A. & ROSSA, D. C. (1998): Planktonic and non-planktonic rotifers in two environments of the upper Parana river floodplain, state of Mato Grosso do Sul, Brazil. *Brazilian Archives of Biology & Technology*, 41: 447–456.
- JOSÉ DE PAGGI, S. (1993): Composition and seasonality of planktonic rotifers in limnetic and littoral region of a floodplain lake (Parana River System). *Revue Hydrobiologie Tropicale*, 26: 53–64.
- JOSÉ DE PAGGI, S. (2001): Diversity of Rotifera (Monogononta) in wetlands of Rio Pilcomayo national park, Ramsar site (Formosa, Argentina). *Hydrobiologia*, 462: 25–34.
- KAUL, V. & PANDIT, A. K. (1982): Biotic factors and food chain structure in some typical wetlands of Kashmir. *Pollution Research*, 1: 49–54.
- KHAN, M. A. (1987): Observations on Zooplankton composition, abundance and periodicity in two flood-plain lakes of the Kashmir Himalayan valley *Acta Hydrochemica Hydrobiologica*, 15: 167–174

- KHAN, R. A. (2003): Faunal diversity of zooplankton in freshwater wetlands of Southeastern West Bengal. *Records of the Zoological Survey of India, Occasional Paper No.*, 204: 1–107.
- KOSTE, W. (1978): *Rotatoria*. Die Rädertiere Mitteleuropas, begründet von Max Voigt. Überordnung Monogononta. Gebrüder Borntraeger, Berlin, Stuttgart. I. pp. 673 und II. Tafelband, pp. 274.
- LUDWIG, J. A. & REYNOLDS, J. F. (1988): *Statistical Ecology: a Primer on Methods and Computing*. John Wiley & Sons, New York, pp. 337.
- MAGURRAN, A. E. (1988): *Ecological Diversity and its Measurement*. Croom Helm Limited, London, pp. 179.
- MICHAEL, R. G. & SHARMA, B. K. (1988): Indian Cladocera. (Crustacea: Branchiopoda: Cladocera). *Fauna of India and adjacent countries Series*. Zoological Survey of India, Calcutta, pp. 262.
- SANJER, L. R. & SHARMA, U. P. (1995): Community structure of plankton in Kawar lake wetland, Begusarai, Bihar: II. Zooplankton. *Journal of Freshwater Biology*, 7: 165–167.
- SANOAMUANG, L. (1998): Rotifera of some freshwater habitats in the floodplains of the River Nan, northern Thailand. *Hydrobiologia*, 387/388: 27–33.
- SEGERS, H. (2008): Global diversity of rotifers (Rotifera) in freshwater. *Hydrobiologia*, 595: 49–59.
- SEGERS, H., NWADIARO, C. S. & DUMONT, H. J. (1993): Rotifera of some lakes in the floodplain of the river Niger (Imo State, Nigeria). II. Faunal composition and diversity. *Hydrobiologia*, 250: 63–71.
- SHARMA, B. K. (1998): Freshwater Rotifers (Rotifera: Eurotatoria). *Fauna of West Bengal. State Fauna Series*, 3(11): 341–461.
- SHARMA, B. K. (2009): Diversity of rotifers (Rotifera, Eurotatoria) of Loktak Lake, Manipur, North-eastern India. *Tropical Ecology*, 50(2): 277–285.
- SHARMA, B. K. (2010): Rotifer communities of Deepor beel, Assam, India: richness, abundance and ecology. *Journal of Threatened Taxa*, 2 (8): 1077–1086.
- SHARMA, B. K. (2011a): Zooplankton communities of Deepor Beel (a Ramsar site), Assam (N. E. India): ecology, richness, and abundance. *Tropical Ecology*, 52(3): 293–302.
- SHARMA, B. K. (2011b): Zooplankton diversity of two floodplain lakes (pats) of Manipur, northeast India. *Opuscula Zoologica Budapest*, 42(2): 185–197.
- SHARMA, B. K. & HUSSAIN, M. D. (2001): Abundance and ecology of Zooplankton in a tropical floodplain lake, Assam (N. E. India). *Ecology, Environment & Conservation*, 7(4): 397–403.
- SHARMA, B. K. & SHARMA, S. (1999a): Freshwater Rotifers (Rotifera : Eurotatoria). *State Fauna Series: Fauna of Meghalaya*, 4(9):11–161.
- SHARMA, B. K. & SHARMA, S. (1999b): Freshwater Cladocerans (Crustacea: Branchiopoda: Cladocera). *State Fauna Series: Fauna of Meghalaya*, 4 (9): 469–550.
- SHARMA, B. K. & SHARMA, S. (2000): Freshwater Rotifers (Rotifera: Eurotatoria). *State Fauna Series: Fauna of Tripura*, 7(4): 163–224.
- SHARMA, B. K. & SHARMA, S. (2011): Zooplankton diversity of Loktak Lake, Manipur, India. *Journal of Threatened Taxa*, 3(5): 1745–1755.
- SHARMA, B. K. & SHARMA, S. (2012): Rotifer diversity of a floodplain lake of the Brahmaputra river basin of lower Assam, Northeast India. *Opuscula Zoologica, Budapest*, 43(1): 67–77.
- SHARMA, S. & SHARMA, B. K. (2008): Zooplankton diversity in floodplain lakes of Assam. *Records of the Zoological Survey of India, Occasional Paper No.*, 290: 1–307.
- SHIEL, R. J., GREEN, J. D. & NIELSEN, D. L. (1998): Floodplain biodiversity: why are there so many species? *Hydrobiologia*, 387/388: 39–46.
- SUGUNAN, V V. (1989): Limnological features in beels: Biotic factors. *Bulletin of the Central Inland Capture Fisheries Research Institute, Barrackpore*, 63: 128–135.
- VASS, K. K. (1989): Beel fisheries resources in West Bengal. *Bulletin of the Central Inland Capture Fisheries Research Institute, Barrackpore*, 63: 29–35.
- YADAVA, Y. S., SINGH, R. K., CHOUDHURY, M. & KOLEKAR, V. (1987): Limnology and productivity in Dighali beel (Assam). *Tropical Ecology*, 28: 137–146.
- YOUSUF, A., MUSTAFA SHAH, R. G. & QADRI, M. Y. (1986): Some limnological aspects of Mirgund wetland. *Geobios new Reports*, 5: 27–30.

Supporting online material: Appendix I–IV. (http://opuscula.elte.hu/PDF/Tomus43_2/Sharma_Appendix.pdf)