The composition and heterogeneity of the rich and diverse rotifers (Rotifera: Eurotatoria) of the floodplain lakes (*beels*) of the Majuli River Island, Assam State (Northeast India)

B. K. SHARMA^{1*} & S. SHARMA²

¹Bhushan Kumar Sharma, Department of Zoology, North-Eastern Hill University, Shillong - 793 022, Meghalaya, India.

²Sumita Sharma, Lady Veronica Road, Shillong - 793 003, Meghalaya, India

*Corresponding author: profbksharma@gmail.com

Abstract: The tropical and subtropical floodplain lakes are hypothesized as one of the globally interesting rotifer rich ecosystems. Our study indicating the biodiverse Rotifera of ten ‘slightly acidic to circum-neutral, moderately hard-water and de-mineralized’ tropical floodplain lakes (*beels*) of the Majuli River Island of the Brahmaputra river basin of northeast India endorses this hypothesis. Total richness, the richness of important families and community similarities affirm heterogeneity of the rotifer species composition amongst the *beels*. The species richness registers significant spatio-temporal variations with seasonal differences amongst the *beels* and individually in each *beel*, and lacks significant influence of the recorded abiotic factors. The constellations of 76-81 species in three *beels* during winter and 76 species in one *beel* during pre-monsoon are noteworthy instances of ‘Rotifera paradox’. The rotifer fauna of the Majuli *beels* registers affinity with Southeast Asian and Oriental faunas, records several species of the regional distribution interest and exhibits the littoral-periphytic nature, while application of $Q_{B/T}$ and $Q_{L/B}$ quotients depicts limitations. This study merits ecological diversity interest for Rotifera vis-à-vis the floodplain lakes of India and elsewhere from the tropics and subtropics, and assumes biodiversity conservation importance due to threat of extinction of the Majuli – an alluvial floodplain of the Brahmaputra basin.

Keywords. Alluvial floodplain, *beels*, Brahmaputra basin, ecological diversity, Rotifera paradox.

INTRODUCTION

The floodplain lakes comprise integral elements of landscapes of large riverine systems world-wide. These generally shallow wetlands are characterized as ecotones with environmental heterogeneity due to variations of hydrological conditions and growth of macrophytes, and are known for high biodiversity and ecological value (Funk *et al.* 2009, Górski *et al.* 2013, Dembowska & Napiórkowski 2015, Napiórkowski *et al.* 2019). Segers *et al.* (1993) hypothesized the tropical and subtropical floodplain lakes as one the globally important Rotifera rich habitats, and the diverse assemblages examined by Shiel *et al.* (1998), Green (2003), Bonecker *et al.* (2005, 2020) and Diniz *et al.* (2021) endorse the global biodiversity importance of these wetlands. Our rotifer diversity studies (Sharma & Sharma 2014a, 2019a) extend Segers’s hypothesis to the floodplain lakes

(*beels* and *pats*) of northeast India (NEI). Referring to NEI in particular, the notable related works of ecological diversity importance are limited to the selected *beels* of Assam (Sharma 2005, Sharma & Sharma 2001, 2008, 2019a, 2019b, Sharma *et al.* 2018a) and *pats* of Manipur (Sharma 2009, Sharma & Sharma 2018a). On the contrary, the reports elsewhere from the Indian floodplains (Sinha *et al.* 1994, Sanjer and Sharma 1995, Khan 1997, 2002, 2003, Ganesan & Khan 2008, Datta 2011, Sharma *et al.* 2011, Chandra *et al.* 2021) indicate poor rotifer biodiversity value due to incomplete species inventories, inadequate sampling, overlooking identification of smaller species of the taxon and limitations of taxonomic expertise (Sharma & Sharma 2021a). The limnology literature thus depicts disparity on Rotifera ecological diversity works from the floodplains of the different river basins of India, and highlights the scope for augmenting intensive studies from

the floodplains lakes of this country as well as NEI *vis-à-vis* the hypothesis of Segers *et al.* (1992) and the 'Rotiferologist effect' (Fontaneto *et al.* 2012).

Realizing the global and regional importance of Rotifera biodiversity assessment of the floodplain lakes, the present study attempts an intensive analysis of the rotifer assemblages of ten floodplain lakes (*beels*) of the Majuli River Island of the Brahmaputra river basin of NEI. Comments are made on the species composition, the richness and its spatio-temporal variations, important taxa and interesting speciose constellations observed from the sampled *beels* of this alluvial floodplain of Assam state. The results are discussed in comparisons with Rotifera faunal diversity reports from the floodplain lakes of India and elsewhere globally, and our earlier preliminary survey (Sharma *et al.* 2015) of certain Majuli *beels*.

MATERIALS AND METHODS

The present study is based on the limnological survey (undertaken during 2016) of ten *beels* (Table 1) of the Majuli River Island (26° 45'N – 27°12'N, 93°39'E–94°35'E) located in the upper reaches of the Brahmaputra river, Assam state of NEI (Fig. 1). The sampled *beels* indicate various aquatic macrophytes namely *Azolla pinnata* Brown, *Eichhornia crassipes* (Martius) Solms, *Euryale ferox* Salisbury, *Hydrilla verticillata* (L.f.) Royle, *Lemna minor* Linnaeus, *Nymphaea carpensis* Thunb., *Nelumbo nucifera* Gaertn., *N. lutea* Willdenow, *Pistia stratiotes* Linnaeus, *Salvinia cucullata* Roxb. ex Bory, *Trapa bispinosa* Roxb., and *Utricularia aurea* Loureiro.

Water and plankton samples were collected from the different *beels* (Table 1) during winter

Figure 1. The district map of Assam state (light yellow color) showing location of the Majuli River Island (red color), inset map of India indicating Assam state (red color) of northeast India (Source: Google map)

Table 1. List of the sampled Majuli *beels*

Beels↓	Location→	Latitude	Longitude
Mohorichuk		26°55'40.4" N	94°01'47.7" E
Baalichapori		26°55'42.0" N	94°02'44.7" E
Dighaliya		26°56'15.5" N	94°03'45.7" E
Karatipar		26°56'39.4" N	94°04'13.5" E
Lingri		26°56'47.4" N	94°12'28.8" E
Khorkhoria		26°57'02.7" N	94°05'05.3" E
Gokhai		26°57'07.0" N	94°09'04.2" E
Noldunga		26°58'09.4" N	94°03'03.4" E
Bor		26°59'25.9" N	94°13'08.0" E
Baatomaari		27°05'13.2" N	94°22'41.8" E

(January – February), pre-monsoon (April – May), monsoon (July – August) and post-monsoon (October – November) seasons. Water samples were examined for certain abiotic factors; water temperature and specific conductivity were recorded with the field probes, dissolved oxygen was determined by Winkler's methods, and total alkalinity and total hardness were estimated following APHA (1992). A total of 600 qualitative plankton samples, including 15 samples per *beel* per season, were collected from the littoral and semi-limnetic regions of the different *beels* by towing plankton net (# 40 µm) and were preserved in 5% formalin. All the collections were screened with WILD binocular microscope, various rotifers were isolated and mounted in polyvinyl alcohol-lactophenol mixture, and observed with Leica (DM 1000) stereoscopic phase contrast microscope fitted with an image analyzer.

Rotifera species are identified following the works of Sharma (1983), Segers (1995), and Sharma & Sharma (1999, 2000, 2008, 2014b, 2014c, 2015, 2021a). The percentage similarities between the rotifer species composition amongst the different *beels* are calculated *vide* Sørensen's index (Sørensen 1948). The hierarchical cluster analysis is done using SPSS (version 20) and dendrogram is plotted using average linkage between groups (community similarity values). Two-way ANOVA is used to ascertain significance of the spatial and temporal Rotifera richness variations amongst the *beels* and seasons, respectively. The relation-

ships between abiotic factors and richness are determined by Pearson's correlation coefficients (*r*); *P* values are calculated and significance is ascertained after Bonferroni corrections.

RESULTS

Water temperature ranged between 23.9 ± 4.2 – $25.2 \pm 3.8^\circ\text{C}$; pH between 6.68 ± 0.14 – 6.79 ± 0.20 ; specific conductivity between 130.2 ± 15.0 – 152.0 ± 14.6 µS/cm; dissolved oxygen between 6.4 ± 0.7 – 7.0 ± 0.8 mg/l; total alkalinity between 74.5 ± 12.6 – 88.2 ± 12.3 mg/l; and total hardness between 69.8 ± 14.3 – 81.2 ± 14.2 mg/l in the Majuli *beels* (Table 2) during this study. The significance of the spatio-temporal (*vide* ANOVA) variations of abiotic factors is indicated in Table 3.

We report a total of 170 Rotifera species belonging to 39 genera and 19 families (Appendix 1). The richness in the individual *beels* ranges between 78–128 species (Fig. 2) and records 57.1–79.5% community similarities *vide* Sørensen's index (Table 4); the hierarchical cluster analysis between Rotifera assemblages is shown in Fig. 3. The cumulative richness of important families namely Lecanidae, Lepadellidae, Brachionidae and Trichocercidae in the different *beels* ranges between 54–90 species (Fig. 2). Individual and cumulative richness contributions of important families of the sampled *beels* are indicated in Table 5. The rotifer richness indicates seasonal variations (Table 6) ranging between 56 ± 7 – 71 ± 9

Table 2. Temporal variations of abiotic parameters (Mean $\pm$ SD) of the Majuli *beels*

Parameters $\rightarrow$ Beels $\downarrow$	Water temperature $^{\circ}\text{C}$	pH	Specific Conductivity $\mu\text{S}/\text{cm}$	Dissolved oxygen mg/l	Total Alkalinity mg/l	Total Hardness mg/l
Mohorichuk	24.7 ± 4.0	6.76 ± 0.12	130.4 ± 10.2	6.5 ± 0.4	74.5 ± 12.6	69.8 ± 14.3
Baalichapori	23.9 ± 4.2	6.69 ± 0.11	131.4 ± 12.7	6.6 ± 0.6	80.8 ± 15.4	76.4 ± 22.6
Dighaliya	24.6 ± 3.8	6.77 ± 0.15	142.6 ± 15.9	6.7 ± 0.8	76.4 ± 12.6	70.2 ± 15.6
Karatipar	24.6 ± 3.9	6.72 ± 0.14	150.2 ± 17.8	6.6 ± 0.8	85.8 ± 14.0	80.2 ± 16.2
Lingri	24.0 ± 3.8	6.68 ± 0.14	152.0 ± 14.6	6.9 ± 0.9	88.2 ± 12.3	81.2 ± 14.2
Khorkhoria	25.2 ± 3.8	6.76 ± 0.12	130.2 ± 15.0	6.8 ± 0.9	77.3 ± 12.2	70.8 ± 12.6
Gokhai	24.7 ± 4.0	6.79 ± 0.20	135.2 ± 16.3	7.0 ± 0.8	82.2 ± 11.4	73.8 ± 10.6
Noldunga	24.9 ± 4.1	6.72 ± 0.20	133.6 ± 15.2	6.6 ± 0.7	80.3 ± 12.3	74.2 ± 14.6
Bor	25.0 ± 3.9	6.71 ± 0.19	134.2 ± 15.9	6.4 ± 0.7	82.5 ± 16.2	79.5 ± 13.2
Baatomaari	24.9 ± 3.9	6.75 ± 0.16	144.2 ± 18.5	6.5 ± 1.0	80.9 ± 12.9	78.4 ± 12.0

Table 3. The spatio-temporal significance of abiotic factors and Rotifera richness

Parameters	Beels	Seasons
Abiotic factors		
Water temperature	-	$F_{3,39}=1247.571, P=4.690\text{E-}29$
pH	-	$F_{3,39}=11.692, P=4.319\text{E-}05$
Specific conductivity	$F_{9,39} = 2.706, P = 0.022$	$F_{3,39} = 249.967, P = 8.428\text{E-}20$
Dissolved oxygen	-	$F_{3,39}=120.100, P=9.990\text{E-}16$
Total alkalinity	$F_{9,39} = 4.057, P = 0.002$	$F_{3,39}=293.610, P=1.032\text{E-}20$
Total hardness	$F_{9,39} = 6.239, P = 9.589\text{E-}05$	$F_{3,39}=354.516, P=8.700\text{-}22$
Biotic factor		
Rotifera richness	$F_{9,39} = 14.637, P = 2.982\text{E-}05$	$F_{3,39}=84.637, P=7.530\text{E-}14$

Figure 2. Richness of Rotifera and important families in the Majuli *beels*
1–Mohorichuk, 2–Baalichapori, 3–Dighaliya, 4–Karatipar, 5–Lingri, 6–Khorkhoria, 7–Gokhai, 8–Noldunga, 9–Bor, 10–Baatomaari

species) amongst the *beels* and between 50 ± 3 – 71 ± 6 species in individual *beels* (50 ± 3 – 71 ± 6 species). The spatio-temporal significance (vide ANOVA) of Rotifera richness variations between *beels* and seasons is indicated in Table 3. Our collections reveal the speciose constellations of 76–81 species in three *beels* during winter and 76 species in one *beel* during pre-monsoon.

The globally interesting species observed in our Majuli collections include the Australasian *Brachionus dichotomus reductus* and *B. kostei*; the Oriental *Filinia camasecla*, *Keratella edmondsoni*, *Lecane blachei*, *L. niwati* and *L. superaculeata*; the Paleotropical *Keratella javana*, *Lepadella discoidea*, *L. vandenbrandei*, *Lecane eswari*, *L. lateralis*, *L. simonneae*, *L. stichoclysta*, *L. unguitata*, *Testudinella brevicaudata*, *T. greeni*, and *T. hollaerti*; the Indian endemic *Testudinella* sp.; the Holarctic *Lecane elongata* and *Trichocerca uncinata*; the Palaearctic *Cephalodella trigona* and *Lecane bifastigata*; the Indo-Chinese *Lecane dorysimilis*; the cosmo (sub) tropical *Brachionus durgae*; and three other species namely *Lecane rhenana*, *Testudinella amphora* and *Trichocerca edmondsoni*.

DISCUSSION

The Majuli *beels* indicate ‘slightly acidic to circum-neutral, moderately hard and oxygenated’ waters, water temperature concurs with geographical location of this river island, and total alkalinity is attributed to bicarbonate ions. Low specific conductivity denotes low ionic concentrations, highlights ‘de-mineralized nature’ and warrants inclusion of the sampled *beels* under ‘Class I category’ of trophic classification vide Talling & Talling (1965). ANOVA affirms significant spatial (between *beels*) and temporal (seasonal) variations of specific conductivity, total alkalinity and total hardness register, while water temperature, pH and dissolved oxygen register significant seasonal variations.

The present study reveals a total of 170 rotifer species belonging to 37 genera and 19 families.

The reported taxa represent significant fractions of species (~39%, ~56% and ~68%), genera (~54%, ~61% and ~80%) and families (76%, 79% and 94%) of the phylum known from India, NEI and Assam, respectively (Sharma & Sharma 2019a, 2021a) and thus highlight the speciose and diverse Rotifera of the Majuli *beels*. The bio-diverse nature of the taxon is hypothesized collectively to habitat diversity and environmental heterogeneity of the sampled *beels* due to occurrence of varied macrophytes (Segers *et al.* 1993, Green 2003, Bonecker *et al.* 2005, 2020, Sharma & Sharma 2019a) and the ‘Rotiferologist effect’ (Fontaneto *et al.* 2012).

The Majuli *beels* reveal diverse Rotifera as compared with the reports from the floodplains of the Danube–Dráva National Park in Hungary (78 species: Schöll & Kiss 2008; 75 taxa: Schöll *et al.* 2010), the river Ravi of Pakistan (101 species: Hussain *et al.* 2016), the Rio Pilcomayo National park (114 species: Jose De Paggi 2001) of Argentina, the river Warta valley of central-western Poland (143 species: Joniak and Kuczyńska-Kippen 2016), the lower Vistula river of Poland (Napiórkowski *et al.* 2019), and the La Plata river basin of South America (106 species: Martins *et al.* 2020). The richness known from the limited geographical area of this alluvial floodplain of the Brahmaputra river basin is relatively lower than the well studied wider areas of the floodplains of Upper Paraná River of Brazil (184 species: Bonecker *et al.* 2005, 224 species: Diniz *et al.* 2021) and the Niger delta of Africa (207 species: Segers *et al.* 1993). Further, the rotifer species examined from the Majuli *beels* merit ecological diversity interest as ~70% and ~78% of species of the phylum known from the floodplain lakes of Assam (244 species: Sharma & Sharma 2021a) and Manipur (218 species: Sharma & Sharma 2021a) states of NEI, while comparisons with the floodplains elsewhere from India are not possible because of poor species inventories. Referring to NEI in particular, our species tally concurs with the report from the *beels* of the Barak river basin of south Assam (170 species: Sharma & Sharma 2019b), and broadly compares with the richness

Figure 3. Hierarchical cluster analysis of Rotifera assemblages of the Majuli beels

Table 4. Percentage similarities between Rotifera assemblages of the Majuli beels

Beels	1	2	3	4	5	6	7	8	9	10
1	-	70.4	63.4	71.3	71.0	70.6	59.5	66.3	71.5	69.0
2		-	71.3	65.2	69.7	70.1	66.3	68.2	69.2	71.5
3			-	67.5	61.2	61.4	60.0	57.1	60.3	64.5
4				-	67.1	67.7	62.3	61.9	71.8	71.3
5					-	69.0	61.9	66.3	79.5	78.5
6						-	69.9	65.2	73.8	75.3
7							-	70.3	61.1	69.4
8								-	67.7	68.0
9									-	77.4
10										-

1–Mohorichuk, 2–Baalichapuri, 3–Dighaliya, 4–Karatipar, 5–Lingri, 6–Khorkhoria, 7–Gokhai, 8–Noldunga, 9–Bor, 10–Baatomaari

Table 5. Richness of important Rotifera families in the Majuli beels

Families↓ Beels→	1	2	3	4	5	6	7	8	9	10
Lecanidae	32	34	30	30	45	37	29	29	48	40
Lepadellidae	11	15	11	13	18	18	17	14	19	20
Brachionidae	12	11	7	9	11	12	8	11	12	12
Trichocercidae	8	9	6	9	13	8	7	8	11	13
Total species	63	69	54	61	87	75	61	62	90	85

1–Mohorichuk, 2–Baalichapuri, 3–Dighaliya, 4–Karatipar, 5–Lingri, 6–Khorkhoria, 7–Gokhai, 8–Noldunga, 9–Bor, 10–Baatomaari

Table 6. Temporal variations of Rotifera Richness in the Majuli *beels*

Beels↓ Richness→	Winter	Pre-monsoon	Monsoon	Post-monsoon	Mean	SD
Mohorichuk	68	64	48	62	61	8
Baalichapori	72	69	50	66	64	8
Dighaliya	60	62	45	57	56	7
Karatipar	67	63	48	59	59	7
Lingri	81	76	56	69	71	9
Khorkhoria	76	69	50	62	64	10
Gokhai	68	66	48	63	61	8
Noldunga	63	65	49	62	60	6
Bor	79	72	55	67	68	9
Baatomari	72	69	52	63	64	8

known from 15 *beels* of lower Assam (164 species: Sharma 2005), and the *beels* of Barpeta (176 species), Dibrugarh (179 species) and Tinsukia (169 species) districts of Assam (Sharma & Sharma 2021a). The Majuli *beels*, however, indicate relatively speciose Rotifera than the reports from four *beels* of lower Assam (160 species: Sharma *et al.* 2018), 15 *pats* of Manipur state (151 species: Sharma 2009), the floodplain lakes of the Kashmir Himalayas (140 species: Sharma & Sharma 2018b) and the Gangetic West Bengal (152 species: Sharma & Sharma 2021a), and the Yamuna river floodplains at Delhi (110 species: Arora & Mehra 2003). The stated comparisons highlight the global biodiversity interest of Rotifera of the tropical Majuli *beels* in conformity with the hypothesis of Segers *et al.* (1993) and categorize these wetlands as one of the rotifer-rich environs of the Indian sub-region. The notable meta-diversity increase as compared with earlier survey of the Majuli floodplain lakes (124 species: Sharma *et al.* 2015) is hypothesized to greater micro-habitat diversity of the varied nature of *beels* sampled presently and the sampling intensity following Fontaneto *et al.* (2012). Further, we record distinctly diverse Rotifera than the report from 12 *beels* of the Pobitora wild-life sanctuary of Assam (64 species: Sharma 2006) limited to analysis of only summer assemblages, and caution on comparisons with incomplete species inventories reported elsewhere from the Indian floodplains (Sinha *et al.* 1994; Sanjer and Sharma 1995, Khan 1997, 2002, 2003, Ganesan & Khan 2008, Sharma *et al.* 2011).

Four monogonont families: Lecanidae > Lepadellidae > Trichocercidae ≥ Brachionidae collectively influence (71% species) total Rotifera richness of the Majuli *beels*. Of these, Lecanidae contributes dominant fraction (~32% species), and Brachionidae (~11% species) deserves cautious mention in view of the paucity of *Brachionus* species; the latter is attributed to slightly acidic to circum-neutral nature of the sampled *beels* concurrent with the reports of Sharma & Sharma (2018a, 2021b). Testudinellidae, Notommatidae, Euchlanidae and Mytilinidae contribute ~16% species. Three genera *Lecane* > *Lepadella* = *Trichocerca* collectively influence total richness (~56% species), and *Testudinella* (9 species) deserves mention *vis-à-vis* richness known from India (Sharma & Sharma 2021a). Our study, however, registers notably high richness of *Lecane*, *Trichocerca* and *Testudinella* in contrast to earlier limited survey of the Majuli *beels* (Sharma *et al.* 2015).

The richness importance of the stated taxa imparts the littoral-periphytic nature to Rotifera of the sampled *beels* concurrent with the remarks of Sharma & Sharma (2019a). The predominance of Lecanidae, represented by 'the tropic centered' *Lecane*, concurs with Southeast Asian Rotifera (Segers 2001, Sa-Ardrit *et al.* 2013); this notable feature also corresponds the composition of the rotifer assemblages from the floodplain lakes of Argentina (Jose De Paggi 2001), Brazil (Bonecker *et al.* 2005, 2020) and Africa (Green 2003).

Our collections include 28 species (16.5 %) of the global biogeographic importance; these merit interest as notable fractions (~25%, ~37 % and ~51%) of globally important species known to-date from India (Sharma & Sharma 2021a), and NEI and Assam (Sharma & Sharma 2019a), respectively. Amongst these, two Australasian, five Oriental, 11 Palearctic and one Indo-Chinese species impart distinct affinity of Rotifera of the Majuli *beels* with the Southeast Asian and Oriental faunas. We hypothesize incursion of these elements through the ‘Assam gateway’— a unique biogeographic corridor of India following the remarks of Sharma & Sharma, (2019a, 2021a). Besides, the reports of the tropical-latitude populations of the Holarctic *Lecane elongata* and *Trichocerca uncinata*, and the Palearctic *Cephalodella trigona* and *Lecane bifastigata* deserve biogeography interest. The globally interesting species, however, mark a distinct contrast to only 10 such species listed vide earlier survey (Sharma *et al.* 2015). Further, our study reveals 27 species (15.9%) with their Indian distribution known to-date restricted to NEI, 23 species (13.5%) indicate regional distribution interest in India, and *Mytilina michelangellii* exhibits restricted disjunct distribution with reports from NEI and the Kashmir Himalayas (Sharma & Sharma 2018b). The present study thus highlights both the global and regional biogeography interest of Rotifera of the Majuli *beels*.

Rotifera record notable richness variations (97±17 species) amongst the Majuli *beels*. Lingri and Bor reveal 128 and 121 species, and Baatomaari, Khorkhoria and Baalichapori *beels* record 114, 101 and 93 species respectively. Higher richness reported from the stated wetlands with more diverse aquatic macrophytes differs from lower richness (78–86 species) observed from the remaining five *beels* invaded by *Eichhornia crassipes*. The richness variations are thus hypothesized to habitat heterogeneity amongst the sampled *beels* resulting from varied macrophytes while specific observations on the rotifer-macrophytic associations are desired from the study area and even on the Indian Rotifera (Sharma & Sharma 2021a). High richness known individually

from Lingri, Bor, Baatomaari and Khorkhoria *beels* merits biodiversity interest as compared with the reports from Thale-Noi Lake (106 species: Segers & Pholpunthin 1997) of Thailand; Lake Guarana (130 species: Bonecker *et al.* 1994) of Brazil; Oguta Lake from Niger delta (124 species: Segers *et al.* 1993) of Africa; Laguana Bufeos (104 species: Segers *et al.* 1998) of Bolivia; and certain *beels* from Assam (103 species, Sharma 2005; 124 species, Sharma *et al.* 2018) and *pats* of Manipur (120 species: Sharma 2009). Besides, our study (78–128 species) indicates Rotifera ecological diversity interest as compared with the reports of 71–103 (Sharma 2005) and 69–93 (Sharma & Sharma 2008) from various *beels* of Assam, and 62–120 species from 15 *pats* of Manipur (Sharma 2009). Further, we report higher richness variations (97±17 species) than earlier survey from the Majuli (77±12 species: Sharma *et al.* 2015) with the majority of *Eichhornia crassipes* infested *beels* indicating 60–82 species.

The rotifer assemblages of the different Majuli *beels* register 57.1–79.5% community similarities (*vide* Sørensen’s index); peak affinity is noted between the speciose Lingri and Bor *beels*, while Dighaliya and Noldunga register the lowest similarity. Lower community similarity values (61–70%) in ~59% instances in the similarity matrix affirm heterogeneity of species composition amongst the different *beels*. The species heterogeneity is further affirmed by the hierarchical cluster groupings which endorse the closer affinity between Lingri and Bor while Dighaliya > Gokhai > Noldunga *beels* register distinct divergence. The rotifer heterogeneity is apparently influenced by rare occurrence of ~51% species amongst the *beels*. Lecanidae, Lepadellidae, Trichocercidae, and Brachionidae collectively (71±12 species) influence total richness variations (97±17 species), record rare occurrence of 24, 11, 12 and 11 species respectively, and notably contribute to species heterogeneity amongst the sampled *beels*. Our results present a notable contrast to Rotifera homogeneity reported earlier (Sharma *et al.* 2015) from the Majuli *beels*; this deviation is attributed to greater microhabitat diversity and

species heterogeneity of the presently sampled *beels* vis-à-vis occurrence of *Eichhornia crassipes* and species composition variations in majority of *beels* noted in the earlier survey.

Rotifera richness registers the spatio-temporal variations in the Majuli *beels* during the present study. This trend is supported by the seasonal species tally varying between 45–62 (56 ± 7) – 56–81 (71 ± 9) species in individual *beels*, and between 62–76 (68 ± 4), 45–55 (50 ± 3), 57–67 (63 ± 3) and 60–81 (71 ± 6) species amongst the *beels* during pre-monsoon, monsoon, post-monsoon and winter seasons, respectively, and is affirmed by the significant seasonal richness variations in individual *beels* and seasonal richness differences amongst the *beels* noted vide ANOVA. Further, all the sampled *beels* record lowest richness during monsoon, the species tally registers partial increase during post-monsoon, and eight *beels* (except Dighaliya and Noldunga) indicate peak richness during winter. Low monsoon richness is hypothesized to increased turbidity and loss of macrophytes due to flooding of these wetlands, while habitat heterogeneity associated with the growth of diverse macrophytes during winter is hypothesized to result in peak richness in majority of the sampled *beels*. Nevertheless, specific observations are desired to affirm the stated remarks. In general, the seasonal richness variations broadly concur with the reports of Sharma (2005) and Sharma & Sharma (2008). The present study, however, lacks significant influence of individual abiotic factors namely water temperature, specific conductivity, dissolved oxygen, total alkalinity and total hardness on the rotifer richness variations of the sampled *beels*.

Our study reveals the speciose winter constellations of 76–81 rotifer species in three *beels* and that 76 species in one *beel* during pre-monsoon. These notable constellations, categorized as ‘Rotifera paradox’ analogous to the reports of Sharma & Sharma (2019a, 2021a) as well as the classical ‘paradox of the plankton’ *vides* Hutchinson (1961), depict an intriguing possibility of the co-existence of a number of species due to high amount of niche overlap as hypothesized by

MacArthur (1965). The stated assemblages concur with the consortia of 79 species from Deepor beel (Sharma & Sharma 2013) of Assam, and 79 species from Loktak Lake (Sharma *et al.* 2016) of Manipur as well as with the recent reports of 85 species each (December and January samples) from Deepor beel, and 84 and 81 species (during May and June) from a *beel* of upper Assam (Sharma & Sharma 2021a). Nevertheless, our results differ distinctly from the earlier reports of only 53 and 54 species per sample from Doriya and Chereki *beels* from the Majuli floodplain (Sharma *et al.* 2015).

Sládeček (1983) proposed $Q_{B/T}$ quotient based on the ratios between *Brachionus*: *Trichocerca* species to depict trophic status of different ecosystems or individual samples. Sharma (2005) and Sharma *et al.* (2018) ascertained suitability of application of Sládeček’s quotient to certain *beels* of Assam. Besides, Sharma *et al.* (2018) proposed $Q_{L/B}$ quotient based on *Lecane*: *Brachionus* species ratios to characterize habitat nature as well as temporal habitat variations of the selected *beels* of lower Assam. Application of the two quotients depicts limitation due to the paucity of *Brachionus* species reported vide the present study from acidic-circumneutral waters of the Majuli *beels*.

To conclude, the rich and diverse Rotifera of the ‘slightly acidic to circum-neutral, moderately hard-water and de-mineralized’ Majuli *beels* reveal sizeable fractions of species of global and regional biogeography interest, and register affinity with Southeast Asian and Oriental faunas. Total richness variations and heterogeneity of species composition are attributed to habitat heterogeneity amongst the *beels*. The significant spatio-temporal variations of species richness with seasonal differences amongst the *beels* and individually in each *beel*, the qualitative predominance of Lecanidae, the species-rich *Lepadella*, *Trichocerca* and *Testudinella* and the paucity of *Brachionus* species are interesting features. The noteworthy instances of speciose constellations of 76–81 species highlight ability of co-existence of high number of species in these ecotones. The plankton and semi-plankton collections examined

from the Majuli *beels* result in the paucity of the sessile and bdelloid rotifers, while the observations on Rotifera-macrophytic associations deserve attention. Our study is a useful contribution to ecological diversity Rotifera from the floodplain lakes of India and elsewhere from the tropics and subtropics.

Acknowledgements – The study is supported by the Ministry of Environment, Forests and Climate Change (Govt. of India) sponsored project. The senior author thanks the Head, Department of Zoology, NEHU, Shillong for laboratory facilities, and Messer's A. Hazarika, B. Hazarika and D. Thakuria for logistic support to facilitate the field work. We thank our anonymous reviewers for the comments and suggestions. The authors declare no conflict of interests.

REFERENCES

- A.P.H.A. (1992): *Standard methods for the examination of water and wastewater* (18th Ed.) American Public Health Association, Washington D.C. 2538 pp.
- ARORA, J. & MEHRA, N.K. (2003): Species diversity of planktonic and epiphytic rotifers in the backwaters of the Delhi segment of the Yamuna River, with remarks on new records from India. *Zoological Studies*, 42(2): 239–247.
- BONECKER, C.C., COSTA, C.L.D., VELHO, L.F.M. & LANSAC-TÔHA, F.A. (2005): Diversity and abundance of the planktonic rotifers in different environments of the Upper Paraná River floodplain (Paraná State – Mato Grosso do Sul State, Brazil). *Hydrobiologia*, 546: 405–414. doi: [10.1007/s10750-005-4283-2](https://doi.org/10.1007/s10750-005-4283-2)
- BONECKER, C.C., DINIZ, L.P., BRAGHIN, L.S.M., MANTOVANO, T., SILVA, J.V.F., BOMFIM, F.F. & LANSAC-TÔHA, F.A. (2020): Synergistic effects of natural and anthropogenic impacts on zooplankton diversity in a subtropical floodplain: A long-term study. *Oecologia Australis*, 24: 524–537. doi: [10.4257/oeco.2020.2402.20](https://doi.org/10.4257/oeco.2020.2402.20)
- BONECKER, C.C., LANSAC-TÔHA, F.A. & STAUB, A. (1994): Qualitative study of Rotifers in different environments of the high Parana River floodplain (Ms), Brazil. *Revista UNIMAR*, 16: 1–16.
- CHANDRA, K., BHARTI, D., KUMAR, S., RAGHUNATHAN, C., GUPTA, D., ALFRED, J.R.B. & CHOWDHURY, B.R. (2021): *Faunal Diversity in Ramsar Wetlands of India*. Jointly published by Zoological Survey of India, and Wetland division, Ministry of Environment, Forest and Climate Change, Government of India, 292 pp.
- DATTA, T. (2011): Zooplankton diversity and physico-chemical conditions of two wetlands of Jalpaiguri district, India. *International Journal of Applied Biology and Pharmaceutical Technology*, 2(3): 576–583.
- DEMBOWSKA, E.A. & NAPIÓRKOWSKI, P. (2015): A case study of the planktonic communities in two hydrologically different oxbow lakes, Vistula River, Central Poland. *Journal of Limnology*, 74(2): 326–337. doi: [10.4081/jlimnol.2014.1057](https://doi.org/10.4081/jlimnol.2014.1057)
- DINIZ, L.P., PETSCH D.K. & BONECKER C.C. (2021): Zooplankton β diversity dynamics and metacommunity structure depend on spatial and temporal scales in a Neotropical floodplain. *Freshwater Biology*, 66(7): 1328–1342. doi: [10.1111/fwb.13719](https://doi.org/10.1111/fwb.13719)
- FONTANETO, D., MÁRCIA BARBOSA, A., SEGERS, H. & PAUTASSO, M. (2012): The ‘rotiferologist’ effect and the other global correlates of species richness in rotifers. *Ecography*, 35: 174–182. doi: [10.1111/j.1600-0587.2011.06850.x](https://doi.org/10.1111/j.1600-0587.2011.06850.x)
- FUNK, A., RECKENDORFER, W., KUCERA-HIRZINGER, V., RAAB R. & SCHIEMER, F. (2009): Aquatic diversity in a former floodplain: Remediation in an urban context. *Ecological Engineering*, 35: 1476–1484. doi: [10.1016/j.ecoleng.2009.06.013](https://doi.org/10.1016/j.ecoleng.2009.06.013)
- GANESAN, L & KHAN, R.A. (2008): *Studies on the ecology of zooplankton in a floodplain wetland of West Bengal*. In: SENGUPTA, M. & DALWANI, R. (Eds.) Proceeding of Taal 2007, the 12th World Lake Conference, p. 67–73. doi: [10.1016/j.ecoleng.2009.06.013](https://doi.org/10.1016/j.ecoleng.2009.06.013)
- GÓRSKI, K., COLLIER, K.J., DUGGAN, I.C., TAYLOR, C.M. & HAMILTON, D.P. (2013): Connectivity and complexity of floodplain habitats govern zooplankton dynamics in a large temperate river system. *Freshwater Biology*, 58: 1458–1470. doi: [10.1111/fwb.12144](https://doi.org/10.1111/fwb.12144)
- GREEN, J. (2003): Associations of planktonic and periphytic rotifers in a tropical swamp, the Okavango Delta, Southern Africa. *Hydrobiologia*, 490: 197–209. doi: [10.1023/A:1023475217987](https://doi.org/10.1023/A:1023475217987)
- HUSSAIN, A., SULEHRIA, A.Q.K., EJAZ, M. & MAQBOOL, A. (2016): Population dynamics of rotifers in the floodplain of river Ravi, Pakistan. *Pakistan Journal of Zoology*, 48(1): 215–225.

- HUTCHINSON, G.E. (1961): The paradox of the plankton. *American Naturalist*, 95: 137–145. doi: [10.1086/282171](https://doi.org/10.1086/282171)
- JONIAK, T. & KUCZYNSKA-KIPPEN, N. (2016): Habitat features and zooplankton community structure of oxbows in the limnophase: reference to transitional phase between flooding and stabilization. *Limnetica*, 35 (1): 37–48. doi: [10.23818/limn.35.03](https://doi.org/10.23818/limn.35.03)
- JOSÉ DE PAGGI, S. (2001): Diversity of Rotifera (Monogononta) in wetlands of Rio Pilcomayo national park, Ramsar site (Formosa, Argentina). *Hydrobiologia*, 462: 25–34. doi: [10.1023/A:1013157914860](https://doi.org/10.1023/A:1013157914860)
- KHAN, M.A. (1987): Observations on Zooplankton composition, abundance and periodicity in two flood-plain lakes of the Kashmir Himalayan valley. *Acta Hydrochemica et Hydrobiologica*, 15: 167–174. doi: [10.1002/ahch.19870150211](https://doi.org/10.1002/ahch.19870150211)
- KHAN, R.A. (2002): The ecology and faunal diversity of two floodplain Ox-bow lakes of South-Eastern West Bengal. *Records of the Zoological Survey of India, Occasional Paper No. 195*: 1–57.
- KHAN, R.A. (2003): Faunal diversity of zooplankton in freshwater wetlands of South-eastern West Bengal. *Records of the Zoological Survey of India, Occasional Paper No. 204*: 1–107.
- MACARTHUR, R.H. (1965): Patterns of species diversity. *Biological Review*, 40: 510–533. doi: [10.1111/j.1469-185X.1965.tb00815.x](https://doi.org/10.1111/j.1469-185X.1965.tb00815.x)
- MARTINS, B.A., COELHO, P.N., NOGUEIRA, M. & PERBICHE-NEVES, G. (2020): Composition and richness of monogonont rotifers from La Plata River Basin, South America. *Biota Neotropica*, 20(4): e20201001. doi: [10.1590/1676-0611-BN-2020-1001](https://doi.org/10.1590/1676-0611-BN-2020-1001)
- NAPIÓRKOWSKI, P., BĄKOWSKA, M., MROZIŃSKA, N., SZYMAŃSKA, M., KOLAROVA, N. & OBOLEWSKI, K. (2019): The effect of hydrological connectivity on the zooplankton structure in floodplain lakes of regulated large river (the Lower Vistula, Poland). *Water*, 11: 1924: 2–17. doi: [10.3390/w11091924](https://doi.org/10.3390/w11091924)
- SA-ARDRIT, P., PHOLPUNTHIN, P. & SEGERS, H. (2013): A checklist of the freshwater rotifer fauna of Thailand (Rotifera, Monogononta, Bdelloidea). *Journal of Limnology*, 72(2): 361–375. doi: [10.4081/jlimnol.2013.s2.e18](https://doi.org/10.4081/jlimnol.2013.s2.e18)
- SANJER, L.R. & SHARMA, U.P. (1995): Community structure of plankton in Kavar lake wetland, Begusarai, Bihar, II Zooplankton. *Journal of Freshwater Biology*, 7: 165–167.
- SCHÖLL, K. & KISS, A. (2008.): Spatial and temporal distribution patterns of zooplankton assemblages (Rotifera, Cladocera, Copepoda) in the water bodies of the Gemenc floodplain (Duna-Dráva National Park, Hungary). *Opuscula Zoologica Budapest*, 39: 65–76.
- SCHÖLL, K., KISS, A., DINKA, M. & BERCZIK, A. (2010): Flood-pulse effects on zooplankton assemblages in a river-floodplain system (Gemenc Floodplain of the Danube, Hungary). *International Review of Hydrobiology* 97(1): 41–54. doi: [10.1002/iroh.201111427](https://doi.org/10.1002/iroh.201111427)
- SEGERS, H. (1995): *Rotifera 2: Lecanidae*. In: DUMONT, H.J. & NOGRADY, T. (Eds.) Guides to identification of the Microinvertebrates of the Continental waters of the world. SPB Academic Publishing bv. Amsterdam, the Netherlands, No. 6, 226 pp.
- SEGERS, H. (2001): Zoogeography of the Southeast Asian Rotifera. *Hydrobiologia*, 446/447: 233–246. doi: [10.1023/A:1017524011783](https://doi.org/10.1023/A:1017524011783)
- SEGERS, H., FERRUFINO, N.L. & DE MEESTER, L. (1998): Diversity and Zoogeography of Rotifera (Monogononta) in a flood plain lake of the Ichilo River, Bolivia, with notes on little known species. *International Review of Hydrobiology*, 83(5–6): 439–448. doi: [10.1002/iroh.19980830512](https://doi.org/10.1002/iroh.19980830512)
- 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. doi: [10.1007/BF00007495](https://doi.org/10.1007/BF00007495)
- SEGERS, H. & PHOLPUNTHIN, P. (1997): New and rare Rotifera from Thale Noi Lake, Pattalang Province, Thailand, with a note on the taxonomy of *Cephalodella* (Notommatidae). *Annals de Limnologie*, 33: 13–21. doi: [10.1051/limn/1997001](https://doi.org/10.1051/limn/1997001)
- SHARMA, B.K. (1983): The Indian species of the genus *Brachionus* (Eurotatoria: Monogononta: Brachionidae). *Hydrobiologia*, 104: 31–39. doi: [10.1007/bf00045949](https://doi.org/10.1007/bf00045949)
- SHARMA, B.K. (2005): Rotifer communities of floodplain lakes of the Brahmaputra basin of lower Assam (N. E. India): biodiversity, distribution and ecology. *Hydrobiologia*, 533: 209–221. doi: [10.1007/s10750-004-2489-3](https://doi.org/10.1007/s10750-004-2489-3)
- SHARMA, B.K. (2009): Rotifer communities of floodplain lakes of Manipur (North-East India), biodiversity, distribution and ecology. *Journal of the Bombay Natural History Society*, 106(1): 45–56.

- SHARMA, B.K., HAOKIP, T.P. & SHARMA, S. (2016): Loktak Lake, Manipur, northeast India: a Ramsar site with rich rotifer (Rotifera: Eurotatoria) diversity and its meta-analysis. *International Journal of Aquatic Biology*, 4(2): 69–79. doi: [10.7508/ijab.2016.02.001](https://doi.org/10.7508/ijab.2016.02.001)
- SHARMA, B.K., KHAN, S.I. & SHARMA, S. (2018): Biodiverse rotifer assemblage (Rotifera: Eurotatoria) of floodplain lakes of the Brahmaputra basin of lower Assam, northeast India: composition and ecosystem diversity. *Journal of Oceanology and Limnology*, 36(2): 362–375. doi: [10.1007/s00343-017-6251-x](https://doi.org/10.1007/s00343-017-6251-x)
- SHARMA, B.K. & SHARMA, S. (1999): Freshwater rotifers (Rotifera, Eurotatoria). *Fauna of Meghalaya, State Fauna Series, Zoological Survey of India, Calcutta*, 4(9): 11–161.
- SHARMA, B.K. & SHARMA, S. (2000): Freshwater rotifers (Rotifera, Eurotatoria). *Fauna of Tripura, State Fauna Series, Zoological Survey of India, Calcutta*, 7(4): 163–224.
- SHARMA, B.K. & SHARMA, S. (2001): Biodiversity of Rotifera in some tropical floodplain lakes of the Brahmaputra river basin, Assam (N. E. India). *Hydrobiologia*, 446/447: 305–313. doi: [10.1023/a:1017517822377](https://doi.org/10.1023/a:1017517822377)
- SHARMA, B.K. & SHARMA, S. (2014a): Northeast India – An important region with a rich biodiversity of Rotifera. In: SHARMA, B.K., DUMONT, H.J. & WALLACE, R.L. (Eds.) Rotifera XIII: Rotifer Biology – A structural and functional Approach. *International Review of Hydrobiology*, 99(1–2): 20–37. doi: [10.1002/iroh.201301701](https://doi.org/10.1002/iroh.201301701)
- SHARMA, B.K. & SHARMA, S. (2014b): Indian Lecanidae (Rotifera: Eurotatoria: Monogononta) and its distribution. In: SHARMA, B.K., DUMONT, H.J. & WALLACE, R.L. (Eds.) Rotifera XIII: Rotifer Biology – a Structural and Functional Approach. *International Review of Hydrobiology*, 99(1–2): 38–47. doi: [10.1002/iroh.201301702](https://doi.org/10.1002/iroh.201301702)
- SHARMA, B.K. & SHARMA, S. (2014c): The diversity of Indian Brachionidae (Rotifera: Eurotatoria: Monogononta) and their distribution. *Opuscula Zoologica Budapest*, 45(2): 165–180.
- SHARMA, B.K. & SHARMA, S. (2015): The diversity and distribution of Lepadellidae (Rotifera: Eurotatoria: Monogononta) of India. *International Review of Hydrobiology*, 100(1): 34–42. doi: [10.1002/iroh.201401739](https://doi.org/10.1002/iroh.201401739)
- SHARMA, B.K. & SHARMA, S. (2018a): Loktak Lake, Manipur revisited: A Ramsar site as the rotifer (Rotifera: Eurotatoria) biodiversity hot-spot of the Indian sub-region. *Bonn zoological Bulletin*, 67(1): 5–13.
- SHARMA, B.K. & SHARMA, S. (2018b): The rotifers (Rotifera: Eurotatoria) from the Kashmir Himalayan floodplains and Rotifera biodiversity of Jammu & Kashmir, north India. *International Journal of Aquatic Biology*, 6(4): 208–220. doi: [10.22034/ijab.v6i4.507](https://doi.org/10.22034/ijab.v6i4.507)
- SHARMA, B.K. & SHARMA, S. (2019a): The biodiverse rotifers (Rotifera: Eurotatoria) of Northeast India: faunal heterogeneity, biogeography, ecosystem diversity and interesting species assemblages. *Bonn zoological Bulletin*, 68(1): 147–162. doi: [10.20363/BZB-2019.68.1.147](https://doi.org/10.20363/BZB-2019.68.1.147)
- SHARMA, B.K. & SHARMA, S. (2019b): The biodiverse rotifers (Rotifera: Eurotatoria) of the floodplain wetlands of Barak valley of Assam state, northeast India. *Opuscula Zoologica Budapest*, 50(1): 3–15. doi: [10.18348/opzool.2019.1.3](https://doi.org/10.18348/opzool.2019.1.3)
- SHARMA, B.K. & SHARMA, S. (2021a): Biodiversity of Indian Rotifers (Rotifera) with remarks on biogeography and richness in diverse ecosystems. *Opuscula Zoologica Budapest*, 52(1): 69–97. doi: [10.18348/opzool.2021.1.69](https://doi.org/10.18348/opzool.2021.1.69)
- SHARMA, B.K. & SHARMA, S. (2021b): Zooplankton diversity of a sub-tropical small urban wetland of Meghalaya, northeast India with remarks on spatial variations. *Journal of Limnology & Freshwater Fisheries Research*, 7(1): 213–228. doi: [10.17216/limnofish-754060](https://doi.org/10.17216/limnofish-754060)
- SHARMA, B.K., SHARMA, S. & HATIMURIA, M.K. (2015): Rotifer assemblages (Rotifera: Eurotatoria) of the floodplain lakes of Majuli River Island, the Brahmaputra river basin, northeast India. *International Journal of Aquatic Biology*, 3(1): 1–13.
- SHARMA, G., SINHA, P. & SINHA, P. (2011): Zooplankton diversity. *Faunal Diversity of Chauris of North Bihar, Wetland Ecosystem Series, Zoological Survey of India, Kolkata*, 14: 7–19.
- SHARMA, S. (2006): Rotifer diversity (Rotifera: Eurotatoria) of floodplain lakes of Pobitora Wild-Life Sanctuary, Assam. *Records of the Zoological Survey of India*, 106(3): 76–89.
- 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.

- SHARMA, S. & SHARMA, B.K. (2013): Faunal diversity of aquatic invertebrates of Deepor Beel (a Ramsar site), Assam, northeast India. *Wetland Ecosystem Series, Zoological Survey of India, Kolkata*, 17: 1–226.
- SHIEL, R.J., GREEN, J.D. & NIELSEN, D.L. (1998.): Floodplain biodiversity: why are there so many species? *Hydrobiologia*, 387/388: 39–46. doi: [10.1023/A:1017056802001](https://doi.org/10.1023/A:1017056802001)
- SINHA, A.K., BARUAH, A., SINGH, D.K. & SHARMA, U.P. (1994): Biodiversity and pollution status in relation to physico-chemical factors of Kawar Lake (Begusarai), North Bihar. *Journal of Freshwater Biology*, 6: 309–331.
- SLADECEK, V. (1983): Rotifera as indicators of water quality. *Hydrobiologia*, 100: 169–201. doi: [10.1007/BF00027429](https://doi.org/10.1007/BF00027429)
- SØRENSEN, T. (1948): A method of establishing group of equal amplitude in plant sociology based on similarity of species content and its application to analyse the vegetation of Danish commons. *Biologiske Skrifter*, 5: 1–34.
- TALLING, J.F. & TALLING, I.B. (1965): The chemical composition of African lake waters. *Internationale Revue der gesamten Hydrobiologie*, 50: 421–463. doi: [10.1002/iroh.19650500307](https://doi.org/10.1002/iroh.19650500307)
-

Appendix 1: Species composition of Rotifera assemblages of the Majuli beels

Rotifer taxa↓	Beels→	1	2	3	4	5	6	7	8	9	10
Order: Ploima											
Subclass: Monogononta											
Family: Asplanchnidae											
<i>Asplanchna priodonta</i> Gosse, 1850**		-	+	+	+	+	+	+	-	+	+
Family: Brachionidae											
<i>Anuraeopsis fissa</i> Gosse, 1851**		+	+	-	+	+	+	+	+	+	-
<i>Brachionus angularis</i> Gosse, 1851*		+	-	-	-	-	-	-	-	+	+
<i>B. calyciflorus</i> Pallas, 1766*		+	-	-	-	+	-	-	+	-	+
<i>B. dichotomus reductus</i> Koste & Shiel, 1980*		-	+	-	-	-	-	-	+	-	-
<i>B. diversicornis</i> (Daday, 1883) *		-	-	-	+	-	+	-	-	-	-
<i>B. durgae</i> Dhanapathi, 1974*		-	-	-	-	-	+	+	-	-	+
<i>B. falcatus</i> Zacharias, 1898		+	-	+	-	+	+	-	+	+	+
<i>B. kostei</i> Shiel, 1983*		-	-	-	-	-	+	-	+	-	-
<i>B. mirabilis</i> Daday, 1897*		+	-	-	+	+	-	-	-	+	-
<i>B. quadridentatus</i> Hermann, 1783**		+	+	+	+	+	+	+	+	+	+
<i>Keratella cochlearis</i> (Gosse, 1851) **		+	+	+	+	+	+	+	+	+	+
<i>K. edmondsoni</i> Ahlstrom, 1943*		-	+	-	-	+	-	-	-	-	+
<i>K. javana</i> Hauer, 1937*		+	-	-	-	-	-	-	-	+	-
<i>K. lenzi</i> Hauer, 1953*		+	+	-	+	+	-	-	-	+	+
<i>K. tecta</i> (Gosse, 1851)		-	+	-	-	-	+	+	+	-	+
<i>K. tropica</i> (Apstein, 1907) **		+	+	+	+	+	+	+	+	+	+
<i>Platylabus leloupi</i> (Gillard, 1967) *		-	+	+	-	-	-	-	-	+	-
<i>P. quadricornis</i> (Ehrenberg, 1832) **		+	+	+	+	+	+	+	+	+	+
<i>Platylabus patulus</i> (O.F. Müller, 1786) **		+	+	+	+	+	+	+	+	+	+
Family: Dicranophoridae											
<i>Dicranophoroides caudatus</i> (Ehrenberg, 1834) *		+	-	-	+	+	-	-	-	+	-
<i>Dicranophorus forcipatus</i> (O.F. Müller, 1786) *		-	-	-	-	+	-	-	+	-	-
Family: Euchlanidae											
<i>Beauchampiella eudactylota</i> (Gosse, 1886) **		+	+	+	+	+	+	-	-	+	+
<i>Dipleuchlanis propatula</i> (Gosse, 1886) **		+	-	+	+	+	+	+	+	+	+
<i>Euchlanis dilatata</i> Ehrenberg, 1832**		+	+	+	+	+	+	+	+	+	+
<i>E. incisa</i> Carlin, 1939*		-	-	+	+	+	-	-	-	+	+
<i>E. triquetra</i> Ehrenberg, 1838*		+	+	-	-	+	-	-	-	+	+
<i>Tripleuchlanis plicata</i> (Levander, 1894)		-	+	+	+	+	-	+	+	-	+
Family: Flosculariidae											
<i>Sinantherina socialis</i> (Linne, 1758)		-	+	-	-	+	+	+	+	+	+
<i>S. spinosa</i> (Thorpe, 1893) **		+	+	+	+	+	+	+	+	+	+
Family: Gastropodidae											
<i>Ascomorpha ovalis</i> (Bergendal, 1892) *		-	-	-	-	+	-	-	-	-	-
Family: Lecanidae											
<i>Lecane aculeata</i> (Jakubski, 1912)		+	+	+	+	+	+	=	=	+	+
<i>L. aeganea</i> Harring, 1914*		-	-	+	+	+	-	-	-	+	+
<i>L. arcuata</i> Harring, 1914*		-	-	-	-	+	+	+	-	+	-
<i>L. bifastigata</i> Hauer, 1938*		+	-	-	+	+	-	-	+	+	+
<i>L. bifurca</i> (Bryce, 1892)		+	-	-	-	+	-	+	+	+	+
<i>L. blachei</i> Berzins, 1973		-	+	+	+	-	+	+	-	+	+
<i>L. bulla</i> (Gosse, 1851) **		+	+	+	+	+	+	+	+	+	+
<i>L. closterocerca</i> (Schmarda, 1859)**		+	+	+	+	+	+	+	+	+	+
<i>L. crepida</i> Harring, 1914		-	+	+	-	+	+	-	-	+	+
<i>L. curvicauda</i> (Murray, 1913) **		+	+	+	+	+	+	+	+	+	+

Rotifer taxa↓	Beels→	1	2	3	4	5	6	7	8	9	10
<i>Lecane decipiens</i> (Murray,1913) *		-	-	-	-	-	+	-	-	+	+
<i>L. doryssa</i> Harring,1914		+	+	-	-	+	+	-	+	+	+
<i>L. dorysimilis</i> Trinh Dang, Segers & Sanoamuang,2015*		-	-	-	-	+	-	+	-	+	+
<i>L. elegans</i> Harring,1914*		-	+	-	-	+	-	-	-	-	-
<i>L. elongata</i> Harring & Myers,1926*		+	-	-	-	-	-	-	-	+	-
<i>L. eswari</i> Dhanapathi,1976*		-	-	+	-	+	-	-	-	-	-
<i>L. flexilis</i> (Gosse,1886)		-	+	-	-	+	-	+	+	+	+
<i>L. furcata</i> (Murray,1913) **		+	+	+	+	+	+	+	+	+	+
<i>L. haliclysta</i> Harring & Myers,1926*		+	-	-	-	+	+	-	-	+	+
<i>L. hamata</i> (Stokes,1896) **		+	+	+	+	+	+	+	+	+	+
<i>L. hastata</i> (Murray,1913) *		-	-	+	+	-	-	-	-	-	+
<i>L. hornemanni</i> (Ehrenberg,1834)		+	+	-	+	+	+	-	-	+	+
<i>L. inermis</i> (Bryce,1892)		+	+	+	-	+	-	-	+	+	+
<i>L. inopinata</i> Harring & Myers,1926		+	+	-	-	+	+	-	-	+	-
<i>L. lateralis</i> Sharma,1978		+	-	+	+	+	+	+	+	-	-
<i>L. leontina</i> (Turner,1892) **		+	+	+	+	+	+	+	+	+	+
<i>L. ludwigii</i> (Eckstein,1883) **		+	+	+	+	+	+	+	+	+	+
<i>L. luna</i> (O.F. Müller,1776) * *		+	+	+	+	+	+	+	+	+	+
<i>L. lunaris</i> (Ehrenberg,1832) **		+	+	+	+	+	+	+	+	+	+
<i>L. monostyla</i> (Daday,1897) *		-	+	-	-	+	+	-	+	+	-
<i>L. nitida</i> (Murray,1913) *		-	+	+	-	+	-	+	+	+	-
<i>L. niwati</i> Segers, Kotethip & Sanoamuang,2004*		-	-	-	+	+	+	-	-	+	+
<i>L. obtusa</i> (Murray,1913) **		+	+	+	+	+	+	-	-	+	+
<i>L. ohioensis</i> (Herrick,1885) **		+	+	-	+	-	+	+	+	+	+
<i>L. papuana</i> (Murray, 1913) **		+	+	+	+	+	+	+	+	+	+
<i>L. paxiana</i> Hauer, 1940*		-	-	-	+	+	+	-	-	+	-
<i>L. ploenensis</i> (Voigt,1902) **		+	+	+	+	+	+	+	+	+	+
<i>L. pusilla</i> Harring, 1914*		+	+	+	-	-	-	+	-	+	+
<i>L. pyriformis</i> (Daday,1905) **		+	+	+	+	+	+	+	+	+	+
<i>L. quadridentata</i> (Ehrenberg,1830) **		+	+	+	+	+	+	+	+	+	+
<i>L. rhenana</i> Hauer,1929*		+	-	-	-	+	-	-	+	+	+
<i>L. rhytida</i> Harring & Myers,1926*		-	-	-	-	-	+	+	-	-	-
<i>L. signifera</i> (Jennings, 1896)		+	+	+	+	+	+	+	+	+	+
<i>L. simonneae</i> Segers,1993*		-	-	-	+	+	-	-	-	+	+
<i>L. stichoclysta</i> Segers,1993*		-	-	-	-	+	-	-	-	+	-
<i>L. stenroosi</i> (Meissner,1908) **		+	+	+	+	+	+	-	-	+	+
<i>L. styrax</i> (Harring & Myers,1926) **		-	+	-	+	+	+	+	+	+	+
<i>L. subtilis</i> Harring & Myers,1926*		+	-	-	-	+	-	-	-	-	-
<i>L. superaculeata</i> Sanoamuang & Segers,1997*		-	+	-	-	-	-	-	-	+	-
<i>L. syngenes</i> (Hauer,1938) *		-	-	+	-	-	-	-	-	-	-
<i>L. tenuiseta</i> Harring,1914*		-	-	-	-	+	+	-	+	+	+
<i>L. thienemanni</i> (Hauer,1938)*		-	-	+	-	-	+	+	-	+	-
<i>L. undulata</i> Hauer,1938**		-	+	-	-	+	+	+	+	+	+
<i>L. unguitata</i> (Fadeev,1925) **		+	+	+	+	+	+	+	+	+	+
<i>L. unguolata</i> (Gosse,1887) **		+	+	+	+	+	+	+	+	+	+
Family: Lepadellidae											
<i>Colurella adriatica</i> Ehrenberg,1831*		-	-	-	+	+	-	-	+	+	+
<i>C. colurus</i> (Ehrenberg,1830) *		-	+	+	-	-	-	-	-	-	-
<i>C. obtusa</i> (Gosse,1886) **		+	+	+	+	+	+	+	+	+	+
<i>C. sulcata</i> (Stenroos,1898) *		-	-	-	-	+	+	-	-	+	-

Rotifer taxa↓	Beels→	1	2	3	4	5	6	7	8	9	10
<i>Colurella uncinata</i> (O.F. Müller, 1773) **		+	+	+	+	+	+	+	+	+	+
<i>Lepadella acuminata</i> (Ehrenberg, 1834) **		+	+	-	+	+	+	-	-	+	+
<i>L. apside</i> Harring, 1916		+	+	-	+	+	-	+	-	+	+
<i>L. apsicora</i> Myers, 1934		+	-	-	-	+	+	-	+	+	-
<i>L. benjamini</i> Harring, 1916**		-	+	+	+	+	+	+	-	+	+
<i>L. biloba</i> Hauer, 1958		-	-	+	+	-	+	-	+	+	+
<i>L. costatoides</i> Segers, 1992		-	+	-	-	+	+	+	+	-	+
<i>L. dactyliseta</i> (Stenroos, 1898) *		-	-	-	-	-	-	+	-	-	-
<i>L. discoidea</i> Segers, 1993		+	+	+	-	+	+	-	+	+	+
<i>L. ehrenbergi</i> Perty, 1850**		+	+	+	+	+	+	+	+	+	+
<i>L. eurysterna</i> Myers, 1942*		-	-	+	-	-	-	-	-	+	+
<i>L. heterostyla</i> (Murray, 1913)		-	+	-	+	+	+	+	+	+	+
<i>L. lindaui</i> Koste, 1981*		-	-	-	-	+	-	-	-	+	+
<i>L. minuta</i> (Weber & Montet, 1918) *		-	+	-	-	-	-	+	+	-	-
<i>L. ovalis</i> (O.F. Müller, 1786) **		+	+	+	+	+	+	+	+	+	+
<i>L. patella</i> (O.F. Müller, 1773) **		+	+	+	+	+	+	+	+	+	+
<i>L. quinquecostata</i> (Lucks, 1912) *		-	-	-	-	-	+	+	-	-	+
<i>L. rhomboides</i> (Gosse, 1886)		+	+	+	-	-	+	+	+	-	+
<i>L. triba</i> Myers, 1934		-	-	-	-	-	+	+	-	+	+
<i>L. triptera</i> Ehrenberg, 1832*		-	-	-	+	+	-	+	+	+	+
<i>L. vandenbrandei</i> Gillard, 1952*		-	-	-	-	+	+	+	-	-	+
<i>Squatinella lamellaris</i> (O.F. Müller, 1786) **		+	+	-	+	+	+	+	-	+	-
Family: Mytilinidae											
<i>Mytilina acanthophora</i> Hauer, 1938		+	+	-	-	+	-	+	+	+	-
<i>M. bisulcata</i> (Lucks, 1912)		+	-	+	+	-	+	+	-	-	+
<i>M. brevispina</i> (Ehrenberg, 1830)		-	-	+	+	+	-	-	-	+	-
<i>M. michelangellii</i> Reid & Turner, 1988*		-	-	-	+	-	+	+	+	+	+
<i>M. ventralis</i> (Ehrenberg, 1830) **		+	+	+	+	+	+	-	-	+	+
Family: Notommatidae											
<i>Cephalodella forficula</i> (Ehrenberg, 1830) *		-	+	+	-	+	-	-	+	+	-
<i>C. gibba</i> (Ehrenberg, 1830) **		+	+	+	+	+	+	+	+	-	-
<i>C. mucronata</i> Myers, 1924*		-	-	-	-	-	-	-	+	+	-
<i>C. trigona</i> (Rousselet, 1895) *		-	+	+	-	+	-	-	-	-	+
<i>Monommata longiseta</i> (O.F. Müller, 1786)		+	+	+	+	+	+	-	-	-	+
<i>M. maculata</i> Haring & Myers, 1930*		-	-	-	-	+	-	-	-	-	+
<i>Notommata pachyura</i> (Gosse, 1886) *		+	-	-	-	-	+	-	-	-	-
Family: Scardiidae											
<i>Scardium longicaudum</i> (O.F. Müller, 1786)		+	+	-	-	+	+	-	+	+	=
Family: Synchaetidae											
<i>Pleosoma lenticulare</i> Herrick, 1885*		-	+	-	-	+	+	+	-	-	+
<i>Polyarthra vulgaris</i> Carlin, 1943		+	+	+	+	+	+	+	+	+	+
Order: Flosculariaceae											
Family: Conochilidae											
<i>Conochilus unicornis</i> Rousselet, 1892*		-	-	-	-	-	+	+	+	+	+
Family: Hexarthridae											
<i>Hexarthra mira</i> (Hudson, 1871) *		-	+	-	-	-	+	-	-	+	+
Family: Testudinellidae											
<i>Testudinella amphora</i> Hauer, 1938*		+	-	-	+	+	-	-	+	+	+
<i>T. brevicaudata</i> Yamamoto, 1951*		-	-	-	-	+	+	-	-	+	+
<i>T. dendradena</i> de Beauchamp, 1955*		-	-	-	+	+	-	-	-	+	-

Rotifer taxa↓	Beels→	1	2	3	4	5	6	7	8	9	10
<i>Testudinella emarginula</i> (Stenroos,1898)**		+	+	+	-	+	+	+	+	+	+
<i>T. greeni</i> Koste,1981*		-	-	+	-	+	-	-	-	-	-
<i>T. parva</i> (Ternetz,1892)*		+	-	-	-	+	-	-	-	-	-
<i>T. patina</i> (Hermann,1783)**		+	+	+	+	+	+	+	+	+	+
<i>T. tridentata</i> Smirnov,1931*		-	-	-	-	+	+	-	+	+	+
<i>T. sp.</i> Sharma and Sharma,2018*		-	+	-	-	-	-	-	-	-	-
<i>Pompholyx sulcata</i> Hudson,1885		+	-	-	+	+	-	+	-	+	+
Family: Trichocercidae											
<i>Trichocerca bidens</i> (Lucks,1912)		+	+	-	+	+	-	-	+	1	+
<i>T. bicristata</i> (Gosse,1887)**		+	-	-	+	+	+	+	+	+	+
<i>T. capucina</i> (Wierzejski & Zacharias,1893)		-	+	+	-	-	-	-	-	-	-
<i>T. cylindrica</i> (Imhof,1891)**		+	+	+	+	+	+	-	-	+	+
<i>T. edmondsoni</i> (Myers,1936)*		-	-	-	-	+	-	-	-	-	+
<i>T. elongata</i> (Gosse,1886)*		-	-	-	+	-	-	+	+	-	+
<i>T. hollaerti</i> De Smet,1990*		-	-	-	+	-	-	-	+	+	-
<i>T. insignis</i> (Herrick,1885)**		+	+	+	-	+	+	+	-	+	+
<i>T. insulana</i> (Hauer,1937)*		-	-	-	-	+	+	-	-	-	+
<i>T. longiseta</i> (Schränk,1802)		-	+	+	+	-	-	-	-	+	-
<i>T. maior</i> Hauer,1936*		-	-	-	+	+	-	-	-	-	+
<i>T. pusilla</i> (Jennings,1903)		+	-	-	-	+	+	-	-	+	-
<i>T. rattus</i> (O.F. Muller,1776)**		+	+	+	+	-	+	+	+	+	+
<i>T. scipio</i> (Gosse,1883)*		-	-	-	-	+	-	+	-	-	+
<i>T. similis</i> (Wierzejski,1893)**		+	+	-	+	+	+	-	+	+	+
<i>T. tenuior</i> (Gosse,1886)*		-	-	-	-	+	-	-	+	+	-
<i>T. tigris</i> (O.F. Muller,1786)		+	+	-	-	+	+	+	+	-	+
<i>T. uncinata</i> (Voigt,1902)*		-	-	+	-	-	-	-	-	-	-
<i>T. voluta</i> (Murray,1913)*		-	+	-	-	-	-	-	-	-	-
<i>T. weberi</i> (Jennings,1903)*		-	-	-	-	+	-	+	-	+	+
Family: Trichotriidae											
<i>Macrochaetus collinsi</i> (Gosse,1867)*		-	-	+	-	+	-	-	-	-	-
<i>M. longipes</i> Myers,1934*		-	+	+	-	+	-	-	+	+	+
<i>M. sericus</i> (Thorpe,1893)		+	+	+	+	+	+	-	-	-	+
<i>Trichotria tetractis</i> (Ehrenberg,1830)**		+	+	+	+	+	+	+	+	+	+
<i>Wolga spinifera</i> (Western,1894)*		-	-	-	-	+	-	-	-	-	-
Family: Trochosphaeridae											
<i>Filinia camasecla</i> Myers,1938*		-	-	-	+	-	+	-	-	+	-
<i>F. longiseta</i> (Ehrenberg,1834)**		+	+	+	+	+	-	+	+	-	+
<i>Trochosphaera aequatorialis</i> Semper,1872*		-	-	-	-	+	+	+	-	-	-
Sub-class: Digononta											
Order: Bdelloidea											
Family: Philodinidae											
<i>Philodina citrina</i> Ehrenberg,1832*		-	-	-	-	+	-	+	-	+	-
<i>Rotaria neptunia</i> (Ehrenberg,1830)*		+	-	-	+	-	+	-	-	+	-
<i>R. rotatoria</i> (Pallas,1766)*		-	-	+	-	+	-	+	-	-	-
TOTAL ROTIFERA RICHNESS		86	93	78	85	128	101	82	83	121	114

+ present; - absent; *rare occurrence; **occurring in all beels or nearly in all beels

The sampled beels: 1–Mohorichuk, 2–Baalichapori, 3–Dighaliya, 4–Karatipar, 5–Lingri, 6–Khorkhoria, 7–Gokhai, 8–Noldunga, 9–Bor, 10–Baatoaari