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Original Article

Rotifers (Rotifera: Eurotatoria) from floodplain lakes of the Dibru Saikhowa Biosphere Reserve, upper Assam, northeast India: ecosystem diversity and biogeography

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Abstract: This study aims to assess ecosystem diversity of Rotifera of the floodplain lakes (beels) of the Brahmaputra river basin with reference to faunal diversity of the taxon in wetlands of conservation areas of India. We observed 141 rotifer species, belonging to 31 genera and 17 families, from three beels of the Dibru-Saikhowa Biosphere Reserve (DSBR) of Assam, northeast India (NEI) with high total richness (117±2 species) in individual beels. One, two and three species are new to the Oriental region, India and Assam state, respectively and 21 species are globally interesting. The diverse Lecanidae > Lepadellidae > Trichocercidae; the paucity and scarceness of Brachionidae and *Brachionus* spp. in particular; and rare nature of *Keratella*, *Filinia*, *Asplanchna*, *Polyarthra*, and *Conochilus* are salient. The monthly richness and community similarities affirmed heterogeneity in species composition in individual beels while this study exhibited overall rotifer homogeneity amongst beels. The richness followed monthly oscillations in the three beels and lacked significant variations amongst beels. The peak richness of 76 species during summer (May, 2014) from No. 11 beel is one of the richest rotifer assemblages known in single date collection from an aquatic ecosystem of South Asia. Our results explained little influence of individual abiotic factors while canonical correspondence analysis endorsed high cumulative influence of 17 abiotic factors on richness in all beels.

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Introduction

Rotifera form an important group of freshwater metazoans and of fish-food-organisms, and an integral link of freshwater food-webs. Segers et al. (1993) hypothesized tropical and subtropical floodplain lakes to be globally important rotifer habitats. The importance of the rotifer diversity of the Indian floodplains in light of Segers's hypothesis have been affirmed for the floodplains of Assam (Sharma and Sharma, 2014a; Sharma et al., 2017) and Manipur (Sharma et al., 2016) states of northeastern India (NEI). To augment our hypothesis on biodiverse nature of the floodplain wetlands of upper Brahmaputra river basin with regard to ecosystem diversity, we analyzed the rotifer communities of three beels of the Dibru-Saikhowa Biosphere Reserve (DSBR) of Assam, northeast India. This study deserves attention in view of limited studies till date on the rotifer diversity from wetlands of conservations areas of India. The notable related works included the reports from the Majuli floodplains (Sharma, 2014; Sharma et al., 2015) and two Ramsar sites of India namely Deepor Beel (Sharma and Sharma, 2015a) and Loktak Lake (Sharma et al., 2016), and Nokrek Biosphere reserve of Meghalaya (Sharma and Sharma, 2011). This study thus merits ecosystem diversity and biogeography importance for the Indian Rotifera and for biodiversity of the taxon in wetlands of conservation areas of India.

Rotifera of three Dibru-Saikhowa Biosphere Reserve beels of the upper Brahmaputra river basin of NEI are analyzed for a period of two years. We provide an inventory of the documented species and several interesting taxa are illustrated to warrant

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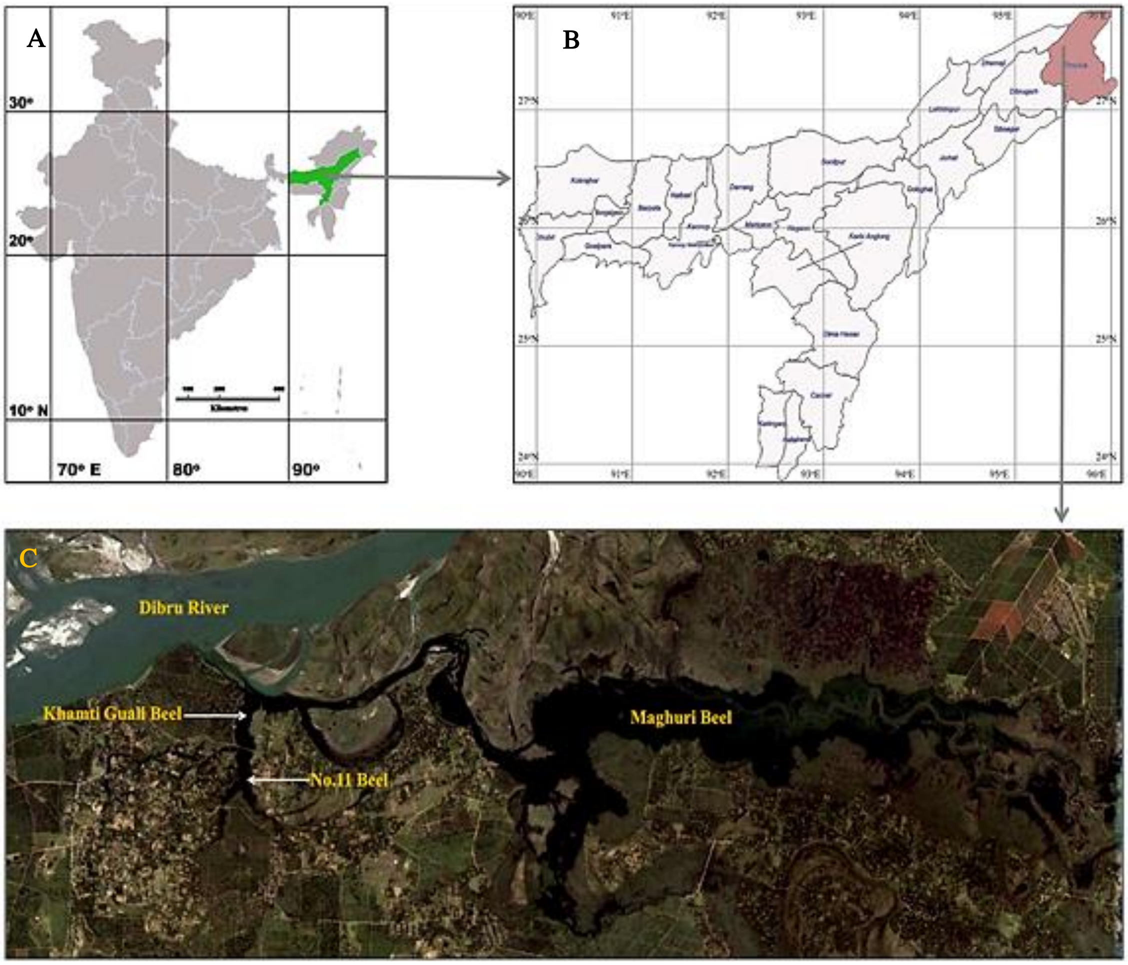

Figure 1. (A) Map of India showing Assam state of northeast India; (B) map of Assam state indicating Tinsukia district; (C) map showing sampled floodplain lakes (Google map).

validation. The nature and composition of the rotifer fauna is discussed with emphasis on new records, taxa of global and regional biogeography interest and distribution of various taxa. Remarks are made on the rotifer diversity of the sampled beels with reference to monthly variations in richness, community similarities and the influence of abiotic factors.

Materials and Methods

This study is part of a limnological survey (October 2013–September 2015) undertaken in three floodplain lakes namely Maghuri (27°34'19.2"-27°34'25.2"N; 95°22'04.5"-95°22'35.2"E), Khamti Guali (27°34' 23.4"-27°34'26.0"N; 95°20'27.4"-95°20'53.8"E) and No. 11 (27°34'04.8"-27°34'11.5"N; 95°20'21.8"-95° 20'25.8"E) beels located in the 'buffer zone' of the Dibru-Saikhowa Biosphere Reserve (DSBR), upper Assam, NEI (Fig. 1). These beels are influenced by intensive fish harvesting and by floodwaters during south-west monsoon. Aquatic vegetation of Maghuri beel was comprised of *Eichhornia crassipes* (Mart.) Solms, *Pistia stratiotes* Linnaeus, *Lemna* sp., *Azolla* sp., *Ludwigia* sp., *Rumex* sp. and *Cabomba caroliniana*; and Khamti Guali and No. 11 beels showed aquatic vegetation composed of *Eichhornia crassipes* (Mart.) Solms, *Pistia stratiotes* Linnaeus, *Hygroryza aristata* (Retz.) Nees, *Trapa natans* Linnaeus, *Eleocharis* sp., *Lemna* sp., and *Nymphaea* sp.

Water samples collected monthly from the three beels were analyzed for 17 environmental parameters. Of these, water temperature, specific conductivity and pH were recorded with field probes, and rainfall data was obtained from local meteorological centre. Dissolved oxygen was estimated by Winkler's method, and free carbon dioxide, total alkalinity, total

Table 1. Variations (mean±SD) in abiotic factors (October 2013–September 2015).

Parameters	Maghuri Beel		Khamti Guali Beel		NO.11 Beel	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Water temp (º C)	15.0-30.8	25.2±5.2	14.0-32.6	25.9±5.7	15.5-30.7	25.6±5.2
Rainfall (mm)	0.0 - 615.0	188.4-193.6	0.0-615.0	188.4-193.6	0.0-615.0	188.4-193.6
pH	6.75-8.09	7.37±0.49	6.84-8.04	7.38±0.46	6.92-7.94	7.28±0.36
Conductivity (µS/cm)	69.0-140.0	104.8±21.2	74.0-150.0	109.7±23.9	46.0-139.0	82.5±26.2
Dissolved oxygen (mg/l)	4.0-8.0	5.8±1.5	4.0-8.8	5.9±1.3	4.0-8.0	5.5±1.1
Free Carbon dioxide (mg/l)	10.0-28.0	15.8±5.3	10.0-24.0	16.3±4.2	8.0-24.0	15.8±4.8
Total alkalinity (mg/l)	40.0-80.0	65.2±12.9	40.0-84.0	59.0±13.8	40.0-80.0	53.8±10.5
Total hardness (mg/l)	54.0-86.0	70.5±11.0	50.0-80.0	67.7±9.9	40.0-80.0	64.2±11.5
Calcium (mg/l)	16.8-25.2	20.5±2.6	14.7-27.3	20.8±3.6	12.7-23.1	18.6±2.8
Magnesium (mg/l)	7.0-16.3	12.2±3.1	7.99-15.4	11.4±2.5	8.1-15.4	11.9±2.5
Chloride (mg/l)	7.99-20.97	13.48±3.20	9.90-19.90	14.69±3.86	10.98-23.97	16.90±4.27
Dissolved organic matter (mg/l)	0.041-0.131	0.095±0.033	0.048-0.131	0.104±0.029	0.045-0.120	0.090±0.026
Total dissolved solids (mg/l)	0.080-0.200	0.131±0.051	0.040-0.240	0.123±0.053	0.040-0.280	0.147±0.078
Phosphate (mg/l)	0.140-0.322	0.212±0.064	0.138-0.351	0.225±0.069	0.142-0.371	0.222±0.075
Nitrate (mg/l)	0.352-1.881	0.862±0.456	0.440-1.702	0.852±0.378	0.369-1.550	0.839±0.374
Sulphate (mg/l)	6.14-25.05	13.49±7.04	6.72-23.99	15.08±6.91	5.77-22.91	13.34±6.931
Silica (mg/l)	0.657-1.361	0.890±0.209	0.678-1.372	0.896±0.212	0.681-1.379	0.893±0.213

hardness, calcium, magnesium, chloride, dissolved organic matter, total dissolved solids, phosphate, nitrate, sulphate and silicate were analyzed following APHA (1992). The qualitative plankton and semi-plankton samples were collected monthly from the selected beels by towing a nylobolt plankton net (# 50 µm) and were preserved in 5% formalin. The rotifers were mounted in Polyvinyl alcohol–lactophenol and were examined with Leica (DM 1000) stereoscopic phase contrast microscope fitted with an image analyzer. We followed Koste (1978), Segers (1995), Sharma (1998), Sharma and Sharma (2008, 2013) for identification of the rotifers. Sørensen's index was followed to calculate rotifer community similarities. Two-way ANOVA was used to investigate significance of the richness variations. The relationships between abiotic factors and rotifer richness were determined by Pearson's correlation coefficients (r); *P* values were computed and their significance was examined after applying Bonferroni correction. The canonical correspondence analysis was done using XLSTAT (2015) to analyze influence of the stated 17 environmental variables on the rotifer richness in the three beels.

Results

The variations (mean±SD) in abiotic factors of the three beels of the Dibru-Saikhowa Biosphere Reserve are indicated in Table 1. A total of 141 species of Rotifera belonging to 31 genera and 17 families are observed in our collections (Appendix 1). *Squatinella bifurca* (Fig. 2 A-B) is a new record from the Oriental region; *Lecane isanensis (*Fig. 2C) and *L. shieli* (Fig. 2D) are new records from India; and *Lecane aeganea* (Fig. 2E), *L. dorysimilis* (Fig. 2F), *Trichocerca maior* (Fig. 2G) and *T. siamensis* (Fig. 2H) are new records from Assam state. *Brachionus dichotomus reductus* (Fig. 3A), *Filinia camasecla* (Fig. 3B), *Keratella edmondsoni* (Fig. 3C), *Lecane blachei* Berzins (Fig. 3D), *L. batillifer* (Fig. 3E), *L. bulla diabolica* (Fig. 3F), *L. lateralis* (Fig. 3G), *L. niwati* (Fig. 3H), *L. simonneae* (Fig. 3I), *L. superaculeata* (Fig. 3J), *Lepadella discoidea* (Fig. 4A), *L. vandenbrandei* (Fig. 4B), *Notommata spinata* (Fig. 4C), *Testudinella amphora* (Fig. 4D), *T. brevicaudata* (Fig. 4E), *T. dendradena* (Fig. 4F), *Trichocerca edmondsoni* (Fig. 4G) and *T. hollaerti* (Fig. 4H) are interesting species with regards to regional distribution.

Total rotifer richness (S) in three beels is observed to vary between 116-120 (117±2) species with No. 11 > Khamti Guali > Maghuri beels and recorded 84.6-99.1% community similarities (Sørensen's index) amongst them. This study indicated annual richness of 107-112, 93-106 and 80-101 species and recorded 87.7%, 78.4% and 68.5% similarities of the rotifer assemblages during the study period; the similarities ranged between 30.0-70.4% and 28.9-71.7%; 27.5-69.0 and 28.9-76.1%: and 29.1-65.0 and 28.6-75.0%

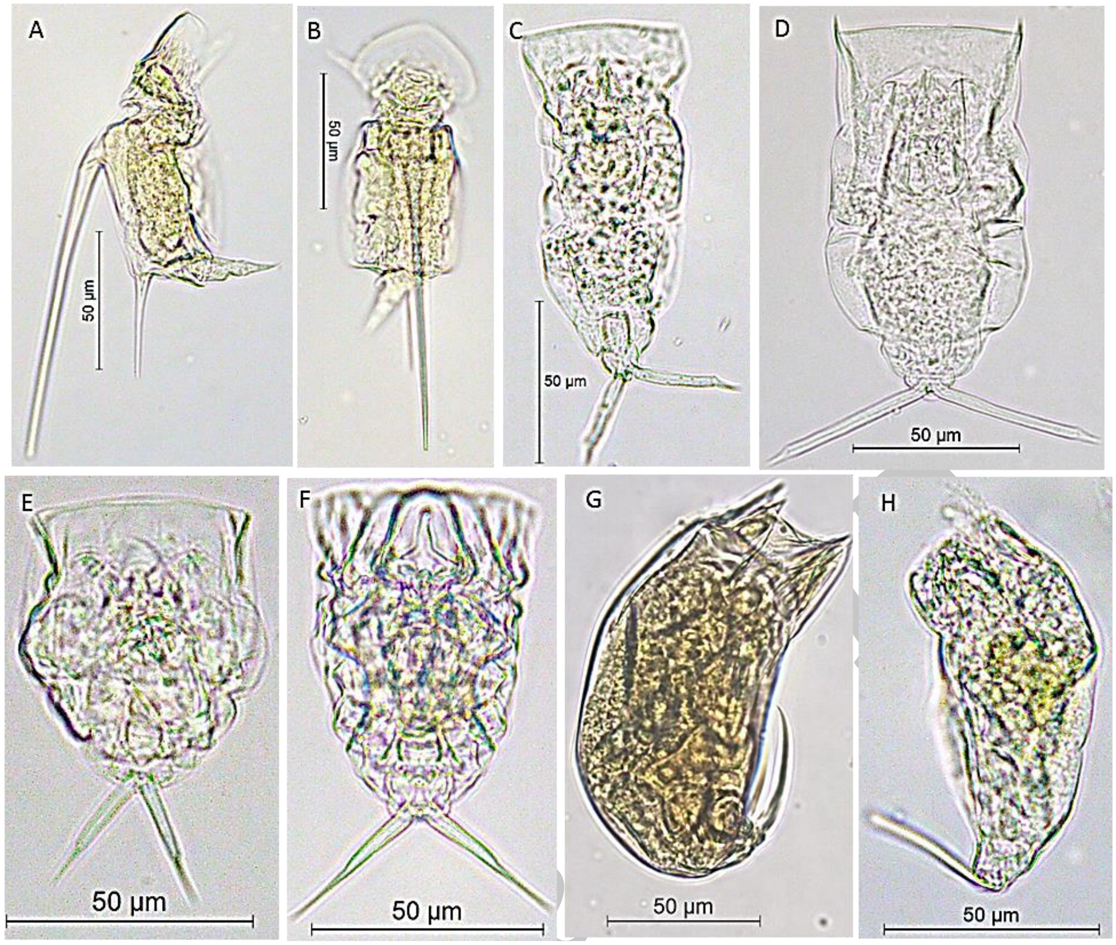

Figure 2. New records. (A) *Squatinella bifurca* (Bolton), lateral view; (B) *Squatinella bifurca* (Bolton), dorsal view; (C) *Lecane isanensis* Sanoamuang & Savatenalinton, ventral view; (D); *Lecane shieli* Segers & Sanoamuang, dorsal view; (E) *Lecane aeganea* Harring, ventral view; (F) *Lecane dorysimilis* Trinh Dang, Segers & Sanoamuang, ventral view; (G) *Trichocerca maior* Hauer, lateral view; (H) *Trichocerca siamensis* Segers & Pholpunthin, lateral view.

during two years in the three beels, respectively. The monthly richness (Figs. 5-7) ranged between 15-61(30±10) species in Maghuri beel, 15-68(34±14) species in Khamti Guali beel and between 13-76(30±10) species in No. 11 beel. Lecanidae and Lepadellidae included 48 and 24 species, respectively and showed higher richness throughout the study (Figs. 5-7). ANOVA registered insignificant richness variations amongst beels but recorded significant monthly variations ($F_{2, 46}$=2.636, *P*=0.0025) between them. It registered significant annual richness variations in Maghuri beel ($F_{1, 23}$=7.604, *P*=0.0186) and significant monthly variations in Khamti Guali beel ($F_{11, 23}$=3.112, *P*=0.0363) but No. 11 beel recorded insignificant monthly and annual variations.

No significant correlation between environmental parameters and species richness could be found in Maghuri beel; Brachionidae richness (r=0.592; *P*=0.0000) was positively influenced by water temperature in Khamti Guali beel; and Lecanidae (r= 0.703; *P*=0.0001) and Testudinellidae (r=0.569; *P*=0.000) richness in No. 11 beel were positively influenced by rainfall. The Canonical correspondence analysis (Fig. 8-10) registered 79.2%, 80.9% and 68.1% influence along first two axes on richness of rotifer assemblages in Maghuri, Khamti Guali and No. 11 beels, respectively.

Discussion

All three beels of the Dibru-Saikhowa Biosphere Reserve (DSBR) are characterized by tropical, circumneutral-alkaline, marginally hard, and moderately oxygenated calcium poor waters. Low ionic concentrations warranted inclusion of these

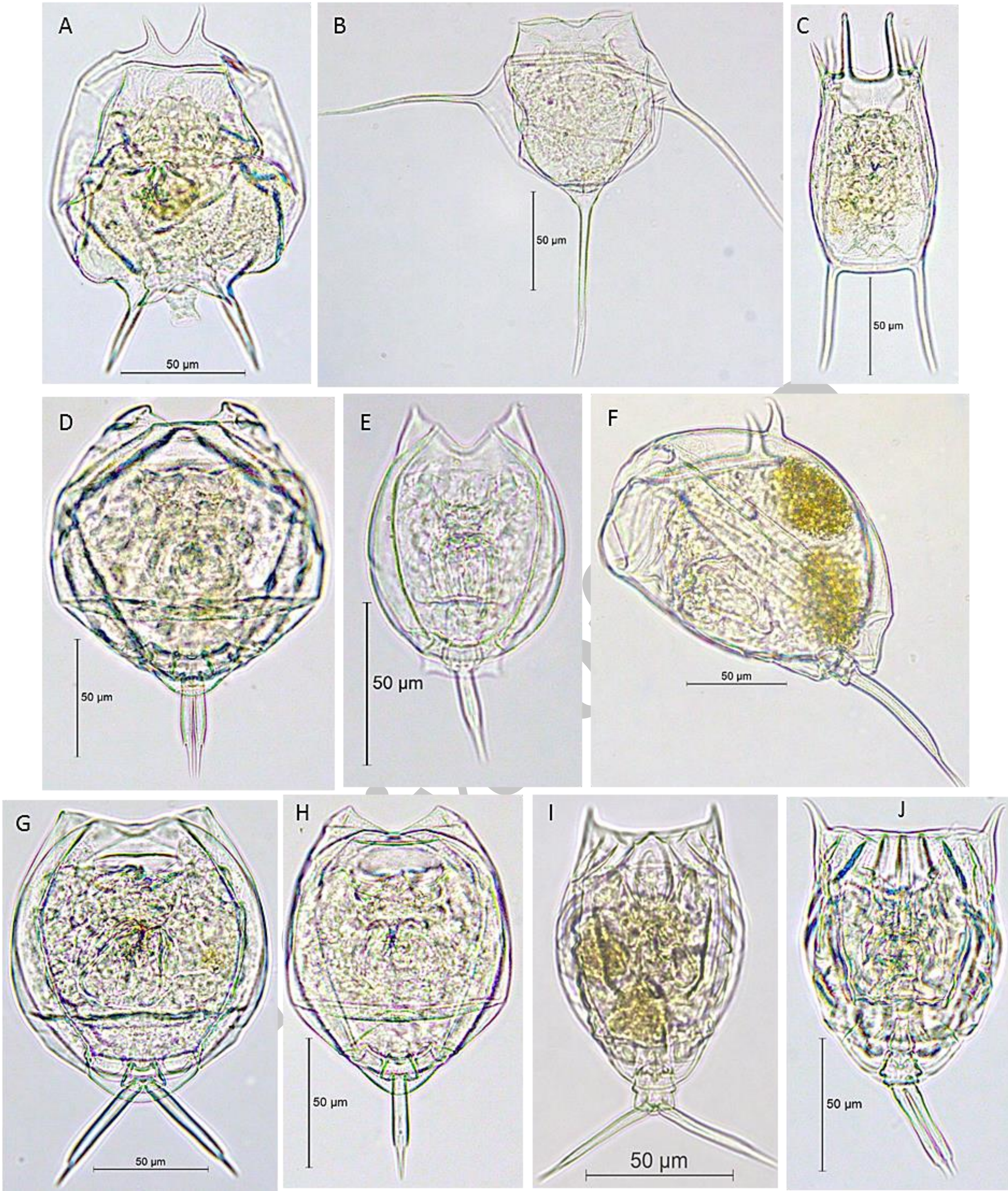

Figure 3. Interesting rotifers. (A) *Brachionus dichotomus reductus* Koste & Shiel, ventral view; (B) *Filinia camasecla* Myers, dorsal view; (C) *Keratella edmondsoni* Ahlstrom, ventral view; (D); *Lecane blachei* Berzins, ventral view; (E) *Lecane batillifer* (Murray), dorsal view; (F) *Lecane bulla diabolica* (Hauer), lateral view; (G) *Lecane lateralis* Sharma, ventral view; (H) *Lecane niwati* Segers, Kothetip & Sanoamuang, ventral view; (I) *Lecane simonneae* Segers, dorsal view; (J) *Lecane superaculeata* Sanoamuang & Segers, ventral view.

beels under Class I category of trophic classification following Talling and Talling (1965). Occurrence of free carbon dioxide throughout the study, total alkalinity attributed to bicarbonate ions, lack of human influence indicated by low chloride concentration and lower nutrients are notable. The relatively higher magnesium content and wide variations in sulphate content are interesting in comparison to various floodplain lakes of NEI (Sharma and Sharma, 2014a; Sharma et al., 2015, 2016).

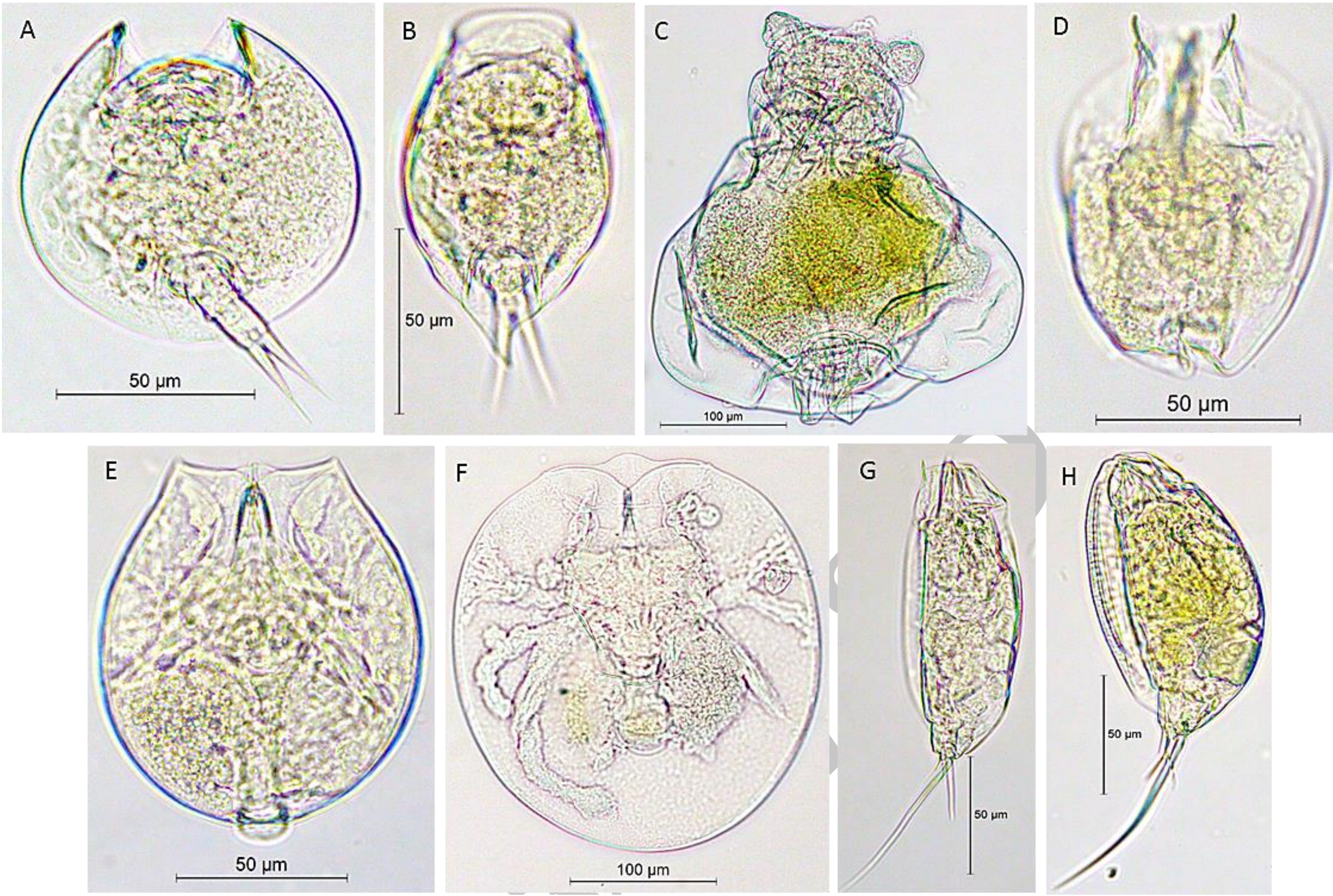

Figure 4. Interesting rotifers. (A)*Lepadella discoidea* Segers; (B) *Lepadella vandenbrandei* Gillard, dorsal view; (C) *Notommata spinata* Koste & Shiel, dorsal view (partially compressed); (D); *Testudinella amphora* Hauer, dorsal view; (E) *Testudinella brevicaudata* Yamamoto, dorsal view; (F) *Testudinella dendradena* de Beauchamp, ventral view; (G) *Trichocerca edmondsoni* (Myers), lateral view; (H) *T. hollaerti* De Smet, lateral view.

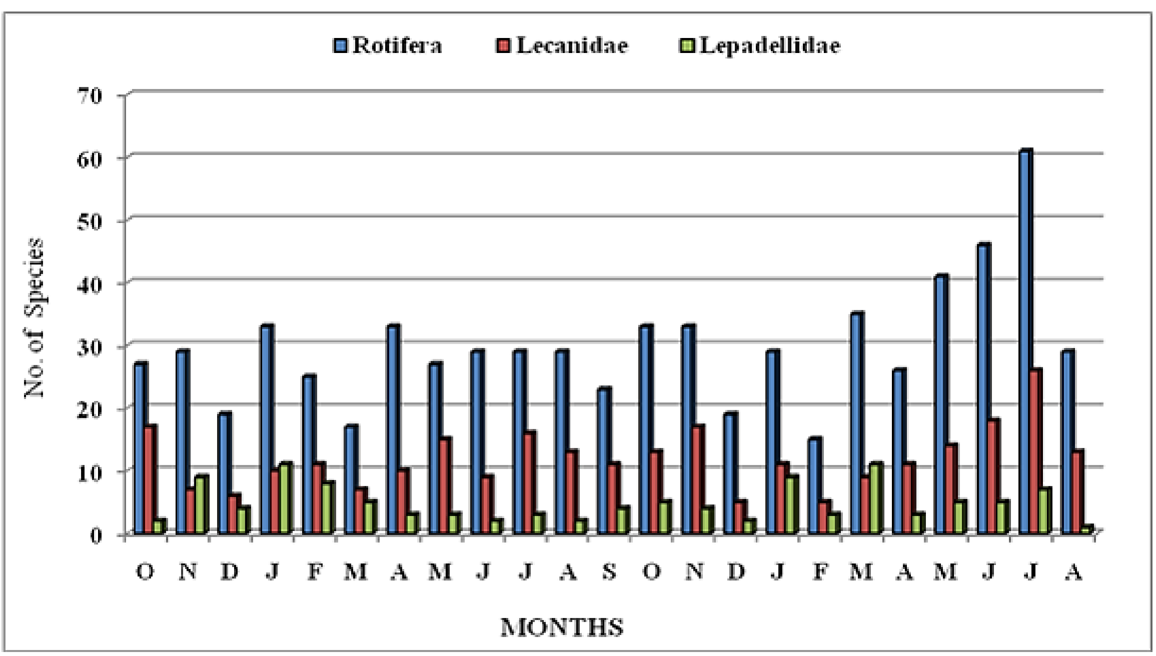

Figure 5. Monthly variations in richness of Rotifera and important families in Maghuri beel (October 2013–September 2015).

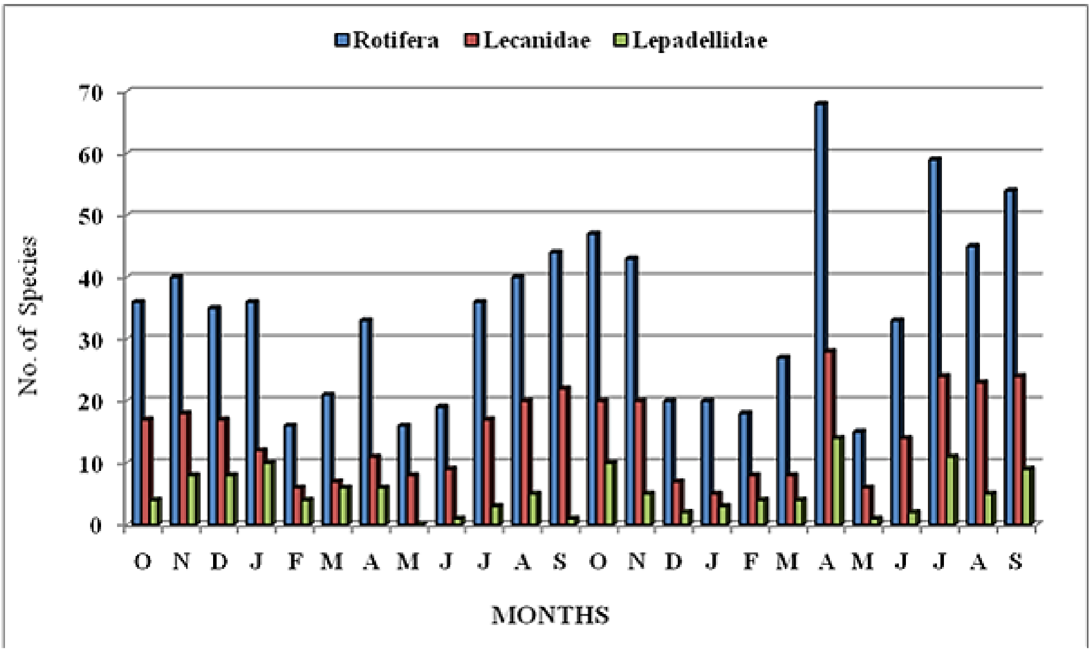

Figure 6. Monthly variations in richness of Rotifera and important families in Khamti Guali beel (October 2013–September 2015).

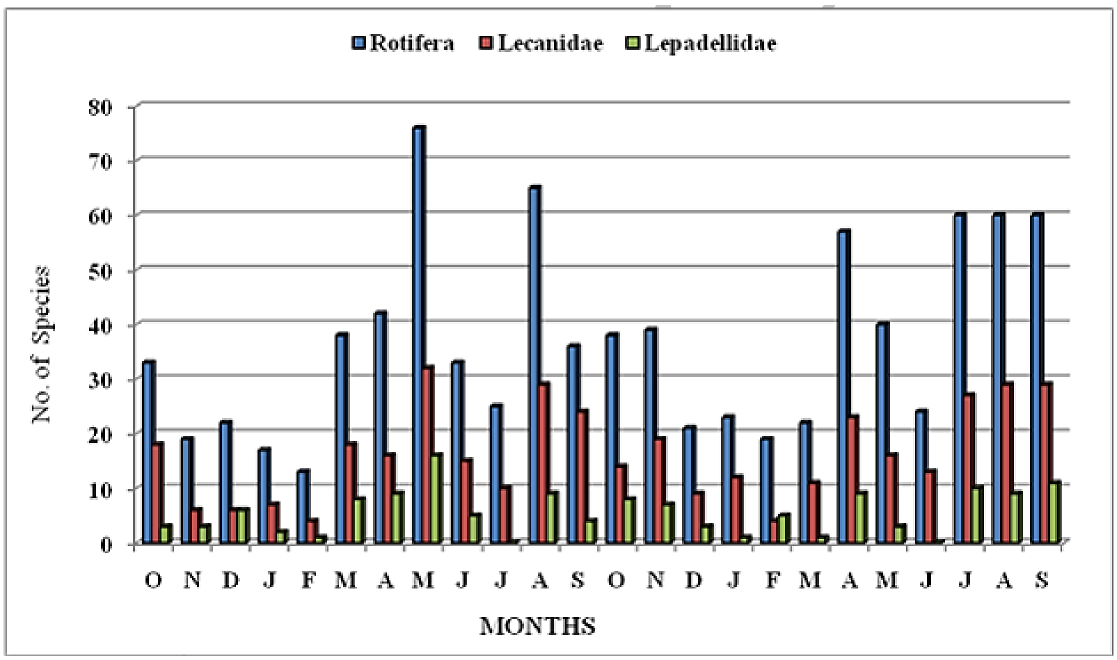

Figure 7. Monthly variations in richness of Rotifera and important families in No. 11 beel (October 2013–September 2015).

Our collections from DSBR beels located in the limited study area of upper Assam revealed total richness (S) of 141 species. The diversity accounts for ~34.0% and ~50.0% of species of the phylum known from India and NEI, respectively and thus affirmed biodiversity importance. The report of 31 genera and 17 families endorsed rich higher diversity of the taxon in light of 50 genera and 23 families known from NEI (BKS, unpublished). The rich and diverse nature of the rotifer biocoenosis indicated high habitat and ecosystem diversity of the three beels in spite of influence of intensive fishing and floods. Our results supported hypothesis of Segers et al. (1993) on the biodiverse nature of tropical and subtropical floodplains and of Sharma (2005), Sharma and Sharma (2014a, 2014b) and Sharma et al. (2017) on wetlands of the Brahmaputra basin of NEI vis-a-vis Rotifera diversity.

Squatinella bifurca is an interesting addition to the species list of the Oriental Rotifera; Known to be a

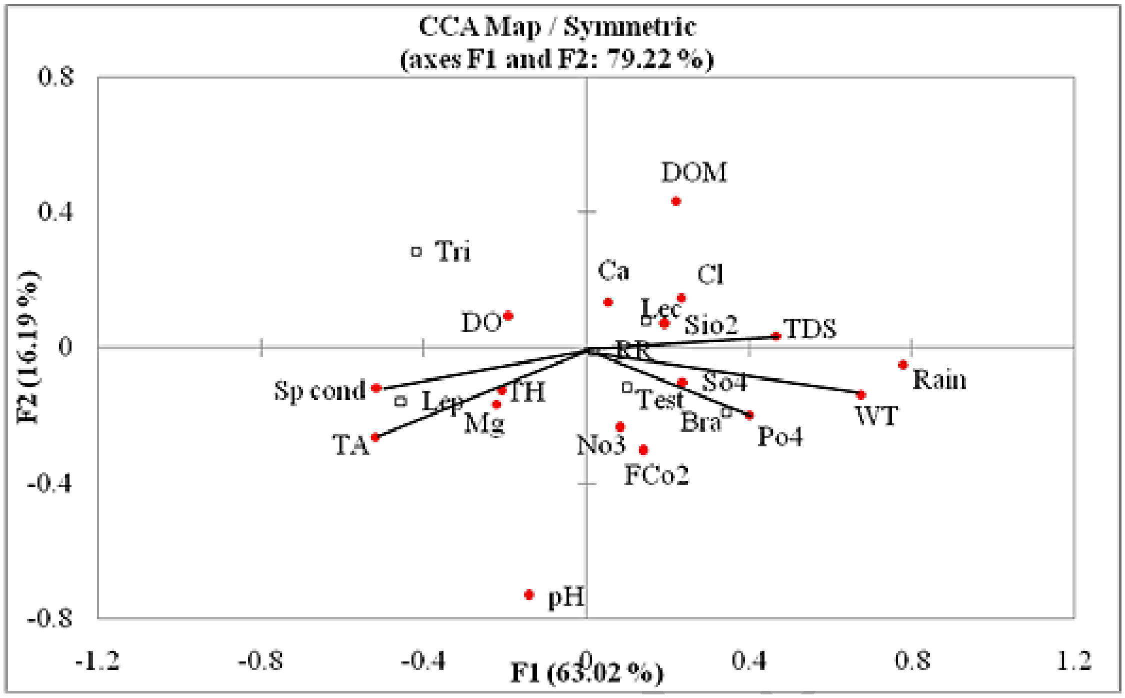

Figure 8. CCA coordination biplot of Rotifer richness and abiotic factors of Maghuri beel. **Abbreviations:** *Abiotic*: Ca (Calcium), Cl (Chloride), DOM (dissolved organic matter), DO (dissolved oxygen), FCO2 (free carbon dioxide), Rain (rainfall), NO3 (nitrate), PO4 (phosphate), SiO2 (silicate), Sp cond (specific conductivity), SO4 (sulphate), TA (total alkalinity), TDS (total dissolved solids), TH (total hardness), pH (hydrogen-ion concentration), Wt (water temperature). *Biotic*: Bra (Brachionidae richness), Lec (Lecanidae richness), Lep (Lepadellidae richness), Test (Testudinellidae) Tri (Trichocercidae richness), RR (Rotifera richness).

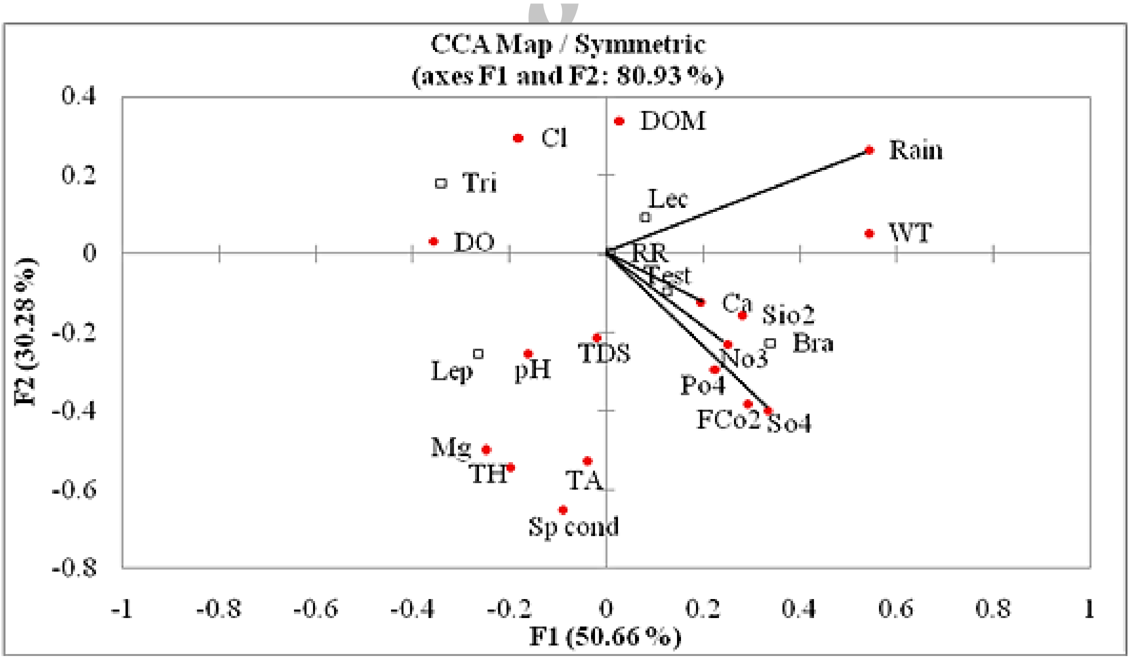

Figure 9. CCA coordination biplot of Rotifer richness and abiotic factors of Khamti Guali beel. **Abbreviations:** *Abiotic:* Ca (Calcium), Cl (Chloride), DOM (dissolved organic matter), DO (dissolved oxygen), FCO2 (free carbon dioxide), Rain (rainfall), NO3 (nitrate), PO4 (phosphate), SiO2 (silicate), Sp cond (specific conductivity), SO4 (sulphate), TA (total alkalinity), TDS (total dissolved solids), TH (total hardness), pH (hydrogen-ion concentration), Wt (water temperature). *Biotic:* Bra (Brachionidae richness), Lec (Lecanidae richness), Lep (Lepadellidae richness), Test (Testudinellidae) Tri (Trichocercidae richness), RR (Rotifera richness).

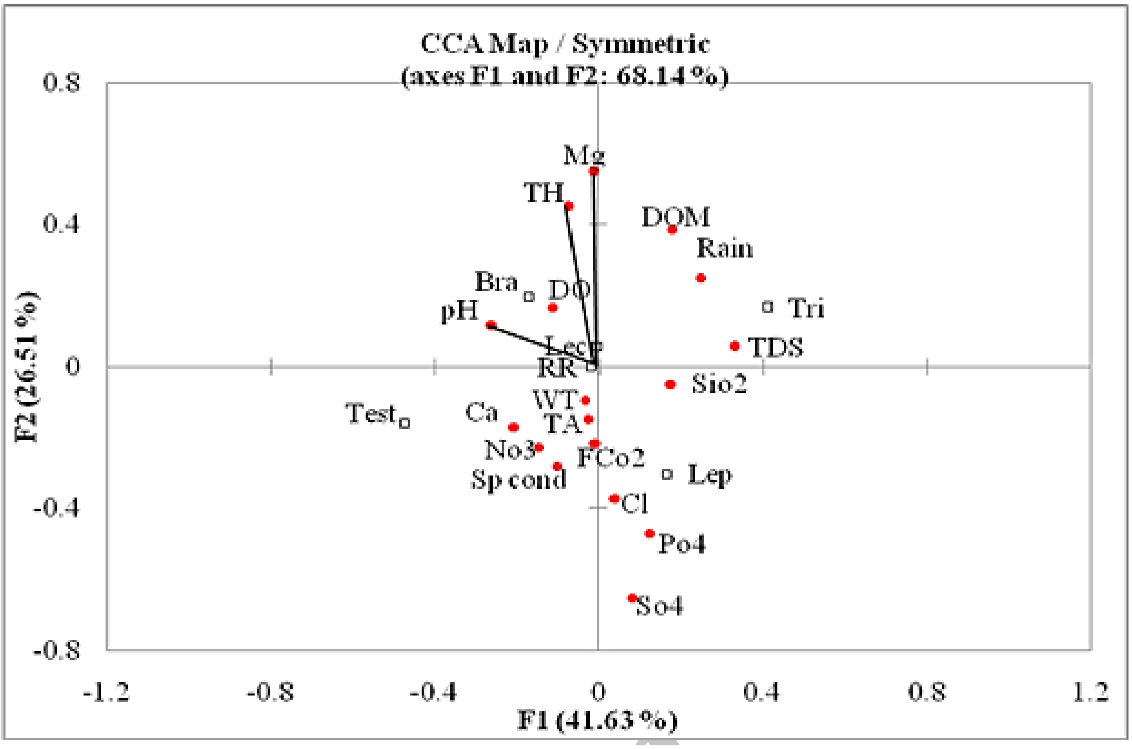

Figure 10. CCA coordination biplot of Rotifer richness and abiotic factors of No.11 beel. **Abbreviations**: *Abiotic*: Ca (Calcium), Cl (Chloride), DOM (dissolved organic matter), DO (dissolved oxygen), FCO2 (free carbon dioxide), Rain (rainfall), NO3 (nitrate), PO4 (phosphate), SiO2 (silicate), Sp cond (specific conductivity), SO4 (sulphate), TA (total alkalinity), TDS (total dissolved solids), TH (total hardness), pH (hydrogen-ion concentration), Wt (water temperature). *Biotic*: Bra (Brachionidae richness), Lec (Lecanidae richness), Lep (Lepadellidae richness), Test (Testudinellidae) Tri (Trichocercidae richness), RR (Rotifera richness).

Palearctic species (Segers, 2007), our report from upper Assam, NEI extended its distribution to the Oriental region. The tropical-latitude population of this cold-water taxon is likely to represent glacial relicts as hypothesized by Segers (1996) while the report of this species at foot hills in eastern Himalayas may be attributed to extension of the Himalayan mountain ranges as hypothesized by Sharma and Sharma (2014c).

Lecane isanensis and *L. shieli* are new records to the Indian Rotifera. The former was described from northeast Thailand (Sanoamuang and Savatenalinton, 2001) and was designated as a Thai endemic (Segers and Savatenalinton, 2010). The report from upper Assam extended its distribution to the Indian sub-region and we thus categorize this lecanid to be an Oriental endemic. The Australasian *Lecane shieli* was described from Nam Pung reservoir, Thailand (Segers and Sanoamuang, 1994) and was subsequently recorded from several localities in Thailand (Sa-Ardrit et al., 2013). Kobayashi et al. (2007) recorded it from Australia and Altındağ et al. (2009) examined specimens from Turkey while it is known as an alien species in different parts of the world (Pociecha et al., 2016).

We observed 21 biogeographically interesting rotifers (~15.0% of S); these included (a) four Australasian endemics *Brachionus dichotomus reductus, Lecane batillifer, L. shieli* and *Notommata spinata*; (b) seven Oriental endemics namely *Keratella edmondsoni*, *Lecane blachei*, *Lecane bulla diabolica, L. isanensis, L. niwati, L. superaculeata* and *Filinia camasecla*; and (c) seven paleotropical species i.e., *Lepadella discoidea*, *L. vandenbrandei*, *Lecane lateralis*, *L. simonneae*, *L. unguitata, Testudinella brevicaudata* and *Trichocerca hollaerti*; (d) the palaearctic *Cephalodella trigona* and *Squatinella bifurca*; and (e) the Indo-Chinese *Lecane dorysimilis.* The first two categories in particular affirmed affinity of our rotifer inventory with those of Southeast Asia and Australia. *Lecane aeganea*, *Trichocerca maior* and *T. siamensis* are new records to the rotifer fauna of

Assam. The first two species were added to the Indian Rotifera based on the reports from Mizoram (Sharma and Sharma, 2015b) while *T. siamensis* was known till date from India from Mizoram and Meghalaya states of NEI. The present report from upper Assam further extended distribution of three species within NEI.

Our samples from DSBR beels contained several species of regional biogeography interest in the Indian sub-region; these included *Brachionus mirabilis, Keratella lenzi, Platyias leloupi, Tripleuchlanis plicata, Lophocharis salpina, Macrochaetus longipes, Mytilina acanthophora, M. bisulcata, M. michelangellii, Lecane doryssa, L. elegans, L. flexilis, L. haliclysta, Lepadella benjamini, L. costatoides, L. dactyliseta, L. lindaui, L. quinquecostata, L. hornemanni, L. inermis, L. monostyla, L. nitida, L. obtusa, L. pusilla, L. rhenana, L. rhytida, L. thienemanni, L. undulata, Monommata grandis, Notommata glyphura, Testudinella amphora, T. dendradena, T. parva, T. tridentata, Trichocerca bidens, T. edmondsoni, T. flagellata, T. insignis, T. scipio, T. tigris* and *T. weberi.* Amongst the taxa of global and regional interest, a notable fraction (~10% of S) namely *Brachionus dichotomus reductus, Cephalodella trigona, Lecane batillifer, L. blachei, L. dorysimilis, L. niwati, L. rhenana, L. superaculeata, Lepadella benjamini, L. vandenbrandei, Mytilina michelangellii, Notommata spinata, Trichocerca hollaerti* and *T. maior* are known from India with distribution exclusively restricted till date to NEI.

Total rotifer richness (S) of DSBR beels was reasonably comparable with 161 species (Sharma et al., 2016) known from Loktak Lake (a Ramsar site), Manipur and 160 species reported from four beels of lower Assam (Sharma et al., 2017). The richness broadly concurred with 144 species known from 12 beels of the Majuli River Island, upper Assam (Sharma, 2014; Sharma et al., 2015) and it is more diverse than the reports of 124 species from seven beels of lower Assam (Sharma and Sharma, 2001) and 110 species (Arora and Mehra, 2003) from the Yamuna floodplains at Delhi. Further, DSBR Rotifera is distinctly rich than 38 species recorded from southwest West Bengal floodplains (Khan, 2003); this comparison deserved caution because of likely overlooking identification of smaller taxa culminating in incomplete species list. A more critical caution is focussed on routine 'ad-hoc' reports of underestimated richness of 16 (Kar and Kar, 2013), two (Gupta and Devi, 2014), 17 (Das and Kar, 2016) and 21 (Kar and Kar (2016) species from beels and wetlands of south Assam.

The diverse nature of Lecanidae (34.0% of S); and the collective importance (27.6% of S) of Lepadellidae > Trichocercidae, and of *Lecane* > *Lepadella* > *Trichocerca* (17.7% of S) impart the littoral-periphytic nature to the rotifer assemblages. The relative importance of the stated taxa endorsed hypothesis of Green (2003) on the possibility of assemblage rules for the periphytic rotifers. This generalization also corroborated with the reports from Indian floodplain wetlands from NEI (Sharma and Sharma, 2015a; Sharma et al., 2015, 2016, 2017). The richness of Brachionidae (13 species) deserved cautious mention because of its notable scarceness in the three beels. The paucity and scarceness of *Brachionus* species (5 species) and rare occurrence of *Keratella, Filinia, Asplanchna, Polyarthra,* and *Conochilus* are salient. These interesting features are hypothesized to lack of limnetic conditions in DBSR beels and even to certain factors limiting distribution of these taxa; the latter yet need to be investigated. In general, the brachionid paucity concurred with the reports (Sharma, 2014; Sharma et al., 2015, 2016) from certain NEI floodplain wetlands. The rich nature and common occurrence of 'tropic-centered' *Lecane* and cosmopolitan species (~63.0% of S), and collective importance (~19.3 % of S) of cosmotropical and pantropical species imparted 'tropical character' to Rotifera of DSBR beels. These features are concurrent with the remarks on tropical rotifer faunas (Green, 1972; Fernando, 1980; Segers, 1996).

Our collections revealed high total richness and limited variations (117±2 species) with No. 11 > Khamti Guali > Maghuri beels. This generalization supported by high community similarities due to common occurrence of large fraction (~68.% of S) of species in the three beels affirmed overall rotifer homogeneity amongst beels. The stated features, in turn, corroborated with the rotifer assemblages of four beels of lower Brahmaputra river basin (Sharma et al., 2017). The richness broadly concurred with the reports of 114 species (Jose de Paggi, 2001) from the floodplains of Argentina; it is marginally more biodiverse than 106 taxa known from Thale-Noi Lake, Thailand (Segers and Pholpunthin, 1997); and 104 species from Laguana Bufeos, Bolivia (Segers et al., 1998). DBSR rotifers are rather diverse than 69-93 and 60-100 species documented from various beels of Assam by Sharma and Sharma (2008) and Sharma et al. (2015), respectively.

The wider monthly variations with lowest and maximum richness between 13-15 species and 61-76 species, respectively; low mean values and lower community similarities with inter-annual variations and maximum instances of below 60% similarities affirmed heterogeneity in the rotifer composition within individual beels. The monthly variations and oscillating patterns of the richness in the three beels may be attributed to habitat disturbances caused due to fishing and floodwaters as hypothesized by Sharma et al. (2017). It may also be attributed to invasion of *Eichhornia crassipes* as indicated by Sharma et al. (2015). ANOVA registered insignificant richness variations amongst beels but recorded significant monthly variations between them. Further, it registered significant annual richness variations in Maghuri beel and significant monthly variations in Khamti Guali beel but No. 11 beel recorded insignificant monthly and annual variations.

The peak richness of 76 species in May, 2014 (summer) single date collection from No. 11 beel indicated ecosystem diversity importance. It broadly concurred with our highest records from the Indian sub-region: 79 species from Deepor beel (Sharma and Sharma, 2013) in July, 2010; 79 species each reported from Loktak Lake – a Ramsar site in December 2002 (Sharma, 2009) and December, 2011 (Sharma et al., 2016). Incidentally, it is one of the richest rotifer assemblages known in single date collection from any freshwater ecosystem of South Asia. Nevertheless, it merits certain interest than the highest global report of 102+ rotifer species in Broa reservoir, Brazil (Segers and Dumont, 1995) in August, 1994 but not withstanding 135 species reported in August, 1999 (Segers and Sanoamuang, 2007) otherwise originating from two wetlands i.e., a Laotian rice field and an adjacent pond.

Sharma et al. (2017) proposed L/B quotient based on *Lecane*: *Brachionus* species ratios to characterize habitat variations of the beels of lower Brahmaputra floodplains of Assam. We are unable to use this quotient in the beels of upper Assam because of characteristic feature of paucity of *Brachionus* spp.. Sladecek's B/T quotient based on *Brachionus*: *Trichocerca* species (Sladecek, 1983) also holds no validity to assess trophic status of DSBR beels for the said paucity of the brachionid taxon.

Our results explained little influence of abiotic parameters on the rotifer richness in the three beels; this remark is supported by lack of significance influence of any individual abiotic factor in Maghuri beel while temperature exerted positive influence on Brachionidae richness in Khamti Guali beel, and rainfall positively influenced Lecanidae and Testudinellidae richness in No. 11 beel. The canonical correspondence analysis, however, indicated high influence of 17 environmental parameters along first two axes on richness of rotifer assemblages in the first two beels and moderately high influence in No. 11 beel, thereby, supporting collective role of abiotic attributes. The importance of different factors vides CCA on richness of various rotifer taxa in the three beels affirmed habitat diversity amongst the sampled wetlands. In general, our report on the collective influence of environmental parameters rather than limited influence of individual factors corroborated with the rotifer assemblages of four beels of lower Brahmaputra river basin (Sharma et al., 2017).

The species rich and diverse Rotifera of DSBR beels, interesting new records and the report of a sizable fraction of species of global and regional distribution interest are features of biodiversity interest for Indian Rotifera and for meta-analysis of diversity of the taxon in the Indian as well as tropical and subtropical floodplains. The littoral-periphytic rotifer assemblages with scarceness and paucity of various taxa; high total richness and homogeneity amongst the three beels in spite of influence of fishing and floods vis-a vis lower monthly richness and the rotifer heterogeneity in individual beels; oscillating monthly richness variations; cumulative influence of 17 abiotic factors on the richness rather than individual role provide useful inputs on ecosystem diversity.

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Appendix 1: Systematic list of Rotifera known from the Dibru-Saikhowa Biosphere Reserve beels.

Phylum: Rotifera

Class: Eurotatoria

Subclass: Monogononta

Order: Ploima

Family: **Brachionidae**

1. *Anuraeopsis fissa* (Gosse, 1851)
2. *Brachionus dichotomus reductus* Koste & Shiel, 1980
3. *B. diversicornis* (Daday, 1883)
4. *B. falcatus* Zacharias, 1898
5. *B. mirabilis* Daday, 1897
6. *B. quadridentatus* Hermann, 1783
7. *Keratella cochlearis* (Gosse, 1851)
8. *K. edmondsoni* Ahlstrom, 1943
9. *K. lenzi* Hauer, 1953
10. *K. tropica* (Apstein, 1907)
11. *Plationus patulus* (O.F. Muller, 1786)
12. *Platyias leloupi* (Gillard, 1967)
13. *P. quadricornis* (Ehrenberg, 1832)

Family: **Euchlanidae**

14. *Beauchampiella eudactylota* (Gosse, 1886)
15. *Dipleuchlanis propatula* (Gosse, 1886)
16. *Euchlanis dilatata* Ehrenberg, 1832
17. *E. incisa* Carlin, 1939
18. *Tripleuchlanis plicata* (Levander, 1894)

Family: **Mytilinidae**

19. *Lophocharis salpina* (Ehrenberg, 1834)
20. *Mytilina acanthophora* Hauer, 1938
21. *Mytilina bisulcata* (Lucks, 1912)
22. *M. brevispina* (Ehrenberg, 1830)
23. *M. michelangellii* Reid & Turner, 1988
24. *M. ventralis* (Ehrenberg, 1830)

Family: **Trichotriidae**

25. *Macrochaetus longipes* Myers, 1934
26. *M. sericus* (Thorpe, 1893)
27. *Trichotria tetractis* (Ehrenberg, 1830)

Family: **Lepadellidae**

28. Co*lurella obtusa* (Gosse, 1886)
29. *C. sulcata* (Stenroos, 1898)
30. *C. uncinata* (O.F. Muller, 1773)
31. *Lepadella acuminata* (Ehrenberg, 1834)
32. *L. apsida* Harring, 1916
33. *L benjamini* Harring, 1916
34. *L. biloba* Hauer, 1958
35. *L. costatoides* Segers, 1992
36. *L. dactyliseta* (Stenroos, 1898)
37. *L. discoidea* Segers, 1993
38. *L. eurysterna* Myers, 1942
39. *L. lindaui* Koste, 1981
40. *L. minuta* (Weber & Montet, 1918)
41. *L. ovalis* (O.F. Muller, 1786)
42. *L. patella* (O.F. Muller, 1773)
43. *L. quinquecostata* (Lucks, 1912)
44. *L. rhomboides* (Gosse, 1886)
45. *L. triptera* Ehrenberg, 1832
46. *L. vandenbrandei* Gillard, 1952
47. *L.* (*H.*) *apsicora* Myers, 1934
48. *L.* (*H.*) *ehrenbergi* (Perty, 1850)
49. *L.* (*H.*) *heterostyla* (Murray, 1913)
50. *Squatinella bifurca* (Bolton, 1884) *
51. *S. lamellaris* (O. F. Müller, 1786)

Family: **Lecanidae**

52. *Lecane aculeata* (Jakubski, 1912)
53. *L. aeganea* Harring, 1914 ***
54. *L. arcuata* (Bryce, 1891)
55. *L. arcula* Harring, 1914
56. *L. batillifer* (Murray, 1913)
57. *L. bifurca* (Bryce, 1892)
58. *L. blachei* Berzins, 1973
59. *L. bulla bulla* (Gosse, 1851)
   L. bulla diabolica (Hauer, 1936)
60. *L. closterocerca* (Schmarda, 1859)
61. *L. crepida* Harring, 1914
62. *L. curvicornis* (Murray, 1913)
63. *L. decipiens* (Murray, 1913)
64. *L. dorysimilis* Trinh Dang, Segers & Sanoamuang, 2015
65. *L. doryssa* Harring, 1914
66. *L. elegans* Harring, 1914
67. *L. flexilis* (Gosse, 1886)
68. *L. furcata* (Murray, 1913)
69. *L. haliclysta* Harring & Myers, 1926
70. *L. hamata* (Stokes, 1896)
71. *L. hornemanni* (Ehrenberg, 1834)
72. *L. inermis* (Bryce, 1892)
73. *L. inopinata* Harring & Myers, 1926
74. *L. isanensis* Sanoamuang & Savatenalinton, 2001 **
75. *L. lateralis* Sharma, 1978
76. *L. leontina* (Turner, 1892)
77. *L. ludwigii* (Eckstein, 1883)
78. *L. luna* (Müller, 1776)
79. *L. lunaris* (Ehrenberg, 1832)
80. *L. monostyla* (Daday, 1897)
81. *L. nitida* (Murray, 1913)
82. *L. niwati* Segers, Kothetip & Sanoamuang, 2004
83. *L. obtusa* (Murray, 1913)
84. *L. ohioensis* (Herrick, 1885)
85. *L. papuana* (Murray, 1913)
86. *L. ploenensis* (Voigt, 1902)
87. *L. pusilla* Harring, 1914
88. *L. pyriformis* (Daday, 1905)
89. *L. quadridentata* (Ehrenberg,1830)
90. *L. rhenana* Hauer, 1929
91. *L. rhytida* Harring & Myers, 1926
92. *L. shieli* Segers & Sanoamuang, 1994 **
93. *L. signifera* (Jennings, 1896)
94. *L. simonneae* Segers, 1993
95. *L. stenroosi* (Meissner, 1908)

96. *L. superaculeata* Sanoamuang & Segers, 1997
97. *L. thienemanni* (Hauer, 1938)
98. *L. undulata* Hauer, 1938
99. *L unguitata* (Fadeev, 1925)
100. *L. ungulata* (Gosse, 1887)

Family: **Notommatidae**
101. *Cephalodella gibba* (Ehrenberg, 1830)
102. *C. mucronata* Myers, 1924
103. *Cephalodella trigona* (Rousselet, 1895)
104. *Monommata. grandis* Tessin, 1890
105. *M. longiseta* (O.F. Müller, 1786)
106. *Notommata glyphura* Wulfert, 1935
107. *N. spinata* Koste & Shiel, 1991

Family: Scaridiidae
108. *Scaridium longicaudum* (O.F. Müller, 1786)

Family: Trichocercidae
109. *Trichocerca bicristata* (Gosse, 1887)
110. *T. bidens* (Lucks, 1912)
111. *T. edmondsoni* (Myers, 1936) ***
112. *T. elongata* (Gosse, 1886)
113. *T. flagellata* Hauer, 1937
114. *T. hollaerti* De Smet, 1990
115. *T insignis* (Herrick, 1885)
116. *T. maior* Hauer, 1936
117. *T. pusilla* (Jennings, 1903)
118. *T. rattus* (O.F. Müller, 1776)
119. *T. scipio* (Gosse, 1886)
120. *T. siamensis* Segers & Pholpunthin, 1997 ***
121. *T. similis* (Wierzejski, 1893)
122. *T. tigris* (O.F. Müller, 1786)
123. *T. weberi* (Jennings, 1903)

Family: Asplanchnidae
124. *Asplanchna brightwelli* Gosse, 1850
125. *A. priodonta* Gosse, 1850

Family: Synchaetidae
126. *Polyarthra vulgaris* Carlin, 1943

Family: Dicranophoridae
127. *Dicranophorus forcipatus* (O.F. Müller, 1786)

Order: **Flosculariaceae**
Family: Flosculariidae
128. *Sinantherina socialis* (Linne, 1758)
129. *S. spinosa* (Thorpe, 1893)

Family: Conochilidae
130. *Conochilus unicornis* Rousselet, 1892

Family: Testudinellidae
131. *Testudinella amphora* Hauer, 1938
132. *T. brevicaudata* Yamamoto, 1951
133. *T. dendradena* de Beauchamp, 1955
134. *T. emarginula* (Stenroos, 1898)
135. *T. parva* (Ternetz, 1892)
136. *T. patina* (Hermann, 1783)
137. *T. tridentata* Smirnov, 1931

Family: Trochosphaeridae
138. *Filinia camasecla* Myers, 1938
139. *F. longiseta* (Ehrenberg, 1834)
140. *F. opoliensis* (Zacharias, 1898)

Sub-class: Digononta
Order: Bdelloidea
Family: Philodinidae
141. *Rotaria neptunia* (Ehrenberg, 1830)

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* New record from the Oriental region; ** New record from India; *** New record from Assam