

Original Article

Rich rotifer assemblage (Rotifera: Eurotatoria) of a sub-tropical wetland of Meghalaya, northeast India: ecosystem diversity and interesting features

Bhushan Kumar Sharma*, Kyapaomai Role Sounii Pou, Sumita Sharma

Freshwater Biology Laboratory, Department of Zoology, North-Eastern Hill University Shillong - 793 022, Meghalaya, India.

Abstract: A total of 90 species, belonging to 29 genera and 15 families, observed from an urban wetland of Meghalaya is the species-rich Rotifera assemblage known till date from any sub-tropical ecosystem of the Indian sub-region. Total richness (S) merits biodiversity value as ~56.0, ~38.0 and ~23.0% of the species recorded from Meghalaya, northeast India (NEI) and India, respectively while several rotifers of global and regional importance impart biogeographic interest. One species is new to NEI and 19 species (including two unidentified) are new to Meghalaya; this study resulted in an earlier report of five and two new records from India and NEI, respectively. The diverse Lecanidae > Lepadellidae together comprising ~57.0% of S; largely littoral periphytonic nature of taxa; and distinct paucity of the Brachionidae and lack of *Brachionus* are notable features. The speciose *Lecane*, high richness of cosmopolitans and occurrence of several tropicopolitan and pantropical species impart broadly 'tropical' character to the fauna. With low monthly richness and low community similarities, our results affirm heterogeneity of rotifer species composition; the richness is positively influenced only by water temperature.

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Introduction

Rotifera, an integral link of aquatic food-webs and valuable contributors to freshwater productivity, have been documented from India since the work of Anderson (1889) but the related literature yet indicated lacunae on biodiversity and ecosystem diversity of the taxon from different states of India (Sharma, 1996, 1998; Sharma and Sharma, 2008) in general and in sub-tropical waters of NEI (Sharma and Sharma, 2014a) in particular. Referring to the latter region, Sharma and Sharma (1999) examined the rotifer fauna from the hill state of Meghalaya with certain additions by Sharma (2008, 2010) and Sharma and Sharma (2011) while Sharma (2006) only dealt with their diversity of the paddy-field ecosystems. The present study is an attempt to analyse ecosystem diversity of the taxon of a sub-tropical wetland vis-a-vis update biodiversity of Meghalaya Rotifera. A list of 90 species documented

from our collections is presented and interesting taxa are illustrated for validation. The diversity of Rotifera assemblage is discussed with reference to the richness, composition, community similarities, interesting species and distribution of various taxa, and the influence of abiotic factors.

Materials and Methods

This study is a part of limnological reconnaissance of a sub-tropical wetland located at the campus of North-Eastern Hill University, Shillong (25°36'32.8"-25°36'36.3"N and 91°53'46.9"-91°54'01.5"E; alt. 1400 m asl), Meghalaya state of NEI undertaken during August 2014-July 2015.

Water samples were collected monthly for various basic abiotic parameters. Water temperature, specific conductivity and pH were recorded by the field probes; dissolved oxygen was estimated by Winkler's method while free carbon dioxide,

* Corresponding author: Bhushan Kumar Sharma
E-mail address: profbksharma@gmail.com

Table 1. Variations in basic abiotic parameters.

Parameters ↓	Range	Mean±SD
Water temperature (°C)	12.0-22.5	17.4±3.2
pH	6.02-6.99	6.59±0.19
Specific conductivity (µs cm ⁻¹)	31.0-51.0	37.4±5.4
Dissolved oxygen (mg L ⁻¹)	5.6-7.6	6.7±0.5
Free carbon dioxide (mg L ⁻¹)	6.0-22.0	11.3±4.3
Total alkalinity (mg L ⁻¹)	18.0-30.0	24.0±3.5
Total hardness (mg L ⁻¹)	20.0-32.0	26.3±3.4
Calcium (mg L ⁻¹)	8.4-23.1	14.4±4.6
Chloride (mg L ⁻¹)	25.0-38.0	32.5±4.1

Table 2. Percentage similarities (Sørensen's index) of Rotifera.

	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Aug	-	43.4	26.0	27.1	31.5	28.5	46.1	27.4	32.1	24.5	44.0	56.7
Sep		-	61.7	34.4	28.5	29.0	50.9	44.0	47.2	28.5	48.2	57.5
Oct			-	44.8	32.1	32.7	27.4	28.0	36.3	28.5	48.2	42.4
Nov				-	47.8	26.6	39.0	40.0	44.4	60.8	41.6	28.5
Dec					-	32.5	25.4	26.3	32.5	36.3	34.7	33.3
Jan						-	36.8	27.0	19.0	27.9	40.0	33.9
Feb							-	42.4	36.8	41.0	34.1	36.7
Mar								-	48.6	31.5	30.0	33.3
Apr									-	23.2	26.6	33.9
May										-	39.1	22.2
Jun											-	28.5
Jul												-

alkalinity, hardness, calcium and chloride were analyzed following APHA (1992). The qualitative plankton and semi-plankton samples were collected monthly by towing a nylobolt plankton net (#50 µm) and preserved in 5% formalin. All collections were screened with a Wild stereoscopic binocular microscope; the rotifers were isolated and mounted in Polyvinyl alcohol-lactophenol, and were observed with Leica (DM 1000) stereoscopic phase contrast microscope fitted with an image analyzer. Interesting taxa were illustrated and the measurements were given in micrometers (µm). Various taxa were identified following Koste (1978), Koste and Shiel (1989), Segers (1995), Sharma (1998) and Sharma and Sharma (1999, 2000, 2008, 2011, 2013, 2014b, 2015a). The percentage similarities between monthly rotifer assemblages were calculated vide Sørensen's index (Sørensen, 1948) and SPSS (Version 20) was used for the hierarchical cluster analysis.

Results

The variations (ranges, mean ± SD) of certain abiotic

parameters of the wetland are indicated in Table 1. Our collections revealed 90 species of Phylum Rotifera spread over 29 genera and 15 families (Appendix 1). *Notommata copeus* (Fig. 1a) is a new record to NEI. *Notommata spinata* (Fig. 1b) is an Australasian species; *Lecane blachei* (Fig. 1c) is an Oriental endemic; *Keratella javana* (Fig. 1d), *Lepadella bicornis* (Fig. 1e), *L. discoidea* (Fig. 1f), *L. vandenbrandei* (Fig. 1g), *Lecane simonneae* (Fig. 1h), *L. unguitata* and *Trichocerca siamensis* (Fig. 1i) are paleotropical species. *Mytilina michelangellii* (Fig. 1j), *Testudinella amphora* (Fig. 1k), *Trichocerca edmondsoni* (Fig. 1l), *Lecane aspasia* (Fig. 1m) and *L. elegans* (Fig. 1n) are other interesting species.

Keratella tecta, *Lecane aspasia*, *L. elegans*, *L. obtusa*, *L. simonneae*, *L. stenroosi*, *L. undulata*, *Lepadella bicornis*, *L. vandenbrandei*, *Macrochaetus subquadratus*, *Notommata spinata*, *Mytilina michelangellii*, *Testudinella amphora*, *Trichocerca bidens*, *T. edmondsoni*, *T. scipio* and *T. siamensis*, and two unidentified species are new records to Meghalaya. *Colurella tessellata*, *Lecane stichaea*,

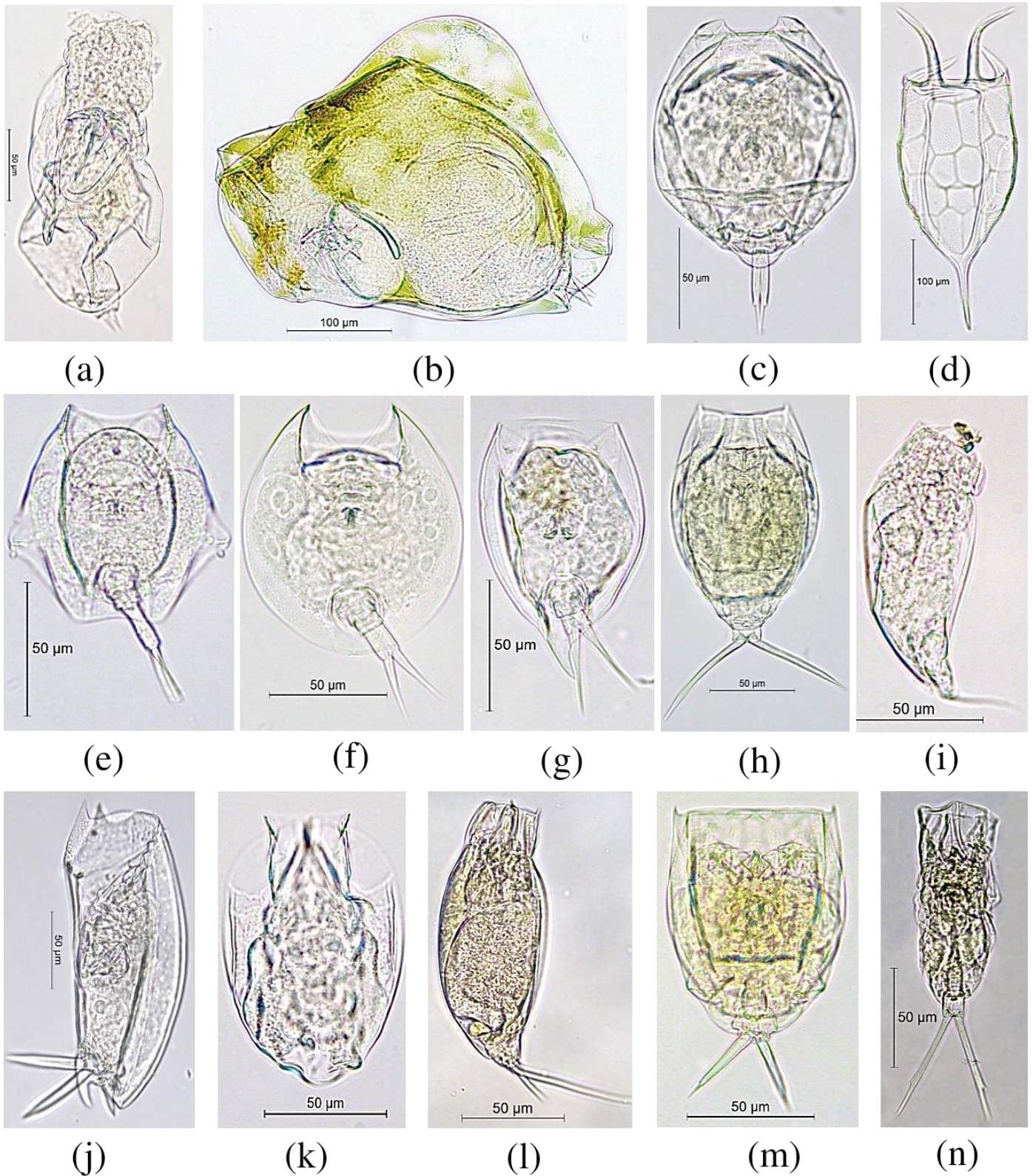


Figure 1. (a) *Notommata copeus* Ehrenberg (dorsal view), (b) *Notommata spinata* Koste & Shiel (lateral view), (c) *Lecane blachei* Bērziņš (ventral view), (d) *Keratella javana* Hauer (ventral view), (e) *Lepadella bicornis* Vasisht & Battish (ventral view), (f) *Lepadella discoidea* Segers (ventral view), (g) *Lepadella vandenbrandei* Gillard (ventral view), (h) *Lecane simonneae* Segers (dorsal view), (i) *Trichocerca siamensis* Segers & Pholpunthin (lateral view), (j) *Mytilina michelangellii* Reid & Turner (lateral view), (k) *Testudinella amphora* Hauer (dorsal view), (l) *Trichocerca edmondsoni* (Myers) (lateral view), (m) *Lecane aspasia* Myers (dorsal view) and (n) *Lecane elegans* Harring (ventral view).

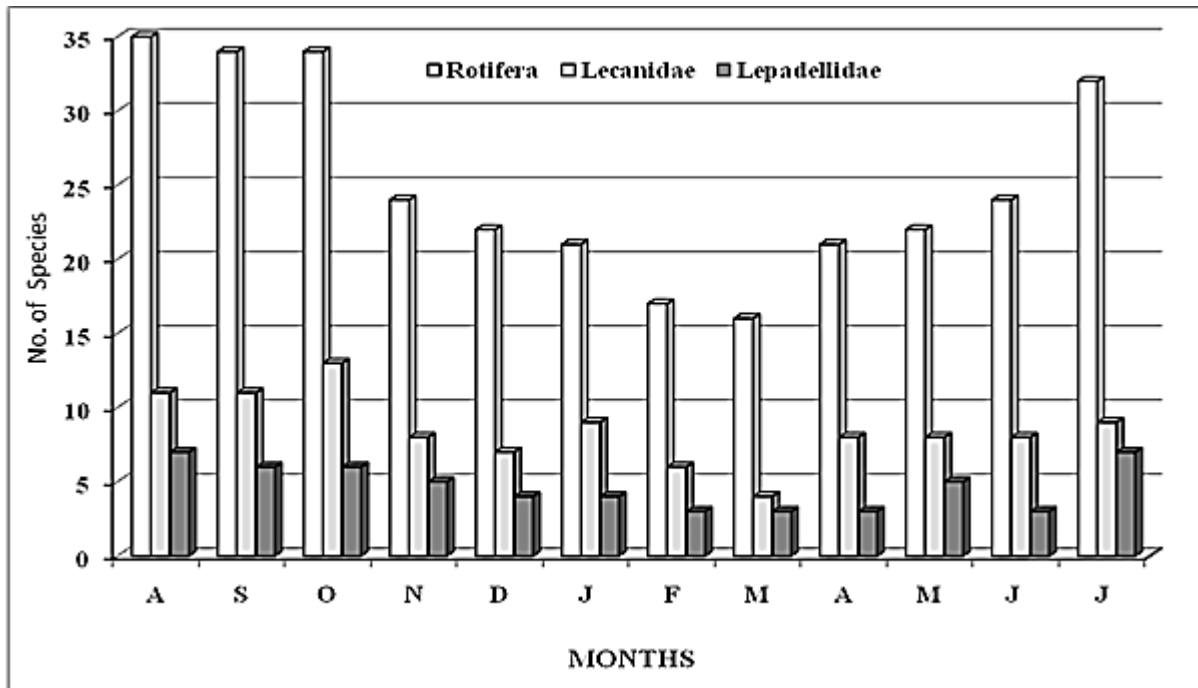


Figure 2. Monthly variations in species richness of Rotifera and important families.

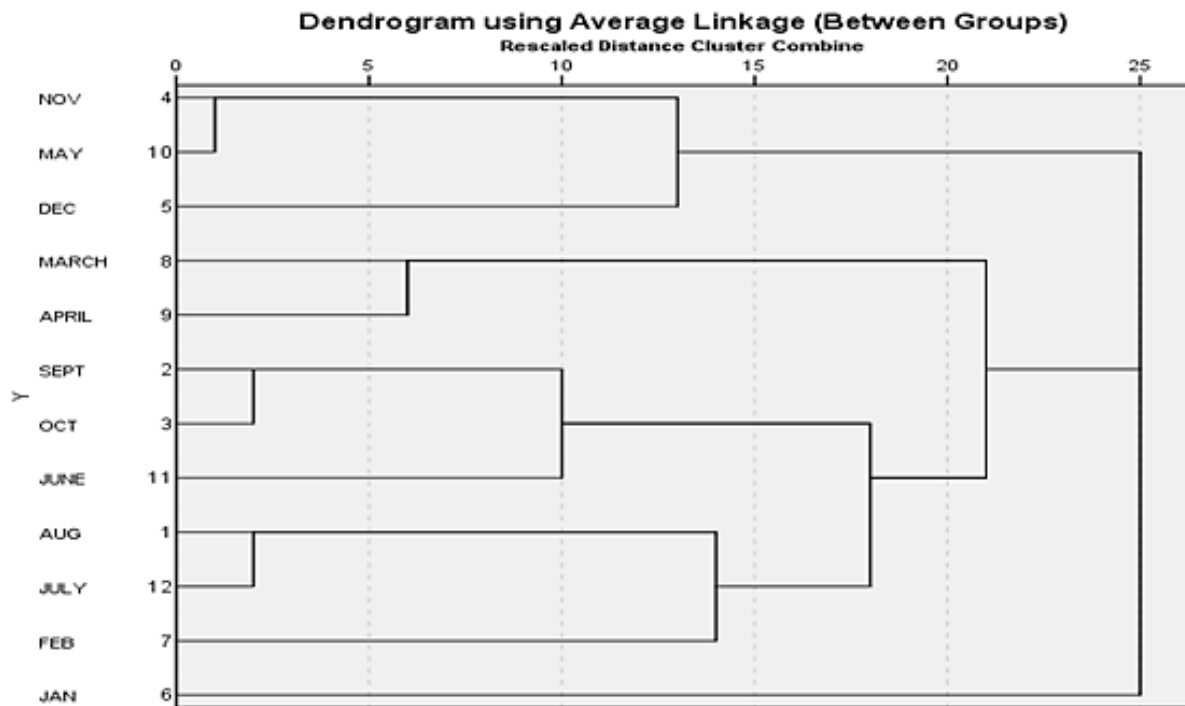


Figure 3. Hierarchical cluster analysis of Rotifera assemblage.

Gastropus minor, *Stephanoceros fimbriatus* and *Dissotrocha aculeata* are recent new additions (Sharma, 2016) to the Indian Rotifera while *Lecane dorysimilis* and *Cupelopagis vorax* are new additions to the rotifer fauna of NEI (Sharma, loc cit.). The rotifer richness ranged between 16-35 (25 ± 6) species (Fig. 2) with Lecanidae > Lepadellidae as main

components, the community similarities (Table 2) ranged between 19.0-61.7% (Sørensen, 1948) and the hierarchical cluster analysis is shown in Figure 3.

Discussion

Water temperature affirmed sub-tropical nature of the wetland concurrent with its geographical

location. The 'slightly acidic - circum neutral', 'soft' and 'calcium poor' waters are characterized by low ionic concentrations; the latter warranted inclusion of this wetland under 'Class I' category of trophic classification vide Talling and Talling (1965). Further, it showed well-oxygenated water and low free carbon dioxide while chloride indicated certain influence of human impact in this seepage and rain-water fed biotope. The abiotic parameters broadly concurred with the reports from sub-tropical waters of Meghalaya (Sharma, 1995, 2001) and Mizoram (Sharma and Pachuau, 2013) hill states of NEI.

A total of 90 species (S), belonging to 29 genera and 15 families, documented from this small urban wetland is the richest Rotifera assemblage known from any sub-tropical ecosystem of the Indian sub-region and one of the richest from any subtropical wetland of South Asia. This interesting feature is hypothesized to habitat diversity and environmental heterogeneity of the sampled wetland. Our report merits biodiversity interest as ~56.0, ~38.0 and ~23.0 % of the species known from Meghalaya, NEI and India, respectively.

Notommata copeus is a new record to NEI; it is known elsewhere from India (BKS, unpublished) from Andhra Pradesh, Jammu and Kashmir, Kerala, Punjab and Tamil Nadu while its unverifiable reports from Karnataka and Maharashtra lacked any validation. *Keratella tecta*, *Lecane aspasia*, *L. elegans*, *L. obtusa*, *L. simonneae*, *L. stenroosi*, *L. undulata*, *Lepadella bicornis*, *L. vandenbrandei*, *Macrochaetus subquadratus*, *N. spinata*, *Mytilina michelangellii*, *Testudinella amphora*, *Trichocerca bidens*, *T. edmondsoni*, *T. scipio* and *T. siamensis*, and two unidentified species are new records to Meghalaya fauna. Besides, our collections resulted in recent additions (Sharma, 2016) of *Colurella tessellata*, *Lecane stichaea*, *Gastropus minor*, *Stephanoceros fimbriatus* and *Dissotrocha aculeata* to the Indian Rotifera while *Lecane dorysimilis* and *Cupelopagis vorax* are additions to the rotifer fauna of NEI. This study thus raised overall rotifer richness of Meghalaya to 161 species spread over 40 genera and 20 families; the former represented ~40.0 % of

the diversity of Indian Rotifera and corresponded with 162 species reported recently from Mizoram (Sharma and Sharma, 2015b) - another hill state of NEI.

Biogeographically interesting elements formed a notable fraction (~14.0% of S) and included the Australasian *Notommata spinata*; the Oriental endemic *Lecane blachei*; the Indo-Chinese *Lecane dorysimilis*; the palaeotropical *Keratella javana*, *Lepadella bicornis*, *L. discoidea*, *L. vandenbrandei*, *Lecane simonneae*, *L. unguitata* and *Trichocerca siamensis*. Besides, *Mytilina michelangellii*, *Testudinella amphora* and *Trichocerca edmondsoni* are other interesting species. Of these, *Lecane simonneae*, *L. unguitata*, *Lepadella discoidea* and *L. vandenbrandei* are categorized as Eastern hemisphere elements following Segers (2001) and Sharma and Sharma (2005, 2015b).

The member of the first category affirmed affinity of the rotifer fauna of Meghalaya with Southeast Asia and Australia and thus affirmed earlier remarks on NEI Rotifera (Sharma, 2005; Sharma and Sharma, 2005, 2008, 2013, 2014a, 2014c, 2015b). Further, *N. spinata* is known from India only from NEI with reports from Assam, Manipur and presently from Meghalaya. The Oriental *L. blachei* deserved attention for its distribution in NEI (Assam, Meghalaya and Manipur) and from West Bengal in eastern India. The Indo-Chinese *Lecane dorysimilis* is yet restricted to NEI (Assam and Meghalaya) and Delhi with likely wider distribution in the former region (Sharma, 2016).

Of the palaeotropical species, *Keratella javana*, *Lepadella vandenbrandei* and *Trichocerca siamensis* are known till date from India from NEI; *Lepadella bicornis* from NEI (Assam and Manipur) and Chandigarh (North India) while its unverifiable report as *L. bicornis* Müller (non Vasisht and Battish) from Kashmir (Ticku and Zutshi, 1993) is invalid (Sharma and Sharma, 2015a). *Lepadella discoidea* (NEI, Delhi and Kerala) and *Lecane simonneae* (NEI, Kerala and Tamil Nadu) exhibited disjunct distribution in India while *L. unguitata* indicated relatively wider occurrence in this country.

Amongst other interesting elements, *Lecane aspasia* is known from Assam (NEI) and Delhi; *Lecane elegans*, *Mytilina michelangellii* and *Testudinella amphora* are restricted to NEI while *Trichocerca edmondsoni* is so far known Kashmir Himalayas and Mizoram (NEI). In addition, our collections included various species of regional distribution value namely *Lecane bifurca*, *L. doryssa*, *L. elegans*, *L. pusilla*, *L. stichaea*, *L. tenuiseta*, *Lepadella costatoides*, *L. dactyliseta*, *L. quinquecostata* and *T. tridentata* with *Lecane elegans*, *L. stichaea* and *T. tridentata* known from India only from NEI.

The most diverse Lecanidae (30 species) > Lepadellidae (21 species) together comprised ~57.0% of S; Trichocercidae ≈ Notommatidae = Testudinellidae collectively formed (~21.0% of S) while rest of the fourteen Eurotatorien families recorded low richness. The species-rich genera *Lecane* > *Lepadella* formed main component (~54.0% of S); *Trichocerca* > *Testudinella* together (13.3% of S) deserved certain attention and the rest of 25 genera recorded poor richness. The speciose nature of the 'tropic-centered' *Lecane* affirmed the role of this thermophile in our collections concurrent with the rotifer fauna NEI (Sharma and Sharma, 2014a, 2014b). The said feature along with occurrence of a large component of cosmopolitans (~73.0% of S) and of various tropicopolitan and pantropical species (~16.0%) impart a general 'tropical character' to the rotifer fauna.

The notable feature of the littoral-periphytic composition of rotifer fauna, with lack of planktonic taxa, is hypothesized to the lack of definite pelagic habitats (De Manuel, 1994) in spite of certain semi-limnetic conditions in a part of the sampled wetland. Our collections are interestingly characterized by poor Brachionidae richness (4 species) in general and absence of *Brachionus* spp. in particular; these interesting aspects deserved further analysis for causative factors in light of the record of 22 and 12 species of the two taxa, respectively from aquatic biotopes of Meghalaya (Sharma and Sharma, 2014c).

The low monthly richness (16-35, 25±6 species) affirmed heterogeneity of rotifer species composition; only three species occurred throughout the study period while other three indicated 50-83% frequency of occurrence and the rest indicated low frequencies of occurrence. This generalization is endorsed by low community similarities (19.0-61.7%) with similarity values below 50% in ~92% cases in the similarity matrix. The heterogeneity in species composition is affirmed by hierarchical cluster which reflected affinity between November vs. May rotifer communities while January > March collections reflected greater divergence. Our results indicated lowest richness during winter-spring and high richness of rotifers as well as important constituent families during monsoon in particular. Of the various abiotic factors, the richness of Rotifera ($r=0.874$, $P=0.0009$), Lecanidae ($r=0.651$, $P=0.415$) and Lepadellidae ($r=0.794$, $P=0.0061$) is positively influenced by water temperature.

Conclusions

The rich and diverse Rotifera assemblage affirmed environmental heterogeneity of the 'slightly acidic - circum neutral', 'soft' and 'calcium poor' waters of the sampled wetland characterized by low ionic concentrations and thus merits biodiversity and ecological interests. Various new records and the report of species of global and regional interest, and Eastern hemisphere elements impart biogeographic value to this study. The specific sampling of periphytic, sessile and benthic taxa are desired for further update and we estimate occurrence of 125+ from this wetland. The interesting features of Rotifera assemblage provide scope for studies on the biodiversity and ecosystem diversity of the taxon in sub-tropical waters of NEI in general and wetlands of the region in particular.

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Appendix 1: Systematic list of the examined rotifer taxa**Phylum:** Rotifera**Super-class:** Eurotatoria**Subclass:** Monogononta**Order:** Ploima**Family:** Brachionidae

1. *Keratella cochlearis* (Gosse, 1851)
2. *K. javana* Hauer, 1937
3. *K. tecta* (Gosse, 1851)*
4. *Plationus patulus* (O.F. Muller, 1786)

Family: Euchlanidae

5. *Dipleuchlanis propatula* (Gosse, 1886)
6. *Euchlanis dilatata* Ehrenberg, 1832

Family: Mytilinidae

7. *Mytilina michelangellii* Reid & Turner, 1988*
8. *M. ventralis* (Ehrenberg, 1830)

Family: Trichotriidae

9. *Macrochaetus sericus* (Thorpe, 1893)
10. *M. subquadratus* Perty, 1850*
11. *Trichotria tetractis* (Ehrenberg, 1830)

Family: Lepadellidae

12. *Colurella sulcata* (Stenroos, 1898)
13. *C. tessellata* (Glascott, 1893)**
14. *C. uncinata* (O.F. Muller, 1773)
15. *Colurella* sp.
16. *Lepadella acuminata* (Ehrenberg, 1834)
17. *Lepadella bicornis* Vasisht & Battish, 1971*
18. *L. biloba* Hauer, 1958
19. *L. costatoides* Segers, 1992
20. *L. cristata* (Rousselet, 1893)
21. *L. dactyliseta* (Stenroos, 1898)
22. *L. discoidea* Segers, 1993
23. *L. ovalis* (O.F. Muller, 1786)
24. *L. patella* (O.F. Muller, 1773)
25. *L. quinquecostata* (Lucks, 1912)
26. *L. rhomboides* (Gosse, 1886)
27. *L. triptera* Ehrenberg, 1832
28. *L. vandenbrandei* Gillard, 1952*
29. *L. (H.) apsicora* Myers, 1934
30. *L. (H.) ehrenbergi* (Perty, 1850)
31. *L. (H.) heterostyla* (Murray, 1913)
32. *Squatinella lamellaris* (O.F. Müller, 1786)

Family: Lecanidae

33. *Lecane aculeata* (Jakubski, 1912)
34. *L. arcua* Haring, 1914
35. *L. aspasia* Myers, 1917 *

36. *L. bifurca* (Bryce, 1892)37. *L. blachei* Bērziņš, 197338. *L. bulla* (Gosse, 1851)39. *L. closteroerca* (Schmarda, 1859)40. *L. decipiens* (Murray, 1913)41. *L. doryssa* Haring, 191442. *L. dorysimilis* Trinh Dang, Segers & Sanoamuang, 2015**43. *L. elegans* Haring, 1914*44. *L. flexilis* (Gosse, 1886)45. *L. furcata* (Murray, 1913)46. *L. hamata* (Stokes, 1896)47. *L. hornemanni* (Ehrenberg, 1834)48. *L. inermis* (Bryce, 1892)49. *L. ludwigii* (Eckstein, 1883)50. *L. lunaris* (Ehrenberg, 1832)51. *L. obtusa* (Murray, 1913)*52. *L. papuana* (Murray, 1913)53. *L. pusilla* Haring, 191454. *L. pyriformis* (Daday, 1905)55. *L. quadridentata* (Ehrenberg, 1830)56. *L. signifera* (Jennings, 1896)57. *L. simonneae* Segers, 1993*58. *L. stenroosi* (Meissner, 1908)*59. *L. stichaea* Haring, 1913***60. *L. tenuiseta* Haring, 191461. *L. undulata* Hauer, 1938*62. *L. unguitata* (Fadeev, 1925)**Family:** Notommatidae

63. *Cephalodella gibba* (Ehrenberg, 1830)
64. *C. mucronata* Myers, 1924
65. *C. ventripes* (Dixon-Nuttall, 1901)
66. *Monommata grandis* Tessin, 1890
67. *Notommata copeus* Ehrenberg, 1834#
68. *N. spinata* Koste & Shiel, 1991*

Family: Gastropodidae

69. *Gastropus minor* (Rousselet, 1892)***

Family: Trichocercidae

70. *Trichocerca bidens* (Lucks, 1912)*
71. *T. edmondsoni* (Myers, 1936)*
72. *T. pusilla* (Jennings, 1903)
73. *T. scipio* (Gosse, 1886)*
74. *T. siamensis* Segers & Pholpunthin, 1997*
75. *T. similis* (Wierzejski, 1893)

Family: Synchaetidae76. *Ploesoma lenticulare* Herrick, 188577. *Polyarthra vulgaris* Carlin, 1943**Family: Dicranophoridae**78. *Dicranophorus forcipatus* (O.F. Müller, 1786)79. *Dicranophorus* sp.**Order: Flosculariaceae****Family: Floscularidae 2**80. *Sinantherina spinosa* (Thorpe, 1893)81. *Stephanoceros fimbriatus* (Goldfusz, 1820)****Family: Testudinellidae**82. *Pompholyx sulcata* Hudson, 188583. *Testudinella amphora* Hauer, 1938*84. *T. emarginula* (Stenroos, 1898)85. *T. parva* (Ternetz, 1892)86. *T. patina* (Hermann, 1783)87. *T. tridentata* Smirnov, 1931**Order: Collothecaceae****Family: Atrochidae**88. *Cupelopagis vorax* (Leidy, 1857)****Subclass: Bdelloidea****Family: Philodinidae**89. *Dissotrocha aculeata* (Ehrenberg, 1832)90. *Rotaria neptunia* (Ehrenberg, 1830)

New record from northeast India (NEI); * New record Meghalaya state;
 ** New record from NEI (Sharma, 2016); *** New record from India (Sharma, 2016)