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Rotifer assemblages (Rotifera: Eurotatoria) of two wetlands of Nagaland, northeast India: ecosystem diversity and interesting features

BK Sharma and Kensibo

Abstract
Small lentic ecosystems are hypothesized to play a critical role in maintaining metazoan biodiversity. This study is undertaken to explore the rotifer diversity of two semi-urban wetlands of Dimapur district of Nagaland, northeast India (NEI) sampled during December, 2014-November, 2016. Our report of 110 species (S) belonging to 31 genera and 17 families indicates rich and diverse Rotifera with 50 species new to Nagaland. The biodiverse nature of the rotifer fauna merits importance as ~39.0 and ~26.0% of species known from NEI and India, respectively. The globally interesting elements (~11% of S) include one Australasian, three Oriental and eight palaeotropical species. Lecanidae > Lepadellidae together comprise ~49.0% of total richness and Brachionidae > Trichocercidae > Testudinellidae are other notable families. *Lecane* > *Lepadella* (45.4% of S) are more diverse genera while *Trichocerca* > *Brachionus* > *Testudinella* form useful fraction. Lower monthly richness and community similarities (*vide* Sørenson index), and the hierarchical cluster analysis affirm rotifer heterogeneity in individual wetlands. Higher richness and high similarities explain overall homogeneity of the taxon amongst the wetlands. ANOVA recorded significant richness variations amongst two wetlands and significant annual variations individually. The richness followed oscillating monthly variations and showed lack of influence of any individual abiotic parameters in each wetland.

Keywords: Composition, habitat diversity, heterogeneity, interesting taxa, richness, variations

1. Introduction

The small lentic biotopes comprise an inherent part of freshwater ecosystems of our biosphere and the interconnected network of global metabolically active sites [1]. They are increasingly considered as biodiversity hotspots both in terms of species composition and biological traits [2] and thus can play a critical role in maintaining biodiversity [3]. A critical analysis of the Indian limnology literature on these ecosystems lays caution on over-emphasis on quantum of publications in view of limited biodiversity content of sizable number of routine 'ad hoc' works with incomplete species reports. This generalization holds valid to more neglected aquatic biodiversity and limnology of small ecosystems of NEI located under varied geomorphic and climatic conditions.

Rotifera or 'wheel animalcules form an important component of freshwater metazoan assemblages and fish food organisms. Though they have been documented from distant parts of India since over last 120 years, our literature yet reflected several lacunae on their biodiversity in general and ecosystem diversity in particular [4] including those in small lentic habitats. An account on the rotifer diversity of northeast India (NEI) [5] highlighted paucity of studies from Nagaland state. This present study is thus an endeavour to augment Rotifera ecosystem diversity status of Nagaland vis-a-vis importance of small lentic environs with regards to their role in maintaining metazoan biodiversity. The observations initiated in two semi-urban wetlands of Nagaland resulted in biodiverse rotifer assemblages with several features of ecosystem diversity and biogeography interest. An inventory of the documented taxa is presented and interesting species are illustrated. The nature and composition of the rotifer diversity is discussed with reference to richness, interesting elements and distribution of various taxa, and monthly variations and influence of abiotic factors.

2. Materials and Methods

This study is a part of limnological reconnaissance of two semi-urban wetlands of Dimapur city of Nagaland state of NEI (Fig. 1, A-D) namely Bolfangdisa (25°46'23.86" N; 093°38'03.49" E, area: 5.2 ha, 178 m ASL) and Madladijam (25°46'36.39" N; 093°38'07.58" E, area: 4.7 ha, 175 m ASL) wetlands undertaken during December, 2014-November, 2016.

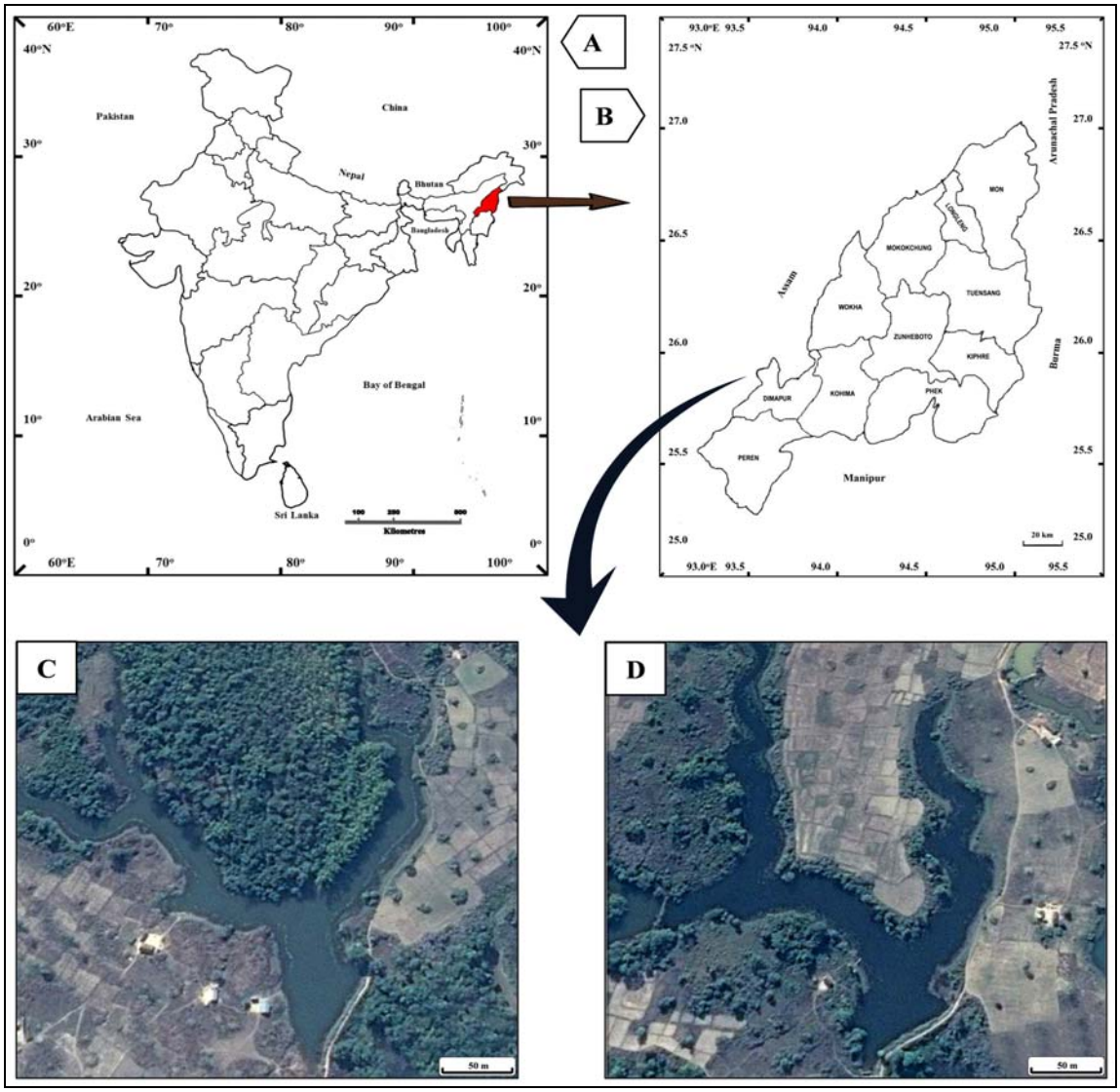

Fig 1: A-D: 1A, map of India indicating Nagaland state; 1B, Map of Nagaland indicating Dimapur district; 1C, Bolfangdisa wetland (Google picture); 1D, Madladijam wetland(Google picture)

Various aquatic macrophytes of these water bodies included *Alternanthera* sp., *Azolla* sp., *Centella* sp., *Ceratophyllum* sp., *Chara* sp., *Commelina bengalensis, Elodea* sp., *Hydrilla verticillata, Juncus* sp., *Nymphaea* sp. and *Scirpus* sp. The fish fauna included *Catla catla*, *Cirrhinus mrigala, Ctenopharyngodon idella*, *Cyprinus carpio, Hypophthalmichthys molitrix*, *Clarias* sp., *Labeo rohita* and *Probarbus jullieni* with some turtles in Bolfangdisa.

Water samples were collected monthly during the study period and were monitored for 17 abiotic parameters. Water temperature, specific conductivity and pH were recorded by the field probes; rainfall data was collected from local meteorological station; dissolved oxygen was estimated by Winkler's method; and the rest of the parameters i.e., free carbon dioxide, total alkalinity, total hardness, calcium, magnesium, chloride, dissolved organic matter, total dissolved solids, phosphate, nitrate, sulphate and silicate were analyzed following APHA [6].

The plankton and semi-plankton samples were collected monthly by towing a nylobolt plankton net (#50 µm) and preserved in 5% formalin. All samples 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 measurements were given in micrometers (µm). Various rotifer taxa were identified following various works [7-12]. The rotifer community similarities were calculated vide Sørensen's index, the hierarchical cluster analysis was done using SPSS (Version 20) and two-way ANOVA was used to ascertain significance of richness variations. The relationships between abiotic factors and richness were determined by Pearson's correlation coefficients (r); P values were computed and their significance was ascertained after application of Boferroni's correction.

3. Results

Table 1: Variations in abiotic parameters

Wetlands→	MADLADIJAM		BOLFANGDISA	
PARAMETERS↓	RANGE	MEAN±SD	RANGE	MEAN±SD
Water Temperature (ºC)	15.00-33.00	26.23±4.22	16.00-36.00	26.83±4.70
Rainfall (mm)	0.00-139.70	61.62±52.63	0.00-139.70	61.62±52.63
pH	6.86-7.25	7.04±0.12	6.81-7.30	7.16±0.16
Specific Conductivity (µS/cm)	33.00-58.00	43.42±6.69	37.00-60.00	47.71±7.44
Dissolve Oxygen (mg/l)	1.60-8.00	4.83±1.48	1.60-7.20	4.75±1.37
Free Carbon Dioxide (mg/l)	6.00-28.00	10.00±5.65	4.00-30.00	10.63±6.27
Total Alkalinity (mg/l)	24.00-72.00	46.75±10.78	32.00-64.00	46.58±7.93
Total Hardness (mg/l)	20.00-70.00	42.00±14.39	24.00-68.00	41.50±13.32
Calcium (mg/l)	2.10-12.60	4.73±2.35	2.31-10.50	5.00±1.87
Magnesium (mg/l)	4.20-24.69	10.54±5.91	4.56-22.77	9.94±5.33
Chloride (mg/l)	20.98-50.95	36.05±7.55	18.98-46.95	34.38±7.65
Dissolved organic matter (mg/l)	0.05-0.16	0.09±0.02	0.05-0.17	0.09±0.03
Total dissolved solids (mg/l)	0.057-0.257	0.104±0.050	0.029-0.200	0.102±0.041
Phosphate (mg/l)	0.027-0.304	0.108±0.072	0.016-0.257	0.087±0.057
Nitrate (mg/l)	0.560-3.175	1.580±0.662	0.454-3.068	1.809±0.725
Sulphate (mg/l)	0.844-7.875	3.094±1.832	0.938-5.906	2.824±1.405
Silicate (mg/l)	0.571-8.000	3.178±1.822	0.857-6.571	3.292±1.745

The variations in abiotic factors (range, mean ± SD) are presented in Table 1. Water temperature varied between 15.00-33.00 ºC, pH between 6.86-7.30 and specific conductivity between 33.00-60.00 µS/cm. Dissolved oxygen (1.60-8.00 mg/l), free Co_2 (4.00-30.00 mg/l), total alkalinity (24.00-72.00 mg/l), total hardness (24.00-70.00 mg/l), Calcium (2.10-12.60 mg/l), Magnesium (4.20-24.69 mg/l) and Chloride (18.98-50.95 mg/l). Dissolved organic matter, total dissolved solids, and nutrients recorded lower values.

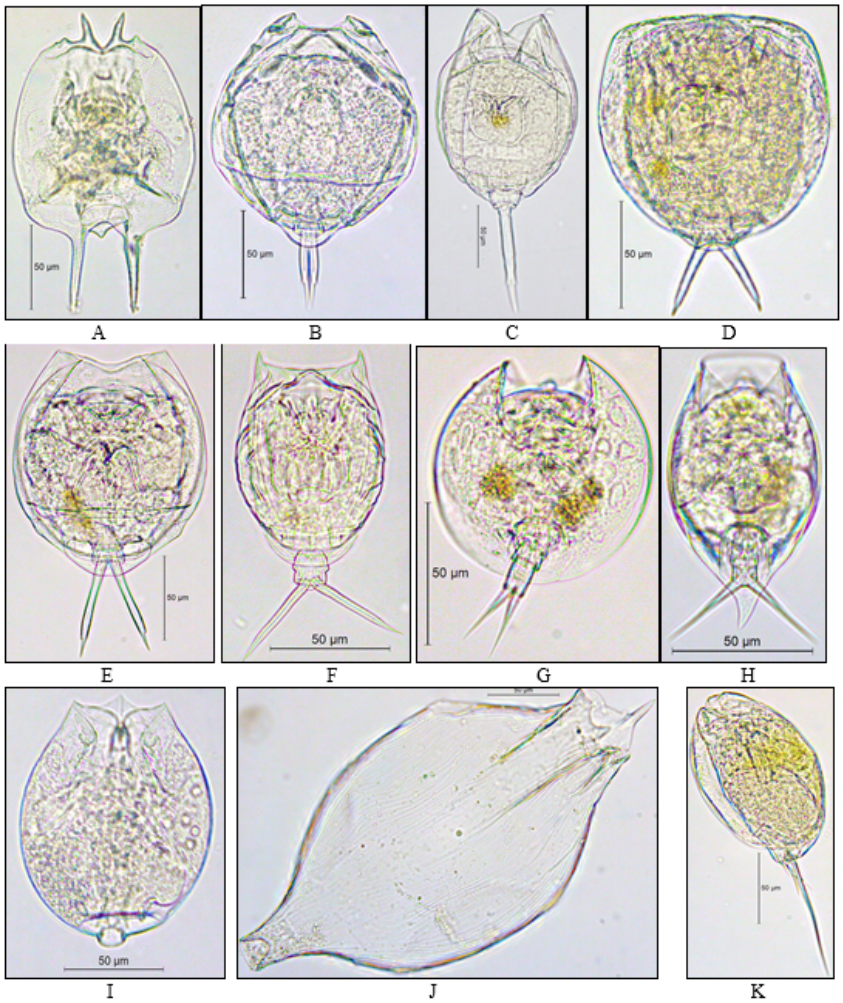

Fig 2A-I: Biogeographically interesting rotifers

2A, *Brachionus dichotomus reductus* (ventral view); 2B, *Lecane blachei* (ventral view); 2C, *L. bulla diabolica* (dorsal view); 2D, *L. latissima* (dorsal view); 2E, *L. lateralis* (ventral view); 2F, *L. simonneae* (dorsal view), 2G, *Lepadella discoidea* (ventral view), 2H, *L. vandenbrandei* (ventral view); 2I, *Testudinella brevicaudata* (ventral view); 2J, *T. greeni* (ventral view); 2K, *Trichocerca hollaerti* (lateral view).

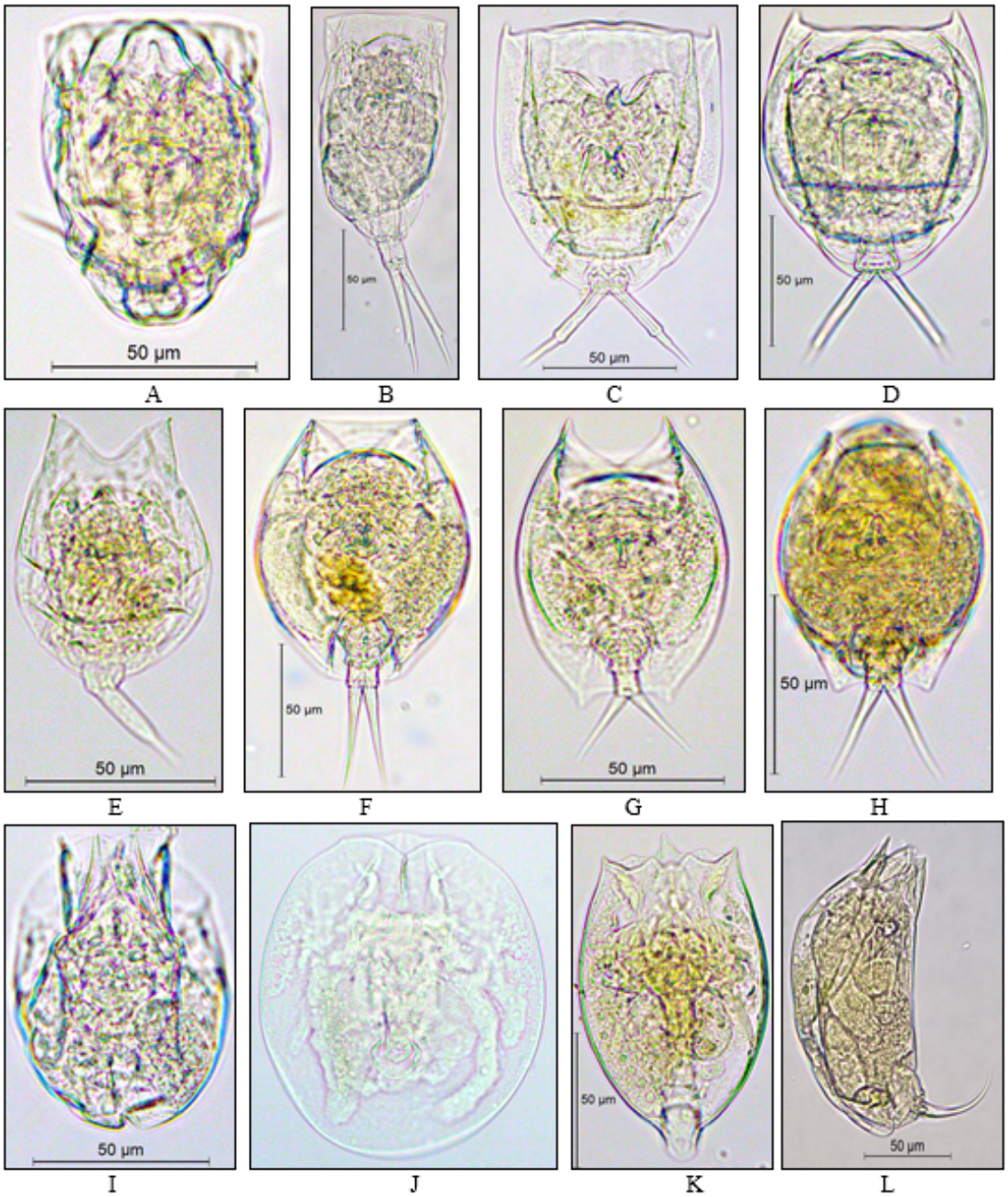

Fig 3 A-L: Rotifer species of regional imporance

3A, *Lecane dorussa* (ventral view); 3B, *L. elegans* (dorsal view); 3C, *L. hastata* (ventral view); 3D, *L. rhenana* (dorsal view); 3E, *L. thienemanni* (ventral view); 3F, *Lepadella benjamini* (ventral view), 3G, *L. costatoides* (ventral view), 3H, *L. dactyliseta* (ventral view); 3I, *Testudinella amphora* (ventral view); 3J, *T. dendradena* (ventral view); 3K, *T. tridentata* (ventral view); 3L, *Trichocerca maior* (lateral view).

A total of 110 species of Rotifera belonging to 31 genera and 17 families are recorded and the detailed systematic list is presented below:

Systematic list of the recorded rotifer species from Nagaland wetlands

Phylum: Rotifera

Class: Eurotatoria

Subclass: Monogononta

Order: Ploima

Family: **Brachionidae**

1. *Anuraeopsis fissa* (Gosse, 1851)
2. *Brachionus angularis* Gosse, 1851
3. *B. caudatus* Barrois & Daday, 1894

4. *B. dichotomus reductus* Koste & Shiel, 1980 *
5. *B. diversicornis* (Daday, 1883)
6. *B. falcatus* Zacharias, 1898
7. *B. forficula* Wierzejski, 1891
8. *B. mirabilis* Daday, 1897*
9. *B. quadridentatus* Hermann, 1783
10. *Keratella cochlearis* (Gosse, 1851)
11. *K. lenzi* Hauer, 1953
12. *K. tropica* (Apstein, 1907)
13. *Plationus patulus* (O.F. Muller, 1786)
14. *Plyatias quadricornis* (Ehrenberg, 1832)

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

Family: **Mytilinidae**
20. *Mytilina acanthophora* Hauer, 1938 *
21. *Mytilina bisulcata* (Lucks, 1912) *
22. *M. ventralis* (Ehrenberg, 1830)

Family: **Trichotriidae**
23. *Macrochaetus sericus* (Thorpe, 1893)
24. *Trichotria tetractis* (Ehrenberg, 1830)

Family: **Lepadellidae**
25. C*olurella obtusa* (Gosse, 1886)
26. *C. sulcata* (Stenroos, 1898) *
27. *C. uncinata* (O.F. Muller, 1773)
28. *Lepadella acuminata* (Ehrenberg, 1834)
29. *L. apsida* Harring, 1916 *
30. *L benjamini* Harring, 1916*
31. *L. biloba* Hauer, 1958*
32. *L. costatoides* Segers, 1992 *
33. *L. dactyliseta* (Stenroos, 1898) *
34. *L. discoidea* Segers, 1993 *
35. *L. ovalis* (O.F. Muller, 1786)
36. *L. patella* (O.F. Muller, 1773)
37. *L. rhomboides* (Gosse, 1886)
38. *L. triptera* Ehrenberg, 1832
39. *L. triba* Myers, 1934 *
40. *L. vandenbrandei* Gillard, 1952 *
41. *L.* (*H.*) *apsicora* Myers, 1934
42. *L.* (*H.*) *ehrenbergi* (Perty, 1850)
43. *L.* (*H.*) *heterostyla* (Murray, 1913)
44. *Squatinella lamellaris* (O. F. Müller, 1786) *

Family: **Lecanidae**
45. *Lecane aculeata* (Jakubski, 1912)
46. *L. blachei* Berzins, 1973 *
47. *L. bulla* (Gosse, 1851)
    L. bulla diabolica (Hauer, 1936) *
48. *L. closterocerca* (Schmarda, 1859)
49. *L. crepida* Harring, 1914
50. *L. curvicornis* (Murray, 1913)
51. *L. doryssa* Harring, 1914 *
52. *L. elegans* Harring, 1914 *
53. *L. furcata* (Murray, 1913)
54. *L. haliclysta* Harring & Myers, 1926 *
55. *L. hamata* (Stokes, 1896)
56. *L. hastata* (Murray, 1913) *
57. *L. hornemanni* (Ehrenberg, 1834)
58. *L. lateralis* Sharma, 1978 *
59. *L. latissima* Yamamoto, 1951 *
60. *L. leontina* (Turner, 1892)
61. *L. ludwigii* (Eckstein, 1883)
62. *L. luna* (Müller, 1776)
63. *L. lunaris* (Ehrenberg, 1832)
64. *L. monostyla* (Daday, 1897) *
65. *L. nitida* (Murray) *
66. *L. obtusa* (Murray, 1913) *
67. *L. papuana* (Murray, 1913)
68. *L. ploenensis* (Voigt, 1902)
69. *L. pyriformis* (Daday, 1905)
70. *L. quadridentata* (Ehrenberg,1830)
71. *L. rhenana* Hauer, 1929 *
72. *L. signifera* (Jennings, 1896)
73. *L. simonneae* Segers, 1993 *
74. *L. stenroosi* (Meissner, 1908)
75. *L. thienemanni* (Hauer, 1938) *
76. *L. undulata* Hauer, 1938 *
77. *L unguitata* (Fadeev, 1925)
78. *L. ungulata* (Gosse, 1887)

Family : Notommatidae
79. *Cephalodella. gibba* (Ehrenberg, 1830)
80. *Monommata longiseta* (O.F. Müller, 1786)
81. *M. maculata* Harring & Myers, 1930 *
82. *Notommata copeus* Ehrenberg, 1834 *

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

Family: **Gastropodidae**
84. *Ascomorpha ovalis* (Bergendal, 1892) *

Family: Trichocercidae
85. *Trichocerca bicristata* (Gosse, 1887) *
86. *T. bidens* (Lucks, 1912) *
87. *T. flagellata* Hauer, 1937*
88. *T. hollaerti* De Smet, 1990 *
89. *T insignis* (Herrick, 1885) *
90. *T. maior* Hauer, 1936 *
91. *T. pusilla* (Jennings, 1903) *
92. *T. rattus* (O.F. Müller, 1776)
93. *T. similis* (Wierzejski, 1893)
94. *T. tigris* (O.F. Müller, 1786) *

Family: Asplanchnidae
95. *Asplanchna priodonta* Gosse, 1850

Family: Synchaetidae
96. *Polyarthra. vulgaris* Carlin, 1943
97. *Synchaeta* sp. *

Family: Dicranophoridae
98. Dicranophorus epicharis Harring & Myers, 1928
Order: **Flosculariaceae**
Family: Floscularidae
99. Sinantherina spinosa (Thorpe, 1893) *

Family: Testudinellidae
100. Pompholyx sulcata Hudson,1885
101. Testudinella amphora Hauer, 1938 *
102.T. brevicaudata Yamamoto, 1951 *

103.T. dendradena de Beauchamp, 1955 *
104.T. emarginula (Stenroos, 1898) *
105. T. greeni Koste, 1981 *
106.T. patina (Hermann, 1783)
107.T. tridentata Smirnov, 1931 *

Family: Trochosphaeridae
108.Filinia longiseta (Ehrenberg, 1834)

Sub-class: Bdelloidea
Family: Philodinidae
109.Dissotrocha aculeata (Ehrenberg, 1832)*
110.Rotaria neptunia (Ehrenberg, 1830)

*new record from Nagaland

Our collecttions indicated 50 new species records (marked *) from Nagaland state of NEI. *Brachionus dichotomus reductus* (Fig. 2A), *Lecane blachei* (Fig. 2B), L. *bulla diabolica* (Fig. 2C), *L. latissima* (Fig. 2D), *L. lateralis* (Fig. 2E), L. *simonneae* (Fig. 2F), *L unguitata*, *Lepadella discoidea* (Fig. 2G), *L. vandenbrandei* (Fig. 2H), *Testudinella brevicaudata* (Fig. 2I), *T. greeni* (Fig. 2J) and *Trichocerca hollaerti* (Fig. 2K) are elements of biogeographic interest. Besides, various species of regional distribution interest included *Lecane doryssa* (Fig. 3A), *L. elegans* (Fig. 3B), *L. hastata* (Fig. 3C), *L. rhenana* (Fig. 3D), *L. thienemanni* (Fig. 3E), *L. undulata*, *Lepadella benjamini* (Fig. 3F), *L. costatoides* (Fig. 3G), *L. Dactyliseta* (Fig. 3H), *Testudinella amphora* (Fig. 3I), *T. dendradena* (Fig. 3J), *T. tridentata* (Fig. 3K) and *Trichocerca maior*(Fig. 3L).

Bolfangdisa wetland recorded a total of 95 species during the study with richness of 88 and 66 species during two years, respectively. Madladijam wetland indicated total 84 species with annual variations of 74 and 54 species, respectively. The rotifer richness recorded 77.1% community similarity amongst two wetlands during the study. The monthly richness ranged between 25±9 and 20±8 species and followed oscillating variations (Figs. 4-5). It recorded 27.6-73.5% and 28.6-72.7% community similarities in two wetlands, respectively and the hierarchical cluster analysis indicated annual differences (Figs.6-7) in similarity and divergence patterns. ANOVA registered significant richness variations amongst four beels ($F_{1, 47}$= 6.469, P= 0.018) and significant monthly variations ($F_{23, 27}$ = 2.589, P=0.013) between them while it registered significant annual variations in Bolfangdisa ($F_{1, 11}$=7.965, P=0.0166) and Madladijam ($F_{1, 11}$=8.825, P=0.0127) wetlands. Lecanidae, Lepadellidae, Brachionidae and Trichocercidae indicated 34, 20, 14 and 10 species, respectively. Testudinellidae (8 species), Euchlanidae (5 species) and Notommatidae (4 species) are other rich families. *Lecane* (34 species), *Lepadella* (16 species), *Trichocerca* (10 species) and *Brachionus* (8 species) are diverse genera.

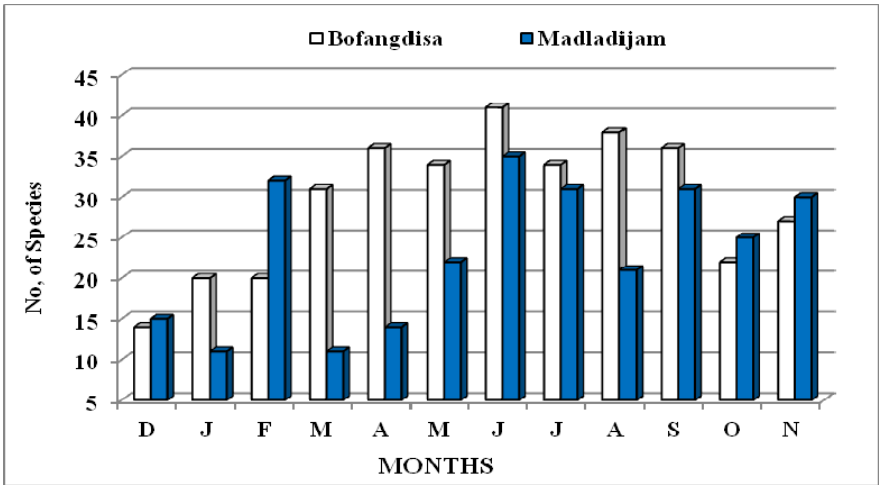

Fig 4: Species richness of Rotifera of Bolfangdisa and Madladijam wetlands (First year)

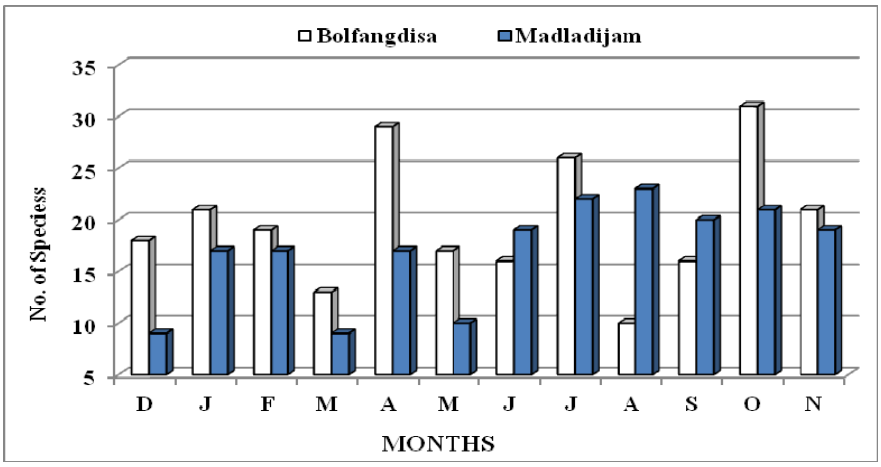

Fig 5: Species richness of Rotifera of Bolfangdisa and Madladijam wetlands (Second year)

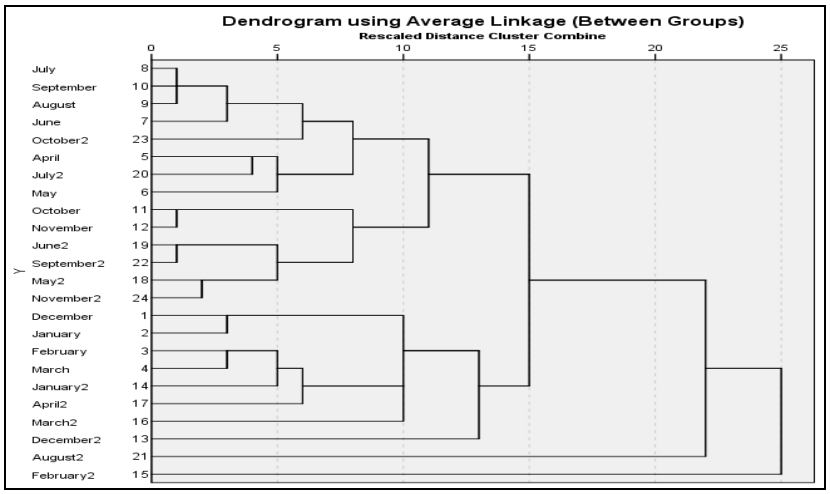

Fig 6: Hierarchichal cluster analysis of Rotifera of Bolfandisa wetland

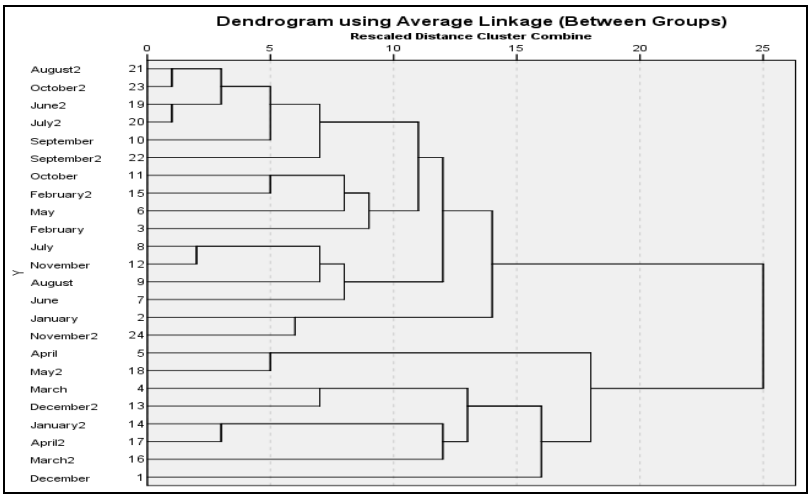

Fig 7: Hierarchichal cluster analysis of Rotifera of Madladijam wetland

4. Discussion

Water temperature affirmed tropical nature of Bolfangdisa and Madladijam wetlands. The 'circum neutral-slightly alkaline', 'soft' and 'calcium poor' waters are characterized with Mg > Ca. The specific conductivity indicated low ionic concentrations of both wetlands and thus warranted inclusion of these water bodies under 'Class I' category of trophic classification [13]. The results indicated variations in dissolved oxygen and free carbon dioxide with moderate mean values during the study period while Chloride indicated certain influence of human impact in these biotopes. Dissolved organic matter, total dissolved solids and phosphate recorded lower values while nitrate, sulphate and silicate recorded more variations.

Our report of total richness (S) of 110 species belonging to 31 genera and 17 families indicates rich and diverse Rotifera assemblage with biodiversity interest as ~39.0 and ~26.0% of species known from NEI and India, respectively. This study also affirmed high overall richness in the two wetlands which is hypothesized to their habitat diversity and environmental heterogeneity individually. Total richness provides a significant update to 66 species, 23 genera, 14 families Rotifer reported earlier from Nagaland [5] while it is higher than a recent high report of 90 species from a small urban sub-tropical wetland of Meghalaya state of NEI [14].

The globally interesting elements formed a notable fraction (11.0% of S). These included the Australasian *Brachionus dichotomus reductus*; three Oriental endemics i.e., *Lecane blachei*, L. *bulla diabolica*, *L. latissima*; and eight palaeotropical species namely *Lepadella discoidea, L. vandenbrandei*, *L. lateralis,* L. *simonneae, L unguitata*, *Testudinella brevicaudata*, *T. greeni* and *Trichocerca hollaerti*. Besides, *Lecane doryssa, L. elegans, L. haliclysta, L. hastata, L. rhenana, L. thienemanni, L. undulata, Lepadella benjamini, L. costatoides, L. dactyliseta, Testudinella amphora, T. dendradena*, *T. tridentata, Trichocerca insignis* and *T. maior* are species of regional distribution interest in the Indian-sub region. Amongst these, twelve species namely *Lepadella benjamini, L. vandenbrandei*, *Lecane elegans, L. latissima, L. rhenana, L. undulata, Testudinella amphora, Testudinella brevicaudata*, *T. dendradena*, *T. greeni*, *Trichocerca hollaerti* and *T. maior* are characterized by their distribution in India till date exclusively restricted to NEI. *Lecane latissima,* an interesting lecanid noticed in our collections, deserved attention. It was originally reported from India from Meghalaya state of NEI [15] as *L. thailandensis* which was subsequently assigned [16] to *L. latissima* following its recent synonymy [17].

Lecanidae > Lepadellidae together comprised major component (~49.0% of S) of the rotifer diversity. In addition, Brachionidae > Trichocercidae > Testudinellidae deserved

attention (~29.0% of S). *Lecane* > *Lepadella* (45.4% of S) are more diverse genera and *Trichocerca* > *Brachionus* > *Testudinella* together formed notable fraction (~23% of S). The richness importance of the stated taxa endorsed the littoral-periphytic character of the rotifer assemblages concurrent with general habitat of the two wetlands. This generalization endorsed the remarks the wetlands of Manipur [18] of the Brahmaputra river basin floodplains of NEI [5, 19]. Nevertheless, the richness of Brachionidae (14 species) and *Brachionus* (8 species) is attributed to certain semi-limnetic conditions in these water bodies. This in contrast to the relative paucity of these taxa reported from Meghalaya wetland [14] in spite of open water conditions. The speciose nature of the `tropic-centred' *Lecane* and *Brachionus* to certain extent; high richness of cosmopolitan species (~62.0% of S); and the reports of several tropicopolitan and pantropical species (~25% of S) imparted a 'tropical character' to the rotifer fauna [5, 12, 19].

The rotifers depicted distinct monthly variations with low richness (10-41, 25±8 species and 9-35, 20±9 species); low community similarities (27.5-73.5% and 28.6-72.7%); with ~ 45% and ~ 52% instances in community matrices indicating values up to 50% similarity and only one and two occurred throughout the study period in Bolfangdisa and Madladijam wetlands, respectively. The hierarchical cluster analysis reflected heterogeneity in cluster groups in the two wetlands; it showed greater affinity July, August and September rotifer assemblages during first year and most divergence in composition during February > August and December during second year in Bolfangdisa. June, July, August and October communities' recorded higher affinity during second year while April and December sampled recorded most divergence during first year in Madladijam wetland. The stated features endorsed general heterogeneity in species composition of Rotifera and are hypothesized to habitat diversity of the two wetlands individually. The former generalization concurred with the reports from wetlands of Meghalaya [14] and lower Assam [20] states of NEI. ANOVA recorded significant richness monthly variations amongst the wetlands and only significant annual variations individually in each of them. The richness followed oscillating monthly variations and showed lack of influence of any individual abiotic parameters during this study in each wetland.

5. Conclusions

This study highlights the rich and diverse Rotifera of the two small wetlands characterized by 'alkaline', and 'calcium poor' waters with low ionic concentrations and thus their affirmed environmental heterogeneity. The report of various species of biogeographic interest, new records, and salient features of richness and composition highlight ecosystem diversity of Rotifera in small lentic ecosystems. The results on low monthly richness and lower community similarities endorse heterogeneity in the rotifer assemblages in individual wetlands on account of habitat diversity while overall rotifer richness and composition affirmed homogeneity amongst two wetlands. Lack of influence of individual abiotic factors on the rotifer richness reflects importance of factors associated with habitat and the role of biotic factors.

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