

Research article[urn:lsid:zoobank.org:pub:839E82AA-0807-47C1-B21E-C5DE2098C146](https://zoobank.org/pub:839E82AA-0807-47C1-B21E-C5DE2098C146)**The biodiverse rotifer assemblages (Rotifera: Eurotatoria) of Arunachal Pradesh, the eastern Himalayas: alpha diversity, distribution and interesting features****Bhushan Kumar Sharma^{1,*} & Sumita Sharma²**^{1,2} Department of Zoology, North-Eastern Hill University, Shillong – 793 022, Meghalaya, India*Corresponding author: Email: profbksharma@gmail.com¹[urn:lsid:zoobank.org:author:FD069583-6E71-46D6-8F45-90A87F35BEFE](https://zoobank.org/author:FD069583-6E71-46D6-8F45-90A87F35BEFE)²[urn:lsid:zoobank.org:author:668E0FE0-C474-4D0D-9339-F01ADFD239D1](https://zoobank.org/author:668E0FE0-C474-4D0D-9339-F01ADFD239D1)

Abstract. The present assessment of Rotifera biodiversity of the eastern Himalayas reveals a total of 172 species belonging to 39 genera and 19 families from Arunachal Pradesh, the northeastern-most state of India. The richness forms ~59% and ~40% of the rotifer species known till date from northeast India (NEI) and India, respectively. Three species are new to the Indian sub-region, four species are new to NEI and 89 species are new to Arunachal Pradesh; 27 species indicate global distribution importance and 25 species reported exclusively from NEI merit regional interest. The rich and diverse alpha diversity and biogeographic interest of Rotifera of this Himalayan biodiversity hot-spot is noteworthy in light of predominance of the small lentic ecosystems. Lecanidae > Brachionidae > Lepadellidae > Trichocercidae collectively comprise ~71% of total rotifer species. Brachionidae records the highest richness known from any state of India. This study indicates the role of thermophiles with overall importance of ‘tropic-centered’ genera *Lecane* and *Brachionus*, and particularly at lower altitudes; species of ‘temperate-centered’ genera *Keratella*, *Notholca* and *Synchaeta* are notable in our collections at middle and higher altitudes, while *Trichocerca* and *Lepadella* are other species-rich genera. The rotifer fauna shows a mixture of ‘tropical’ and ‘cold-water’ elements, depicts the littoral-periphytonic character, and records a large component of cosmopolitan species. The study of more collections from middle and higher altitudes of Arunachal Pradesh are desired for an update on Rotifera from the eastern Himalayas.

Key words. Biodiversity, biogeography, habitat heterogeneity, Himalayan hot-spot, interesting species.

INTRODUCTION

Rotifera, an important group of aquatic metazoans and an integral link of aquatic food-webs, have been inadequately documented from several states of India in spite of over 120 years of taxonomic contributions (Sharma & Sharma 2017, 2018a). This generalization holds valid for the eastern-most hill state of Arunachal Pradesh of northeast India (NEI) with an earlier report of 76 species (Sharma & Sharma 2014a). On the other hand, a recent document on ‘Faunal diversity of Indian Himalayas’ (Chandra et al. 2018) listed only 24 species without taking due cognizance of our report in spite of its citation, and Sinha (2018) enlisted 45 rotifer species while collating information on zooplankton fauna of Arunachal Pradesh. The present study is thus an endeavor to augment the status of Rotifera biodiversity of the eastern Himalayas and NEI in particular as well as our work on Fauna volume on the Indian Freshwater Rotifera.

Arunachal Pradesh, “the land of dawn-lit mountains”, is the northeastern-most state of India. Geographically, it is the largest amongst eight sister states of NEI and more importantly, it forms a part of the Himalayan biodiversity

hot-spot. This eastern Himalayan hill state is characterized predominantly by small lentic biotopes located under varied climatic regimes that range from the low altitude humid subtropical climate to high altitude and very high altitude areas with subtropical highland climate and alpine climate. We hypothesize the lentic ecosystems of Arunachal Pradesh to harbor biodiverse Rotifera in view of likely habitat heterogeneity under varied ecological regimes. Our plankton and semi-plankton collections from different districts and largely from small lentic ecosystems of this state interestingly reveal rich and diverse Rotifera assemblages. We present an inventory of the rotifer species observed from Arunachal Pradesh with illustrations of interesting elements. Comments are made on the rotifer alpha diversity with emphasis on the nature and composition, new records, elements of global and regional biogeographic interest and other salient features. This study marks a notable contribution to biodiversity and biogeography of the Indian and Asian Rotifera and that of the eastern Himalayas in particular.

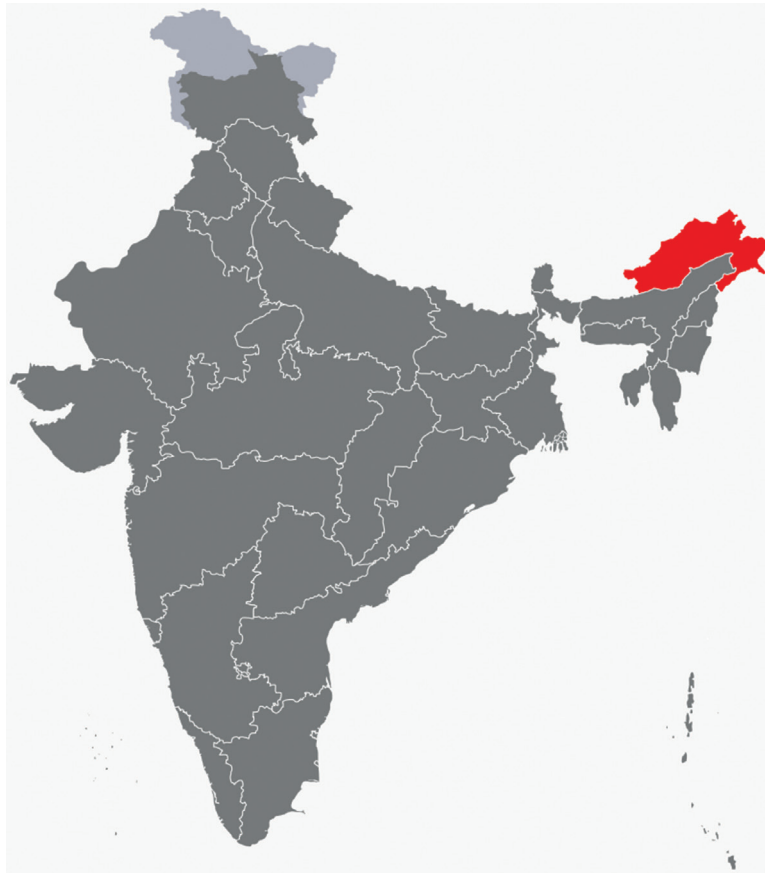
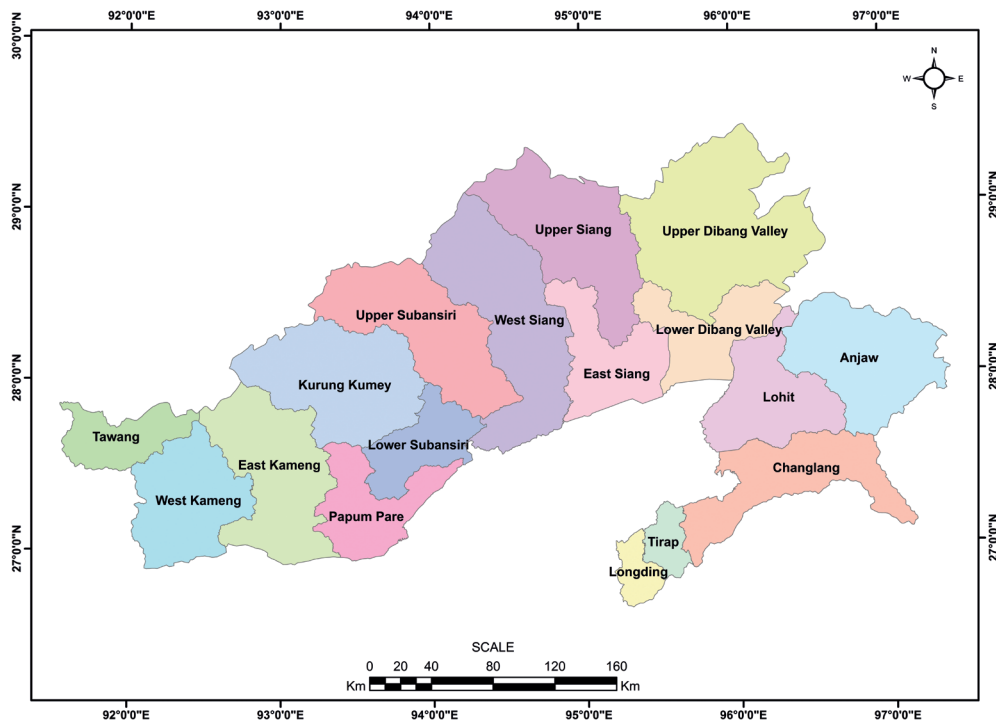
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Fig. 1A–B. **A.** Map of India indicating the state of Arunachal Pradesh; **B.** District map of Arunachal Pradesh.

MATERIALS & METHODS

The present study is based on analysis of our plankton and semi-plankton samples collected during January and March, 2013; February, August and November, 2013; February, 2014 from different districts of Arunachal Pradesh (26.28°–29.30° N latitude; 91.20°–97.30° E longitude) as well as during September, 2013 and June, 2014 from Twang and East Kameng districts. A total of 419 samples collected from scattered localities of Tawang, East Kameng, Lower Subansiri, Upper Subansiri, West Siang, Lower Siang, East Siang, Upper Dibang Valley, Lower Dibang Valley, Namsai, Lohit, Changlang and Tirap districts were examined (Fig. 1, A–B). The collections largely covered the localities from the lower altitudes particularly from the districts adjoining the state of Assam with limited samples from middle altitudes and higher altitudes because of logistic difficulties for sampling namely restricted area and lack of access; infrastructure, difficult terrain and financial support constrains for intensive sampling. The small lentic ecosystems were mainly sampled while the collections were also examined from certain floodplain wetlands from lower altitudes.

Water samples were taken from various aquatic biotopes; water temperature, pH and specific conductivity were recorded with the relevant field probes to provide information on some basic abiotic attributes. The plankton samples were collected by towing a nylobolt plankton net (No. 25; # 50µm) and were preserved in 5% formalin. Individual samples were screened with a Wild stereoscopic binocular microscope; the rotifer taxa were isolated and mounted in Polyvinyl alcohol-lactophenol, and were observed with Leica (DM 1000) stereoscopic phase contrast microscope fitted with an image analyzer. The micro-photographs were provided for interesting species and measurements were given in micrometers (µm). The rotifer taxa were identified following Koste (1978), Koste and Shiel (1987, 1989, 1990), Shiel and Koste (1992, 1993), Segers (1995), Sharma (1983, 1987, 1998) and Sharma & Sharma (1999, 2000, 2008, 2013) and Jersabek & Leitner (2013). Segers (2007) and Jersabek & Leitner (2013) were followed for distributional records of various taxa. The percentage similarities between the rotifer communities were calculated vide Sorenson's index (Sorenson 1948). The voucher collections are deposited in the holdings of Zoological Survey of India, Kolkata.

RESULTS

The plankton and semi-plankton collections from Arunachal Pradesh reveal 172 species of Rotifera belonging to 39 genera and 19 families. A detailed systematic list of the recorded taxa is presented below:

Systematic list of Rotifera recorded from Arunachal Pradesh

Phylum: Rotifera

Class: Eurotatoria

Subclass: Monogononta

Order: Ploima

Family: Brachionidae

1. *Anuraeopsis coelata* De Beauchamp, 1932
2. *A. fissa* Gosse, 1851
3. *Brachionus angularis* Gosse, 1851
4. *B. bennini* Leissling, 1924 **
5. *B. bidentatus* Anderson, 1889
6. *B. budapestinensis* Daday, 1885 **
7. *B. calyciflorus* Pallas, 1766
8. *B. caudatus* Barrois & Daday, 1894
9. *B. dichotomus reductus* Koste & Shiel, 1980 **
10. *B. dimidiatus* Bryce, 1931 *
11. *B. diversicornis* (Daday, 1883) **
12. *B. falcatus* Zacharias, 1898
13. *B. forficula* Wierzejski, 1891
14. *B. kostei* Shiel, 1983 **
15. *B. lyratus* Shephard, 1911 #
16. *B. mirabilis* Daday, 1897 **
17. *B. murphyi* Sudzuki, 1989 **
18. *B. quadridentatus* Hermann, 1783
19. *B. rubens* Ehrenberg, 1838 **
20. *Keratella cochlearis* Gosse, 1851
21. *K. edmondsoni* Ahlstrom, 1943 **
22. *K. javana* Hauer, 1937 **
23. *K. lenzi* Hauer, 1953 **
24. *K. serrulata* (Ehrenberg, 1838)
25. *K. tecta* (Gosse, 1851) **
26. *K. ticinensis* (Callerio, 1921) *
27. *K. tropica* (Apstein, 1907)
28. *Notholca acuminata* (Ehrenberg, 1832)
29. *N. labis* Gosse, 1887 *
30. *N. squamula* (O.F. Muller, 1786)
31. *Platyonus patulus* (O.F. Müller, 1786)
32. *Platylabus leloupi* Gillard, 1957 **
33. *P. quadricornis* (Ehrenberg, 1832)

Family: Epiphanidae

34. *Epiphanes brachionus* (Ehrenberg, 1837) **

Family: Euchlanidae

35. *Beauchampiella eudactylota* (Gosse, 1886)
36. *Dipleuchlanis propatula* (Gosse, 1886)
37. *Euchlanis dilatata* Ehrenberg, 1832
38. *E. incisa* Carlin, 1939
39. *E. triquetra* Ehrenberg, 1838 **
40. *Tripleuchlanis plicata* (Levander, 1894) **

Family: Mytilinidae

41. *Lophocharis salpina* (Ehrenberg, 1834) **
42. *Mytilina acanthophora* Hauer, 1938 **

43. *M. bisulcata* (Lucks, 1912) **
44. *M. brevispina* (Ehrenberg, 1830) **
45. *M. michelangellii* Reid & Turner, 1988 **
46. *M. ventralis* (Ehrenberg, 1830)

Family: Trichotriidae

47. *Macrochaetus danneelae* Koste & Shiel, 1983 **
48. *M. longipes* Myers, 1934 **
49. *M. sericus* (Thorpe, 1893)
50. *Trichotria tetractis* (Ehrenberg, 1830)
51. *Wolga spinifera* (Western, 1894) **

Family: Lepadellidae

52. *Colurella adriatica* Ehrenberg, 1831 **
53. *C. obtusa* (Gosse, 1886)
54. *C. sulcata* (Stenroos, 1898) **
55. *C. uncinata* (O.F. Müller, 1773)
56. *Lepadella acuminata* (Ehrenberg, 1834)
57. *L. apsicora* Myers, 1934
58. *L. apsida* Harring, 1916 **
59. *L. benjamini* Harring, 1916 **
60. *L. biloba* Hauer, 1938 **
61. *L. costatoides* Segers, 1992 **
62. *L. dactyliseta* (Stenroos, 1898) **
63. *L. discoidea* Segers, 1993 **
64. *L. ehrenbergi* (Perty, 1850)
65. *L. heterostyla* (Murray, 1913)
66. *L. minuta* (Weber & Montet, 1918) **
67. *L. ovalis* (O. F. Müller, 1786)
68. *L. patella* (O.F. Müller, 1773)
69. *L. quinquecostata* (Lucks, 1912) **
70. *L. rhomboides* (Gosse, 1886)
71. *L. triba* Myers, 1934 **
72. *L. triptera* Ehrenberg, 1830
73. *L. vandenbrandei* Gillard, 1952 **
74. *Squatinella lamellaris* (O. F. Müller, 1786) **

Family: Lecanidae

75. *Lecane aculeata* (Jakubski, 1912)
76. *L. aeganea* Harring, 1914 **
77. *L. arcula* Harring, 1914
78. *L. bifurca* (Bryce, 1892) **
79. *L. blachei* Berzins, 1973 **
80. *L. bulla* (Gosse, 1851)
81. *L. closterocerca* (Schmarda, 1898)
82. *L. crepida* Harring, 1914
83. *L. curvicornis* (Murray, 1913)
84. *L. decipiens* (Murray, 1913)
85. *L. dorysimilis* Trinh Dang, Segers & Sanoamuang, 2015 **
86. *L. doryssa* Harring, 1914 **
87. *L. elegans* Harring, 1914 **
88. *L. flexilis* (Gosse, 1886) **
89. *L. furcata* (Murray, 1913)
90. *L. haliclysta* Harring & Myers, 1926 **
91. *L. hastata* (Murray, 1913) **
92. *L. hamata* (Stokes, 1896)

93. *L. hornemanni* (Ehrenberg, 1834) **
94. *L. inermis* (Bryce, 1892) **
95. *L. inopinata* Harring & Myers, 1926 **
96. *L. lateralis* Sharma, 1978 **
97. *L. leontina* (Turner, 1892)
98. *L. ludwigii* (Eckstein, 1883)
99. *L. luna* (O.F. Müller, 1776)
100. *L. lunaris* (Ehrenberg, 1882)
101. *L. monostyla* (Daday, 1897) **
102. *L. nitida* (Murray, 1913) **
103. *L. niwati* Segers, Kotethip & Sanoamuang, 2004 **
104. *L. obtusa* (Murray, 1913) **
105. *L. papuana* (Murray, 1913)
106. *L. paxiana* Hauer, 1940 **
107. *L. ploenensis* (Voigt, 1902)
108. *L. pusilla* Harring, 1914 **
109. *L. pyriformis* (Daday, 1905)
110. *L. quadridentata* (Ehrenberg, 1830)
111. *L. rhenana* Hauer, 1929 **
112. *L. rhytida* Harring & Myers, 1926 **
113. *L. signifera* (Jennings, 1896)
114. *L. stenroosi* (Meissner, 1908) **
115. *L. stichoclysta* Segers, 1993 #
116. *L. superaculeata* Sanoamuang & Segers, 1997 **
117. *L. undulata* Hauer, 1938 **
118. *L. unguitata* (Fadeev, 1925)
119. *L. unguolata* (Gosse, 1887)

Family: Notommatidae

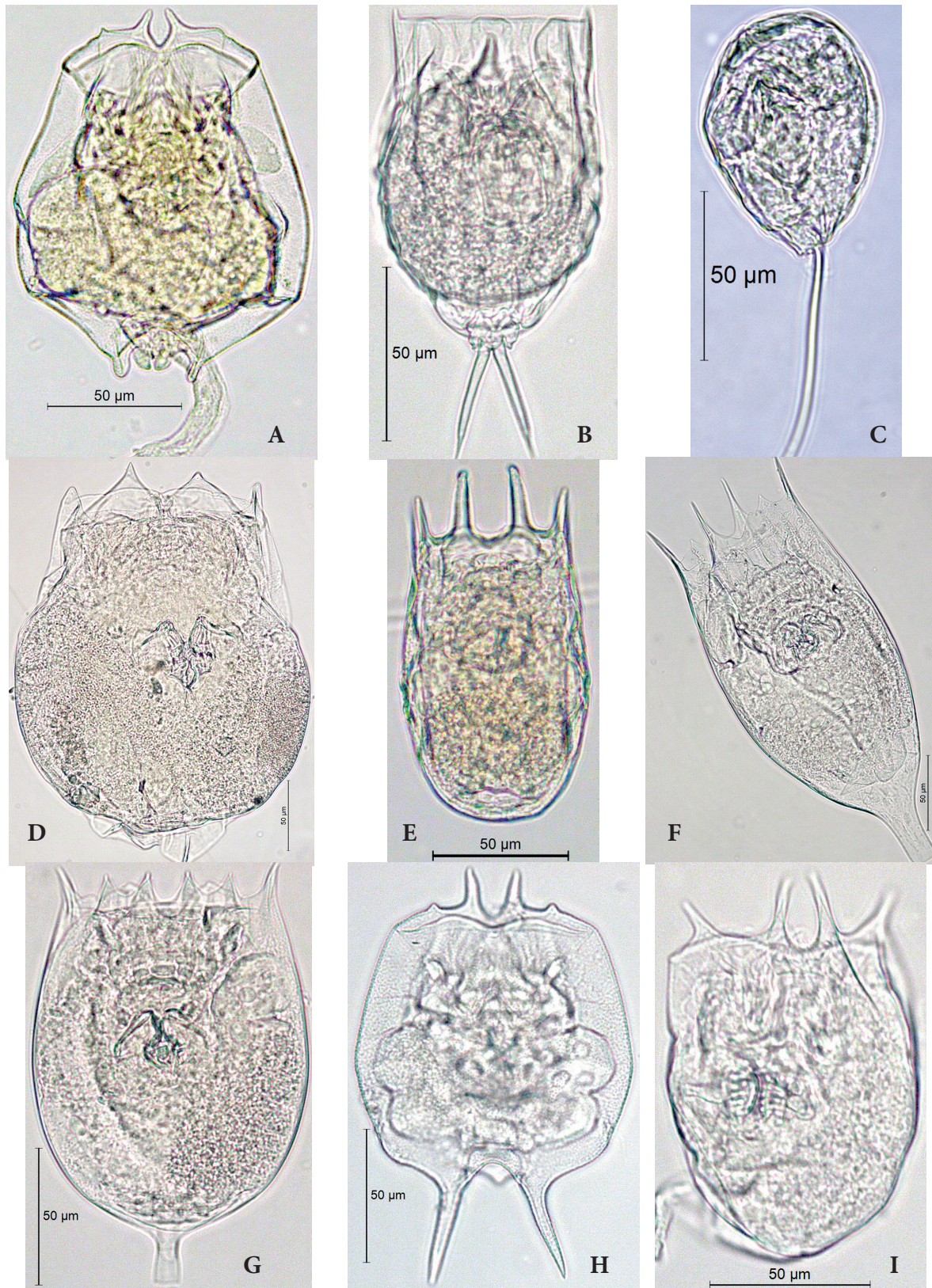
120. *Cephalodella forficula* (Ehrenberg, 1832)
121. *C. gibba* (Ehrenberg, 1830)
122. *C. intuta* Myers, 1924 **
123. *C. mucronata* Myers, 1934
124. *C. trigona* (Rousselet, 1895) **
125. *Monommata longiseta* (O.F. Müller, 1786) **
126. *Notommata pachyura* (Harring & Myers, 1924) **

Family: Scaridiidae

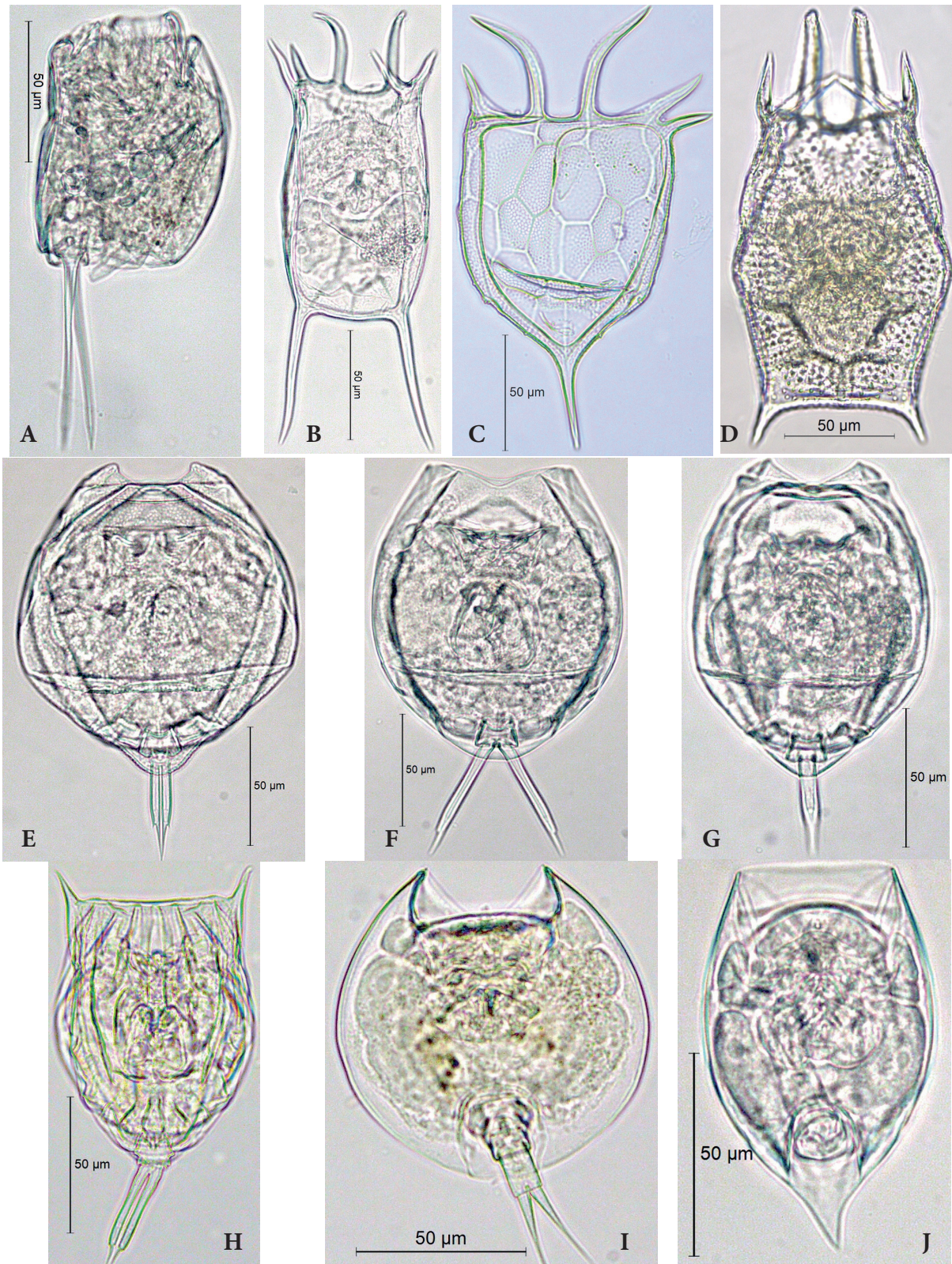
127. *Scaridium longicaudum* (O.F. Müller, 1786)

Family: Trichocercidae

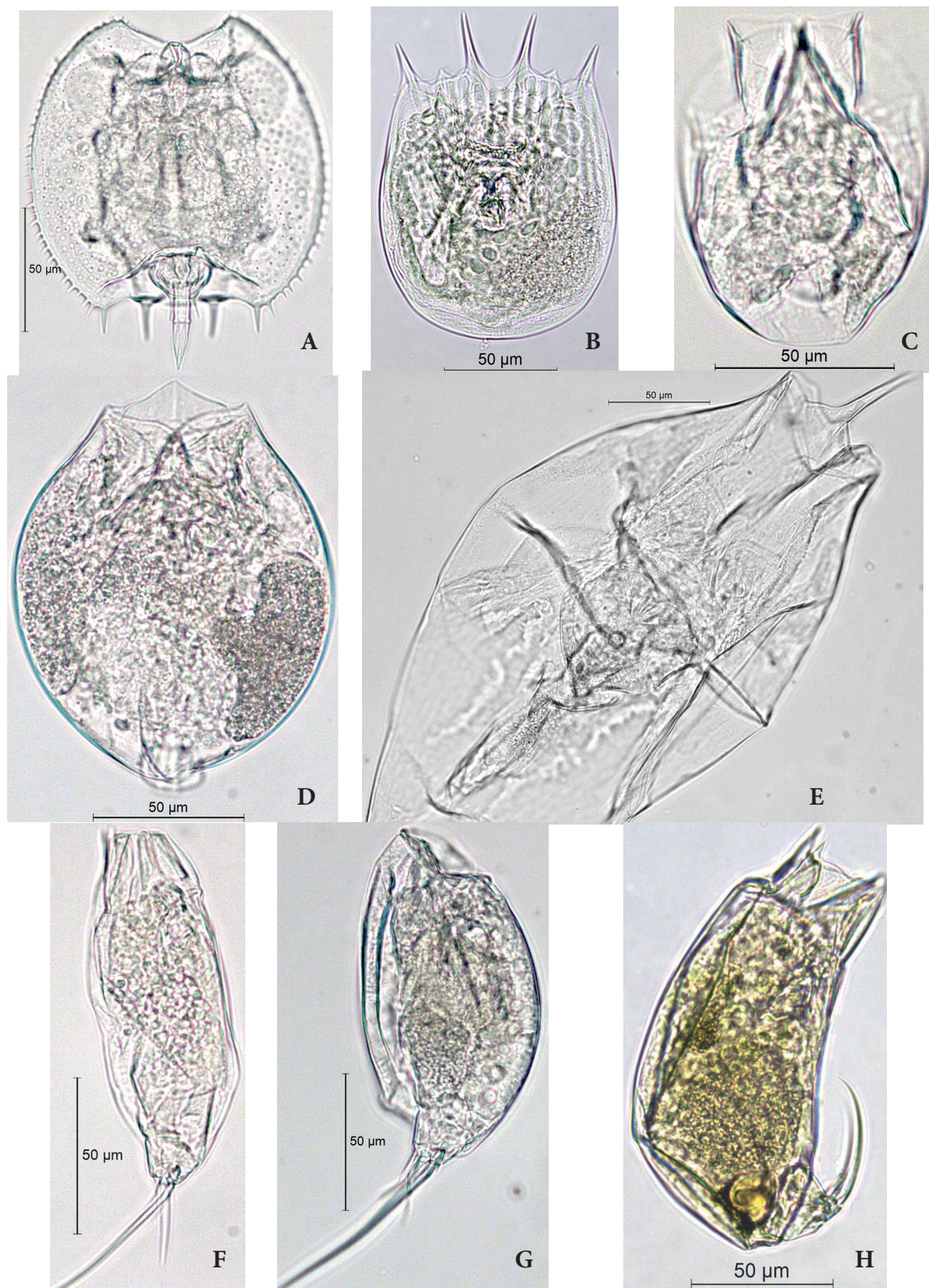
128. *Trichocerca bidens* (Lucks, 1912) **
129. *T. bicristata* (Gosse, 1887) **
130. *T. capucina* (Wierzejski & Zacharias, 1893) **
131. *T. cylindrica* (Imhof, 1891)
132. *T. edmondsoni* (Myers, 1936) **
133. *T. elongata* (Gosse, 1886)
134. *T. flagellata* Hauer, 1938 **
135. *T. hollaerti* De Smet, 1990 **
136. *T. insignis* (Herrick, 1886) **
137. *T. longiseta* (Schränk, 1802)
138. *T. maior* Hauer, 1936 **
139. *T. mus* Hauer, 1938 #
140. *T. pusilla* (Lauterborn, 1898) **
141. *T. rattus* (O.F. Müller, 1786)
142. *T. similis* (Wierzejski, 1893)



Figs. 2A–I. New Rotifera records and species of biogeographic interest. **A.** *Brachionus lyratus* Shephard (ventral view); **B.** *Lecane stichochysta* Segers (ventral view); **C.** *Trichocerca mus* Hauer (lateral view); **D.** *Brachionus dimidiatus* Bryce (ventral view); **E.** *Keratella ticinensis* (Callerio) (dorsal view); **F.** *Notholca acuminata* (Ehrenberg) (dorsal view); **G.** *Notholca labis* Gosse (ventral view); **H.** *Brachionus dichotomus reductus* Koste & Shiel (ventral view); **I.** *Brachionus murphyi* Sudzuki (dorsal view).



Figs. 3A–J. Rotifera species of biogeographic interest. **A.** *Cephalodella trigona* (Rousselet) (lateral view); **B.** *Keratella edmondsoni* Ahlstrom (dorsal view); **C.** *Keratella javana* Hauer (ventral view); **D.** *Keratella serrulata* (Ehrenberg) (ventral view); **E.** *Lecane blachei* Berzins (ventral view); **F.** *Lecane lateralis* Sharma (ventral view); **G.** *Lecane niwati* Segers, Kotethip & Sanoamuang (ventral view); **H.** *Lecane superaculeata* Sanoamuang & Segers (ventral view); **I.** *Lepadella discoidea* Segers (ventral view); **J.** *Lepadella vandenbrandei* Gillard (ventral view).



Figs. 4A–H. Rotifera species of biogeographic interest. **A.** *Macrochaetus danneelae* Koste & Shiel (ventral view); **B.** *Notholca squamula* (O.F. Muller) (dorsal view); **C.** *Testudinella amphora* Hauer (ventral view); **D.** *Testudinella brevicaudata* Yamamoto (ventral view); **E.** *Testudinella greeni* Koste (dorsal view); **F.** *Trichocerca edmondsoni* (Myers) (lateral view); **G.** *Trichocerca hollaerti* De Smet (lateral view); **H.** *Trichocerca maior* Hauer (lateral view).

143. *T. tigris* (O.F. Muller, 1786) **
144. *T. stylata* (Gosse, 1851) **
145. *T. uncinata* (Voigt, 1902) **
146. *T. weberi* (Jennings, 1903) **

Family: Asplanchnidae

147. *Asplanchna priodonta* Gosse, 1850

Family: Synchaetidae

148. *Ploesoma lenticulare* Herrick, 1885 **
149. *Polyarthra vulgaris* Carlin, 1943
150. *Synchaeta oblonga* Ehrenberg, 1832 **
151. *S. longipes* Gosse, 1887
152. *S. pectinata* Ehrenberg, 1832

Family: Dicranophoridae

153. *Dicranophoroides caudatus* (Ehrenberg, 1834)
154. *Dicranophorus forcipatus* (O.F. Müller, 1786) **

Order: Flosculariaceae

Family: Floscularidae

155. *Sinantherina semibullata* (Thorpe, 1893) **
156. *S. spinosa* (Thorpe, 1893)

Family: Hexarthridae

157. *Hexarthra mira* (Hudson, 1871)

Family: Testudinellidae

158. *Pompholyx sulcata* Hudson, 1885
159. *Testudinella amphora* Hauer, 1938 **
160. *T. dendradena* de Beauchamp, 1955 **
161. *T. brevicaudata* Yamamoto, 1951 **
162. *T. emarginula* (Stenroos, 1898)
163. *T. greeni* Koste, 1981 **
164. *T. parva* (Ternetz, 1892) **
165. *T. patina* (Hermann, 1783)
166. *T. tridentata* Smirnov, 1931 **

Family: Trochosphaeridae

167. *Filinia camasecla* Myers, 1938 **
168. *F. longiseta* (Ehrenberg, 1834)
169. *F. opoliensis* (Zacharias, 1898)

Order: Collothecaceae

Family: Collothecidae

170. *Collotheca ornata* (Ehrenberg, 1832) **

Subclass: Bdelloidea

Order: Philodinida

Family: Philodinidae

171. *Dissotrocha aculeata* (Ehrenberg, 1832)
172. *Rotaria neptunia* (Ehrenberg, 1832)

New record from India; * new record from northeast India (NEI); ** new record from Arunachal Pradesh

Water temperature of the sampled water bodies ranged between 8–23 °C, pH ranged between 5.3–7.4 and specific conductivity varied between 18.5–89.7 µS/cm.

Brachionus lyratus (Fig. 2A), *Lecane stichoclysta* (Fig. 2B) and *Trichocerca mus* (Fig. 2C) are new records from India. *Brachionus dimidiatus* (Fig. 2D), *Keratella tacinensis* (Fig. 2E) and *Notholca acuminata* (Fig. 2F) and *N. labis* (Fig. 2G) are new records from northeast India (NEI), and 89 species (marked by **) are additions to the rotifer fauna of Arunachal Pradesh. Various other interesting species observed in our collections include *Brachionus dichotomus reductus* (Fig. 2H), *B. murphyi* (Fig. 2I), *Cephalodella trigona*, (Fig. 3A), *Keratella edmondsoni* (Fig. 3B), *K. javana* (Fig. 3C), *K. serrulata* (Fig. 3D), *Lecane blachei* (Fig. 3E), *L. lateralis* (Fig. 3F), *L. niwati* (Fig. 3G), *L. superaculeata* (Fig. 3H), *Lepadella discoidea* (Fig. 3I), *L. vandenbrandei* (Fig. 3J), *Macrochaetus danneelae* (Fig. 4A), *Notholca squamula* (Fig. 4B), *Testudinella amphora* (Fig. 4C), *T. brevicaudata* (Fig. 4D), *T. greeni* (Fig. 4E), *Trichocerca edmondsoni* (Fig. 4F), *T. hollaerti* (Fig. 4G), *T. maior* (Fig. 4H), and *T. uncinata*. *Lecane* (Lecanidae) indicates 45 species; Brachionidae records 33 species with 17 species of *Brachionus*; Colurellidae (23 species) includes 18 species of *Lepadella*; *Trichocerca* (Trichocercidae) indicates 19 species while *Keratella* and *Testudinella* include eight species each.

DISCUSSION

The water bodies of Arunachal Pradesh depict 'sub-tropical to temperate' nature concurrent with their altitudinal locations and are characterized by 'slightly acidic–circum neutral–slightly alkaline waters' while specific conductivity highlights general 'soft-water nature with distinctly low ionic concentrations'. The last feature warrants inclusion of the sampled lentic ecosystems under 'Class I' category of trophic classification *vides* Talling & Talling (1965).

The present report of total richness (S) of 172 Rotifera species from Arunachal Pradesh, belonging to 39 genera and 19 families, comprises ~59% and ~40% of the species of the phylum known till date from NEI and India, respectively. The biodiverse rotifer assemblage is hypothesized to function of habitat heterogeneity of small lentic biotopes of this hill state located under varied ecological regimes and also to certain extent to the 'rotiferologist effect' *vide* Fontaneto et al. (2012) though we are aware of the sampling limitations. The results endorse our hypothesis on importance of small lentic environs as one of the rotifer diverse habitats (Sharma & Kensibo 2017; Sharma et al. 2017) of the Indian sub-region. This study marks a significant increase (~126%) of the rotifer tally of the eastern Himalayas than 76 species recorded by Sharma & Sharma (2014a) but is contrastingly higher than 24

and 45 species listed by Chandra et al. (2018) and Sinha (2018), respectively. Our results record richer alpha diversity than 162 (Sharma & Sharma 2015), 161 (Sharma unpublished) and 150 (Sharma et al. 2017) rotifer species known from hill states of NEI namely Mizoram, Meghalaya and Nagaland, respectively. On the other hand, the richness is relatively lower than 189 species observed from the floodplain wetlands of Manipur (Sharma & Sharma 2018a) state of NEI. The rotifer species examined from the eastern Himalayas register higher affinity (83.8% community similarity vide Sorenson's index) with the fauna of adjacent hill state of Nagaland; these indicate 71.0% and 74.8% similarities with the faunas of Manipur and Mizoram, respectively but records more divergence in species composition (66.7% similarity) than the rotifers known from Meghalaya. We caution on the stated comparisons in view of our yet limited collections particularly from the higher altitudes of Arunachal Pradesh. Further, our report from the eastern Himalayas though concurs with 173 species known from Jammu & Kashmir state of the western Himalayas (Sharma & Sharma 2018b) but is characterized by only 53.3% community similarity (vide Sorenson's index) thus reflecting notable divergence in species composition than the latter.

Brachionus lyratus, *Lecane stichoclysta* and *Trichocerca mus* are new records from the Indian sub-region; these species are known elsewhere from the Oriental region from Thailand (Sa-Ardrit et al. 2013). *Brachionus lyratus*, described from Australia, resembles with *B. angularis* but is differentiated from the latter by its short foot-opening flanked by blunt spines. We opine wider distribution of the former brachionid in India because of its likely over-looking as *B. angularis*. *L. stichoclysta*, described from Oguta Lake of Nigeria (Segers 1993), is diagnosed by completely separated claws, nearly square and covered foot pseudosegment, and relatively short toes. Besides, *T. mus*, originally described from Indonesia, is now categorized as thermophilic pan (sub) tropical species vide Segers (2003).

Brachionus dimidiatus, *Keratella ticinensis*, *Notholca acuminata* and *N. labis* are new records from NEI. *B. dimidiatus* is validly known from India from Delhi (Sarma, 1988) while we consider its report from Rajasthan (Nayar 1968) as unverifiable due to lack of any validation. *K. ticinensis* is examined from Dal Lake (Kashmir) by Sarma (1988) while its other un-authenticated Indian reports are categorized as dubious (Sharma & Sharma 2014b). *N. acuminata* is listed from Jammu & Kashmir (Sharma & Sharma 2018b) but without any validation while its indiscriminate reports elsewhere from India are considered dubious (Sharma & Sharma 2014b). *N. labis* is known from Yamuna River, Delhi (Sarma 1988; Arora & Mehra 2003). The present report of these four brachionid species extends their distribution to the eastern Himalayas. In addition, our study adds 89 species as new records to the rotifer fauna of Arunachal Pradesh

and thus marks significant update to Rotifera biodiversity of the eastern Himalayas.

Our collections from Arunachal Pradesh indicate 27 species (~15.7% of S) of global biogeographic importance. These include the Australasian *Brachionus dichotomus reductus*, *B. lyratus* and *Macrochaetus danneelae*; the Oriental endemics *Brachionus murphyi*, *Keratella edmondsoni*, *Filinia camasecla*, *Lecane blachei*, *L. niwati* and *L. superaculeata*; the Indo-Chinese *Lecane dorysimilis*; the Paleotropical *Keratella javana*, *Lepadella discoidea*, *L. vandenbrandei*, *Lecane lateralis*, *L. stichoclysta*, *L. unguitata*, *Testudinella brevicaudata*, *T. greeni* and *Trichocerca hollaerti*; the Holarctic *Trichocerca uncinata*; and seven other species with restricted global occurrence namely *Brachionus kostei*, *Cephalodella trigona*, *Notholca acuminata*, *N. labis*, *Trichocerca edmondsoni*, *T. maior*, and *Testudinella amphora*. Overall richness of the globally notable elements outnumbers the reports of such taxa from the states of Meghalaya, Mizoram, Nagaland and Tripura of NEI (Sharma & Sharma 2014a, 2017) and elsewhere from India (Sharma & Sharma 2017). Interestingly, 25 species (~14% of S) namely *Brachionus kostei*, *B. lyratus*, *B. murphyi*, *Cephalodella trigona*, *Keratella javana*, *Lecane aeganea*, *L. dorysimilis*, *L. niwati*, *L. rhenana*, *L. rhytida*, *L. stichoclysta*, *Macrochaetus danneelae*, *Mytilina michelangellii*, *L. superaculeata*, *Lepadella benjamini*, *L. vandenbrandei*, *Testudinella amphora*, *T. brevicaudata*, *T. dendradena*, *T. tridentata*, *Trichocerca edmondsoni*, *T. hollaerti*, *T. maior*, *T. mus* and *T. uncinata* are notable for their Indian distribution restricted till date exclusively to NEI (Sharma & Sharma 2017). The species of the two categories impart global and regional biogeographic interest to the rotifer fauna of Arunachal Pradesh. The regional importance of the eastern Himalayan Rotifera is augmented by occurrence of more species of restricted distribution in India i.e., *Brachionus bennini*, *Coleurella adriatica*, *Keratella serrulata*, *Lepadella costatoides*, *L. dactyliseata*, *L. quinquecostata*, *Lecane bifurca*, *L. elegans*, *L. haliclysta*, *L. hastata*, *L. paxiana*, *L. pusilla*, *Trichocerca bidens*, *T. insignis*, *T. stylata*, *T. tigris*, *Testudinella parva*, *Platylas leloupi*, and *Wolga spinifera*. We attribute sizable fractions of species of biogeographic interest in the eastern Himalayas to the fact that our collections largely covered the localities from the lower and middle altitudes from the districts adjoining the state of Assam of NEI. The latter itself assumes interest as 'the Assam-gateway' – an important phase in the biogeographic evolution of India and a vital corridor that facilitated extensive interchanges between the Indian and Asian biota (Mani 1974), thus changing the modern biotic composition of the epigeal ecosystems of India (Ranga Reddy 2013).

Lecanidae > Brachionidae > Lepadellidae > Trichocercidae collectively comprise ~71% of the rotifers species of Arunachal Pradesh. The dominance pattern concurs with that of the Indian Rotifera (Sharma & Sharma 2017)

but differs from the composition of NEI rotifers particularly with regards Brachionidae. The latter is interestingly notable for the highest richness (33 species) known from any state of India which even exceeds our report of maximum diversity of 32 species from Assam state of NEI (Sharma & Sharma 2014b). In fact, our collections indicate ~72% and ~92% of the brachionid species known till date from India and NEI, respectively. This feature is attributed to *Brachionus* richness (17 species), the record number of eight species of *Keratella* out of 11 species of the brachionid genus known from India (Sharma & Sharma 2014b) and three species of *Notholca*. Overall richness importance of Brachionidae as well as *Brachionus* spp. marks a salient departure than the relative paucity of these taxa indicated from the states of Meghalaya (Sharma & Sharma 1999; Sharma unpublished), Mizoram (Sharma & Sharma 2015), Nagaland (Sharma et al. 2017) and Manipur (Sharma & Sharma 2018) of NEI.

Lecane (45 species) > *Trichocerca* (19 species) > *Lepadella* (18 species) are species-rich genera while *Brachionus* (17 species) also deserves attention. The collective role of first three genera (~48 % of S) assigns the littoral-periphytic character to the rotifer fauna of Arunachal Pradesh. The richness importance of *Lecane*, *Trichocerca* and *Lepadella* endorses possibility of rules for composition of the periphytic rotifer assemblages as hypothesized by Green (2003) and affirmed by the reports of Sharma (2014), Sharma & Sharma (2014a, 2015, 2017, 2018) and Sharma et al. (2018). The richness of *Testudinella*, *Coleurella*, *Cephalodella* and *Mytilina*, and even several non-planktonic brachionids as well as the paucity of the planktonic genera *Hexarthra* and *Filinia*, and lack of *Conochilus* species in particular endorse our remarks on the littoral-periphytic nature of Rotifera of Arunachal Pradesh. The rotifer fauna indicates a number of small-sized species of *Coleurella*, *Lecane*, *Lepadella* and *Trichocerca* concurrent with the reports of Sharma (2005, 2014), Sharma & Sharma (2014a, 2015, 2018a, 2018b); this feature is hypothesized to predation influence of juvenile fish and invertebrates (Baumgartner et al. 1997). Though morphological variability is inherent in all natural populations of metazoans, the extant of variations noted in *Brachionus angularis*, *B. bidentatus*, *B. caudatus*, *Lecane bulla*, *L. curvicornis*, *L. hamata*, *L. leontina*, *L. luna*, *L. lunaris*, *L. ludwigii*, *L. papuana*, *L. quadridentata*, *L. signifera*, *L. unguitata*, *L. unguolata*, *Lepadella costatoides*, *L. ovalis*, *L. patella*, *Testudinella emarginula*, *T. patina*, *T. tridentata* and *Plationus patulus* populations from Arunachal Pradesh needs attention for cryptic diversity analysis.

Segers (2001) remarked on the role of thermophiles in the rotifer fauna of Southeast Asia while Sharma & Sharma (2005, 2008, 2014a, 2015, 2017, 2018a) extended this generalization to the rotifer assemblages of India. Our collections from Arunachal Pradesh highlight overall

importance of species of the 'tropic-centered' *Lecane* and *Brachionus* and particularly in water bodies at lower altitudes, while species of 'temperate-centered' *Keratella*, *Notholca* and *Synchaeta* are notable in collections from middle and higher altitudes with the notable reports of 'cold-water' *K. serrulata*, *Notholca acuminata*, *N. labis* and *N. squamula* in particular from the eastern Himalayas. Intensive future collections from middle and higher reaches of Arunachal Pradesh are likely to add more species of the second category. The rotifer fauna of the eastern Himalayas shows a combination of 'tropical' and 'cold-water' elements and thus marks a distinct departure from other states of NEI (Sharma & Sharma 2014a, 2015, 2017) except the Sikkim Himalayas which is yet nearly un-explored. Further, cosmopolitan species form a notable fraction (~64%) of the rotifer assemblages in our collections while tropical and subtropical species comprise 18% of total richness; overall importance of the stated taxa endorses the reports of Sharma & Sharma (2014a, 2017).

To sum up, the rich and diverse Rotifera assemblage of the eastern Himalayas observed vide this study is hypothesized to function of habitat heterogeneity which, in turn, highlights overall biodiverse nature of small lentic biotopes of Arunachal Pradesh located under different ecological regimes. The reports of several new records; notable fraction of species of global and regional biogeographic interest, the littoral-periphytic nature of the rotifer fauna, several small-sized species, the mixture of 'tropical and temperate' elements, and high richness of Brachionidae elements are notable features. This study marks a significant contribution to biodiversity and biogeography of the Indian and Asian Rotifera and that of the eastern Himalayas in particular. Our collections are yet biased towards planktonic and semi-planktonic taxa and thus specific analysis of sessile, colonial and benthic taxa, and of cryptic diversity in certain species-groups merit interest for future Rotifera biodiversity update of the eastern Himalayas.

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REFERENCES

- Arora J, Mehra NK (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
- Baumgartner G, Nakataki KM, Cavicchiolo M, Baumgartner MS (1997) Some aspects of the ecology of fish larvae in the

- floodplain of the high Parana river, Brazil. Review Brazilian Zoology 14: 551–563
- Chandra K, Gopi KC, Rao DV, Valarmathi K, Alfred JRB (eds) (2018) Current status of freshwater faunal diversity in India. Zoological Survey of India, Kolkata
- 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
- Green J (2003) Associations of planktonic and periphytic rotifers in a tropical swamp, the Okavango Delta, Southern Africa. Hydrobiologia 490: 197–209
- Jersabek CD, Leitner MF (2013) The Rotifer World Catalog. World Wide Web electronic publication. <http://www.rotifera.hausdennatur.at/> accessed {17.07.2018}
- Koste W (1978) Rotatoria. Die Rädertiere Mitteleuropas, begründet von Max Voigt. Überordnung Monogononta. Gebrüder Borntraeger, Berlin, Stuttgart. I. 673 pp U. II. Tafelbd. (T. 234)
- Koste W, Shiel RJ (1987) Rotifera from Australian inland waters. II. Epiphanidae and Brachionidae (Rotifera: Monogononta). Invertebrate Taxonomy 7: 949–1021
- Koste W, Shiel RJ (1989) Rotifera from Australian inland waters. IV. Colurellidae (Rotifera: Monogononta). Transactions of the Royal Society of South Australia 113: 119–143
- Koste W, Shiel RJ (1990) Rotifera from Australian inland waters V. Lecanidae (Rotifera: Monogononta). Transactions of the Royal Society of South Australia 114 (1): 1–36
- Mani MS (1974) Biogeographical evolution in India, In: Mani MS (ed.) Ecology and Biogeography in India. Dr. W. Junk b.v. Publishers, The Hague. pp. 698–724
- Nayar CKG (1968) Rotifers fauna of Rajasthan, India. Hydrobiologia 31 (2): 168–185
- Ranga Reddy Y (2013) *Neodiaptomus prateek* n. sp., a new freshwater copepod from Assam, India, with critical review of generic assignment of *Neodiaptomus* spp. and a note on diaptomid species richness (Calanoida: Diaptomidae). Journal of Crustacean Biology 33 (6): 849–865
- 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
- Sarma SSS (1988) New records of fresh water rotifers (Rotifera) from Indian waters. Hydrobiologia 160: 263–269
- Segers H (1993) Rotifera of some lakes in the floodplain of the river Niger (Imo State, Nigeria). I. New species and other taxonomic considerations. Hydrobiologia 250: 39–61
- Segers H (1995) Rotifera 2: Lecanidae. 6. pp: 1–226. In: Dumont HJ, Nogrady T (eds) Guides to identification of the Microinvertebrates of the Continental waters of the world. SPB Academic Publishing. Amsterdam, the Netherlands.
- Segers H (2001) Zoogeography of the Southeast Asian Rotifera. Hydrobiologia 446/447: 233–246
- Segers H (2003) A biogeographical analysis of rotifers of the genus *Trichocerca* Lamarck, 1801 (Trichocercidae, Monogononta, Rotifera), with notes on taxonomy. Hydrobiologia 500: 103–114
- Segers H (2007) Annotated checklist of the rotifers (Phylum Rotifera), with notes on nomenclature, taxonomy and distribution. Zootaxa 1564: 1–104
- Sharma BK (1983) The Indian species of the genus *Brachionus* (Eurotatoria: Monogononta: Brachionidae). Hydrobiologia 104: 31–39
- Sharma BK (1987) Indian Brachionidae (Eurotatoria: Monogononta) and their distribution. Hydrobiologia 144: 269–275
- Sharma BK (1998) Freshwater Rotifers (Rotifera: Eurotatoria). In: Fauna of West Bengal. State Fauna Series 3 (11): 341–461. Zoological Survey of India, Calcutta.
- Sharma BK (2005) Rotifer communities of floodplain lakes of the Brahmaputra basin of lower Assam (N. E. India): biodiversity, distribution and ecology. Hydrobiologia 533: 209–221.
- Sharma BK (2014) Rotifers (Rotifera: Eurotatoria) from wetlands of Majuli – the largest river island, the Brahmaputra river basin of upper Assam, northeast India. Check List 10 (2): 292–298
- Sharma BK, Khan SI, 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
- Sharma BK, Kensibo (2017) Rotifer assemblages (Rotifera: Eurotatoria) of two wetlands of Nagaland, northeast India: ecosystem diversity and interesting features. International Journal of Fisheries and Aquatic Studies 5 (2): 609–617
- Sharma BK, Kensibo, Sharma S (2017) Biodiversity of rotifers (Rotifera: Eurotatoria) of Nagaland, northeast India; richness, composition and ecosystem diversity. International Journal of Fisheries and Aquatic Studies 5 (5): 180–187
- Sharma BK, Raghunathan C, Sharma S (2017) Rich freshwater Rotifer (Rotifera: Eurotatoria) fauna of small lentic ecosystems of south Andaman, India. Opuscula Zoologica, Budapest 48 (2): 185–192
- Sharma BK, Sharma S (1999) Freshwater Rotifers (Rotifera: Eurotatoria). In: Fauna of Meghalaya. State Fauna Series 4(9): 11–161. Zoological Survey of India, Calcutta
- Sharma BK, Sharma S (2000). Freshwater Rotifers (Rotifera: Eurotatoria). In: Fauna of Tripura: State Fauna Series 7 (4): 163–224. Zoological Survey of India, Calcutta
- Sharma BK, Sharma S (2005) Biodiversity of freshwater rotifers (Rotifera: Eurotatoria) from North-Eastern India. Mitteilungen aus dem Museum für Naturkunde Berlin, Zoologische Reihe 81: 81–88
- Sharma BK, Sharma S (2014a) Northeast India – An important region with a rich biodiversity of Rotifera. In: Sharma BK, Dumont HJ, Wallace RL (eds) Rotifera XIII: Rotifer Biology – A structural and functional Approach. International Review of Hydrobiology 99 (1–2): 20–37
- Sharma BK, Sharma S (2014b) The diversity of Indian Brachionidae (Rotifera: Eurotatoria: Monogononta) and their distribution Opuscula Zoologica, Budapest 45(2):165–180
- Sharma BK, Sharma S (2015) Biodiversity of freshwater rotifers (Rotifera: Eurotatoria) of Mizoram, Northeast India: composition, new records and interesting features. International Journal of Aquatic Biology 3 (5): 301–313
- Sharma BK, Sharma S (2017) Rotifera: Eurotatoria (Rotifers). Chapter 7: 93–113. In: Kailash Chandra, Gopi KC, Rao DV, Valarmathi K, Alfred JRB (eds) Current status of freshwater faunal diversity in India. Zoological Survey of India, Kolkata
- Sharma BK, 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 BK, 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.
- Sharma S, Sharma BK (2008) Zooplankton diversity in floodplain lakes of Assam. Records of the Zoological Survey of India, Occasional Paper No. 290: 1–307

- Sharma S, Sharma BK (2013) Faunal diversity of aquatic invertebrates of Deepor Beel (a Ramsar site), Assam, northeast India. *Wetland Ecosystem Series*, 17: 1–226
- Shiel RJ, Koste W (1992) Rotifera from Australian inland waters VIII. Trichocercidae (Monogononta). *Transactions of Royal Society of South Australia* 116 (1): 1–27
- Shiel RJ, Koste W (1993) Rotifera from Australian inland waters. IX. Gastropodidae, Synchaetidae, Asplanchnidae (Rotifera: Monogononta). *Transactions of Royal Society of South Australia* 117 (1): 111–139
- Sinha B (2018) Status of studies on zooplankton fauna of Arunachal Pradesh, India. *Journal of Threatened Taxa* 10 (11): 12552–12560
- 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 JF, Talling IB (1965) The chemical composition of African lake waters. *Internationale Revue der gesamten Hydrobiologie* 50: 421–463