

Research article

[urn:lsid:zoobank.org:pub:D9308652-B9BF-4BBB-B573-F1C4B53E1AC5](https://zoobank.org/pub/D9308652-B9BF-4BBB-B573-F1C4B53E1AC5)

The biodiverse rotifers (Rotifera: Eurotatoria) of Northeast India: faunal heterogeneity, biogeography, richness in diverse ecosystems and interesting species assemblages

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.com

¹[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 biodiverse Rotifera of northeast India (NEI) revealed 303 species belonging to 53 genera and 24 families; ~96% of these species examined from seven states of NEI affirm the rotifer heterogeneity of our plankton and semi-plankton collections. This study documents the record number of species of global and regional biogeographic interest, highlights affinity with Southeast Asian and Australian faunas, and indicates notable heterogeneity in richness and composition amongst the seven northeastern states. The speciose rotifers of small lentic biotopes of Arunachal Pradesh, Mizoram, Nagaland, Meghalaya, Manipur and Tripura, the floodplain lakes (*beels*) and small wetlands (*dobas* and *dubies*) of the Brahmaputra and the Barak floodplains of Assam, and the floodplain lakes (*pats*) of Manipur are noteworthy. Deepor Beel and Loktak Lake (two Ramsar sites) are the globally rich rotifer 'hotspots'. Interesting assemblages per sample of 80+ species in certain *beels* and *pats*, and up to 50 species in *dobas* and *dubies* depict the 'Rotifera paradox'. The most diverse and interesting Rotifera of NEI, than any other region of India, is attributed to habitat and ecosystem heterogeneity of water bodies spread over varied ecological regimes, the location of the region in the Himalayan and Indo-Burma Biodiversity hotspots, vital biogeographic corridor of 'the Assam gateway', 'the rotiferologist effect' and the sampling intensity. Our study marks a valuable contribution to biodiversity and biogeography of the Indian, Asian and Oriental Rotifera.

Key words. Biodiversity, distribution, important taxa, species assemblages, Rotifera paradox.

INTRODUCTION

Northeast India (NEI), a geographic division of India, originally consisted of the contiguous seven 'sister-states' of Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland and Tripura; the logistically distant state of Sikkim was recently added to this easternmost region of India. NEI occupies a unique geographic location in the Indo-Chinese sub-division of the Oriental region, forms part of both the Himalayan and the Indo-Burma biodiversity 'hot-spots', and includes 'the Assam-gateway' as a vital biogeographic corridor of India (Mani, 1974). This region is known for diverse freshwater ecosystems, ranging from small lentic biotopes to the fluvial floodplains, located under varied geo-morphologic and ecological regimes which impart special biodiversity and ecological diversity interest to assessment of aquatic metazoan diversity of NEI. Referring particularly to this aspect, Sharma & Sharma (2014a) initially commented on the importance of NEI vis-a-vis the rich biodiversity of Rotifera – an important group of freshwater zooplankton. Nevertheless, this work highlighted distinct gaps relating to the poorly explored states of Arunachal Pradesh (the eastern Himalayas), Nagaland, Manipur and Mizoram as

well as stressed on the need for overall augmentation of faunal analyses from other states of this region.

The present study, a follow up of our earlier work (Sharma & Sharma 2014a), endeavors to provide a comprehensive assessment of Rotifera biodiversity of NEI based on intensive collections from the former seven 'sister-states' of Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland and Tripura. We present an exhaustive species inventory of the rotifers known to date from NEI and provide illustrations of selected rare and interesting species to provide validations otherwise routinely lacking in the Indian works (Sharma & Sharma 2014a, 2017). Remarks are made on Rotifera heterogeneity of NEI with reference to species richness, nature and composition, elements of global and regional biogeographic interest, important taxa, and comparison of the rotifer faunas of the sampled seven states. We also comment on ecological diversity and interesting species assemblages found in our studies on the floodplain lakes (*beels*) and small wetlands (*dobas* and *dubies*) of the Brahmaputra and the Barak river floodplains of Assam; the floodplain lakes (*pats*) of Manipur; and small lentic ecosystems of Arunachal Pradesh, Mizoram, Nagaland, Meghalaya, Manipur and Tripura. This intensive study

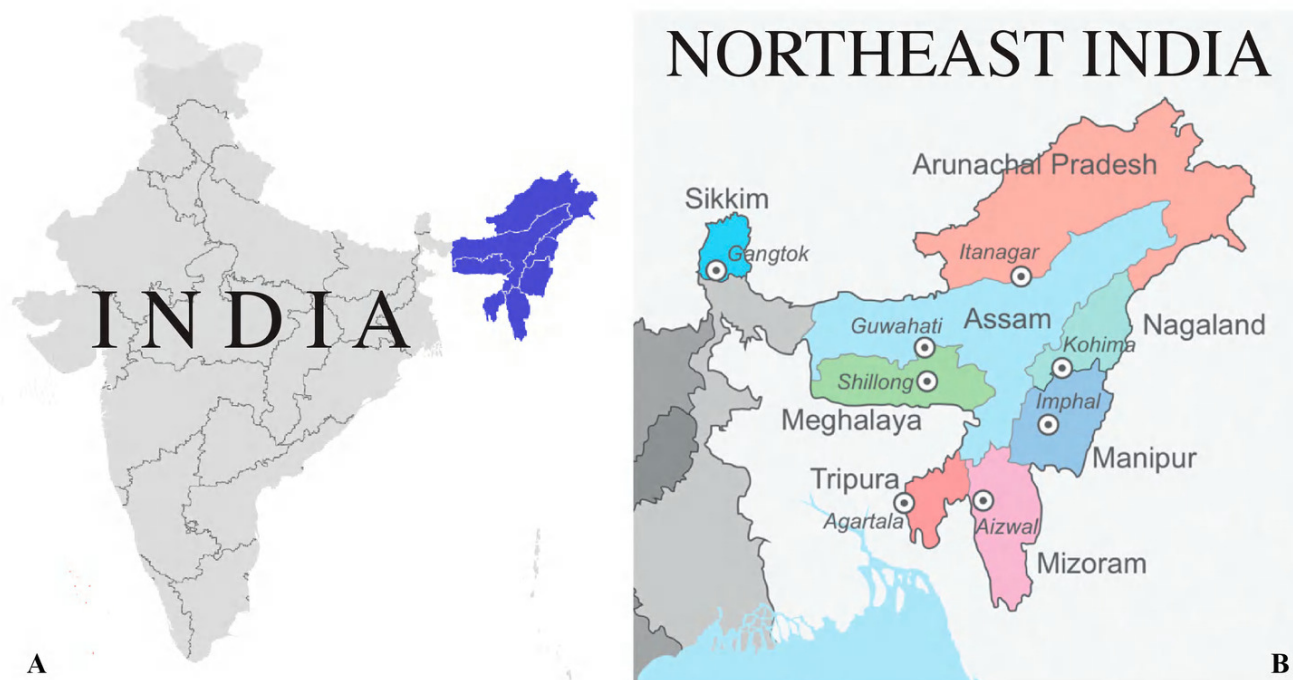


Fig. 1A–B. **A.** Map of India showing (in blue color) northeast India (NEI). **B.** Map of NEI indicating the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura.

marks an important contribution to biodiversity and biogeography of Rotifera of India, Asia and the Oriental region as well as of the tropical and subtropical floodplains and small lentic ecosystems.

MATERIALS & METHODS

This study is based on analysis of plankton and semi-plankton samples collected, during several faunal and limnological surveys undertaken between 1998–2017, from scattered localities of the seven states (between 90–94°E, 22–28°N) of NEI (Fig. 1A–B). The samples were collected from the Brahmaputra valley (90°–93°E, 26°–27°N) and the Barak valley (24°48′–24°80′N, 92°45′–92°75′E) of Assam; Tripura (92°10′–92°20′E, 22°56′–24°32′N); Arunachal Pradesh (26°28′–29°30′N, 91°20′–97°30′E), Mizoram (21°58′–24°35′N, 92°15′–93°29′E), Meghalaya (90°05′–92°40′E, 25°10′–26°15′N); and Nagaland (25°4′–27°0′N, 93°3′–93°5′E). The collections were obtained from small ephemeral and perennial lentic ecosystems of Arunachal Pradesh, Mizoram, Meghalaya, Manipur, Nagaland and Tripura; small floodplain wetlands (*dobas* or *dubies*) as well as floodplain lakes (*beels*) of the Brahmaputra and Barak river basins, respectively and beels of Majuli River Island of Assam; the floodplain lakes (*pats*) of the Iral, Imphal and Thoubal river basins of Manipur; selected reservoirs of Meghalaya, Mizoram and Tripura; and intensive limnological surveys of two Ramsar sites namely Loktak Lake (Manipur) and Deepor

beel (Assam). The voucher collections are deposited in the holdings of Zoological Survey of India, Kolkata. In addition, our species inventory includes certain sessile and bdelloid rotifers not observed in our collections but otherwise recorded from NEI (Sharma & Sharma 2014a).

All the samples were collected by towing a nylobolt plankton net (mesh size # 50 µm) from varied freshwater ecosystems in seven states of NEI and were preserved in 5% formalin. In addition, some collections were not preserved to examine live rotifers. Individual collections were screened with a Wild stereoscopic binocular microscope; the rotifers were isolated and mounted in polyvinyl alcohol-lactophenol mixture, and were observed with a Leica DM 1000 image analyzer fitted with a drawing-tube. The micro-photographs were taken with a Leica DM 1000 image analyzer. Rotifera species were identified following the works of Koste (1978), Koste and Shiel (1987, 1989, 1990), Segers (1995), Sharma (1983, 1987a, 1987b, 1998, 2014), Sharma & Sharma (1997, 1999, 2000, 2008, 2014b, 2014c, 2015a, 2018a, 2018b) and Jersabek & Leitner (2013). Segers (2002) was followed for the system of Rotifera classification and comments on the distribution of various taxa were made following Segers (2007) and Jersabek & Leitner (2013). The community similarities were calculated using Sørensen's index (Sørensen 1948). Hierarchical cluster analysis, based on Sørensen's similarities, was done using SPSS (version 11.0) to examine the rotifer community groupings.

RESULTS

We record a total of 303 species of Rotifera (Table 1) belonging to 53 genera and 24 families from Northeast India (NEI). Of these, 292 species (~96%) are observed in our plankton and semi-plankton collections from seven 'sister states' of NEI. A detailed systematic list of the documented taxa is presented below:

Systematic list of Rotifera recorded from Northeast India

Phylum: Rotifera

Class: Eurotatoria

Subclass: Monogononta

Order: Ploima

Family: Brachionidae

1. *Amuraeopsis coelata* De Beauchamp, 1932
2. *A. fissa* Gosse, 1851
3. *A. navicula* Rousselet, 1911
4. *Brachionus ahlstromi* Lindeman, 1939
5. *B. angularis* Gosse, 1851
6. *B. bennini* Leissling, 1924
7. *B. bidentatus* Anderson, 1889
8. *B. budapestinensis* Daday, 1885
9. *B. calyciflorus* Pallas, 1766
10. *B. caudatus* Barrois & Daday, 1894
11. *B. dichotomus reductus* Koste & Shiel, 1980
12. *B. dimidiatus* Bryce, 1931
13. *B. diversicornis* (Daday, 1883)
14. *B. donneri* Brehm, 1951
15. *B. durgae* Dhanapathi, 1974
16. *B. falcatus* Zacharias, 1898
17. *B. falcatus reductus* Koste & Shiel, 1987
18. *B. forficula* Wierzejski, 1891
19. *B. kostei* Shiel, 1993
20. *B. leydigii* Cohn, 1862
21. *B. lyratus* Shephard, 1911
22. *B. mirabilis* Daday, 1897
23. *B. murphyi* Sudzuki, 1989
24. *B. nilsoni* Ahlstrom, 1940
25. *B. quadridentatus* Hermann, 1783
26. *B. rubens* Ehrenberg, 1838
27. *B. srisumonae* Segers, Kotethip & Sanoamuang, 2004
28. *Keratella cochlearis* (Gosse, 1851)
29. *K. edmondsoni* Ahlstrom, 1943
30. *K. javana* Hauer, 1937
31. *K. lenzi* Hauer, 1953
32. *K. procurva* (Thorpe, 1891)
33. *K. quadrata* (Müller, 1786)
34. *K. serrulata* (Ehrenberg, 1838)
35. *K. tecta* (Gosse, 1851)
36. *K. ticinensis* (Callerio, 1921)
37. *K. tropica* (Apstein, 1907)

37. *Notholca acuminata* (Ehrenberg, 1832)
38. *N. labis* Gosse, 1887
39. *N. squamula* (Müller, 1786)
40. *Platyonus patulus* (Müller, 1786)
41. *Platyias leloupi* (Gillard, 1967)
42. *P. quadricornis* (Ehrenberg, 1832)

Family: Epiphanidae

43. *Epiphanes brachionus* (Ehrenberg, 1837)
44. *E. senta* (Müller, 1773)

Family: Euchlanidae

45. *Beauchampiella eudactylota* (Gosse, 1886)
46. *Dipleuchlanis ornata* Segers, 1993
47. *D. propatula* (Gosse, 1886)
48. *Euchlanis dilatata* Ehrenberg, 1832
49. *E. incisa* Carlin, 1939
50. *E. meneta* Myers, 1930
51. *E. oropha* Gosse, 1887
52. *E. semicarinata* Segers, 1993
53. *E. triquetra* Ehrenberg, 1838
54. *Tripleuchlanis plicata* (Levander, 1894)

Family: Mytilinidae

55. *Lophocharis oxysternon* (Gosse, 1851)
56. *L. salpina* (Ehrenberg, 1834)
57. *Mytilina acanthophora* Hauer, 1938
58. *M. bisulcata* (Lucks, 1912)
59. *M. brevispina* (Ehrenberg, 1830)
60. *M. lobata* Pourriot, 1996
61. *M. michelangellii* Reid & Turner, 1988
62. *M. ventralis* (Ehrenberg, 1830)

Family: Trichotriidae

63. *Macrochaetus collinsi* (Gosse, 1867)
64. *M. danneelae* Koste & Shiel, 1983
65. *M. longipes* Myers, 1934
66. *M. sericus* (Thorpe, 1893)
67. *M. subquadratus* (Perty, 1850)
68. *Trichotria tetractis* (Ehrenberg, 1830)
69. *Wolga spinifera* (Western, 1894)

Family: Lepadellidae

70. *Cohurella adriatica* Ehrenberg, 1831
71. *C. colurus* (Ehrenberg, 1830)
72. *C. obtusa* (Gosse, 1886)
73. *C. sanoamuangae* Chittapun, Pholpunthin & Segers, 1999
74. *C. sulcata* (Stenroos, 1898)
75. *C. tessellata* (Glascott, 1893)
76. *C. uncinata* (Müller, 1773)
77. *C. uncinata bicuspidata* (Ehrenberg, 1832)
78. *Lepadella acuminata* (Ehrenberg, 1834)
79. *L. apside* Harring, 1916
80. *L. benjamini* Harring, 1916
81. *L. bicornis* Vasisht & Battish 1971

81. *L. biloba* Hauer, 1938
 82. *L. costatoides* Segers, 1992
 83. *L. cristata* (Rousselet, 1893)
 84. *L. dactyliseta* (Stenroos, 1898)
 85. *L. desmeti* Segers & Chittapun, 2001
 86. *L. discoidea* Segers, 1993
 87. *L. elongata* Koste, 1992
 88. *L. eurysterna* Myers, 1942
 89. *L. cf. favorita* Klement, 1962
 90. *L. latusinus* (Hilgendorf, 1889)
 91. *L. lindaui* Koste, 1981
 92. *L. minoruoides* Koste & Robertson, 1983
 93. *L. minuta* (Weber & Montet, 1918)
 94. *L. nartiangensis* Sharma & Sharma, 1987
 95. *L. neglecta* Segers & Dumont, 1995
 96. *L. ovalis* (Müller, 1786)
 97. *L. patella patella* (Muller, 1773)
 - L. patella elongata* Sharma & Sharma, 1987
 - L. patella oblonga* (Ehrenberg, 1834)
 98. *L. quadricarinata* (Stenroos, 1898)
 99. *L. quinquecostata* (Lucks, 1912)
 100. *L. rhomboides* (Gosse, 1886)
 101. *L. rhomboidula* (Bryce, 1890)
 102. *L. triba* Myers, 1934
 103. *L. triptera* Ehrenberg, 1830
 - L. triptera alata* (Myers, 1934)
 104. *L. vandenbrandei* Gillard, 1952
 105. *L. (Heterolepadella) apsicora* Myers, 1934
 106. *L. (H.) ehrenbergi* (Perty, 1850)
 107. *L. (H.) heterostyla* (Murray, 1913)
 108. *L. (H.) heterodactyla* Fadeev, 1925
 109. *Squatinella bifurca* (Bolton, 1884)
 110. *S. lamellaris* (Müller, 1786)
- Family: Lecanidae**
111. *Lecane acanthinula* (Hauer, 1938)
 112. *L. aculeata* (Jakubski, 1912)
 113. *L. aeganea* Harring, 1914
 114. *L. arcula* Harring, 1914
 115. *L. aspasia* Myers, 1917
 116. *L. batillifer* (Murray, 1913)
 117. *L. bifastigata* Hauer, 1938
 118. *L. bifurca* (Bryce, 1892)
 119. *L. blachei* Berzins, 1973
 120. *L. braumi* Koste, 1988
 121. *L. bulla* (Gosse, 1851)
 - L. bulla diabolica* (Hauer, 1936)
 122. *L. calcaria* Harring & Myers, 1926
 123. *L. clara* (Bryce, 1892)
 124. *L. closterocerca* (Schmarda, 1898)
 125. *L. crepida* Harring, 1914
 126. *L. curvicornis* (Murray, 1913)
 127. *L. decipiens* (Murray, 1913)
 128. *L. dorysimilis* Trinh Dang, Segers & Sanoamuang, 2015
 129. *L. doryssa* Harring, 1914
 130. *L. elegans* Harring, 1914
 131. *L. elongata* Harring & Myers, 1926
 132. *L. flexilis* (Gosse, 1886)
 133. *L. furcata* (Murray, 1913)
 134. *L. glypta* Harring & Myers, 1926
 135. *L. halichysta* Harring & Myers, 1926
 136. *L. hamata* (Stokes, 1896)
 137. *L. hastata* (Murray, 1913)
 138. *L. hornemanni* (Ehrenberg, 1834)
 139. *L. inermis* (Bryce, 1892)
 140. *L. inopinata* Harring & Myers, 1926
 141. *L. isanensis* Sanoamuang & Savatnalinton, 2001
 142. *L. jaintiaensis* Sharma, 1987
 143. *L. lateralis* Sharma, 1978
 144. *L. latissima* Yamamoto, 1951
 145. *L. leontina* (Turner, 1892)
 146. *L. levistyla* (Olofsson, 1917)
 147. *L. ludwigii* (Eckstein, 1883)
 148. *L. luna* (Müller, 1776)
 149. *L. lunaris* (Ehrenberg, 1834)
 150. *L. marchantaria* Koste & Robertson, 1983
 151. *L. monostyla* (Daday, 1897)
 152. *L. nana* (Murray, 1913)
 153. *L. nitida* (Murray, 1913)
 154. *L. niwati* Segers, Kotethip & Sanoamuang, 2004
 155. *L. obtusa* (Murray, 1913)
 156. *L. ohioensis* (Herrick, 1885)
 157. *L. papuana* (Murray, 1913)
 158. *L. paxiana* Hauer, 1940
 159. *L. pertica* Harring & Myers, 1926
 160. *L. ploenensis* (Voigt, 1902)
 161. *L. pusilla* Harring, 1914
 162. *L. pyriformis* (Daday, 1905)
 163. *L. quadridentata* (Ehrenberg, 1830)
 164. *L. rhenana* Hauer, 1929
 165. *L. rhytida* Harring & Myers, 1926
 166. *L. rugosa* (Harring, 1914)
 167. *L. ruttneri* Hauer, 1938
 168. *L. scutata* (Harring & Myers, 1926)
 169. *L. shieli* Segers & Sanoamuang, 1994
 170. *L. signifera* (Jennings, 1896)
 171. *L. simonneae* Segers, 1993
 172. *L. sola* Hauer, 1936
 173. *L. solfatara* (Hauer, 1928)
 174. *L. stenroosi* (Meissner, 1908)
 175. *L. stichaea* Harring, 1913
 176. *L. stichochysta* Segers, 1993
 177. *L. styrax* (Harring & Myers, 1926)
 178. *L. superaculeata* Sanoamuang & Segers, 1997
 179. *L. sympoda* Hauer, 1929
 180. *L. syngenes* (Hauer, 1938)
 181. *L. tensuiseta* Harring, 1914
 182. *L. thienemanni* (Hauer, 1938)
 183. *L. undulata* Hauer, 1938
 184. *L. unguitata* (Fadeev, 1925)
 185. *L. unguilata* (Gosse, 1887)

Family: Notommatidae

186. *Cephalodella catellina* (Müller, 1786)
187. *C. forficata* (Ehrenberg, 1832)
188. *C. forficula* (Ehrenberg, 1832)
189. *C. gibba* (Ehrenberg, 1830)
190. *C. intuta* Myers, 1924
191. *C. mucronata* Myers, 1924
192. *C. trigona* (Rousselet, 1895)
193. *C. ventripes* (Dixon-Nuttal, 1901)
194. *Monommata grandis* Tessin, 1890
195. *M. longiseta* (Müller, 1786)
196. *M. maculata* (Harring & Myers, 1930)
197. *Notommata pachyura* (Gosse, 1886)
198. *N. spinata* Koste & Shiel, 1991
199. *Taphrocampa annulosa* Gosse, 1851

Family: Scaridiidae

200. *Scaridium longicaudum* (Müller, 1786)

Family: Gastropodidae

201. *Ascomorpha ecaudis* Perty, 1850
202. *A. ovalis* (Bergendal, 1892)
203. *A. saltans* Bartsch, 1870
204. *Gastropus minor* (Rousselet, 1892)

Family: Trichocercidae

205. *Trichocerca abilioi* Segers & Sarma, 1993
206. *T. bidens* (Lucks, 1912)
207. *T. bicristata* (Gosse, 1887)
208. *T. braziliensis* Murray, 1913
209. *T. capucina* (Wierzejski & Zacharias, 1893)
210. *T. cylindrica* (Imhof, 1891)
211. *T. edmondsoni* (Myers, 1936)
212. *T. elongata* (Gosse, 1886)
213. *T. flagellata* Hauer, 1937
214. *T. hollaerti* De Smet, 1990
215. *T. iernis* (Gosse, 1887)
216. *T. insignis* (Herrick, 1885)
217. *T. insulana* (Hauer, 1937)
218. *T. kostei* Segers, 1993
219. *T. longiseta* (Schränk, 1802)
220. *T. maior* (Hauer, 1935)
221. *T. mus* Hauer, 1938
222. *T. porcellus* (Gosse, 1851)
223. *T. pusilla* (Jennings, 1903)
224. *T. rattus* (Müller, 1776)
225. *T. ruttneri* Donner, 1953
226. *T. scipio* (Gosse, 1886)
227. *T. siamensis* Segers & Pholpunthin, 1997
228. *T. similis* (Wierzejski, 1893)
229. *T. stylata* (Gosse, 1851)
230. *T. sulcata* (Jennings, 1894)
231. *T. taurocephala* (Hauer, 1931)
232. *T. tenuior* (Gosse, 1886)
233. *T. tigris* (Müller, 1786)
234. *T. uncinata* (Voigt, 1902)

235. *T. voluta* (Murray, 1913)

236. *T. weberi* (Jennings, 1903)

Family: Asplanchnidae

237. *Asplanchna brightwelli* Gosse, 1850

238. *A. priodonta* Gosse, 1850

Family: Synchaetidae

239. *Ploesoma lenticulare* Herrick, 1855

240. *Polyarthra euryptera* Wierzejski, 1891

241. *P. vulgaris* Carlin, 1943

242. *Synchaeta oblonga* Ehrenberg, 1832

243. *S. pectinata* Ehrenberg, 1832

Family: Dicranophoridae

244. *Dicranophoroides caudatus* (Ehrenberg, 1834)

245. *Dicranophorus forcipatus* (Müller, 1786)

Order: Flosculariaceae**Family: Floscularidae**

246. *Floscularia ringens* (Linnaeus, 1758)

247. *Lacimularia flosculosa* (Müller, 1773)

248. *L. racemovata* Thorpe, 1893

249. *Limnias ceratophylli* Schrank, 1803

250. *Ptygura melicerta* Ehrenberg, 1832

251. *P. tacita* Edmondson, 1940

252. *Sinantherina procera* (Thorpe, 1893) *

253. *S. semibullata* (Thorpe, 1893)

254. *S. socialis* (Linnaeus, 1758)

255. *S. spinosa* (Thorpe, 1893)

256. *Stephanoceros fimbriatus* (Goldfusz, 1820)

Family: Conochilidae

257. *Conochilus unicornis* Rousselet, 1892

Family: Hexarthridae

258. *Hexarthra intermedia* Wiszniewski, 1929

259. *H. mira* (Hudson, 1871)

Family: Testudinellidae

260. *Pompholyx sulcata* Hudson, 1885

261. *Testudinella amphora* Hauer, 1938

262. *T. brevicaudata* Yamamoto, 1951

263. *T. dendradena* de Beauchamp, 1955

264. *T. emarginula* (Stenroos, 1898)

265. *T. greeni* Koste, 1981

266. *T. parva* (Ternetz, 1892)

- T. parva bidentata* (Ternetz, 1892)

- T. parva semiparva* (Hauer, 1938)

267. *T. patina* (Hermann, 1783)

268. *T. tridentata* Smirnov, 1931

269. *T. walkeri* Koste & Shiel, 1980

270. *T. sp.* Sharma & Sharma 2018a

271. *T. sp.1* Sharma & Sharma 2018a

Family: Trochosphaeridae

272. *Filinia brachiata* (Rousselet, 1901)
 273. *F. camasecla* Myers, 1938
 274. *F. longiseta* (Ehrenberg, 1834)
 275. *F. opoliensis* (Zacharias, 1898)
 276. *F. pejeri* Hutchinson, 1964
 277. *F. saltator* (Gosse, 1886)
 278. *F. terminalis* (Plate, 1886)
 279. *Horaella brehmi* Donner, 1949
 280. *Trochosphaera aequatorialis* Semper, 1872

Order: Collothecaceae**Family: Atrochidae**

281. *Cupelopagis vorax* (Leidy, 1857)

Family: Collothecidae

282. *Collothea hexalobata* Banik, 2002*
 283. *C. ornata* (Ehrenberg, 1832)
 284. *C. mutabilis* (Hudson, 1885)
 285. *C. tenuilobata* (Anderson, 1889)
 286. *C. tetralobata* Banik, 2002 *
 287. *C. trilobata* (Collins, 1872) *

Sub-class: Bdelloidea**Order: Philodinida****Family: Adinetidae**

288. *Adineta longicornis* Murray, 1906 *
 289. *A. vaga* (Davis, 1873)

Family: Habrotrichidae

290. *Habrotricha angusticollis* (Murray, 1905)
 291. *H. angusticollis attenuata* (Murray, 1906) *
 292. *H. lata* (Bryce, 1892) *
 293. *H. leitgebii* (Zelinka, 1886)*
 294. *H. microcephala* (Murray, 1906) *

Family: Philodinidae

295. *Dissotrocha aculeata* (Ehrenberg, 1832)
 296. *Macrotrachela multispinosa* Thompson, 1892

297. *Philodina citrina* Ehrenberg, 1832
 298. *Rotaria macroceros* (Gosse, 1851)
 299. *R. mento* (Anderson, 1889)
 300. *R. neptunia* (Ehrenberg, 1830)
 301. *R. neptunoida* Harring, 1913*
 302. *R. rotatoria* (Pallas, 1766)
 303. *R. tardigrada* (Ehrenberg, 1830) *

* Not observed in our collections

Brachionus dichotomus reductus (Fig. 2A), *B. donneri* (Fig. 2B), *B. falcatus reductus* (Fig. 2C), *B. kostei* (Fig. 2D), *B. lyratus* (Fig. 2E), *B. murphyi* (Fig. 2F), *B. nilsoni* (Fig. 2G), *B. srisumona* (Fig. 2H), *Collothea hexalobata*, *C. tetralobata*, *Colurella sanoamuangae*, *C. tessellata* (Fig. 2I), *Dipleuchlanis ornata* (Fig. 2J–K), *Euchlanis semicarinata* (Fig. 2L–M), *Gastropus minor* (Fig. 3A), *Keratella edmondsoni* (Fig. 3B), *K. javana* (Fig. 3C), *K. serrulata* (Fig. 3D), *K. tacinensis*, *Lecane batillifer*, *L. bifastigata*, *L. calcaria* (Fig. 3E), *L. clara* (Fig. 3F), *L. dorysimilis* (Fig. 3G), *L. jaintiaensis*, *L. isanensis* (Fig. 3H), *L. latissima* (Fig. 3I), *L. marchantaria* (Fig. 3J), *L. niwati* (Fig. 3K), *L. rhenana*, *L. shieli* (Fig. 3L), *L. superaculeata* (Fig. 4A), *Lepadella desmeti* (Fig. 4B), *L. elongata*, *L. minoruoides*, *L. neglecta* (Fig. 4C), *L. vandenbrandei*, *Macrochaetus danneelae* (Fig. 4D), *Mytilina lobata* (Fig. 4E), *M. michelangellii*, *Notholca acuminata*, *N. labis* (Fig. 4F), *N. squamula*, *Squatinella bifurca* (Fig. 4G–H), *Testudinella amphora*, *T. brevicaudata*, *T. greeni*, *T. parva bidentata*, *T. tridentata*, *T. walkeri* (Fig. 4I), *Trichocerca edmondsoni*, *T. hol-laerti*, *T. maior*, *T. mus* (Fig. 4J), *T. siamensis* (Fig. 4K), *T. taurocephala* (Fig. 4L), and *T. uncinata*, observed in our collections from the sampled seven states, are rotifers with global or regional biogeographic interest or their Indian distribution yet restricted to NEI. Of these, certain rare and interesting species are illustrated to warrant for validations and to serve as source of reference for the future workers.

Table 1. Rotifera taxa recorded from Northeast India and seven states.

States / NEI↓ Taxa→	Present study			Earlier Report (Sharma & Sharma 2014a)			Species added
	Species	Genera	Families	Species	Genera	Families	
Arunachal Pradesh	172	39	19	76	29	18	96
Assam	244	46	21	216	46	21	28
Manipur	200	48	23	155	45	23	45
Meghalaya	161	40	20	135	36	19	26
Mizoram	162	35	19	76	28	17	86
Nagaland	150	37	19	66	23	14	84
Tripura	176	36	20	152	36	20	24
Northeast India	303	53	24	238	50	23	65

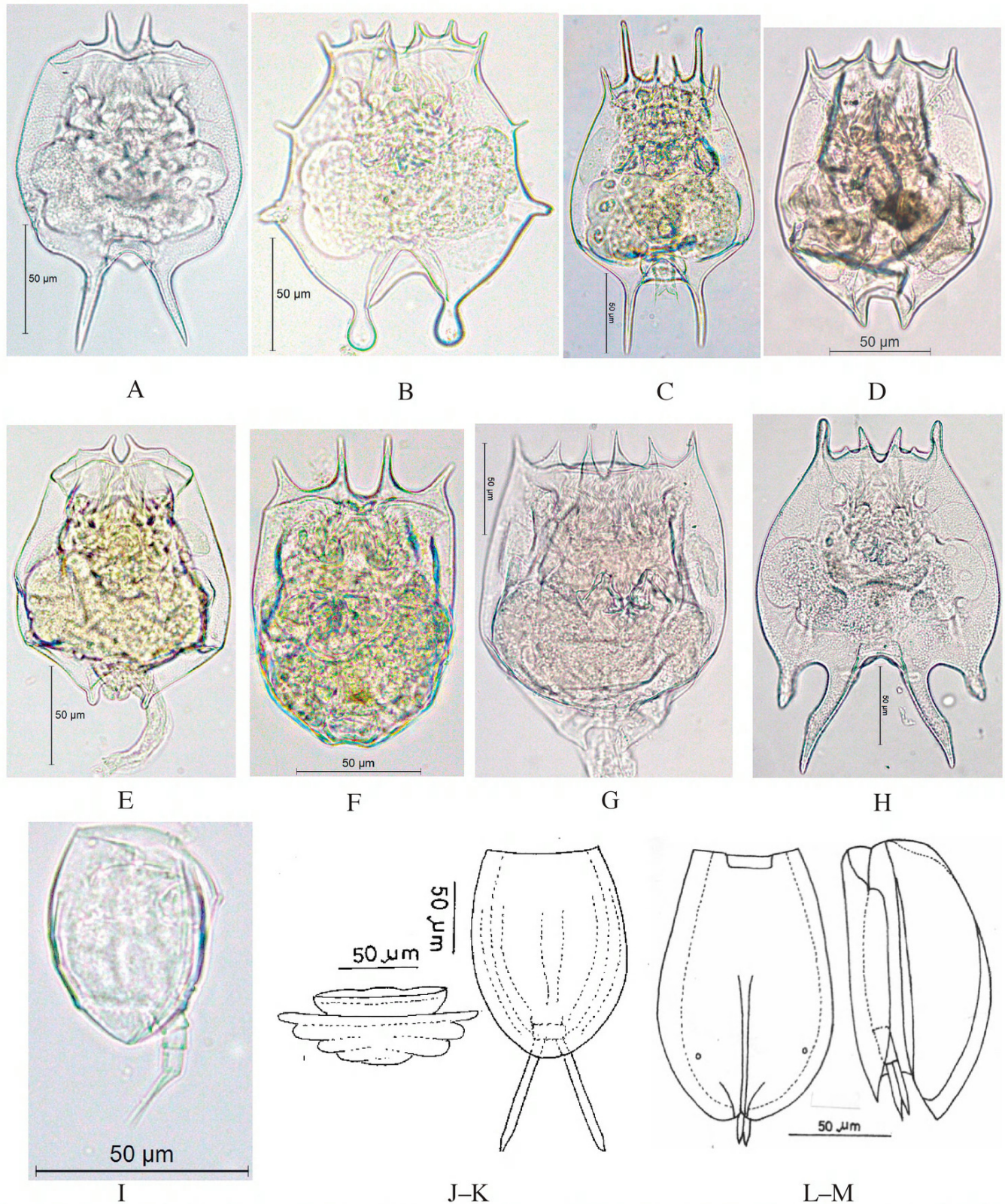


Fig. 2A–M. Interesting Rotifera from Northeast India. **A.** *Brachionus dichotomus reductus* Koste & Shiel, ventral view. **B.** *Brachionus donneri* Brehm, ventral view. **C.** *Brachionus falcatus reductus* Koste & Shiel, ventral view. **D.** *Brachionus kostei* Shiel, dorsal view. **E.** *Brachionus lyratus* Shephard, ventral view. **F.** *Brachionus murphyi* Sudzuki, ventral view. **G.** *Brachionus nilsoni* Ahlstrom, ventral view. **H.** *Brachionus srisumona* Segers, Kotethip & Sanoamuang, dorsal view. **I.** *Cohurella tessellata* (Glascott), lateral view. **J–K.** *Dipleuchlanis ornata* Segers, ventral view and cross-section (after Sharma, 2005). **L–M.** *Euchlanis semicarinata* Segers, dorsal and lateral views.

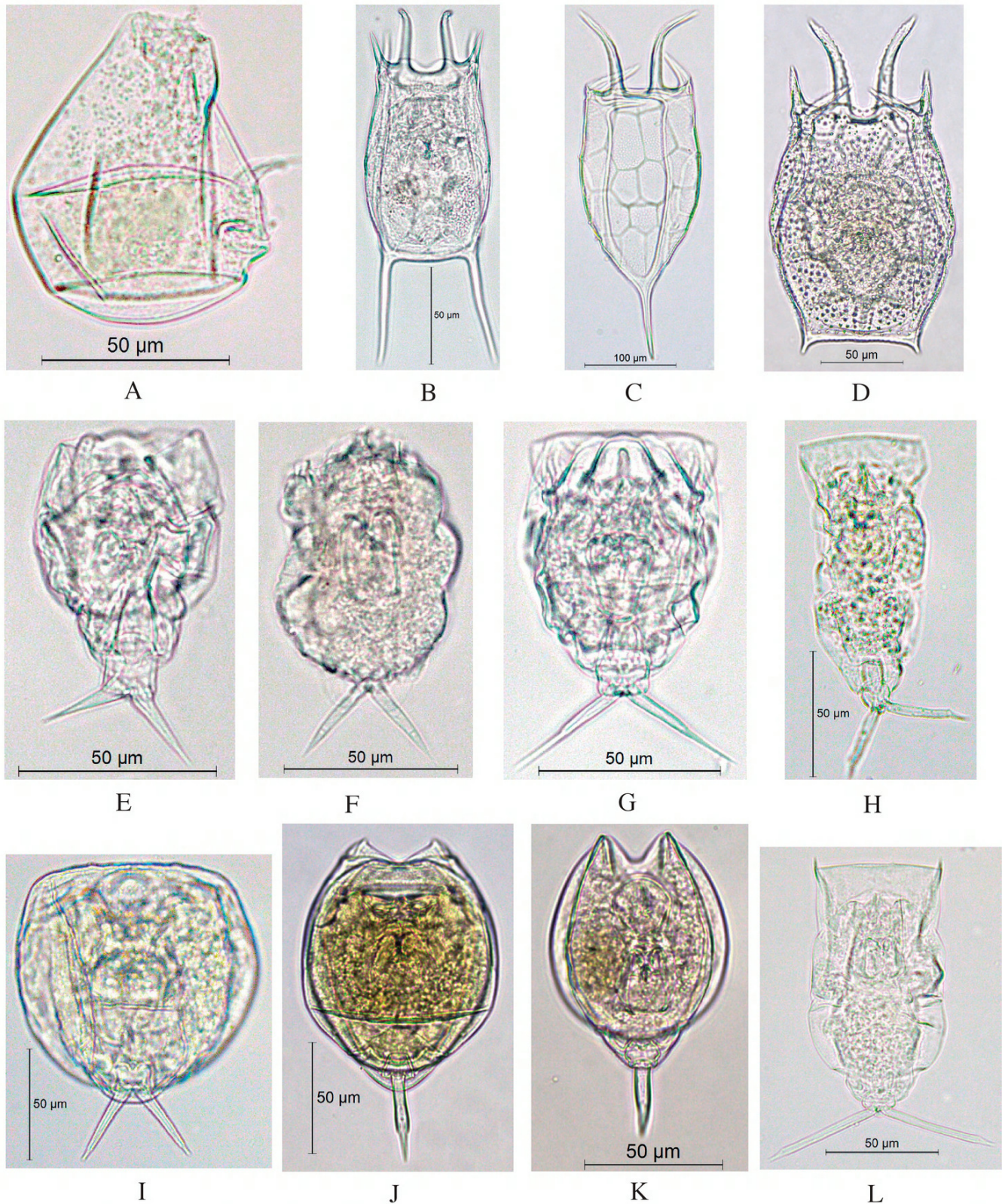


Fig. 3A–L. Interesting Rotifera from Northeast India. **A.** *Gastropus minor* (Rousselet), lateral view. **B.** *Keratella edmondsoni* Ahlstrom, dorsal view. **C.** *Keratella javana* Hauer, ventral view. **D.** *Keratella serrulata* (Ehrenberg), ventral view. **E.** *Lecane calcaria* Haring & Myers, ventral view. **F.** *Lecane clara* (Bryce), dorsal view. **G.** *Lecane dorysimilis* Trinh Dang, Segers & Sanoamuang, dorsal view. **H.** *Lecane isanensis* Sanoamuang & Savatnalinton, ventral view. **I.** *Lecane latissima* Yamamoto, dorsal view. **J.** *Lecane niwati* Segers, Kotethip & Sanoamuang, ventral view. **K.** *Lecane marchantaria* Koste & Robertson, dorsal view. **L.** *Lecane shieli* Segers & Sanoamuang, dorsal view.

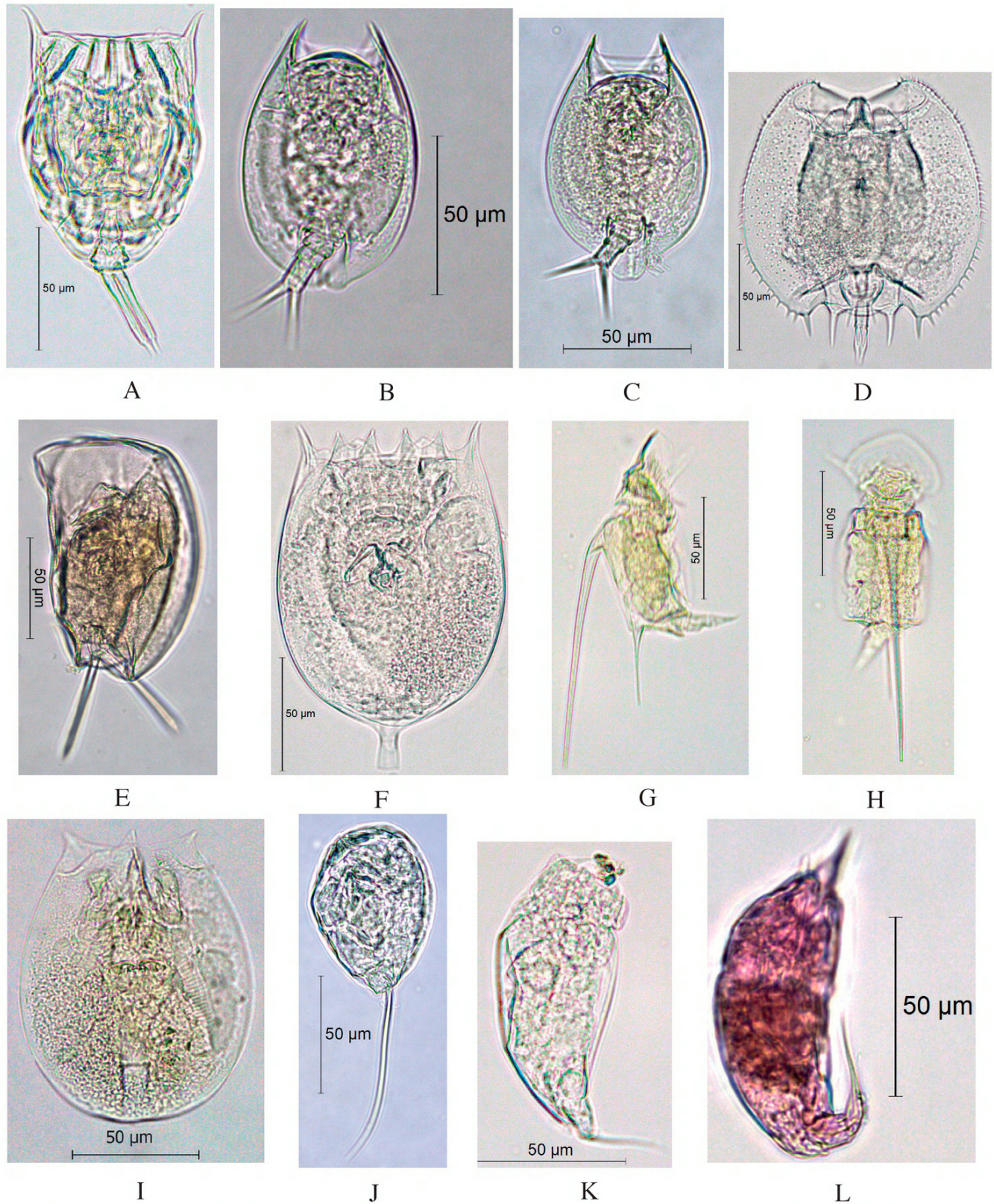


Fig. 4A–L. Interesting Rotifera from Northeast India. **A.** *Lecane superaculeata* Sanoamuang & Segers, ventral view. **B.** *Lepadella desmeti* Segers & Chittapun, ventral view. **C.** *Lepadella neglecta* Segers & Dumont, ventral view. **D.** *Macrochaetus danneelae* Koste & Shiel, ventral view. **E.** *Mytilina lobata* Pourriot, lateral view. **F.** *Notholca labis* Gosse, ventral view. **G–H.** *Squatinella bifurca* (Bolton), lateral and dorsal views. **I.** *Testudinella walkeri* Koste & Shiel, ventral view. **J.** *Trichocerca mus* Hauer, lateral view. **K.** *Trichocerca siamensis* Segers & Pholpunthin, lateral view. **L.** *Trichocerca taurocephala* (Hauer), lateral view.

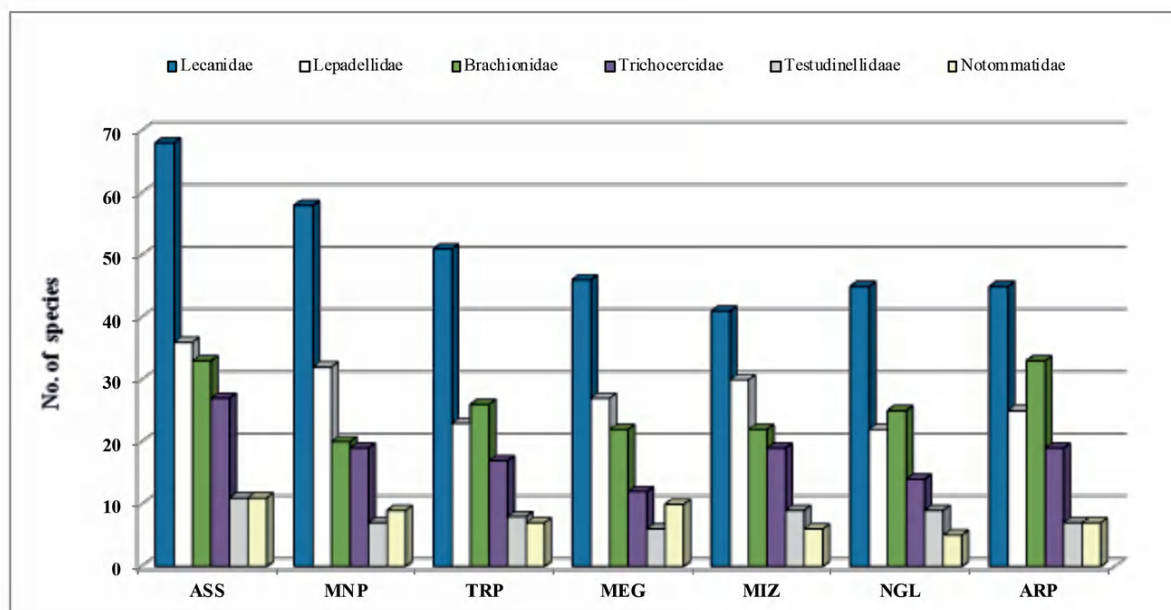


Fig. 5. Species richness of important Rotifera families of seven states of NEI; ASS-Assam; MNP-Manipur; TRP-Tripura; MEG-Meghalaya; MIZ-Mizoram, NGL-Nagaland; ARP-Arunachal Pradesh.

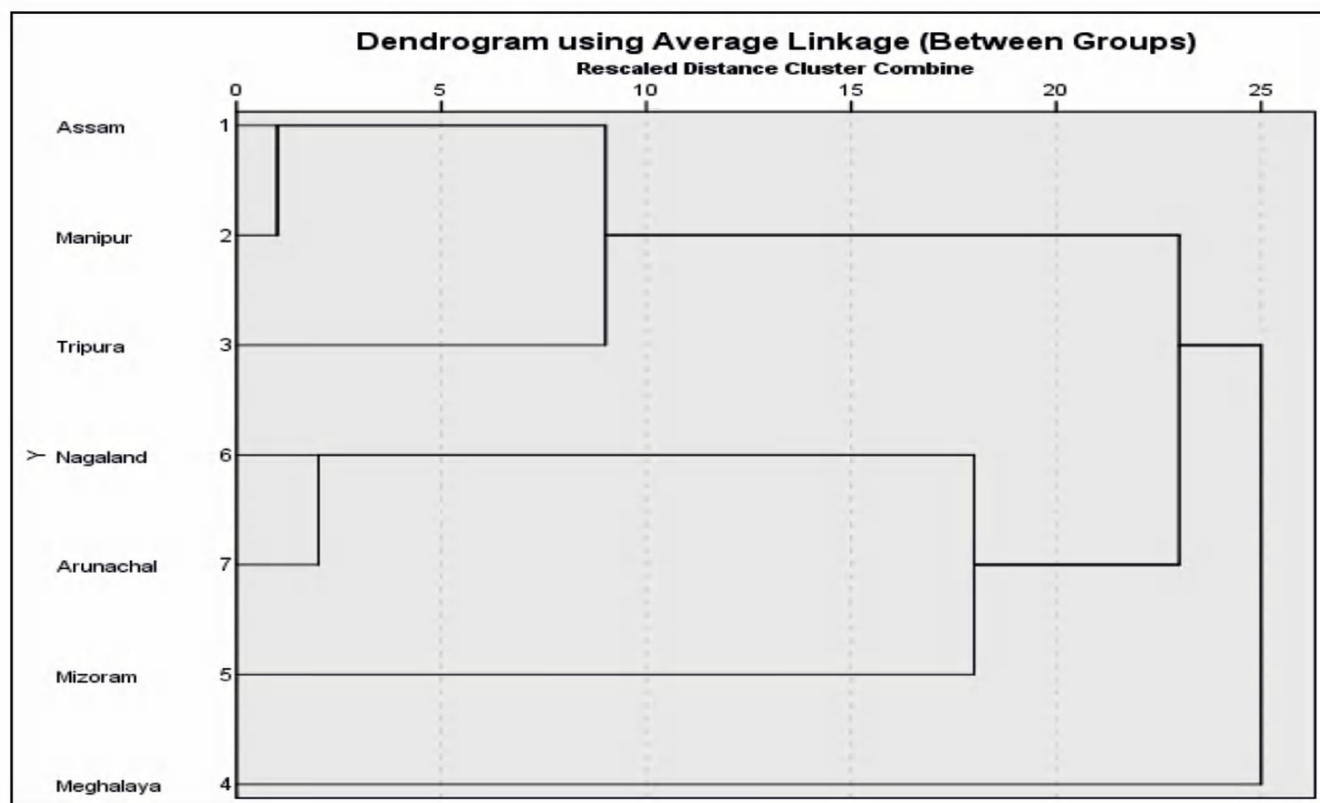


Fig. 6. Hierarchical cluster analysis of Rotifera assemblages of seven states of NEI.

Rotifera of Northeast India contained 287 species of Monogononta and 16 of Bdelloidea. The rotifer richness of seven states varied (Table 1) between 150–244 (181 ± 39 species) and 244, 200, 176, 172, 162, 161 and

150 species were observed from Assam, Manipur, Tripura, Arunachal Pradesh, Mizoram, Meghalaya and Nagaland, respectively. Lecanidae, Brachionidae, Lepadellidae, Trichocercidae, Notommatidae, Testudinellidae,

Table 2. Rotifer community richness by aquatic ecosystem types of Northeast India.

Study sites	Species	Genera	Families
Ramsar sites			
Loktak Lake (93°46'–93°55'E, 24°25'–24°42'N)	200	48	23
Deepor Beel (91°35'–91°43'E, 26°05'–26°11'N)	183	36	20
Floodplain lakes (<i>beels</i>) of Brahmaputra Basin, Assam			
Barpeta (6 <i>beels</i>) (90°52'–91°42'E, 26°17'–26°40'N)	176	35	19
Majuli River Island (10 <i>beels</i>) (93°–95°E, 25°–27°N)	174	34	18
Dibru-Saikhowa Biosphere Reserve (DSBR) (5 <i>beels</i>) (95°22'–95°24'E, 27°34'–27°55'N)	162	32	18
Tinsukia (5 <i>beels</i>) (95°22'–96°35'E, 27°14'–28°40'N)	169	33	19
Dibrugarh (6 <i>beels</i>) (93°22'–95°35'E, 26°19'–27°30'N)	179	35	19
Floodplain lakes (<i>pats</i>) of Manipur			
Manipur valley (15 <i>pats</i>) (93°45'–94°00'E, 24°25'–24°45'N)	200	48	23
Small floodplain wetlands (<i>dobas</i> or <i>dubies</i>) of Assam			
A. Brahmaputra valley (90°–93°E, 26°–27°N)	167	34	18
a. Lower Assam	154	34	18
b. Central Assam	150	31	19
c. Upper Assam	135	30	17
B. Barak valley, south Assam (92°45'–92°75'E, 24°48'–24°80'N)	159	35	19
Small lentic ecosystems			
Arunachal Pradesh (91°20'–97°30'E, 26°28'–29°30'N)	165	37	19
Nagaland (93°3'–93°5'E, 25°4'–27°0'N)	150	37	19
Mizoram (92°15'–93°29'E, 21°58'–24°35'N)	162	35	19
Meghalaya (90°05'–92°40'E, 25°10'–26°15'N)	161	40	20
Tripura (92°10'–92°20'E, 22°56'–24°32'N)	163	35	19
Manipur (93°50'–94°00'E, 24°10'–24°55'N)	169	44	22

Floscularidae and Euchlanidae were represented by 75, 42, 41, 32, 14, 11 and 10 species, respectively; Trochospaeridae and Philodinidae comprised 9 species each; and Trichotriidae and Collothecidae included 8 and 7 species, respectively. Brachionidae and Flosculariidae each yielded six genera. The richness variations of speciose six Eurotatoria families in seven states of NEI are shown in Fig. 5. The rotifer communities of the sampled seven states had similarities ranging between 72.1–82.3% (vide Sørensen's index). The hierarchical cluster analysis (Fig. 6) showed highest affinity between the rotifer assemblages of Assam and Manipur, while Meghalaya fauna showed the highest divergence.

Our observations on faunal diversity of Rotifera in the floodplain lakes, small floodplain wetlands and small

lentic ecosystems of NEI recorded richness variations as indicated in Table 2. Two Ramsar sites: Loktak Lake and Deepor Beel yielded 200 species belonging to 48 genera and 23 families, and 183 species belonging to 36 genera and 20 families, respectively. The small floodplain wetlands (*dobas* or *dubies*) of the Brahmaputra river basin had 157 species with marginal variations from lower (154 species), central (150 species) and upper Assam (135 species); and *dobas* or *dubies* from Barak valley of south Assam had 159 species. The sampled small lentic ecosystems of Arunachal Pradesh, Nagaland, Mizoram, Meghalaya, Tripura and Manipur had 150–165 species. Richness ranged from 162 to 179 in various floodplain lakes (*beels*) of Assam and Manipur floodplain lakes (*pats*) had 200 species.

DISCUSSION

The rotifer assemblages of NEI reveal total richness (S) of 303 species belonging to 53 genera and 24 families; these represent ~70%, ~81% and 96% of species, genera and families of the phylum known to date from India, respectively, and thus highlight highly biodiverse character vis-à-vis the Indian Rotifera. Further, 292 species (~96% of S) observed from seven northeastern states affirm the high rotifer heterogeneity found in our plankton and semi-plankton collections. To date, Rotifera of NEI is the most speciose and diverse than any region of India (Sharma & Sharma 2017) and Sri Lanka (Fernando 1980) – the only reasonably well sampled country of the Indian subcontinent. The diverse nature of rotifer fauna is attributed to overall habitat diversity and ecological heterogeneity of aquatic ecosystems located across varied ecological and geomorphic regimes, the location of NEI in the Himalayan and Indo-Burma Biodiversity hotspots, the ‘rotiferologist effect’ vide Fontaneto et al. (2012), and sampling intensity. The rotifer richness documented from this interesting biogeographic region of India is similar to that of Cambodia (304 species: Sor et al. 2015) although less than the 398 species known from well studied fauna of Thailand (Sa-Ardrit et al. 2013). On the other hand, our tally is distinctly higher than other Southeast Asian faunas including Laos (Segers & Sanoamuang 2007), Philippines (Tuyor & Segers 1999), Malaysia (Segers 2004; Fontaneto & Ricci 2004), Myanmar (Koste 1990), and Singapore (Fernando & Zankai 1981) and Vietnam (Trinh et al. 2019).

This study records high Rotifera richness amongst seven states (150–244, 181±39 species; 49.5–80.5% of S) of NEI than 66–216 species reported earlier (Sharma & Sharma 2014a). Our observations show a distinct > two-fold increase in species known each from Arunachal Pradesh (Sharma & Sharma 2019a), Mizoram (Sharma & Sharma 2015b), and Nagaland (Sharma et al. 2017). In addition, we report richness updates from Manipur (29%); Assam (12.9%) and Meghalaya (19.2%) and Tripura (17.8%) and overall species update of 27.3% from NEI. Assam > Manipur depict highest number of species of the phylum known from any state of India, while Manipur also reflects rich higher diversity (genera and families). The state-wise richness variations from NEI concur with the report of ‘All Taxa Biological Inventories (ATBI)’ vide Dumont & Segers (1996) for the tropical and subtropical rotifer assemblages. With nearly 1/3 species known from all seven states, the rotifers communities showed 72.1–82.3% similarities (vide Sørensen’s index). Assam and Manipur rotifers had the maximum affinity (82.3%) and it was followed by 81.5% similarity between two hills states of Arunachal Pradesh and Nagaland, while Meghalaya had the greatest dissimilarity to other assemblages.

Rotifera of NEI is characterized by sizable fraction of species (~ 24% of S) of global biogeographic interest which are categorized as follows:

- a) Australasian species: *Brachionus dichotomus reductus*, *B. falcatus reductus*, *B. kostei*, *B. lyratus*, *B. murphyi*, *Lecane batillifer*, *L. latissima*, *L. shieli*, *Macrochaetus danneelae*, *Notommata spinata* and *Testudinella walkeri*;
- b) Oriental endemics: *Brachionus donneri*, *B. srisumanae*, *Colurella sanoamuangae*, *Keratella edmondsoni*, *Lecane acanthinula*, *L. blachei*, *L. bulla diabolica*, *L. isanensis*, *L. niwati*, *L. solfatara*, *L. superaculeata* and *Filinia camasecla*;
- c) Indo-Chinese species: *Lecane dorysimilis*;
- d) Indian endemics: *Collotheca hexalobata* C. *tetralobata*, *Lecane jaintiaensis*, *Lepadella nartiangensis*, and undetermined *Testudinella* sp. and *T. sp.1* (vide Sharma & Sharma 2018a).
- e) Paleotropical species: *Dipleuchlanis ornata*, *Euchlanis semicarinata*, *Keratella javana*, *Lecane braumi*, *L. lateralis*, *L. simonneae*, *L. stichoclysta*, *L. unguitata*, *Lepadella bicornis*, *L. discoidea*, *L. minoruoides*, *L. vandenbrandei*, *Testudinella brevicaudata*, *T. greeni*, *Trichocerca abilioi*, *T. braziliensis*, *T. hollaerti* and *T. kostei*;
- f) Palaearctic species: *Cephalodella trigona*, *Lecane bifastigata* and *Squatinella bifurca*;
- g) Holarctic species: *Lecane elongata*, *L. levistyla*, *Trichocerca taurocephala* and *T. uncinata*;
- h) Nearctic and Palearctic species: *Trichocerca maior*;
- i) Neotropical species: *Lecane calcaria*, *L. marchantaria*, *L. rugosa*, *L. sola*, *Lepadella neglecta*, *Mytilina lobata*;
- j) Neotropical-Pacific species: *Lepadella desmeti* and *L. elongata*;
- k) Cosmo (sub) tropical species: *Brachionus durgae*;
- l) Other interesting species: *Lecane calcaria*, *L. rhenana*, *L. ruttneri*, *L. patella oblonga*, *Mytilina michelangellii*, *Ptygura tacita*, *Testudinella amphora*, *Trichocerca edmondsoni* and *T. siamensis*.

Our collections highlight the record richness of 91% and 87% of the Australasian and the Oriental elements known from India, respectively with ~81% and ~67% species of the two categories exclusively restricted to NEI, respectively. This diagnostic feature, affirming strong affinity of Rotifera of NEI with that of Southeast Asia and Australia, is hypothesized to invasion of these elements through ‘the Assam gateway’ – a vital biogeographic corridor of India (Mani 1974) which is known to facilitate interchanges between the Indian and Asian biota (Ranga Reddy 2013) and presently even with Australian Rotifera. About ~72% species of the listed 12 categories are reported to date from India exclusively from NEI. Besides, 32 species (10.6%) namely *Adineta vaga*, *A. lon-*

gicornis, *Cephalodella intuta*, *C. ventripes*, *Colurella tessellata*, *Habrotrocha angusticollis*, *H. angusticollis attenuata*, *H. lata*, *H. leitgebii*, *H. microcephala*, *Keratella javana*, *Lecane aeganea*, *L. clara*, *L. glypta*, *L. rhytida*, *L. stichaea*, *Lepadella heterodactyla*, *L. latusinus*, *L. patella oblonga*, *Monommata grandis*, *M. maculata*, *Stephanoceros fimbriatus*, *Taphrocampa annulosa*, *Testudinella dendradena*, *T. tridentata*, *Trichocerca bidens*, *T. insignis*, *T. insulana*, *T. mus*, *T. scipio* and *T. sulcata* are characterized by the Indian distribution restricted to NEI. Our remarks thus impart both the global and regional biogeographic interest to Rotifera fauna of NEI and, hence, assign it a contrasting identity than the rotifer assemblages of the rest of India. The relative paucity of the Indian endemics in NEI is secondary as (a) a number of such species namely *Brachionus srisumona*, *Colurella sanoamuangae*, *Lecane dorysimilis*, *L. isanensis*, *L. latissima*, *L. niwati*, *L. shieli*, *L. superaculeata*, *Lepadella desmeti* and *Trichocerca siamensis* are described as new species from Thailand and elsewhere from southeast Asia; (b) about eight potential new species from NEI are awaiting descriptions pending analysis of more specimens (BKS, unpublished); and (c) collections from high and middle altitudes of Arunachal Pradesh, and the most unexplored eastern Himalayan state of Sikkim are likely to add interesting species.

Lecanidae (75 species) forms a notable fraction of Rotifera of NEI (24.8%) and that of individual states (51 ± 9 species), while Brachionidae (42, 28 ± 5 species) \geq Lepadellidae (41, 26 ± 5 species) $>$ Trichocercidae (32, 18 ± 4 species) contribute 38.1%. The four families collectively comprise sizable components of 62.9% and $66.9 \pm 3.4\%$ of Rotifera species known from NEI and the seven states, respectively. The order of importance deviates as Lepadellidae $>$ Brachionidae in our collections from Manipur, Meghalaya and Nagaland in particular due to diagnostic paucity of the brachionids. On the contrary, the Brachionidae-rich Rotifera of Assam and Arunachal Pradesh (33 species each) are noteworthy. Lecanidae, Lepadellidae, Trichocercidae and Brachionidae richness of NEI represents $\sim 81\%$, $\sim 91\%$, $\sim 86\%$ and $\sim 84\%$ of the species of these taxa known from India. The cumulative importance of these families concurs with the reports from Thailand (Sa-Ardrit et al. 2013), Africa (Segers et al. 1993; Green 2003), Argentina (Jose de Paggi 2001), and Brazil (Serafim Jr. et al. 2003; Bonecker et al. 2005, 2009). Notommatidae, Testudinellidae, Trochosphaeriidae, Mytilinidae and Trichotriidae are other Monogonont families with richness interest. The stated features of richness impart a broadly littoral-periphytic character to the rotifer fauna of NEI which, in turn, is largely attributed to nature of the sampled water bodies, and even paucity of planktonic rotifers in small lentic ecosystems predominant in hill states of Arunachal Pradesh, Mizoram, Nagaland and Meghalaya, and largely sampled from Tripura and Manipur.

The importance of 'tropic-centered' *Lecane* throughout the seven states ($27.7 \pm 1.7\%$ of S) confirms the most important role of this thermophile in Rotifera communities of NEI as found in southeast Asia (Segers 1996, 2001). This generalization, inclusive of the eastern Himalayan state of Arunachal Pradesh (Sharma & Sharma 2019a), marks a notable contrast to its relative paucity from the western Himalayas (Sharma & Sharma 2018c). The richness of 'tropic-centered' *Brachionus* merits caution in light of the relative paucity of its species in Manipur as well as in hill states of Meghalaya, Mizoram, Nagaland and Arunachal Pradesh. This salient feature is attributed to slightly acidic waters (Sharma & Sharma 2005, 2014a) of hilly areas, lack of permanent limnetic habitats (Sharma & Sharma 2014c) and is hypothesized to result from certain factors otherwise limiting the regional distribution of *Brachionus* spp. (BKS, unpublished); the last aspect yet needs to be investigated. The rotifer fauna of NEI indicates highest richness (10 species) of 'temperate centered' *Keratella*, amongst 11 known Indian species (Sharma & Sharma 2014c), but with the 'cold-water' *Keratella serrulata* and *K. tacinensis* found exclusively from Arunachal Pradesh (Sharma & Sharma 2019a). Further, the three species of 'temperate centered' *Notolca* are known only from this eastern Himalayan state (Sharma & Sharma 2019a). Our observations also focus attention on the paucity of *Mytilina* and *Filinia* spp., and lack of *Conochilus* from Arunachal Pradesh, Nagaland and Mizoram; and paucity of *Filinia*, and scarceness of *Hexarthra* and *Conochilus* species in Manipur. Overall importance of 'tropic-centered' taxa, restricted occurrence of 'cold-water' species, high richness of cosmopolitan species ($\sim 65\%$) and collective richness ($\sim 21\%$) of cosmopolitan and (sub) tropical species impart a broadly tropical character to Rotifera of NEI.

Segers et al. (1993) hypothesized (sub) tropical floodplain lakes as the globally rich rotifer habitats, while Sharma & Sharma (2008, 2014a, 2018b) extended this hypothesis to the floodplains of NEI. While augmenting the studies supporting our hypothesis, we now report 200 and 183 species from Loktak Lake and Deepor beel, respectively; the two Ramsar sites are thus categorized as Rotifera 'hot-spots' of the Indian sub-region as well as one of the globally most biodiverse rotifer biotopes. Besides, the selected beels of Barpeta district (176 species), the Dibru-Saikhowa Biosphere Reserve (162 species), the Majuli River island (174 species), Dibrugarh district (179 species) and Tinsukia district (169 species) of the Brahmaputra river basin of Assam, and selected *pats* of Manipur (200 species) reveal speciose assemblages. The richness known from various *beels* and *pats* of NEI largely compares with 184 species from the well-sampled Upper Paraná floodplain (Bonecker et al. 1994, 1998, 2005) of Brazil, while it is more biodiverse than the records from the Rio Pilcomayo National Park (a Ramsar site), Argentina (Jose de Paggi 2001); Oguta lake and Iyi-Efi

lake from the Niger delta (Segers et al. 1993), Africa; Lake Guarana, Brazil (Bonecker et al. 1994); Thale-Noi Lake, a Ramsar site of Thailand (Segers and Pholpunthin 1997); Laguna Bufeos of Bolivia (Segers et al. 1998; Koste 1974), and from Rio Tapajos and Lago Camaleao (Koste and Robertson 1983) of Brazil, respectively; and the Kashmir Himalayan floodplains (Sharma & Sharma 2018c).

We focus attention on the high species richness of Rotifera of small lentic ecosystems of NEI; the latter deserve attention as hotspots both in terms of species composition and biological traits (EPCN 2008), and are considered as keystone systems for analyses and conservation of biodiversity (Oertli et al. 2010; Céréghino et al. 2014; Vad et al. 2017; Oertli 2018). These water bodies are largely ignored in India while Sharma & Kensibo (2017) hypothesized these biotopes to be one of the biodiverse Rotifera habitats of the Indian sub-region. The small lentic habitats predominant in the hill states of Arunachal Pradesh, Nagaland, Mizoram and Meghalaya had 165, 150, 162 and 161 species, respectively. Besides, small floodplain wetlands (*dobas* or *dubies*) of Assam are the rotifer rich habitats with record richness of 167 species from the Brahmaputra valley with marginal variations of 154, 150 and 135 species from *dobas* or *dubies* of lower, central and upper Assam regions, while *dobas* or *dubies* of Barak valley of south Assam have ~93% of the rotifer species reported from the floodplains of south Assam (Sharma & Sharma 2019b). The results thus endorse our hypothesis on overall importance of varied small lentic ecosystems of NEI vis-à-vis Rotifera biodiversity.

This study highlights the record richness of 84 and 81 species found in May and June, 2017 collections from a floodplain lake (*beel*) of upper Assam; 85 species each from December 2016 and January 2017 samples from Deepor beel (Ramsar site) and the record richness of 86 and 89 species from Loktak Lake basin of Manipur in November and December 2017 samples. The assemblages of 80+ species are described as the 'Rotifera paradox', analogous to the classical 'paradox of the plankton' reported by Hutchinson (1961), which reveal the intriguing possibility of the co-existence of a number of rotifer species in the floodplain ecotones and are attributed to high amount of niche overlap (MacArthur 1965). The said reports merit interest as compared with the highest global assemblage of 102+ species known from Broa reservoir, Brazil (Segers & Dumont 1995). Our results are more biodiverse than earlier highest individual Indian reports of 76 species from a beel of DSBK (Sharma et al. 2017), 79 species from Deepor beel (Sharma & Sharma 2013) and 79 species from Loktak Lake (Sharma 2009; Sharma et al. (2016). Further, our collections from unstructured small floodplain wetlands (*dobas* or *dubies*) of the Majuli River Island and upper Assam highlight the 'Rotifera paradox' with speciose assemblages of up to 50 species per sample (Sharma & Sharma 2019c).

In summary, the most biodiverse Rotifera of NEI, than known from any region of the Indian subcontinent, is noteworthy. High richness of species of global and regional biogeographic interest with a large fraction exclusively restricted to NEI, the littoral-periphytic rotifer assemblages with broadly tropical character except that of the eastern Himalayan state of Arunachal Pradesh, and notable rotifer heterogeneity amongst the seven north-eastern states are notable attributes. The high affinity of NEI Rotifera with Southeast Asian and Australian faunas highlights the role of 'the Assam-gateway' that facilitates the invasion of the Australasian, Oriental, the Indo-Chinese and the Southeast Asian species. The species-rich rotifer assemblages of small lentic environs of Arunachal Pradesh, Mizoram, Nagaland, Meghalaya, Manipur and Tripura; *beels* and *dobas* and *dubies* of the Brahmaputra and the Barak river floodplains of Assam, and *pats* of Manipur; the examples of 'the Rotifera paradox' in certain *beels* and *pats*, and *dobas* and *dubies* highlight the tremendous ecological diversity of this phylum in NEI. This study is an important contribution to biodiversity and biogeography of Rotifera of India, Asia and the Oriental region. Our results affirm the importance of intensive sampling and taxonomic expertise in enabling comprehensive faunal analyses and documentation of small rotifer species that are usually over-looked in the Indian works. Analyses of the littoral-periphytic, sessile, colonial and benthic rotifers from the unexplored eastern Himalayan state of Sikkim, high and middle altitudes of Arunachal Pradesh and also other states are desired for future biodiversity update.

Acknowledgements. The senior author is thankful to the Ministry of Environment, Forests and Climate Change (Govt. of India) for AICOPTAX project, the G.B. Pant Institute of Himalayan Environmental Development, Almora for a research grant, and to "University with Potential for Excellence Program (Biosciences)" program of North-Eastern Hill University, Shillong for a research program which facilitated the sampling. The senior author is thankful to the Head, Department of Zoology, NEHU, Shillong, for facilities and collectively to Drs L. Pachau, M.K. Hatimuria, G. Thangjam, K.R. Sounii Pou, S.I. Khan and N. Noroh for their help in the field collections on several occasions. We thank our peers: Dr Russell J. Shiel, Australia and an anonymous reviewer for useful comments and suggestions. Our special personal thanks to Dr Russell J. Shiel for his critical post-peer review scrutiny of our Ms. We wish to thank Dr Ralph S. Peters and Dr Bernhard Huber (Bonn zoological Bulletin) for help and suggestions during the peer review. The authors have no conflict of interests.

REFERENCES

- Bonecker CC, Aoyagui ASM, Santos RM (2009) The impact of impoundment on the rotifer communities in two tropical floodplain environments: interannual pulse variations. Brazilian Journal of Biology 69: 529–537

- Bonecker CC, Costa CLD, Velho LFM, Lansac-Tôha FA (2005) Diversity and abundance of the planktonic rotifers in different environments of the Upper Paraná River floodplain (Paraná State – Mato Grosso do Sul State, Brazil). *Hydrobiologia* 546: 405–414
- Bonecker CC, Lansac-Toha FA, Rossa DC (1998) Planktonic and non-planktonic rotifers in two environments of the upper Parana River floodplain, state of Mato Grosso do Sul, Brazil. *Brazilian Archives of Biology & Technology* 41: 447–456
- Bonecker CC, Lansac-Tôha FA, Staub A (1994) Qualitative study of Rotifers in different environments of the high Parana River floodplain (Ms), Brazil. *Revista UNIMAR*, 16(1): 1–16
- Céréghino R, Boix D, Cauchie HM, Martens K, Oertli B (2014) The ecological role of ponds in a changing world. *Hydrobiologia* 723(1):1–6
- Dumont HJ, Segers H (1996) Estimating lacustrine zooplankton species richness and complementarity. *Hydrobiologia* 341: 125–132
- EPCN (2008) The Pond Manifesto. Available: <http://campus.hesge.ch/epcn/projects.asp>.
- Fernando CH (1980) The freshwater zooplankton of Sri Lanka, with a discussion of tropical freshwater zooplankton composition. *Internationale Revue der gesamten Hydrobiologie* 65: 411–426
- Fernando CH, Zankei NP (1981) The Rotifera of Malaysia and Singapore with remarks on some species. *Hydrobiologia* 78: 205–219
- 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
- Fontaneto D, Ricci C (2004) Rotifera: Bdelloidea. Pp.121–126. In: Yule CM, Sen YH (eds) *Freshwater Invertebrates of the Malaysian Region*. Academy of Sciences Malaysia
- Green J (2003) Associations of planktonic and periphytic rotifers in a tropical swamp, the Okavango Delta, Southern Africa. *Hydrobiologia* 490: 197–209
- Hutchinson GE (1961) The paradox of the plankton. *American Naturalist* 95: 137–145
- Jersabek CD, Leitner MF (2013) The Rotifer World Catalog. World Wide Web electronic publication. <http://www.rotifera.hausdennatur.at/accessed> {17.07.2018}
- José De Paggi S (2001) Diversity of Rotifera (Monogononta) in wetlands of Rio Pilcomayo national park, Ramsar site (Formosa, Argentina). *Hydrobiologia* 462: 25–34
- Koste W (1974) Zur Kenntnis der Rotatorienfauna der ‘schwimmenden Weise’ einer Uferlagune in der Varzea Amazoniens, Brasilien. *Amazoniana* 5: 25–60
- Koste W (1978) Rotatoria. Die Rädertiere Mitteleuropas, begründet von Max Voigt. Überordnung Monogononta. Gebürder Borntaeger, Berlin, Stuttgart. I. 673 pp U. II. Tafelbd. (T. 234)
- Koste W (1990) Zur Kenntnis der Rädertierfauna des Kinda-Stausees in Zentral-Burma (Aschelminthes: Rotatoria). *Osnabrücker Naturwissenschaftliche Mitteilungen* 16: 83–110
- Koste W, Robertson B (1983) Taxonomic studies of the Rotifera (Phylum Aschelminthes) from a central Amazonian varzea lake, Lago Camaleao (Ilha de Marchantaria, Rio Solimoes, Amazonas, Brazil). *Amazoniana* 7(2): 225–254.
- 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
- Mac Arthur, RH (1965) Patterns of species diversity. *Biological Revue* 40: 510–533
- 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
- Oertli B (2018) Freshwater biodiversity conservation: The role of artificial ponds in the 21st century. *Aquatic Conservation Marine and Freshwater Ecosystems* 28: 264–269
- Oertli B, Biggs J, Céréghino R, Declerck S, Hull A, Miracle MR. (eds) (2010) *Pond Conservation in Europe*. Dordrecht, the Netherlands: Springer
- Ranga Reddy Y (2013) *Neodiptomus prateek* n. sp., a new freshwater copepod from Assam, India, with critical review of generic assignment of *Neodiptomus* 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
- 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 bv. Amsterdam, the Netherlands.
- Segers H (1996) The biogeography of littoral *Lecane* Rotifera. *Hydrobiologia* 323: 169–197
- Segers H (2001) Zoogeography of the Southeast Asian Rotifera. *Hydrobiologia* 446/447: 233–246
- Segers H (2002) The nomenclature of the Rotifera, annotated checklist of valid family– and genus–group names. *Journal of Natural History* 36: 621–640
- Segers H (2004) Rotifera: Monogononta. Pp.106–119. In: Yule CM, Sen YH (eds) *Freshwater Invertebrates of the Malaysian Region*. Academy of Sciences Malaysia.
- Segers H (2007) Annotated checklist of the rotifers (Phylum Rotifera), with notes on nomenclature, taxonomy and distribution. *Zootaxa* 1564: 1–104
- Segers H, Dumont HJ (1995) 102+ rotifer species (Rotifera: Monogononta) in Broa reservoir (SP., Brazil) on 26 August 1994, with the description of three new species. *Hydrobiologia* 316: 183–197
- Segers H, Ferrufino NL, De Meester L (1998) Diversity and zoogeography of Rotifera (Monogononta) in a flood plain lake of the Ichilo River, Bolivia, with notes on little known species. *International Review of Hydrobiology* 83: 439–448
- Segers H, Nwadiaro CS, Dumont HJ (1993) Rotifera of some lakes in the floodplain of the river Niger (Imo State, Nigeria). II. Faunal composition and diversity. *Hydrobiologia* 250: 63–71
- Segers H, Pholpunthin P (1997) New and rare Rotifera from Rivers for Life Thale Noi Lake, Pattalang Province, Thailand, with a note on the taxonomy of Cephalodella (Notommatidae). *Annals Limnologie* 33: 13–21
- Segers H, Sanoamuang L (2007) Note on a highly diverse rotifer assemblage (Rotifera: Monogononta) in a Laotian rice paddy and adjacent pond. *Internationale Revue Hydrobiologie* 92(6): 640–646
- Serafim M Jr, Bonecker CC, Rossa DC, Lansac-Tôha FA, Costa CL (2003) Rotifers of the Upper Paraná River floodplain: additions to the checklist. *Brazilian Journal of Biology* 63(2): 207–212

- Sharma BK (1983) The Indian species of the genus *Brachionus* (Eurotatoria: Monogononta: Brachionidae). *Hydrobiologia* 104: 31–39
- Sharma BK (1987a) Indian Brachionidae (Eurotatoria: Monogononta) and their distribution. *Hydrobiologia* 144: 269–275
- Sharma BK (1987b). On the distribution of lecanid rotifers (Rotifera: Monogononta: Lecanidae) in North-Eastern India. *Revue Hydrobiologie tropicale* 20: 101–105
- 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 (2009) Diversity of Rotifers (Rotifera: Eurotatoria) of Loktak lake, North-eastern India. *Tropical Ecology* 50(2): 277–285.
- 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, Haokip TP, Sharma S (2016) Loktak lake, Manipur, northeast India: a Ramsar with rich rotifer (Rotifera: Eurotatoria) diversity and its meta-analysis. *International Journal of Aquatic Biology* 4(2): 69–79
- 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, Noroh N, Sharma S (2017) Rotifers (Rotifera: Eurotatoria) from floodplain lakes of the Dibru Saikhowa Biosphere Reserve, upper Assam, northeast India: ecosystem diversity and biogeography. *International Journal of Aquatic Biology* 5(2): 79–94.
- Sharma BK, Sharma S (1997) Lecanid rotifers (Rotifera: Monogononta: Lecanidae) from North-Eastern India. *Hydrobiologia* 356: 157–163
- 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) Indian Lecanidae (Rotifera: Eurotatoria: Monogononta) and its distribution. In: Sharma BK, Dumont HJ, Wallace RL (eds) Rotifera XIII: Rotifer Biology – a Structural and Functional Approach. *International Review of Hydrobiology* 99(1–2): 38–47
- Sharma BK, Sharma S (2014c) The diversity of Indian Brachionidae (Rotifera: Eurotatoria: Monogononta) and their distribution. *Opuscula Zoologica Budapest* 45(2): 165–180
- Sharma BK, Sharma S (2015a) The diversity and distribution of Lepadellidae (Rotifera: Eurotatoria: Monogononta) of India. *International Review of Hydrobiology* 100 (1): 34–42
- Sharma BK, Sharma S (2015b) 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) The Indian species of *Testudinella* (Rotifera: Flosculariacea: Testudinellidae) and their distribution. *International Journal of Aquatic Biology* 6(1): 15–20.
- Sharma BK, Sharma S (2018b) 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 (2018c) 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 BK, Sharma S (2019a) The biodiverse rotifer assemblages (Rotifera: Eurotatoria) of Arunachal Pradesh, the eastern Himalayas: alpha diversity, distribution and interesting features. *Bonn zoological Bulletin* 68(1): 1–12
- Sharma BK, Sharma S (2019b) The biodiverse rotifers (Rotifera: Eurotatoria) of the floodplain wetlands of Barak valley of Assam state, northeast India. *Opuscula Zoologica Budapest* 50(1): 3–15.
- Sharma BK, Sharma S (2019c) The biodiverse rotifers (Rotifera: Eurotatoria) from small wetlands of the Brahmaputra river floodplains of lower and upper Assam, northeast India. *Journal of Limnology and Freshwater Fisheries Research* DOI: 10.17216/LimnoFish-15981
- 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. Zoological Survey of India, Kolkata
- Sor R, Meas S, Wong KY, Min M, Segers H (2015) Diversity of Monogononta rotifer species among standing water bodies in northern Cambodia. *Journal of Limnology* 74(1): 192–204
- 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
- Trinh MD, Vo MV, Traw ANQ, Le HTN, Tran SN (2019) Species diversity of rotifers (Rotifera: Eurotatoria) of Phu Ninh Lake with five new records from Vietnam. *International Journal of Aquatic Biology* 7(1): 38–44.
- Tuyor JB, Segers H (1999) Contribution to the knowledge of the Philippine freshwater zooplankton: new records of monogonont Rotifera. *International Review of Hydrobiology* 84: 175–180.
- Vad CF, Péntek A, Cozma NJ, Földi A, Tóth A, Tóth B, Böde NA, Móra A, Ptacnik R, Ács E, Zsuga K, Horváth Z (2017) Wartime scars or reservoirs of biodiversity? The value of bomb crater ponds in aquatic conservation. *Biological Conservation* 209: 253–262



Sharma, Bhushan Kumar and Sharma, Sumita. 2019. "The biodiverse rotifers (Rotifera: Eurotatoria) of Northeast India: faunal heterogeneity, biogeography, richness in diverse ecosystems and interesting species assemblages." *Bonn zoological bulletin* 68(1), 147–162.

View This Item Online: <https://www.biodiversitylibrary.org/item/314381>

Permalink: <https://www.biodiversitylibrary.org/partpdf/409805>

Holding Institution

Zoologisches Forschungsmuseum Alexander Koenig

Sponsored by

Zoologische Forschungsmuseum Alexander Koenig

Copyright & Reuse

Copyright Status: In copyright. Digitized with the permission of the rights holder.

Rights Holder: Zoologisches Forschungsmuseum Alexander Koenig

License: <http://creativecommons.org/licenses/by-nc-sa/4.0/>

Rights: <http://biodiversitylibrary.org/permissions>

This document was created from content at the **Biodiversity Heritage Library**, the world's largest open access digital library for biodiversity literature and archives. Visit BHL at <https://www.biodiversitylibrary.org>.