

Original Article

The rotifers (Rotifera: Eurotatoria) from the Kashmir Himalayan floodplains and Rotifera biodiversity of Jammu and Kashmir, north India

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Abstract: Our plankton and semi-plankton collections from the floodplain wetlands of the Kashmir valley reveal 140 rotifer species belonging to 43 genera and 22 families. The richness forms ~81% of 173 species, belonging to 51 genera and 23 families, recognized as validly known from Jammu and Kashmir (J&K) vide the present biodiversity evaluation. The rotifer assemblages of the Kashmir Himalayan wetlands and J&K comprise ~33% and ~41%, respectively of the Indian Rotifera; their biodiverse nature is hypothesized to habitat diversity and ecological heterogeneity of aquatic environs of this state of north India. One species is new to India and 25 species are new to northwest India. Lecanidae > Brachionidae form ~33% and Trichocercidae = Lepadellidae > Notommatidae > Euchlanidae comprise ~31% of the rotifer fauna of J&K which includes species of global and regional biogeographic interest and, a large component of cosmopolitan species (~81%). *Lecane* > *Trichocerca* > *Brachionus* = *Lepadella* collectively comprise ~39%; *Keratella* > *Euchlanis* > *Synchaeta* are notable (~12%); and *Notholca* and *Cephalodella* species deserve attention from J&K. Rotifera of the Kashmir Himalayan floodplains and J&K indicate the littoral-periphytic character, cold-water elements, small-sized species, and the relative paucity of *Brachionus*, *Lepadella* and *Lecane* richness. We estimate 260+ rotifer species from J&K pending analysis of intensive latitudinal and longitudinal collections including samples from Ramsar sites, high altitude lakes and other water bodies with emphasis on colonial, sessile and benthic taxa, and analysis of likely cryptic diversity of certain species.

Article history:

Received 11 July 2018

Accepted 20 August 2018

Available online 25 August 2018

Keywords:

Composition

Distribution

Evaluation

Important taxa

Interesting species

Richness

Wetlands

Introduction

Rotifera has been studied from scattered localities of India ever since the first taxonomic survey by Anderson (1889). Nevertheless, the Indian literature still lacks intensive biodiversity works from various states or regions; and it is loaded with anomalous, ambiguous and fuzzy reports, and ad-hoc species lists due to unverifiable taxa (Sharma and Sharma, 2014a, 2014b; 2017, 2018a). These lacunae impede effective biodiversity evaluation notwithstanding that the Indian Rotifera is yet by no means fully explored. The stated generalizations hold valid for the rotifer fauna of Jammu and Kashmir (J&K) state of north India in spite of a sizable number of limnological studies (Shah et al., 2015) from the Kashmir valley and Jammu Province invariably enlisting the rotifers. Ironically, the compilation on the rotifers of Kashmir Himalayas by Shah (loc. cit) deserves caution due to inclusion of

duplicate species entries, invalid reports, misidentifications, and several un-validated species reports; the lapsi question the objectives of 'documentation' and 'authentication' of the stated work and its utility as a viable biodiversity reference. Further, the recent report of Litvinchuk (2018) lists only six rotifer species from the Kashmir Himalayas because of paucity of collections.

The state of Jammu and Kashmir, a part of the Himalayan biodiversity 'hot-spot', is dotted with Ramsar sites, the floodplain wetlands, and lakes and water bodies located under varied ecological regimes which offer prime scope for exploration of aquatic metazoan biodiversity and that of Phylum Rotifera in particular. The latter taxon has received inadequate attention from J&K in spite of 35+ publications (Shah et al., 2015) and several unpublished research dissertations listing the rotifers ever since the first

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report by Edmondson and Hutchinson (1934). Additionally, the published works from this state are frequented with sloppy identifications and fuzzy records warranting validations, and incomplete species lists due to overlooking identification of the smaller rotifer taxa (Sharma and Sharma, 2017). The present endeavor is thus an attempt to provide an evaluation of Rotifera biodiversity of J&K based on our collections from the floodplains of the Kashmir Himalayas as well as 'critical assessment and validation' of the viable published records. We provide a detailed inventory of the valid and authenticated rotifer taxa known till date from J&K while certain interesting taxa are illustrated to warrant validations. Comments are made on nature and composition of the faunal diversity, anomalous records, distribution of several species, important taxa, and salient features of the rotifer assemblages of the Kashmir Himalayan floodplains and J&K. This study merits interest for biodiversity and biogeography of Rotifera of India, the Kashmir Himalayas and the Indian floodplains.

Materials and Methods

The present observations are based on analysis of our plankton and semi-plankton samples collected, during January-February 2014, July-August 2014, February 2015, June 2015 and November 2016 from various lakes and small wetlands from the floodplains of the Kashmir valley (Fig. 1A-C). The samples were collected by towing a nylobolt plankton net (50 μm) and were preserved in 5% formalin. All the samples were screened with Wild-stereoscopic binocular, individual rotifers were isolated and mounted in polyvinyl alcohol-lactophenol mixture and were observed with a Leica DM 1000 phase contrast microscope. The micro-photographs of various species were taken using an image analyzer. The rotifer taxa were identified following Koste (1978), Segers (1995, 2003), Sharma (1983, 1998), Sharma and Sharma (1999, 2000, 2008, 2013, 2018b) and Jersabek and Leitner (2013). The voucher collections were in the holdings of Department of Zoology, North-Eastern Hill University, Shillong. In addition,

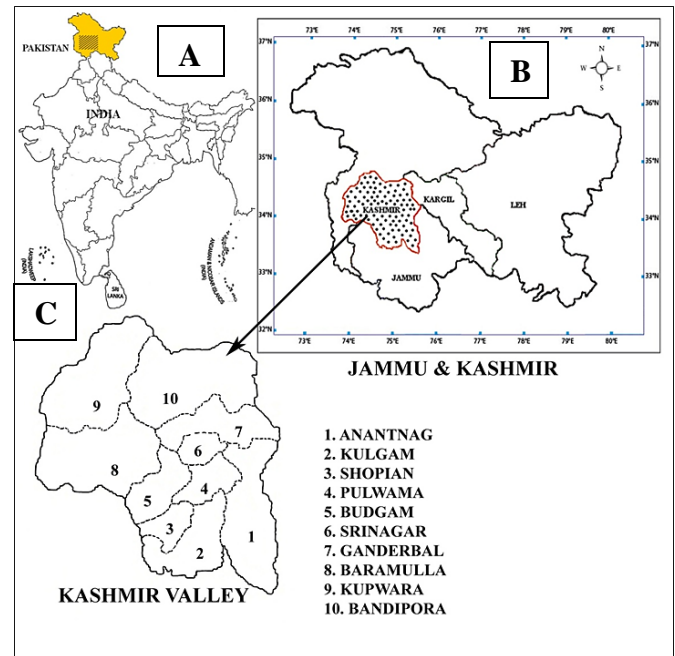


Figure 1. A-C: (A) Map of India indicating the state of Jammu and Kashmir, (B) map of Jammu and Kashmir indicating Kashmir valley and (C) map of Kashmir valley indicating the sampled districts.

the viable published records from Jammu and Kashmir State were evaluated for the validity and inclusion in our rotifer species inventory.

Results

A total of 140 Rotifera species (marked as *: Appendix I), spread over 43 genera and 22 families, are observed from our collections from the floodplain wetlands of the Kashmir valley, while we present a detailed systematic list of 173 species, belonging to 51 genera and 23 families, considered as validly recorded from J&K (Appendix I).

Lecane bulla diabolica (Fig. 2a) and *Testudinella insinuata* (Fig. 2b) are the Oriental endemics; and *Brachionus durgae* (Fig. 2c) is a cosmo (sub) tropical species. *Keratella hiemalis* (Fig. 2d), *K. serrulata* (Fig. 2e), *K. ticinensis* (Fig. 2f), *Notholca acuminata* (Fig. 2g), *N. labis* (Fig. 2h), *N. squamula* (Fig. 2j), *Testudinella mucronata* (Fig. 2k), *Trichocerca edmondsoni* (Fig. 2l) and *T. maior* (Fig. 2m) are other interesting species observed in our collections. Twenty-five species are new records from northwest India; these include *B. durgae*, *B. urceolaris*, *Beauchampiella eudactylota*, *Dissotrocha aculeata*,

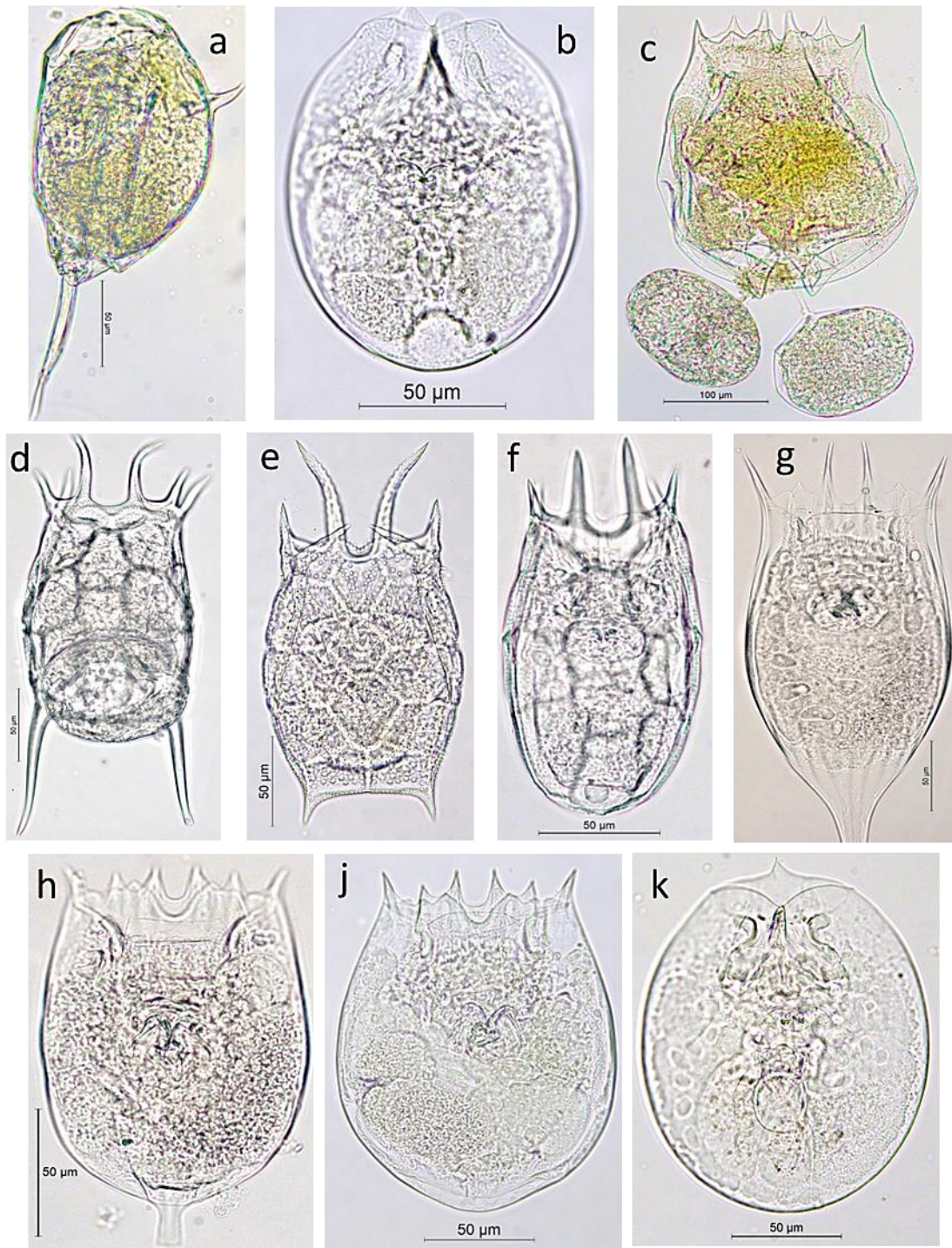


Figure 2. Interesting Rotifers from Jammu and Kashmir. (a) *Lecane bulla diabolica* (Hauer)(lateral view), (b) *Testudinella insinuata* Hauer (ventral view), after Sharma and Sharma (2018a), (c) *Brachionus durgae* Dhanapathi with parthenogenetic eggs (ventral view), (d) *Keratella hiemalis* Carlin (ventral view), (e) *Keratella serrulata* (Ehrenberg) (dorsal view), (f) *Keratella ticinensis* (Callerio) (ventral view), (g) *Notholca acuminata* (Ehrenberg) (ventral view), (h) *Notholca labis* Gosse (ventral view), (j) *Notholca squamula* (O.F. Muller) (ventral view) and (k) *Testudinella mucronata* (Gosse) (ventral view).

Keratella tecta, *Mytilina acanthophora* (Fig. 2n), *M. michelangellii* (Fig. 2o), *Lepadella benjamini* (Fig. 2p), *L. eurysterna*, *L. quadricarinata* (Fig. 2q), *Lecane arcula*, *L. bulla diabolica*, *L. hornemanni*,

L. inopinata, *L. monostyla*, *L. paxiana* (Fig. 2r), *L. obtusa*, *L. signifera*, *L. stenroosi*, *L. tenuiseta* (Fig. 2s), *L. undulata*, *Sinantherina socialis*, *Testudinella emarginula*, *T. parva* (Fig. 2t) and

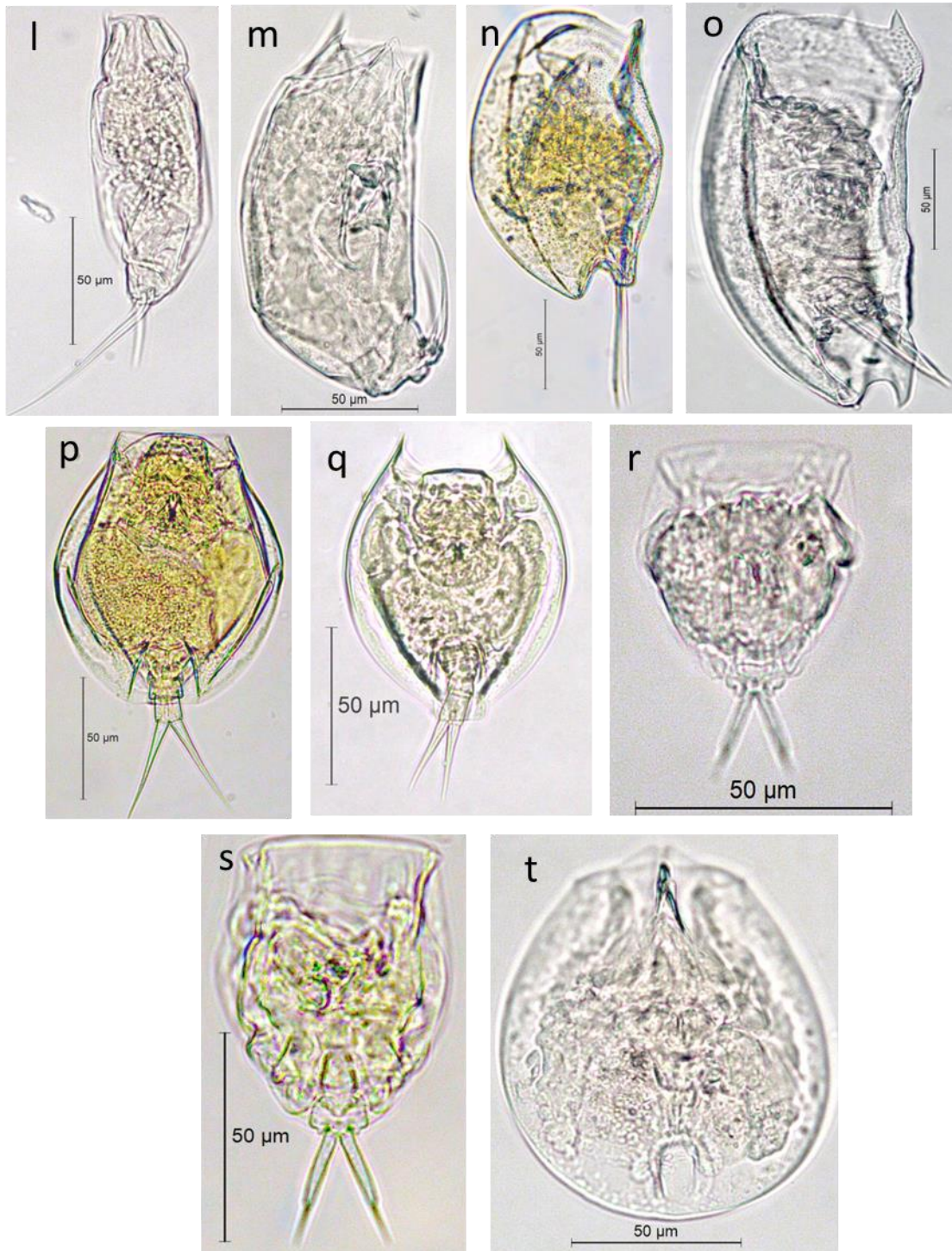


Figure 2. Continued. (l) *Trichocerca edmondsoni* (Myers) (lateral view), (m) *Trichocerca maior* Hauer (lateral view), (n) *Mytilina acanthophora* Hauer (lateral view), (o) *Mytilina michelangellii* Reid & Turner (lateral view), (p) *Lepadella benjamini* Haring (dorsal view), (q) *Lepadella quadricarinata* (Stenroos) (ventral view), (r) *Lecane paxiana* Hauer (ventral view), (s) *Lecane tenuiseta* Haring (ventral view) and (t) *Testudinella parva* (Ternetz) (ventral view).

Trichocerca maior.

Fourteen species recorded from J&K warrant validations; these are designated as 'un-verifiable', and thus are not included in our inventory:

Brachionus leydigii Cohn, 1862

Dicranophorus robustus Haring & Myers, 1928

Lecane arcuata (Bryce, 1891)

L. arcuata (Bryce, 1891) Unconfirmed

L. cornuta (Müller, 1786)

L. crenata (Haring, 1913)

L. depressa (Bryce, 1891)

L. elasma Haring & Myers, 1926

Notholca striata (Müller, 1786)

Platyias polycanthus Ehrenberg, 1834

Polyarthra remata Skorikov, 1896

Resticula melandocus (Gosse, 1887)

Sphyras lofuana (Rousselet, 1910)

Squatinella rostrum (Schmarda, 1846)

Cephalodella wiszniewskii Edmondson and Hutchinson 1934, described from Jammu and Kashmir, is a *species inquirendus* while *Diplois* sp. denotes *genus inquirendus*. *Keratella brehmi*, *Colurella oblonga*, *L. angulata*, *L. periptera* and *T. tetractis* are invalid species, while *K. valga* is a classic example of misidentification. A total of 83 species (marked as @: Appendix I) are not listed in the compilation by Shah et al. (2015).

Discussion

Our collections from the floodplain wetlands of the Kashmir valley record 140 rotifer species belonging to 43 genera and 22 families, while we consider 173 species, belonging to 51 genera and 23 families, as validly known as per the present evaluation of Rotifera biodiversity of Jammu and Kashmir (J&K) state of north India. Interestingly, the former represent a notable fraction (~81%) of the rotifer fauna of J&K and form ~33% of the Indian Rotifera. The richness recorded from J&K comprises ~40% of the rotifer species known from India (Sharma and Sharma, 2017), and this study records one of the richest higher level diversity of Eurotatoria genera and families known from India (Sharma and Sharma, 2017). The rich and diverse rotifer assemblages of J&K and the Kashmir Himalayan floodplains are hypothesized to habitat diversity and ecological heterogeneity of aquatic environs of this state in general and the floodplain wetlands in particular. The rotifer richness known from J&K concurs with 172 species observed from the eastern Himalayas (BKS, unpublished) as well as broadly with mean richness (177±29 species) examined from seven states of NEI (BKS, unpublished), while it presents distinct variations than 152, 162, 161, 150 and 189 species known from the states of Tripura (Sharma

and Sharma, 2000), Mizoram (Sharma and Sharma, 2015), Meghalaya (Sharma et al., 2016), Nagaland (Sharma et al., 2017) and Manipur (Sharma and Sharma, 2018a) of NEI, respectively. The comparisons, however, are not tenable with regards the detailed species composition of the rotifer assemblages of J&K and individual states of NEI.

The rotifer assemblages of the Kashmir Himalayan floodplains are biodiverse than the reports from certain global floodplains i.e., 114 species (Jose de Paggi, 2001) from the Rio Pilcomayo National Park (a Ramsar site) of Argentina; 124 species (Oguta lake) from the Niger delta (Segers et al., 1993) of Africa; 130 species from Lake Guarana, Brazil (Bonecker et al., 1994); 106 taxa from Thale-Noi Lake, a Ramsar site in Thailand (Segers and Pholpunthin, 1997); and 104 species from Laguana Bufeos of Bolivia (Segers et al., 1998) while it largely compares with the reports of 136 species (Iyi-Efi lake) from the Niger delta (Segers et al., 1993) of Africa and 151 (Koste, 1974) and 148 species from Rio Tapajos and Lago Camaleao (Koste and Robertson, 1983) of Brazil, respectively.

The species-rich and diverse nature of the rotifers of the Kashmir valley wetlands endorses our reports from the floodplains of NEI (Sharma and Sharma, 2014a, 2014b, 2017, 2018a) while yet fragmentary information from other floodplains of India hinders any effective comparison. The observed richness compares with the reports of 144 species from the Majuli River Island floodplains, upper Assam (Sharma et al., 2015) and 141 species from the floodplain lakes of the Dibru-Saikhowa Biosphere Reserve of the Brahmaputra river basin, upper Assam (Sharma et al., 2017), while it is lower than the reports of 164 species from 15 beels of lower Assam (Sharma, 2005); 162 species from Loktak Lake, Manipur (Sharma et al., 2016) and 160 species from four beels of Barpeta district of lower Assam (Sharma et al., 2018). The Kashmir valley wetlands, however, indicate higher rotifer richness than 110 species (Arora and Mehra, 2003) examined from the floodplains of the river Yamuna at Delhi. On the other hand, our rotifer inventory is distinctly biodiverse than the reports of 27 species from two floodplain lakes of Kashmir (Khan, 1987) and 38 species from four ox-

bow lakes and nine floodplain lakes of South-eastern West Bengal (Khan, 2003); these comparisons deserve caution because of incomplete species lists due to lack of adequate sampling and taxonomic delineations.

Rotifera richness presently reported from J&K and from the Kashmir valley floodplains marks a notable increase over 110 species enlisted from the Kashmir Himalayas by Shah et al. (2015). This comparison even assumes more prominence in light of much lower effective richness known vide the latter work because of anomalous inclusions of duplicate entries of 14 species, six invalid species, one lapsus and eight unvalidated species, while 22 taxa lack species determinations. Our biodiversity evaluation marks yet another distinct departure for non-inclusion of 83 species, belonging to 18 families, in the compilation by Shah et al. (2015). The stated aspects limit the objectives of 'documentation' and 'authentication' of the latter publication vis-a-vis our analysis of Rotifera of the Kashmir Himalayan wetlands. This state-of-art is attributed to routine species lists without validations in various 'ad-hoc' ecology works from J&K, lack of adequate sampling, overlooking identification of small rotifer taxa and even lack of taxonomic expertise. Our species inventory, however, excludes 14 species designated as 'reports inquerenda' without validations in any published work; the actual richness is thus likely to increase subjected to the future conformation and validation of these reports. Further, we categorize *Cephalodella wiszniewskii*, described as a new species from Jammu and Kashmir by Edmondson and Hutchinson (1934), as *species inquirendus* and *Diplois* sp. as *genus inquirendus* following Segers (2007), Jersabek and Leitner (2013) and Sharma and Sharma (2017). In addition, we consider the records (vide Shah et al., 2015) of *K. brehmi*, *C. oblonga*, *L. angulata*, *L. periptera* and *T. tetractis* as 'invalid species', while the reports of *K. valga* from J&K and elsewhere from India are examples of misidentification (Sharma and Sharma, 2014b).

The Oriental endemics *T. insinuata* and *L. bulla diabolica*; the cosmo (sub) tropical *B. durgae*, and *K. hiemalis*, *K. serrulata*, *N. acuminata*, *N. labis*, *T. edmondsoni* and *T. maior* are fewer species of global

distribution interest observed from J&K vide our collections from the Kashmir Himalayas. The relative paucity of the members of this category is hypothesized to 'geographic barrier' nature of high northern and western Himalayan mountains vis-à-vis Rotifera biogeography. This salient feature marks a significant departure than a sizable fraction of species of global biogeographic importance observed from the rotifer assemblages of NEI (Sharma and Sharma, 2005, 2014a, 2017, 2018a) and that of the eastern Himalayas (BKS, unpublished) in particular. The rotifer fauna of J&K is, however, notable for several examples of regional distribution interest for the Indian Rotifera namely: *Asplanchnopus multiceps*, *Cephalodella catellina*, *C. panarista*, *Conochilus hippocrepis*, *Collotheca campanulata*, *Cupelopagis vorax*, *Dicranophorus myriophylli*, *Eosphora najas*, *Euchlanis alata*, *Floscularia conifera*, *Hexarthra bulgarica*, *Horaella brehmi*, *Itura aurita*, *Lecane paxiana*, *L. tenuiseta*, *Lepadella benjamini*, *L. quadricarinata*, *Pompholyx complanata*, *Proales decipiens* *Mytilina acanthophora*, *M. bisulcata*, *M. michelangellii*, *M. mucronata*, *Notommata aurita*, *N. copeus*, *N. tripus*, *Synchaeta stylata*, *S. tremula*, *Testudinella mucronata*, *Trichocerca brachyura* and *T. cavia*. Of these, 14 species are reported from this state only by Edmondson and Hutchinson (1934) with *C. panarista*, *D. myriophylli*, *H. bulgarica*, *I. aurita*, *N. aurita*, *T. brachyura* and *S. tremula* even solely known from India vide the stated work. *Lecane paxiana*, *L. tenuiseta*, *Lepadella benjamini* and *L. quadricarinata* are exclusively observed in our collections from the Kashmir valley while *T. mucronata* is validly known from India only from J&K (Sharma and Sharma, 2018b).

Testudinella insinuata is added as a new record to the Indian Rotifera by Sharma and Sharma (2018b). Our collections from the wetlands of the Kashmir Himalayas reveal 25 species new to northwest India namely *B. durgae*, *B. urceolaris*, *Beauchampiella eudactylota*, *Dissotrocha aculeata*, *Keratella tecta*, *Mytilina acanthophora*, *M. michelangellii*, *Lepadella benjamini*, *L. eurysterna*, *L. quadricarinata*, *Lecane arcua*, *L. bulla diabolica*, *L. hornemanni*, *L. inopinata*,

L. monostyla, *L. paxiana*, *L. obtusa*, *L. signifera*, *L. stenroosi*, *L. tenuiseta*, *L. undulata*, *Sinantherina socialis*, *Testudinella emarginula*, *T. parva* and *Trichocerca maior*. The report of the Oriental endemic *L. bulla diabolica* from J&K indicates notable extension of distribution of this lecanid to north India with its disjunct populations known till date from NEI and Tamil Nadu (Sharma and Sharma, 2014a, 2017). Besides, this study marks extension of distribution ranges of *Dissotrocha aculeata*, *M. michelangellii*, *L. benjamini*, *L. tenuiseta*, and *T. maior* to the Kashmir Himalayas as against earlier Indian reports only from NEI (Sharma and Sharma, 2017).

Eleven Eurotatoria families comprise bulk (~83%) of species known from J&K thus depicting widespread nature of the rotifer species composition. Of these, Lecanidae ≥ Brachionidae form ~33%; Trichocercidae = Lepadellidae > Notommatidae > Euchlanidae comprise ~31% while Synchaetidae, Testudinellidae, Mytilinidae, Gastropodidae and Trochosphaeridae collectively represent ~19%. This trend is also observed in the collections from the Kashmir Himalayan floodplains with increased importance of the first five families (~70% of species known from wetlands) but with Lepadellidae > Trichocercidae while Synchaetidae, Testudinellidae and Mytilinidae are other three notable families (13.6%). Nevertheless, the relatively lower richness of Lecanidae and Lepadellidae marks a distinct contrast to composition of Rotifera of NEI and its floodplains (Sharma and Sharma, 2014a, 2018a) as well as elsewhere from India (Sharma and Sharma, 2017). The relatively rich Brachionidae is due to occurrence of species of the record seven genera (Sharma and Sharma, 2014b). The importance pattern of the stated families in general imparts the littoral-periphytic character to the rotifer assemblages of J&K and to the floodplain wetland of the Kashmir Himalayas. The latter are characterized by several small-sized species of *Colurella*, *Lecane*, *Lepadella* and *Trichocerca*; this feature is hypothesized to influence of juvenile fish and invertebrate predation (Baumgartner et al., 1997) concurrent with our remarks from NEI floodplains (Sharma, 2005, 2014; Sharma and Sharma, 2014a, 2018a).

The 'tropic-centred' *Lecane* is relatively speciose genus (~17% and ~21%); *Trichocerca* > *Brachionus* = *Lepadella* collectively comprise ~22% and ~25% and species of the 'temperate-centred' *Keratella* > *Cephalodella* > *Synchaeta* are noteworthy (~12%, ~10%) features of the rotifer assemblages of J&K and that of the Kashmir Himalayan wetlands, respectively. The 'temperate-centred' *Keratella*, *Notholca* and *Cephalodella* also deserve attention while the report of eight *Keratella* spp. marks a notable feature of the Indian Brachionidae (Sharma and Sharma, 2014b, 2017) which holds parallel to our exclusive report from the eastern Himalayas (BKS, unpublished). The rotifers from J&K and the Kashmir valley floodplains highlight relative paucity of *Brachionus*, *Lepadella* and even of *Lecane* richness than known from NEI (Sharma and Sharma, 2014a, 2018a) and elsewhere from India (Sharma and Sharma, 2017). The paucity of *Brachionus* spp., however, corresponds with our reports from the floodplains of the Majuli River Island (Sharma, 2014) and the Dibru-Saikhowa Biosphere reserve (Sharma et al., 2017) of upper Assam, and the Loktak Lake basin of Manipur (Sharma and Sharma, 2018a), NEI. The rotifer faunas of J&K and the Kashmir wetlands thus shows a combination of 'tropic' and 'cold-water' elements concurrent with our report (BKS, unpublished) from the eastern Himalayas but this feature is in distinct departure to the reports from other states of NEI (Sharma and Sharma, 2014a, 2015, 2018a). Further, the cosmopolitan species form a large fraction (~81%), while tropicopolitan and pantropical species together comprise ~13% of the rotifer fauna of J&K; the former out-number the reports from NEI (Sharma and Sharma, 2014a) and elsewhere from India (Sharma and Sharma, 2017).

The collections from the Kashmir valley floodplains are notable for morphological variations of *Brachionus angularis*, *B. bidentatus*, *B. calyciflorus*, *B. caudatus*, *B. quadridentatus*, *Euchlanis dilatata*, *Keratella cochlearis*, *Lecane bulla*, *L. closteroerca*, *L. curvicornis*, *L. hamata*, *L. leontina*, *L. luna*, *L. lunaris*, *L. ludwigii*, *L. papuana*, *L. quadridentata*, *L. signifera*, *L. unguitata*, *L. ungulata*, *Lepadella costatoides*, *L. ovalis*, *L. patella*, *Plationus patulus*,

Testudinella emarginula, *T. patina* and *T. tridentata* populations. Molecular analysis of likely cryptic diversity of the stated species is desired in light of some interesting related works of Schröder and Walsh (2010) and Mills et al. (2017). In addition, the concept of 'reverse taxonomy' by combining morphometric, morphological and phylogenetic analyses (Michaloudi et al., 2018) merits future interest.

To sum up, the present study highlights the species-rich and diverse Rotifera assemblages of J&K and the floodplain wetlands of the Kashmir Himalayas which, in turn, are hypothesized to habitat diversity and environmental heterogeneity of the sampled aquatic biotopes. Various new records; species of global and regional biogeographic interest with relative paucity of the former; the littoral-periphytic nature of the two assemblages with reports of several small-sized species; the occurrence of 'tropical vs. temperate' taxa; high richness of Brachionidae and the relatively low richness of Lepadellidae and even of Lecanidae are notable features. This study merits biodiversity and biogeographic importance as the first-ever critical evaluation and validation of Rotifera biodiversity J&K and ecosystem diversity interest for the Kashmir Himalayan floodplains in particular. As our collections are biased to the planktonic and semi-planktonic taxa, specific analysis of sessile, colonial and benthic taxa are desired along with intensive latitudinal and longitudinal collections, including those from Ramsar sites and high altitude lakes and other water bodies. Analysis of likely cryptic diversity in certain species-groups following 'molecular vs. reverse taxonomy' marks future interest. We estimate 260+ Rotifera species from J&K with more interesting elements from the Kashmir Himalayas and Ladak plateau with the latter as yet being practically un-explored vis-a-vis the Indian Rotifera.

Acknowledgements

The senior author (BKS) thanks the Head, Department of Zoology, North-Eastern Hill University, Shillong for laboratory facilities. The collection for this study was initiated by A. Perrey who joined research under the senior author but decided to discontinue without any

response to the official contacts till date. This work would not have been completed without help of N. Ahmad Bhat, Research Scholar, Centre for Advanced Studies in Botany, North-Eastern Hill University, Shillong and various friends for helping us in the subsequent collections from the Kashmir valley. The authors have no conflict of interests.

References

- Anderson H.H. (1889). Notes on Indian Rotifers. Journal of the Asiatic Society of Bengal, 58: 345-358.
- Arora J., Mehra N.K. (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 K.M., Cavicchiolo M., Baugartner M.S. (1997). Some aspects of the ecology of fish larvae in the floodplain of the high Parana River, Brazilian Review of Zoology, 14: 551-563.
- Bonecker C.C., Lansac-Tôha F.A., Staub A. (1994). Qualitative study of Rotifers in different environments of the high Para-na River floodplain (Ms), Brazil. Revista UNIMAR, 16: 1-16.
- Edmondson W.T., Hutchinson G.E. (1934). Yale North Indian expedition. Article IX, Report on Rotatoria. Memoirs of the Connecticut Academy of Arts, Science and Letters, 10: 153-186.
- Jersabek C.D., Leitner M.F. (2013). The Rotifer world catalog. <http://www.rotifera.hausdernatur.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.
- Khan M.A. (1987). Observations on zooplankton composition, abundance and periodicity in two flood-plain lakes of the Kashmir Himalayan valley. Acta Hydrochemica Hydrobiologica, 15: 167-174.
- Khan R.A. (2003). Faunal diversity of zooplankton in freshwater wetlands of Southeastern West Bengal. Records of the Zoological Survey of India, Occasional Paper, 204: 1-107.
- 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.

- Gebrüder Borntraeger, Berlin, Stuttgart. I. 673 pp U. II. Tafelbd. (T. 234).
- 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.
- Litvinchuk L.F. (2018). Zooplankton of mountain and lowland water bodies of northwestern India. *Proceeding of the Zoological institute of Russian Academy of Sciences*, 322 (1): 66-83. (In Russian)
- Michaloudi E., Papakostas S., Stamou G., Neděla V., Tihlaříková E., Wei Zhang W., Declerck S.A.J. (2018). Reverse taxonomy applied to the *Brachionus calyciflorus* cryptic species complex: morphometric analysis confirms species delimitations revealed by molecular phylogenetic analysis and allows the (re) description of four species. *PLoS ONE* 13(9): e0203168.
- Mills S., Alcántara-Rodríguez J.A., Ciroso-Pérez J., Gómez A., Hagiwara A., Galindo K.H., Jersabek C.D., Malekzadeh-Viayeh Leasi R.F., Lee J.S., Mark Welch D.B., Papakostas S., Riss S., Segers H., Serra M., Shiel R., Smolak R., Snell T.W., Stelzer C.P., Tang C.Q., Wallace R.L., Fontaneto D, Walsh E.J. (2017). Fifteen species in one: deciphering the *Brachionus plicatilis* species complex (Rotifera, Monogononta) through DNA taxonomy. *Hydrobiologia*, 96: 39-58.
- Schröder T., Walsh E.J. (2010). Genetic differentiation, behavioural reproductive isolation and mixis cues in three sibling species of monogonont rotifers. *Freshwater Biology*, 55: 2570-2584.
- Segers H. (1995). Rotifera 2: Lecanidae. In: H.J. Dumont, T. Nogrady (Eds). *Guides to identification of the microinvertebrates of the Continental Waters of the World*. Amsterdam, the Netherlands: SPB Academic Publishing. pp: 1-226.
- 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.
- Segers H., Ferrufino N.L., 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 C.S., Dumont H.J. (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, Thai-land, with a note on the taxonomy of *Cephalodella* (Notommatidae). *Annals Limnologiae*, 33: 13-21.
- Shah J.A., Pandit A.K., Mustafa Shah G. (2015). A research on rotifers of aquatic ecosystems of Kashmir Himalaya for documentation and authentication. *Proceedings of National Academy of Sciences, India: Section B Biological Sciences*, 85(1): 13-19.
- Sharma B.K. (1983). The Indian species of the genus *Brachionus* (Eurotatoria: Monogononta: Brachionidae). *Hydrobiologia*, 104: 31-39.
- Sharma B.K. (1998). Freshwater Rotifers (Rotifera: Eurotatoria). In: *Fauna of West Bengal. State Fauna Series*, 3(11): 341– 461.
- Sharma B.K. (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 B.K. (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 B.K., Haokip T.P., Sharma S. (2016). Loktak Lake, Manipur, northeast India: a Ramsar site with rich rotifer (Rotifera: Eurotatoria) diversity and its meta-analysis. *International Journal of Aquatic Biology*, 4(2): 69-79.
- Sharma B.K., Khan S.I., 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 B.K., 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 B.K., Sharma S. (1999). Freshwater Rotifers (Rotifera: Eurotatoria). In: *Fauna of Meghalaya. State Fauna Series*, Zoological Survey of India, Calcutta, 4(9): 11-161.
- Sharma B.K., Sharma S. (2000). Freshwater Rotifers (Rotifera: Eurotatoria). In: *Fauna of Tripura: State Fauna Series*, Zoological Survey of India, Calcutta, 7(4): 163-

224.

- Sharma B.K., Sharma S. (2005a). Biodiversity of freshwater rotifers (Rotifera: Eurotatoria) from North-Eastern India. *Mitteilungen aus dem Museum für Naturkunde Berlin, Zoologische Reihe*, 81: 81-88.
- Sharma B.K., Sharma S. (2014a). Northeast India - An important region with a rich biodiversity of Rotifera. In: B.K. Sharma, H.J. Dumont, R.L. Wallace (Eds.). *Rotifera XIII: Rotifer Biology - A structural and functional Approach*. *International Review of Hydrobiology*, 99(1-2): 20-37.
- Sharma B.K., Sharma S. (2014b). The diversity of Indian Brachionidae (Rotifera: Eurotatoria: Monogononta) and their distribution *Opuscula Zoologica Budapest*, 45(2): 165-180.
- Sharma B.K., 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 B.K., Sharma S. (2017). Rotifera: Eurotatoria (Rotifers). In: K. Chandra, K.C. Gopi, D.V. Rao, K. Valarmathi, J.R.B Alfred (Eds.). *Current status of freshwater faunal diversity in India*, Zoological Survey of India, Kolkata. pp: 93-113.
- Sharma B.K., 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 B.K., Sharma S. (2018b). The Indian species of *Testudinella* (Rotifera: Flosculariacea: Testudinellidae) and their distribution. *International Journal of Aquatic Biology*, 6(1): 15-20.
- Sharma B.K., Sharma S., Hatimuria M.K. (2015). Rotifer assemblages (Rotifera: Eurotatoria) of the floodplain lakes of Majuli River Island, the Brahmaputra river basin, northeast India. *International Journal of Aquatic Biology*, 3(1): 1-13.
- Sharma S., Sharma B.K. (2008). Zooplankton diversity in floodplain lakes of Assam. *Records of the Zoological Survey of India, Occasional Paper*, 290: 1-307.
- Sharma S., Sharma B.K. (2013). Faunal diversity of aquatic invertebrates of Deepor Beel (a Ramsar site), Assam, northeast India. *Wetland Ecosystem Series*, 17: 1-226.

Appendix I: Systematic list of Rotifera known from Jammu and Kashmir.**Phylum: Rotifera****Class: Eurotatoria****Subclass: Monogononta****Order: Ploima****Family: Brachionidae**

1. *Anuraeopsis fissa* (Gosse, 1851) *
2. *A. navicula* Rousselet, 1911*
3. *Brachionus angularis* Gosse, 1851 *
4. *B. bidentatus* Anderson, 1889 *
5. *B. calyciflorus* Pallas, 1766 *
6. *B. caudatus* Barrois & Daday, 1894 *
7. *B. durgae* Dhanapathi, 1974 *#@
8. *B. falcatus* Zacharias, 1898 *
9. *B. forficula* Wierzejski, 1891 *
10. *B. plicatilis* O.F. Muller, 1786
11. *B. quadridentatus* Hermann, 1783 *
12. *B. rubens* Ehrenberg, 1838 *
13. *B. urceolaris* O. F. Muller, 1773 *#@
14. *Kellicottia longispina* (Kellicott)
15. *Keratella cochlearis* (Gosse, 1851) *
16. *K. hiemalis* Carlin, 1943 *
17. *K. procurva* (Thorpe, 1891) *
18. *K. quadrata* (O. F. Muller, 1786) *
19. *K. serrulata* (Ehrenberg, 1838) *@
20. *K. tecta* (Gosse, 1851) *#@
21. *K. ticinensis* (Callerio, 1921) *@
22. *K. tropica* (Apstein, 1907) *
23. *Notholca acuminata* (Ehrenberg, 1832) *@
24. *N. labis* Gosse, 1887 *
25. *N. squamula* (O.F. Muller, 1786) *@
26. *Plationus patulus* (O.F. Muller, 1786) *
27. *Platylabus quadricornis* (Ehrenberg, 1832) *

Family: Epiphanidae

28. *Epiphanes brachionus* (Ehrenberg, 1837) * @
29. *E. senta* (O.F. Muller, 1773)

Family: Euchlanidae

30. *Beauchampiella eudactylota* (Gosse, 1886) *#@
31. *Dipleuchlanis propatula* (Gosse, 1886) *@
32. *Euchlanis alata* Voronkov, 1912
33. *E. calpidia* (Myers, 1930)
34. *E. deflexa* Gosse, 1851
35. *E. dilatata* Ehrenberg, 1832 *
36. *E. incisa* Carlin, 1939 *@
37. *E. meneta* Myers, 1930@
38. *E. oropha* Gosse, 1887 * @
39. *Tripleuchlanis plicata* (Levander, 1894) *@

Family: Mytilinidae

40. *Lophocharis oxyterson* (Gosse, 1851) *@
41. *L. salpina* (Ehrenberg, 1834) *@
42. *Mytilina acanthophora* Hauer, 1938 *#@

43. *M. bisulcata* (Lucks, 2012) *@
44. *M. michelangellii* Reid & Turner, 1988 *#@
45. *M. mucronata* (O.F. Muller, 1773) *
46. *M. ventralis* (Ehrenberg, 1830) *

Family: Trichotriidae

47. *Macrochaetus collinsi* (Gosse, 1867) *
48. *Trichotria pocillum* (O.F. Muller, 1776)
49. *T. tetractis* (Ehrenberg, 1830) *

Family: Lepadellidae

50. *Colurella adriatica* Ehrenberg, 1831 *
51. *C. colurus* (Ehrenberg, 1830) *@
52. *C. obtusa* (Gosse, 1886) *
53. *C. uncinata* (O.F. Muller, 1773) *
54. *Lepadella acuminata* (Ehrenberg, 1834) *
55. *L. benjamini* Haring, 1916 *#@
56. *L. cristata* (Rousselet, 1893) * @
57. *L. ehrenbergi* (Perty, 1850) *
58. *L. eurysterna* Myers, 1942*#@
59. *L. heterostyla* (Murray, 1913) * @
60. *L. ovalis* (O.F. Muller, 1786) *
61. *L. patella* (O.F. Muller, 1773) *
62. *L. quadricarinata* (Stenroos, 1898) *#@
63. *L. rhomboides* (Gosse, 1886) *
64. *L. triptera* Ehrenberg, 1832*@
65. *Squatinella lamellaris* (O. F. Müller, 1786) *

Family: Lecanidae

66. *Lecane aculeata* (Jakubski, 1912) *
67. *L. arcula* Haring, 1914 *#@
68. *L. bulla* (Gosse, 1851) *
L. bulla diabolica (Hauer, 1936) *@
69. *L. closterocerca* (Schmarda, 1859) *
70. *L. crepida* Haring, 1914 *
71. *L. curvicornis* (Murray, 1913) *@
72. *L. decipiens* (Murray, 1913) *
73. *L. flexilis* (Gosse, 1886) *
74. *L. furcata* (Murray, 1913) *
75. *L. hamata* (Stokes, 1896) *
76. *L. hornemanni* (Ehrenberg, 1834) *#@
77. *L. inermis* (Bryce, 1892) *#@
78. *L. inopinata* Haring & Myers, 1926 *#@
79. *L. leontina* (Turner, 1892) *@
80. *L. ludwigii* (Eckstein, 1883) *
81. *L. luna* (Müller, 1776) *
82. *L. lunaris* (Ehrenberg, 1832) *
83. *L. monostyla* (Daday, 1897) *#@
84. *L. nana* (Murray, 1913) *

85. *L. obtusa* (Murray, 1913) *#@
 86. *L. papuana* (Murray, 1913) *@
 87. *L. paxiana* Hauer, 1940 *#@
 88. *L. pyriformis* (Daday, 1905) *
 89. *L. quadridentata* (Ehrenberg, 1830) *
 90. *L. signifera* (Jennings, 1896) *#@
 91. *L. stenroosi* (Meissner, 1908) *#@
 92. *L. sympoda* Hauer, 1929 *
 93. *L. tensuiseta* Haring, 1914 *#@
 94. *L. undulata* Hauer, 1938 *#@
 95. *L. unguolata* (Gosse, 1887) *

Family: Proalidae

96. *Proales decipiens* (Ehrenberg, 1832) @

Family: Notommatidae

97. *Cephalodella auriculata* (O.F. Müller, 1773) @
 98. *C. catellina* (O.F. Müller, 1786) *@
 99. *C. exigua* (Gosse, 1886) *
 100. *C. gibba* (Ehrenberg, 1830) *
 101. *C. intuta* Myers, 1924@
 102. *C. panarista* Myers, 1924 @
 103. *Eosphora najas* Ehrenberg, 1830@
 104. *Itura aurita* (Ehrenberg, 1830) @
 105. *Monommata grandis* Tessin, 1890 *@
 106. *Notommata aurita* (Müller, 1786) @
 107. *N. copeus* Ehrenberg, 1834* @
 108. *N. tripus* Ehrenberg, 1838* @

Family: Scaridiidae

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

Family: Gastropodidae

110. *Ascomorpha ecaudis* Perty, 1850
 111. *A. saltans* Bartsch, 1870 *
 112. *A. ovalis* (Bergendal, 1892) *@
 113. *Ascomorphella volvocicola* (Plate, 1886)
 114. *Gastropus hyptopus* (Ehrenberg, 1838) *@
 115. *G. stylifer* Imhof, 1891@

Family: Trichocercidae

116. *Trichocerca bicristata* (Gosse, 1887) *@
 117. *T. brachyura* (Gosse, 1851) *@
 118. *T. cavia* (Gosse, 1886) @
 119. *T. cylindrica* (Imhof, 1891) *
 120. *T. edmondsoni* (Myers, 1936) *
 121. *T. elongata* (Gosse, 1886) *@
 122. *T. iernis* (Gosse, 1887) *@
 123. *T. insignis* (Herrick, 1885) *
 124. *T. longiseta* (Schrank, 1802) *
 125. *T. maior* Hauer, 1936 *#
 126. *T. porcellus* (Gosse, 1881)
 127. *T. rattus* (O.F. Müller, 1776) *
 128. *T. ruttneri* Donner, 1953 *@
 129. *T. similis* (Wierzejski, 1893) *@
 130. *T. tigris* (O.F. Müller, 1786) *
 131. *T. weberi* (Jennings, 1903) *

Family: Asplanchnidae

132. *Asplanchna brightwelli* Gosse, 1850 *

133. *A. priodonta* Gosse, 1850 *
 134. *A. sieboldi* (Leydig, 1854)
 135. *Asplanchnopus multiceps* (Schrank, 1793)

Family: Synchaetidae

136. *Ploesoma lenticulare* Herrick, 1885 * @
 137. *Polyarthra dolichoptera* Idelson, 1925 *@
 138. *P. euryptera* Wierzejski, 1891
 139. *P. vulgaris* Carlin, 1943 *
 140. *Synchaeta oblonga* Ehrenberg, 1832 *@
 141. *S. pectinata* Ehrenberg, 1832 *
 142. *S. stylata* Wierzejski, 1893 *
 143. *S. tremula* (O.F. Müller, 1786) @

Family: Dicranophoridae

144. *Dicranophorus epicharis* Haring & Myers, 1928 *
 145. *D. myriophylli* (Haring, 1913) @
 146. *D. robustus* Haring & Myers, 1928

Order: Flosculariaceae**Family: Floscularidae**

147. *Floscularia conifera* (Hudson, 1886) @
 148. *Sinatherina socialis* (Linne, 1758) *#@

Family: Conochilidae

149. *Conochilus dossuarius* Hudson, 1885@
 150. *C. hippocrepis* (Schrank, 1803) @
 151. *C. unicornis* Rousset, 1892 *

Family: Hexarthridae

152. *Hexarthra bulgarica* (Wiszniewski, 1933) @
 153. *H. intermedia* (Wiszniewski, 1929)
 154. *H. mira* (Hudson, 1871) *

Family: Testudinellidae

155. *Pompholyx complanata* Gosse, 1851
 156. *P. sulcata* Hudson, 1885 *@
 157. *Testudinella emarginula* (Stenroos, 1898) *#@
 158. *T. insinuata* Hauer, 1938 *@
 159. *T. mucronata* (Gosse, 1886) *@
 160. *T. parva* (Ternetz, 1892) *#@
 161. *T. patina* (Hermann, 1783) *@

Family: Trochosphaeridae

162. *Filinia longiseta* (Ehrenberg, 1834) *
 163. *F. opoliensis* (Zacharias, 1898) *
 164. *F. terminalis* (Plate, 1886) *
 165. *Horaella brehmi* Donner, 1949
 166. *Trochosphaera solstitialis* Thorpe, 1893 *

Order: Collothecaceae**Family: Atrochidae**

167. *Cupelopagis vorax* (Leidy, 1857) *@

Family: Collothecidae

168. *Collothea campanulata* (Dobie, 1849) @
 169. *C. ornata* (Ehrenberg, 1832) *

Sub-class: Digononta**Order: Bdelloidea****Family: Philodinidae**

170. *Dissotrocha aculeata* (Ehrenberg, 1832) *#@

171. *Philodina roseola* Ehrenberg, 1832*@

172. *Rotaria neptunia* (Ehrenberg, 1830) *

173. *R. rotatoria* (Pallas, 1766) *@

* Recorded in our collection from the Kashmir Himalayas; # new record from northwest India (NWI);
@ not listed in the compilation by Shah et al. (2015).