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Cover: Watercolour illustrations—Striped Tiger *Danaus genutia*, Common Silverline *Cigaritis vulcanus*, Tamil Lacewing *Cethosia mahratta*. © Mayur Nandikar.

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ARTICLE

First report of five monogonont rotifers from Jammu, J&K UT, India, with remarks on their distribution

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Abstract: Rotifers are microscopic metazoans which are generally predominant in freshwater ecosystems both in terms of species richness and species abundance. Despite their small size, they are crucial in maintaining ecological balance. In the present investigation, plankton samples collected during February 2019–January 2021 from two lentic water sources of Jammu region of Jammu & Kashmir revealed 58 species of rotifers belonging to 16 families, among which five species of monogonont rotifers from three genera were recorded to be the first reports from this region. These include three species from family Lecanidae: *Lecane arcula, L. inermis, L.* (*Monostyla*) *unguitata*; one species from family Brachionidae: *Anuraeopsis coelata*; and species *Pompholyx sulcata* of family Testudinellidae. Among these five monogonont species, *Anuraeopsis coelata* shows pantropical distribution, *Lecane unguitata* is a palaeotropical species, while other three are cosmopolitan in occurrence. Furthermore, comments are made on the diagnosis, seasonality, biogeographical, and ecological distribution of these species.

Keywords: Abundance, first reports, freshwater invertebrates, Jammu and Kashmir, Lecanidae, morphology, physico-chemical parameters, rotifers, seasonal distribution, Zooplankton.

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Author contributions: Nidhi Sharma—carried out the fieldwork, sampling, species identification, data collection, analysis & interpretation and manuscript writing. Sarbjeet Kour—study design, supervision and guidance in sample collection, careful examination and confirmation of identified species, thorough checking, and final approval to the manuscript. Aayushi Dogra—data analysis, intellectual input, review and Editing

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INTRODUCTION

Rotifera are unsegmented, bilaterally symmetrical invertebrates commonly known as 'wheel animalcules' which form an important constituent of freshwater zooplankton and an integral link of aquatic food chain (Sharma 1998). They can be planktonic, semi-planktonic or sessile, and are identified by the presence of an anterior ciliary apparatus, the corona, and a specialized muscular pharynx or mastax containing complex jaws, the trophi (Shiel 1995). Nearly 2,500 species of this phylum have been described from all over the world. Earlier, the taxon was divided into two classes, Monogononta and Digononta (Pennak 1978). Wallace et al. (2019) described two classes Pararotatoria and Eurotatoria under this phylum which are further divided into subclasses Seisonoidea (Pararotatoria) and Bdelloidea & Monogononta (Eurotatoria), respectively. Monogononta include rotifer genera which are mostly free living, but few are also parasitic and as the name suggests, all possess a single gonad. It is the largest group of rotifers composed of more than 1,500 species, spread over 30 families and more than 100 genera globally. Since Anderson's initial taxonomic survey in 1889, Rotifera have been documented from a variety of locations in India. Based on the current evaluation of rotifer biodiversity of India, 434 Rotifera species (~24% of global record), representing 25 families and 68 taxa, considered to be known from the country, among which 396 species of monogonont rotifers belonging to 22 families and 61 genera have been validly described.

The Jammu & Kashmir UT, located in the Himalayan biodiversity hotspot, is blessed with various water bodies including Ramsar sites, floodplain wetlands, lakes, and ponds that provide excellent opportunities to study the biodiversity of aquatic metazoans, particularly that of rotifers. Sharma & Sharma (2018) have given a systematic list of 173 rotifer species (40% Indian record) from J&K and 140 species from Kashmir valley in particular, among which they recorded 25 first reports from northwestern India. Jammu region of J&K lies at the foothills of Shivalik range of Himalaya which is to its north, while northern plains lie to its south. It has a humid subtropical climate and is an abode to many freshwater lotic & lentic sources like rivers, lakes, and ponds. Among these aquatic ecosystems, the small ponds are significant by being large repository of microfaunal biodiversity.

Investigations on rotifer diversity from different regions of Jammu division have been contributed by Jyoti & Sehgal (1979), Kumar et al. (1991), Kour (2006), Shvetambri (2007), Slathia & Dutta (2008), Sharma et al. (2013). However, the water bodies of Jammu plains have not been fully explored due to which regional data on this important fauna is insufficient. Thus, the present communication, a part of a study to document Eurotatoria diversity from two lentic sources of Jammu plains, provides first record of five monogonont rotifer species from Jammu region and it incorporates brief taxonomic description, illustration, seasonality, biogeography, and ecological distribution of the examined species. Present study extends the distribution range of these monogonont rotifer species to this region of northwestern India and this data on regional diversity will further make addition to the freshwater biodiversity of Jammu & Kashmir.

MATERIAL AND METHODS

Study Area

The present study is a part of limnological investigation of two small lentic water bodies; Kanjak di Chhapadi (Station I) and Bhatyari pond (Station II), located in Bishnah region (32.6108 ^{0}N, 74.8595 ^{0}E) of Jammu, J&K (Figure 1; Image 1) . The former is a sacred pond located in the vicinity of a temple of Hindu deity named as 'Kanjak Darwaar'. This is a subtropical and perennial pond situated amidst the agricultural fields. This pond is roughly rectangular in shape with concrete embankment and it is spread over an area of 2,583.38 m^2. This pond is inhabited by fish *Puntius sophore* and it is believed to have great religious and therapeutic significance (Image 1a). Bhatyari pond is a roadside natural pond, surrounded by human habitation on one side and agricultural fields on the other sides. It is spread over an area of about 3,843.36 m^2 and is a roughly rectangular pond having soft, muddy embankment surrounded by weeds. The weed *Alternantheria* sp. can be seen growing here. People use its water for irrigation (Image 1b).

Methods

Sampling was done for a period of two years (February 2019–January 2021) on a monthly basis. Water samples were collected in clean polyethylene bottles to analyse their physico-chemical parameters as per standard methods specified in Adoni (1985) and APHA (1992). Sixteen abiotic parameters were measured, viz., air temperature, water temperature, pH, transparency, free carbon dioxide (FCO_2), dissolved oxygen (DO), chlorides, calcium, magnesium, carbonates, bicarbonates, total hardness, biological oxygen demand (BOD), sulphates, nitrates, and phosphates. Plankton samples were collected by filtering 50l of water sample through plankton

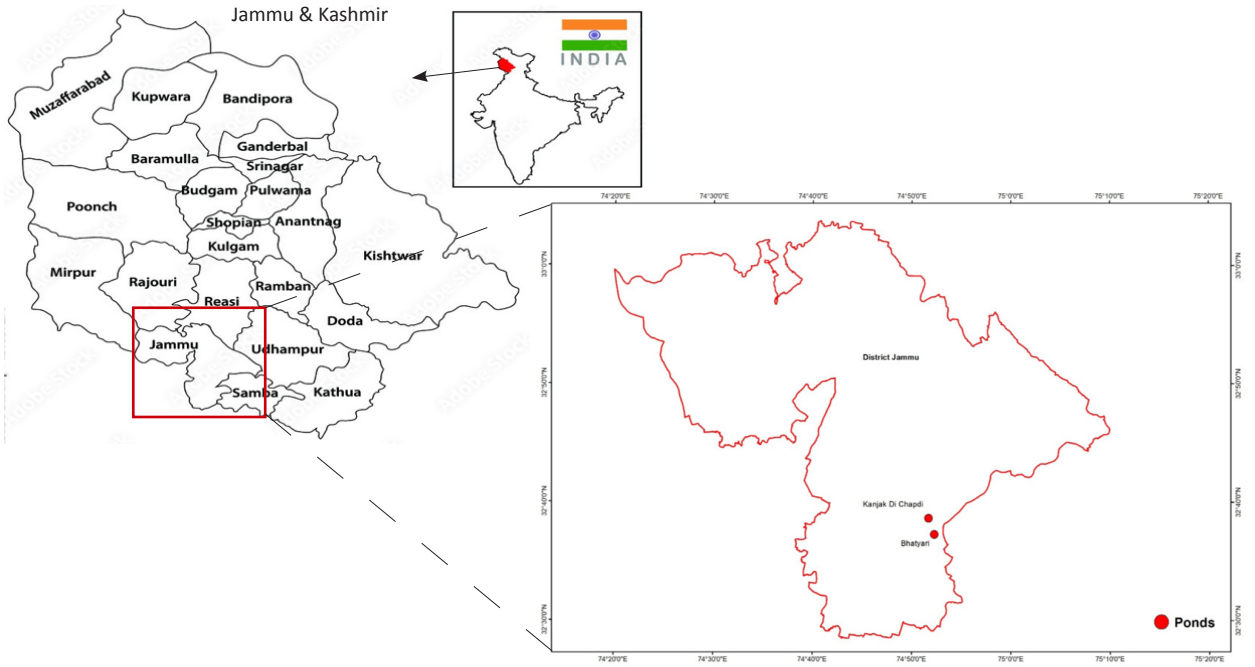

Figure 1. Map of sampling sites.

Image 1a. Station I (Kanjak di Chhapadi). © Nidhi Sharma.

Image 1b. Station II (Bhatyari pond). © Nidhi Sharma.

net (mesh size 40 µm) made of bolting silk (no. 25). The filtered sample was concentrated to 20 ml volume and preserved with 4% formalin. The preserved samples were examined under an Olympus compound light microscope (model CH20i). Measurements were taken with the help of an ocular micrometer and drawings were made with the help of glass type camera Lucida & Rotring Germany 1928 pens. The rotifer taxa were identified by following standard identification keys provided by Edmondson & Winberg (1971), Pennak (1978), Battish (1992), Segers (1995, 2012), and Sharma (1998).

RESULTS AND DISCUSSION

Group Rotifera was represented by 25 genera and 58 species (33.52% of total record from J&K) belonging to 16 families. Presently, highest number of rotifer taxa were reported at station II, i.e., 49 species. Station I, however, was characterized by the presence of 35 rotifer species during the study period (2019–2021). Of the total 16 families reported, family Brachionidae contributed the maximum species, i.e., 16 species followed by family Lecanidae with 15 species. According to Dumont (1983), dominance of Lecanidae and Brachionidae

families is typical of tropical environment. Genera *Lecane* outnumbered the genus *Brachionus* in terms of species richness by contributing 15 species to the total rotifer fauna, whereas genus *Brachionus* was represented by eight species. The species rich status of genus *Lecane* in tropical waters has also been postulated by Arora & Mehra (2003). *Keratella tropica* and *Brachionus calyciflorus* had the maximum annual count at station I, whereas *B. rubens* and *B. falcatus* were the largest contributors to population abundance at station II.

In this study, we identified three lecanid species and two planktonic genera each from families Brachionidae and Testudinellidae which were previously unrecorded from the region under study. Lecanids are of major biogeographical interest and they particularly thrive in littoral habitats of varying environments like freshwater & saline water (Segers 1996; Khaleqsefat et al. 2011). The genus *Anuraeopsis* is one of the seven genera belonging to family Brachionidae which form an important component of planktonic rotifers. Genera *Pompholyx*, one of the two genera belonging to family Testudinellidae also includes pelagic species.

Systematic list of first records from Jammu waters

Phylum: Rotifera Cuvier, 1817
Class: Eurotatoria De Ridder, 1957
Subclass: Monogononta Plate, 1889
Order: Ploima Hudson & Gosse, 1886
Family: Brachionidae Ehrenberg, 1838
Genus: *Anuraeopsis* Lauterborn, 1900
1. *Anuraeopsis coelata* (De Beauchamp, 1932)

Family: Lecanidae Remane, 1933
Genus: *Lecane* Nitzsch, 1827
2. *Lecane arcula* (Harring, 1914)
3. *Lecane inermis* (Bryce, 1892)
4. *Lecane unguitata* (Fadeev, 1925)

Family: Testudinellidae Harring, 1913
Genus: *Pompholyx* Gosse, 1851
5. *Pompholyx sulcata* (Hudson, 1885)

Short description of first reports

1. *Anuraeopsis coelata* (De Beauchamp, 1932)

Lorica ellipsoidal elongated. Two longitudinal ridges run parallel to each other on the dorsal plate that get united at the posterior end forming a U shape. Anterior dorsal margin with a broad median sinus and is without any spines or serrations. Three marginal facets present at the posterior end that continue in long lateral facets on each side (Image 2A&B)

Differential diagnosis: The present specimens differ from those of West Bengal (Sharma 1998) with respect to the distal end of dorsal surface in which the longitudinal ridges terminate into a single short ridge forming a Y shaped structure, whereas in the present specimens, U shaped structure ends into a terminal plate.

2. *Lecane arcula* (Harring, 1914)

Lorica little longer than broad; external angles of ventral plate raised into two small antero-lateral spines. Clear surface markings on dorsal plate. Ventral plate oval and slightly narrower than dorsal plate. Posterior segment is small and rounded. Toes with small, slightly out curved claws (Image 3A&B).

Differential diagnosis: It is distinguished from very similar species *Lecane aculeata* by its relatively shorter lorica and antero-lateral spines.

3. *Lecane inermis* (Bryce, 1892)

Lorica is soft, flexible, and elongated with indistinguishable dorsal and ventral plates. Anterior margins nearly straight, without any spines at anterior external angles. Toes are small and these terminate into long and pointed claws (Image 4A&B).

Differential Diagnosis: *L. inermis* is one of the 14 illoricated *Lecane* species among which it shows close similarity to *L. elegans* and *L. margalefi* (Yang & Min 2021). It may be recognized from these two congeners, by its toes with comparatively long claws (Segers 1995).

4. *Lecane unguitata* (Fadeev, 1925)

Lorica almost circular with relatively small anterior opening. Anterior margin of dorsal plate is straight; antero-ventral margin with a distinct median sinus and rounded external corners. Dorsal plate truncate posteriorly and smaller than ventral plate. Single toe having two pointed and long pseudoclaws (Image 5A&B).

Differential diagnosis: *Lecane unguitata* can be misidentified with *Lecane stephensae*, but the latter has short toe and pseudoclaws (Segers 1995; 1996).

5. *Pompholyx sulcata* (Hudson, 1885)

Lorica oval/egg shaped, not dorso-ventrally flattened; four longitudinal grooves divide it into four lobes in cross-section. Anterior end produced into a lobe-like projection dorsally; a shallow median sinus on ventral margin is flanked by two lateral elevations. Eggs attached on retractile threads passing through the cloacal aperture at the posterior end (Image 6A&B).

Differential diagnosis: *Pompholyx sulcata* can be distinguished from *Pompholyx complanata* by its egg

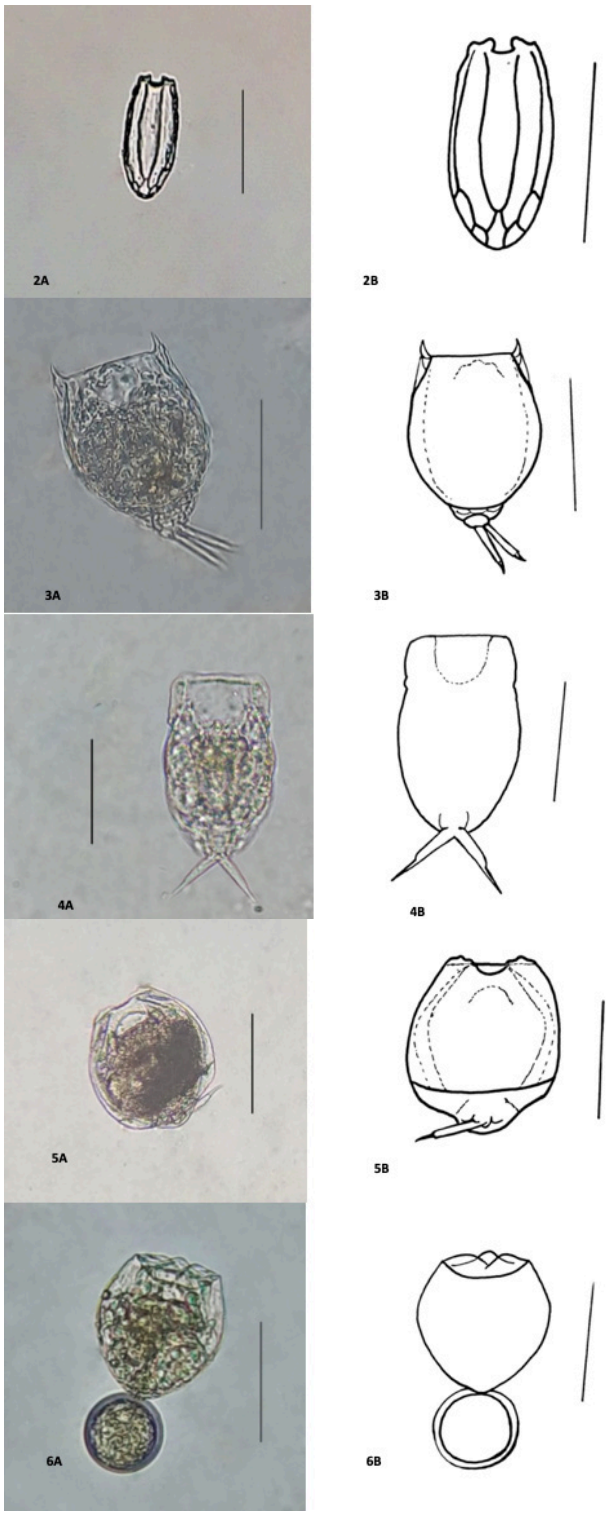

Image 2–6. 2—Illustrations of *Anuraeopsis coelata* (De Beauchamp, 1932): A—Image, B—Line drawing | 3—Illustrations of *Lecane arcula* (Harring, 1914): A—Image, B—Line drawing | 4. Illustrations of *Lecane inermis* (Bryce, 1892): A—Image, B—Line drawing | 5—Illustrations of *Lecane unguitata* (Fadeev, 1925): A—Image, B—Line drawing | 6—Illustrations of *Pompholyx sulcata* (Hudson, 1885): A—Image, B—Line drawing. Scale Bar: 50 µ.

shaped lorica, while the latter has a circular body.

Seasonal and spatial distribution

Tables 1 and 2 highlight the mean & standard deviation and range of values of 16 abiotic parameters of sampling stations. The water bodies had air temperature ranging from 6.5–35 ˚C, water temperature 8–34 ˚C, pH ranging 6.1–9.5 and a dissolved oxygen value ranging 2.88–11.2 mg/l throughout the study period. *Anuraeopsis coelata* showed restricted distribution only to station I. The occurrence of *Lecane unguitata* and *L. arcula* was restricted to station II; while *Pompholyx sulcata* and *L. inermis* were observed at both the stations. Seasonally, *Anuraeopsis coelata* was observed in summer, monsoon, and post-monsoon (25–29 ˚C) with maximum density during monsoon season. *Pompholyx sulcata* was observed during summer (25–28 ˚C) and winter months (9–11.5 ˚C) with no appearance of species in intermediate seasons. All the *Lecane* species were represented by few numbers of individuals (Table 3) at each station. *Lecane unguitata* showed its presence in summer and post-monsoon, *Lecane inermis* was present during summer to post-monsoon period, while *Lecane arcula* showed rare occurrence, and was observed only once in post-monsoon period (18˚C).

Biogeographical distribution

Many of the presently recorded species of rotifers are cosmopolitan in distribution. But among the species reported for the first time, *Anuraeopsis coelata is* a pantropical species and from India, it has been reported from Assam, West Bengal, Odisha, and Gujarat. This species has not been listed in inventory of Sharma & Sharma (2018) which marks its first ever record from entire J&K UT. *Lecane arcula* is tropicopolitan in distribution; it has been earlier recorded from Haryana, Andhra Pradesh, West Bengal, Kashmir, and Mizoram.

Both *Pompholyx sulcata* and *Lecane inermis are* cosmopolitan species. Indian records of *Pompholyx sulcata* include those from West Bengal, Assam, Odisha, Karnataka, Punjab, Kashmir, Ladakh, and Nagaland. *Lecane inermis* has been reported from Asian countries like Cambodia, China, India, Thailand, and Laos. From India, it has shown its records from Kashmir, West Bengal, and Meghalaya. *Lecane unguitata*, according to Segers (1996), is a biogeographically interesting paleotropical species common in tropical and subtropical environment of Eastern Hemisphere. This species is widely distributed in India and has been earlier reported from the states of West Bengal, Assam, Meghalaya, Tamil Nadu, and Gujarat.

Table 1. Annual mean values and ranges of various physicochemical parameters at the two stations from February 2019 to January 2020.

	Parameter	Station I		Station II	
		Range	Mean ± SD	Range	Mean ± SD
1	Air temperature (˚C)	6.5–35	16.95 ± 9.65	7–34	23.66 ± 8.24
2	Water temperature (˚C)	8–34	17.16 ± 8.20	9–33	23.23 ± 7.46
3	pH	7.5–9.3	8.3 ± 0.44	6.8–8.7	7.86 ± 0.56
4	Transparency (cms.)	19–48.5	30.72 ± 10.84	9–33	21.66 ± 9.27
5	Dissolved Oxygen (mg/l)	3.2–9.6	5.11 ± 1.87	2.88–10.24	5.82 ± 2.34
6	Free Carbon Dioxide (mg/l)	0–14.96	8.88 ± 4.69	0–9.12	6.85 ± 1.66
7	Carbonate (mg/l)	0–18	11.37 ± 5.79	0–13.2	9.2 ± 4.99
8	Bicarbonate (mg/l)	92.72–244	171.20 ± 41.47	158.6–280.6	216.04 ± 37.12
9	Chloride (mg/l)	18.01–39.04	24.85 ± 7.81	56.06–82.09	65.98 ± 8.15
10	Calcium (mg/l)	8.41–31.95	19.63 ± 8.16	8.41–44.57	29.36 ± 12.67
11	Magnesium (mg/l)	2.55–16.81	10.47 ± 4.09	6.97–23.20	15.40 ± 5.74
12	Total Hardness (mg/l)	42–128	92.2 ± 27.30	52–194	136.75 ± 53.85
13	BOD (mg/l)	1.06–5.41	2.34 ± 1.89	0.32–2.18	1.17 ± 0.55
14	Sulphate (mg/l)	2.59– 20.38	9.83 ± 5.82	5.73–15.59	9.52 ± 3.03
15	Phosphate (mg/l)	0.019–0.207	0.087 ± 0.05	0.010–0.256	0.08 ± 0.06
16	Nitrate (mg/l)	0.59–2.54	1.39 ± 0.75	0.051–1.88	0.78 ± 0.65

Table 2. Annual mean values and ranges of various physicochemical parameters at the two stations from February 2020 to January 2021.

	Parameter	Station I		Station II	
		Range	Mean ± SD	Range	Mean ± SD
1	Air temperature (˚C)	11.5–34	22.79 ± 7.34	10–35	22.33 ± 7.69
2	Water temperature (˚C)	10–29	20.83 ± 6.78	10–30	21.62 ± 6.91
3	pH	7.1–9.2	8.20 ± 0.58	6.1–9.5	7.68 ± 1.05
4	Transparency	24.5–54	40.20 ± 9.61	13.5– 30.5	22.33 ± 5.64
5	Dissolved Oxygen (mg/l)	2.88–10.56	5.35 ± 2.17	3.20– 11.2	5.19 ± 2.25
6	Free Carbon Dioxide (mg/l)	0–26.4	8.51 ± 9.83	0–28.16	14.29 ± 7.94
7	Carbonate (mg/l)	0–22.8	16.9 ± 5.09	0– 35.16	20.54 ± 10.10
8	Bicarbonate (mg/l)	138–221.3	170.97 ± 22.52	150.2– 239.45	192.03 ± 28.53
9	Chloride (mg/l)	18.52–31.03	24.69 ± 3.61	49.05– 87.03	62.55 ± 15.28
10	Calcium (mg/l)	16.39–37.84	27.13 ± 6.95	10.09– 32.79	21.52 ± 6.18
11	Magnesium (mg/l)	8.16–19.31	13.81 ± 3.04	9.13– 20.42	14.72 ± 4.23
12	Total Hardness (mg/l)	84–154	124.61 ± 22.55	66– 146	114.38 ± 24.50
13	BOD (mg/l)	0.22–3.14	1.20 ± 0.89	0.81– 3.97	1.99 ± 1.03
14	Sulphate (mg/l)	9.03–21.68	15.58 ± 3.79	11.46– 24.04	17.52 ± 3.66
15	Phosphate (mg/l)	0.022– 0.212	0.08 ± 0.05	0.025– 0.264	0.08 ± 0.06
16	Nitrate (mg/l)	0.49–2.42	1.10 ± 0.60	0.011– 1.93	0.67 ± 0.64

Ecological distribution

Anuraeopsis and *Pompholyx* are two planktonic-bacterivorous genera. *Anuraeopsis coelata* occured only during warmer months at a temperature above 25˚C and at alkaline pH above 7.9. Segers (2007) suggested that all *Anuraeopsis* species are warm water inhabitants. It is considered to be a eutrophic indicator (Nogrady 1983) and presently, it was found coexisting with other

Table 3. Monthly quantitative abundance of rotifers (Organism/litre) during the study period.

Rotifer species	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Mean
Station I (2019–2020)													
Anuraeopsis coelata	-	-	-	7.28	-	-	9.84	-	0.64	-	-	-	**5.92**
Pompholyx sulcata	-	-	-	1.28	-	-	-	-	-	-	-	-	**1.28**
Station I (2020–2021)													
Anuraeopsis coelata	-	-	6.34		0.06	0.72	0.72	-	-	-	-	-	**1.96**
Lecane inermis	-	-	-	-	-	0.24	-	-	-	-	-	-	**0.24**
Station II (2019–2020)													
Lecane unguitata	-	-	-	-	-	0.32	-	-	0.72	0.16	-	-	**0.4**
Pompholyx sulcata	-	-	-	10.32	-	-	-	-	-	-	7.52	0.88	**6.24**
Station II (2020–2021)													
Lecane inermis	-	-	-	-	-	0.48	0.16	0.08	0.67	1.76	-	-	**0.63**
Lecane arcula	-	-	-	-	-	-	-	-	-	0.24	-	-	**0.24**
Lecane unguitata	-	-	-	0.16	-	-	-	-	-	-	-	-	**0.16**

eutrophy indicator rotifers like *Brachionus calyciflorus*, *B. angularis*, *Filinia longiseta*, *Keratella cochlearis*, *F. tecta*, and Cladocera species *Chydorus sphaericus. Pompholyx sulcata* is a detritivorous species (Ejsmont-Karabin et al. 2020; Gilbert 2022). This confirms its high abundance at station rich in vegetation which after decaying provided them with lot of detritus and periphyton. It is a planktonic species which most commonly inhabits meso-eutrophic and alkaline eutrophic waters. The association of bacterivorous species like *Anuraeopsis fissa* and *Pompholyx sulcata* with eutrophication has been suggested earlier by Gannon & Stemberger (1978) and Pejler (1983). Ejsmont-Karabin et al. (2020) considered it a warm stenothermic species owing to its common occurrence in summer. In the present study, it was equally abundant during both summer (10.32 ind./l in May 2020) & winter (7.52 ind./l in December) and showed its abundance during extremes of environmental parameters like temperature (9–28 ˚C), pH (6.1–8.5), transparency (10.5–33 cm), and dissolved oxygen (3.20–8.64 mg/l); which also indicates its wide tolerance to variable environmental conditions. It co-occurred with rotifer *Platyias patulus*, Cladocera species *Diaphanosoma senegal*, *Ceriodaphnia cornuta,* and copepods *Phylodiaptomus blanci* & *Cryptocyclops bicolor* in the present investigation.

Lecanids are non-planktonic rotifers that prefer littoral-periphytic zone. They are usually not restricted to any specific macrophyte but are found to be euryecious in periphytic environment. The genus *Lecane* Nitzsch, 1827 of family Lecanidae is one of the largest and most species rich genera within the subclass Monogononta comprising nearly 200 species (Jersabek & Leitner 2013; Yang & Min 2021). Scarcity in the population of *Lecane* species observed in the present study might be attributed to insufficiency of periphytic collections. *Lecane arcula*, an oligotrophy indicator species (Yin et al. 2018) was observed to be a rare species that occurred only once at station II with a very low population density of 0.24 ind./l in our collection. Present investigation revealed higher nitrate concentration at station I than station II. Being an oligotrophy indicator (Yin et al. 2018), presence of *L. arcula* only at station II can be attributed to comparatively low nitrate concentration of this station than station I. But very low population count of this species can be due to the relatively high nutrient status of this pond which might not be tolerable & favorable for its growth and reproduction. Segers (1995) categorized it as a warm stenotherm species. *Lecane inermis,* a eurythermal species, was recorded between a slightly acidic to alkaline pH range of 6.8–8.8 and a temperature ranging from 18–30 ˚C. It co-existed with *Lecane curvicornis* at one of the stations while it was present together with *L. arcula* and *L. bulla* at other station. Donner (1970) suggested that it can tolerate wide range of temperature as well as salinity as he detected it in extreme environments of thermal springs and at geyser temperature of 62.5˚C. Glime (2017) suggested its general preferred pH to be 7.3 while Sharma (1987) also recorded it in acidic waters (5.6–6.5). Report of *Lecane arcula* and *L. inermis* from Kashmir Himalayan floodplains (Sharma & Sharma 2018) formed their first ever record from northwestern India. *L. unguitata* exhibited preference for warm weather and was accompanied by other congeneric species such as *L. bulla*, *L. curvicornis*, *L. ludwigi,* and *L. luna*.

CONCLUSION

The results obtained during the present investigation demonstrated high rotifer richness in two lentic water bodies of Jammu with a record of 58 species in which cosmopolitan species formed the major component. Family Brachionidae was the most species rich followed by Lecanidae. Of the total species recorded, five monogonont species representing families Lecanidae, Brachionidae, and Testudinellidae formed the first record from the region; out of which two species are cosmopolitan, one palaeotropical, one pantropical, and one species is tropicopolitan. Seasonally, all these species were present during post-monsoon season except *Pompholyx sulcata*, which showed its presence in summer and winter. The three *Lecane* species recorded in the present study were noticed to be low in abundance. Furthermore, ecological distribution highlighted *Anuraeopsis coelata* and *Pompholyx sulcata* as eutrophic indicator species.

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