Rotifers of Bahia State, Brazil: News records and limitations to studies

Rotiferos do Estado da Bahia, Brasil: Novos registros e limitações dos estudos

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Abstract

A first checklist of Rotifer species in freshwater environments in Bahia State, in northeastern Brazil, is provided. The list includes sampling data from 26 aquatic environments (lotic and lentic) undertaken from 2010 to 2016. One hundred and fifty-five species were recorded, with 68 new records for the state. The family Brachionidae and Lecanidae were the most representative (54.8%). The greatest richness was recorded in the Colônia River (57 species). Those results reflect the low numbers of studies previously undertaken in the region, indicating more research needs to be focused on Rotifer biodiversity in Bahia, the fifth largest state in Brazil (567,295 km²) with large numbers of freshwater bodies.

Keywords: first records, inventory, freshwater, northeast Brazil, zooplankton.

1. Introduction

Rotifers are microscopic eukaryotic metazoaan (50-2000 μm), with approximately 2030 described species represented by two classes: Pararotatoria and Eutroptora (Segers, 2002). The former includes only the order Seisonacea, while Eutroptora comprises the subclasses Monogononta and Bdelloidea. Seisonacea is the least representative group, consisting of four epizootic marine species of branchiae crustaceans, Seison africanaus, S. nebaliae, Paraseison annulatus, and P. kisfaludyi (Riccì et al., 1993; Sørensen et al., 2005; Leasi et al., 2012). Bdelloidea and Monogononta are the best known and most diversified, with approximately 2000 species between them (Monogononta –1600, and Bdelloidea –360) (Segers, 2007; Serra et al., 2019).

Rotifers are cosmopolitan organisms, although largely restricted to continental waters, and constitute important components of the zooplankton in lakes, rivers, and reservoirs (Serafim et al., 2003; Tundisi and Matsumura-Tundisi, 2008); they are considered opportunistic, having well-developed adaptive abilities that allow them to quickly colonize a wide variety of habitats under favorable conditions (Sharma and Sharma, 2005; Bonecker et al., 2009). Rotifers make up part of the fundamental food chains of continental waters, occupying the ecological niche of small filterers. They are considered indicators of specific ecological conditions and can be used in evaluating the trophic states of bodies of water (Bérzinis and Pejler, 1989; Duggan et al., 2001). Some species develop well in highly eutrophic sites, while others are more sensitive to organic and chemical residues (Edmonson and Litt, 1982). Keratella cochlearis, Polyarthra vulgaris, Brachionus urceolaris, and Pompholyx sulcata, for example, are known to indicate eutrophic conditions due to their saprobic valences (Dorak, 2019).
A complete inventory of species and reliable quantitative data are required to accurately describe the structures and functioning of zooplankton communities (Karjalainen et al., 1996) – important groups in terms of our knowledge of global biodiversity, and relevant to all macroecological analyses (Tittensor et al., 2010). A total of 625 Rotifera species are known to Brazil (representing 84 genera), including 103 species of Lecanidae and 72 of Brachionidae (the most representative families) (Garraffoni and Lourenço, 2012).

Exclusively taxonomic inventories (checklists) of the Rotifera in Brazil have been published by Oliveira-Neto and Moreno (1999), Melo et al. (2007), Roche and Silva (2017), Souza-Soares et al. (2011), and Garraffoni and Lourenço (2012). All of those publications, except Melo Jr. et al. (2007), sampled both Bdelloidea and Monogononta species, with Bdelloidea demonstrating lower diversity. Several ecological surveys have also been published (e.g., Aguiar et al., 2017; Montavano et al., 2015; Bonfim et al., 2015; Dias et al., 2014; Jorge Filho et al., 2014; Rossa et al., 2007; Bonecker et al., 2005; Leitão et al., 1992).

It is estimated that about 14% of the Rotifera species recorded globally can be found in Brazil (Lewinsohn and Prado, 2002), although the true biodiversity of that group in continental aquatic ecosystems in that country is still only poorly understood and difficult to estimate (Agostinho et al., 2005). While a number of studies focusing on the Rotifera community in the continental waters of Bahia State have been published (Neumann-Leitão and Nogueira-Paranhos, 1987; Crispim and Watanabe, 2000; Souza et al., 2004; Oliveira et al., 2015; Araújo and Nogueira, 2016, Santos et al., 2019), most were reports, monographs, dissertations, and theses. Bahia is the largest state in Brazil (covering approximately 564,732 km²) (IBGE, 2017) and detailed Rotifera inventories will surely identify significant species richness there.

We undertook a taxonomic inventory of the planktonic Rotifera inhabiting continental aquatic environments in Bahia State (the first such survey for the region), citing new occurrences and discussing the limitations of studies of those microorganisms.

### 2. Material and Methods

The list of species presented here was based on a literature search for published studies concerning the Rotifera of Bahia State (Neumann-Leitão and Nogueira-Paranhos, 1987; Crispim and Watanabe, 2000; Souza et al., 2004; Oliveira et al., 2015; Araújo and Nogueira, 2016; Santos et al., 2019). Sampling was also undertaken at 23 sites in lentic and lotic environments, during the period between 2010 and 2016, including the southern portion of the state (near the cities of Vitória da Conquista and Mucugê) (Table 1) (Figure 1). Three sites were sampled in the Lagoa das Bateias lake, three sites in the reservoir at the Fazenda Beija-flor farm, four sites in the Cumbuca River, four sites in the Piabinha River, and nine sites in the Cachoeira River basin.

Published articles concerning field collections of Rotifera generally employed sample volumes of 25 to 100 L of water and horizontal drags for 10 minutes, except Santos et al. (2019), who collected 100 L of water using a graduated bucket. The samples were collected using plankton nets with 50 μm, 65 μm, and 68 μm meshes, and the captured specimens were fixed with 4% formaldehyde; in some cases they were neutralized with sodium tetraborate, and some with a saturated sugar solution or precipitated calcium carbonate.

The surveys we conducted between 2010 and 2016 used plankton net nets (20 μm mesh) and the specimens were fixed in 4% formaldehyde buffered with Hexamethylenetetramine. The samples were obtained using horizontal subsurface drags with a 30X70 cm conical plankton net for five minutes per collecting site, covering a drag distance of approximately 10 m² (except in the CRB, where 400 L of water (using a graduated bucket) per point was filtered.

The samples were processed in Sedgewick-Rafter type chambers and viewed using an optical microscope; the individual Rotifers found were separated on slides with glycerin for better visualization and manipulation. When necessary, a 75% hypochlorite solution was used for trophos extraction, and rose bengal staining was used to better visualize the specimens. An Olympus CX31 microscope with a coupled digital camera was used to photograph the specimens.

Some forms of Rotifera, principally the Bdelloidea group, and representatives of the families of Dicranophoridae and Notommatidae, must be alive for accurate taxonomic identification, as the fixation solution causes contraction into their lorica. The samples analyzed from 2010 to 2016 were fixed in formaldehyde, however, and thus only useful for studying the Monogononta group.

Segers (2007) was consulted to elucidate questionable nomenclature for the species; those not classified are indicated in the list of species occurrences. Only the lowest possible taxonomic level was considered in the compilation of data presented in the published literature (e.g., Polyarthra sp. de Souza et al. (2004) was not included in the list).

The frequency of occurrence (FO%) of the species was determined considering the number of samples in which they occurred in relation to the total number of samples, with the species being classified as constant (present in more than 80% of samples), frequent (present in between 50 to 80% of the samples), common (from 20 to 50%), or rare (<20%) (Dajoz, 1983).

The Jackknife2 richness estimator was calculated based on the presence and absence data of species using EstimateS 9.1 software. We generated an accumulation curve to verify that the analyzed samples were sufficient to estimate Rotifera richness using asymptotic behavior analysis (Santos et al., 2019). The average percentage of richness extrapolation was calculated based on Heck Junior et al. (1975).

The specimens collected between 2010 and 2016 were deposited in the limnological collection of the Federal University of Bahia - Anísio Teixeira Campus and in the Laboratory of Plankton Ecology at the State University of Santa Cruz (UESC).
3. Results

A total of 155 Rotifera species were recorded, distributed among 36 genera and 21 families (Table 2) (Figure 2 and 3). The richest families were Lecanidae (44 species) and Brachionidae (41 species), together representing 56.6% of Rotifera richness, followed by Trichocercidae (18 species). The others families totaled 70 species (Figure 4); 62 species were characterized as new occurrences for Bahia (Table 2).

The frequency of occurrence indicated Trichocerca pusilla as the only constant species (80%); Keratella americana (66.67%), Lecane bulla bulla (53.33%), Lecane leontina and Polyarthra dolichoptera (60.00% each) were the frequent species; 44 species were common; most species were considered rare (106 species) (Table 2).

Analyses of the numbers of species in the sampled areas showed that the Reservoir of Pedra do Cavalo (70 species) was the most species rich, followed by Colônia river (57 species), the rivers Cachoeira, Salgado, and Lagoa das Bateias (47 species, each), and the reservoir at Fazenda Beija-flor (22 species); the least representative areas were: the tilapia cultivation tank, the São Francisco River (municipalities of Sobradinho and Rodelas), and the Salgado River (each 10 species), followed by the Sobradinho reservoir (nine species) (Figure 5).

The rarefaction curve evidence that the Rotifera samples taken in Bahia were not sufficient to define an asymptotic trend (Figure 6). The average percentage of wealth extrapolation calculations indicated the rotifer data was able to assess approximately 67% of the species.

| Sample sites | Code | Locality | Municipality | Environment | Coordinates (S-W) | References |
|--------------|------|----------|--------------|-------------|-------------------|------------|
| 1            | TT   | Tilapia cultivation tank - CDDTA | Paulo Afonso (PA) | Lentic | 9°24'36.21" - 38°13'17.16" | Oliveira et al (2015) |
| 2            | RN   | Natural Reservoir | Povoado Olhos D’água do Souza, Glória (GL) | Lentic | 9°21'29.86" - 38°15'38.23" | Araújo and Nogueira (2016) |
| 3            | BS   | Barrage Sobradinho | Casa Nova (CS) | Lentic | 9°25’34.78" - 41°09’24.80" | Crispim and Watanabe (2000) |
| 4            | SFb  | São Francisco River | Barra (BR) | Lotic | 11°05’56.46" - 43°08’23.62" | Neumann-Leitão and Nogueira-Paranhos (1987) |
| 5            | SFX  | São Francisco River | Xique-Xique (XX) | Lotic | 11°00’02.85" - 43°02’42.46" | Neumann-Leitão and Nogueira-Paranhos (1987) |
| 6            | SFs  | São Francisco River | Sobradinho (SD) | Lotic | 9°26’31.36" - 40°47’57.05" | Neumann-Leitão and Nogueira-Paranhos (1987) |
| 7            | SFr  | São Francisco River | Rodelas (RD) | Lotic | 8°59’14.64" - 38°39’32.78" | Neumann-Leitão and Nogueira-Paranhos (1987) |
| 8            | RPC  | Reservoir of Pedra do Cavalo | Feira de Santana | Lentic | 12°35’ - 38°59’ | Santos et al (2019) |
| 9            | LB   | Lagoon of Bateias | Vitória da Conquista (VC) | Lentic | 14°51’15.45" - 40°52’12.06" | Data of 2010 - 2011 |
| 10           | PNSV | National Park of Sempre Vivas | Mucugê (MC) | Lotic | 12°59’35.9" - 41°20’25.8" | Data of 2011 – 2012 |
| 11           | RFBF | Reservoir of Fazenda Beija-flor | Vitória da Conquista | Lentic | 14°58’12.74" - 40°49’12.61" | Data of 2012 – 2013 |
| 12           | RS   | Salgado River | | | 14°53’56.47" - 39°42’21.53" | data of 2014 - 2016 |
| 13           | RCo  | Colônia River | | | 15°06’18.19" - 39°56’12.04" | data of 2014 - 2017 |
| 14           | RCA  | Cachoeira River | | | 14°54’44.16" - 39°23’15.74" | data of 2014 - 2018 |
4. Discussion

The only checklist available of the Rotifera of northeastern Brazil was prepared by Melo and Almeida (2007) for Pernambuco State, and listed 64 planktonic species for 19 freshwater environments. That total is lower than described here for Bahia. Souza-Soares et al. (2011) studied 250 aquatic environments in São Paulo State and recorded 277 species, highlighting the potential for significant increases in species richness if additional efforts were undertaken in Bahia.

Brachionidae and Lecanidae, the most representative families in our study, are highly diversified in the tropics (Segers, 1995), and considered the main representatives of Rotifera in tropical freshwater environments in South America (Rocha et al., 1995; Aoyagui and Bonecker, 2004; Melo and Almeida, 2007). Among the genera registered in Bahia State, *Brachionus* (considered endemic to Australia and South America) (Dumont, 1983) and *Lecane* stand out; the species included in those genera have been identified as bioindicators of eutrophic environments (Sládecek, 1983; Pontin and Langley, 1993). *Lecane* is a predominantly subtropical or warm-water genus, with numerous regional and local endemics, but also comprises numerous Holarctic, Palaeotropical, Australasian, New World, and Old World species (Segers 2008). They are predominantly non-planktonic (Borges and Pedrozo, 2009) and associated with aquatic macrophytes (Duggan et al., 2001; Kuczyn'ska-Kippen, 2009), although they are frequently recorded as plankton.

Although the Rotifera richness in Bahia can appear high when compared to other studies with more intense sampling efforts (Souza-Soares et al., 2011), the accumulation curve for Rotifera species has not yet reached its asymptote, indicating that much more sampling needs to be done. Heck Junior et al. (1975) noted, however, that inventories where 50 to 75% of the species represent common taxa can be considered satisfactory. Due to differences in sampling efforts, it was not possible to infer Rotifera diversity patterns in the available published studies. Reservoir systems, natural lakes, and rivers are all distinct environments, with reservoirs generally being more complex than natural lakes due to their interactions with entire river basins, and the inflow from many tributaries (Straskraba and Tundisi, 1999). Aquatic communities will therefore vary among different bodies of water, with their compositions and dynamics being influenced by surrounding environmental conditions and dependent on a variety of factors – whether local or regional. Biological, physical, and chemical factors, as well as interactions between them, all play important roles in the selection of predominant species (Casanova et al., 2009).

In the present study, the Cachoeira River Basin and Lagoa das Bateias were observed to have the highest nutrient concentrations, mainly due to the inflow of organic sewage, quite different from the Cumbuca and Piabinha rivers in the

**Figure 1.** Map of Bahia State, Brazil, highlighting in the 13 sampling sites. Sampling sites described in Table 1.
Table 2. List of occurrence and Frequency of occurrence (FO%) of Rotifera species in freshwater, state of Bahia, Brazil. Families are featured in bold. †¤ Taxa not identified following Segers (2007). ** New occurrences for the State. From PA to RD indicates the survey of species of published data. From VC to CRB indicates the survey of species in this study of 2010 to 2016. Meaning of the codes follows table 1.

| Published studies | Sampling in this study |
|-------------------|-----------------------|
|                   | TCT | GL | CS | BR | XX | SD | SD | FS | VC | MC | CRB | FO (%) |
| DIGONONTA (=BDELLIOIDEA) |     |    |    |    |    |    |    |    |    |    |    |       |
| Philodinidae Ehrenberg, 1838 |     |    |    |    |    |    |    |    |    |    |    |       |
| Rotaria rotatoria (Pallas, 1766) | x  |    |    |    |    |    | 6.67 |
| MONOGONONTA |     |    |    |    |    |    |    |    |    |    |    |       |
| Asplanchinidae Eckstein, 1883 |     |    |    |    |    |    |    |    |    |    |    |       |
| Asplanchna priodonta Gosse, 1850 | x  |    |    |    |    |    | 6.67 |
| Asplanchnopus multiceps (Schrank, 1793)** | x  | x  | x  | 20.00 |
| Brachionidae Ehrenberg, 1838 |     |    |    |    |    |    |    |    |    |    |    |       |
| Anuraeopsis navicula Rousselet, 1911 | x  |    |    |    |    |    | 6.67 |
| Anuraeopsis fissa Gosse, 1851** | x  | x  | x  | x  | x  | 26.67 |
| Brachionus angularis Gosse, 1851 | x  | x  | x  | 20.00 |
| Brachionus angularis angularis Gosse, 1851** | x  | x  | x  | 20.00 |
| Brachionus bidentatus Anderson, 1889 | x  |    |    |    |    | 6.67 |
| Brachionus brevipes Ehrenberg, 1832 | x  | x  | 13.33 |
| Brachionus calyciflorus Pallas, 1766 | x  | x  | x  | x  | x  | x  | 40.00 |
| Brachionus calyciflorus calyciflorus Pallas, 1766 | x  | x  | 13.33 |
| Brachionus caudatus Barrois & Daday, 1894 | x  | x  | x  | x  | x  | x  | 46.67 |
| Brachionus dolabratus Waning, 1914 | x  | x  | 13.33 |
| Brachionidae Ehrenberg, 1838 |     |    |    |    |    |    |    |    |    |    |    |       |
| †¤ Brachionus caudatus f. austrogenitus Ahlstrom, 1940** | x  |    |    |    |    |    | 6.67 |
| †¤ Brachionus caudatus f. majusculus Ahlstrom 1940** | x  |    |    |    |    | 6.67 |
| †¤ Brachionus caudatus f. vulgatus Ahlstrom 1940** | x  | x  | x  | 20.00 |
| Brachionus falcatus Zacharias, 1898** | x  | x  | x  | x  | x  | x  | 40.00 |
| Brachionus havanaensis Rousselet, 1991** | x  | x  | x  | x  | x  | x  | 26.67 |
| Brachionus mirus Daday, 1905 | x  |    |    |    |    |    | 6.67 |
| †¤ Brachionus pala anuraeiformis Brehm, 1909 | x  | x  | x  | 20.00 |
| †¤ Brachionus patulus Müller, 1786 | x  |    |    |    |    |    | 6.67 |
| †¤ Brachionus patulus patulus Müller, 1786** | x  | x  | x  | x  | x  | x  | 33.33 |
| †¤ Brachionus patulus var. macrocanthus Jakubski, 1912** | x  |    |    |    |    | 6.67 |
| Brachionus plicatilis Muller, 1786** | x  |    |    |    |    | 6.67 |
| Published studies                          | Sampling in this study | FO (%) |
|-------------------------------------------|------------------------|--------|
| **Brachionus plicatilis plicatilis** Müller, 1786** | x x x x | 26.67 |
| Brachionus polyacanthoide Berzinš, 1943**  | x                | 6.67  |
| Brachionus pterodinoides Rousselet, 1913** | x                | 6.67  |
| Brachionus quadridentatus Hermann, 1783   | x x x x | 40.00 |
| Brachionus quadridentatus f. cluniorbicularis Skorikov, 1894** | x                | 6.67  |
| Brachionus quadridentatus quadridentatus Hermann, 1783** | x x x | 20.00 |
| Brachionus q. q. cluniorbicularis Skorikov, 1894** | x      | 6.67  |
| Brachionus rubens Ehrenberg, 1838          | x                | 6.67  |
| Brachionus urceolaris Müller, 1773**       | x x x x | 26.67 |
| Brachionus urceolaris nilsoni (Ahlstrom, 1940)** | x              | 6.67  |
| Brachionus variabilis Hempel, 1896**       | x                | 6.67  |
| Keratella americana Carlin, 1943           | x x x x x x x x | 66.67 |
| Brachionidae Ehrenberg, 1838               |                   |       |
| Keratella cochlearis (Gosse, 1851)         | x x x x x x x x | 46.67 |
| Keratella cochlearis f. hispida (Lauterborn, 1898) | x        | 6.67  |
| Keratella cochlearis f. texta (Gosse, 1851) | x        | 6.67  |
| Keratella lenzi Hauer, 1953                | x                | 6.67  |
| Keratella tropicalis (Apstein, 1907)       | x x x x x x x | 46.67 |
| Keratella tropicalis reducta Fadeev, 1927  | x x | 13.33 |
| *Platypus quadricornis* (Ehrenberg, 1832)** | x x x x x x x | 40.00 |
| *Platysmus patulus* (Muller, 1786)         | x                | 6.67  |
| Conochilidae Harring, 1913                 |                   |       |
| Conochilus coenobasis (Skorikov, 1914)     | x                | 6.67  |
| Conochilus doussarius Hudson, 1885         | x x | 13.33 |
| Conochilus unicornis Rousselet, 1892       | x                | 6.67  |
| Conochilus cf. unicornis Rousselet, 1892   | x                | 6.67  |
| Dicranophoridae Harring, 1913              |                   |       |
| *Dicranophorus epicharis* Harring & Myers, 1928 | x        | 6.67  |
| Epiphanidae Harring, 1913                  |                   |       |
Table 2. Continued...

| Published studies | Sampling in this study |
|-------------------|------------------------|
|                   | PA | GL | CS | BR | XX | SD | RD | FS | VC | MC | CRB | FO (%) |
| Epiphanes clavatula (Ehrenberg, 1832) | x |     |     |     |     |     |     |     |     |     |     | 6.67 |
| Epiphanes macroura (Barrois & Daday, 1894)** | x |     |     |     |     |     |     |     |     |     |     | 6.67 |
| Proalides tentaculatus de Beauchamp, 1907 | x |     |     |     |     |     |     |     |     |     |     | 6.67 |
| Rotifera (Grassé, 1959)** |     |     |     |     |     |     |     |     |     |     |     |     |
| Filinia longiseta (Ehrenberg, 1834) | x | x | x | x | x |     |     |     |     |     |     | 46.67 |
| Filinia longiseta var. passa Ehrenberg, 1834** | x | x |     |     |     |     |     |     |     |     |     | 13.33 |
| Filinia minuta (Smirnov, 1928)** | x | x |     |     |     |     |     |     |     |     |     | 13.33 |
| Filinia opoliensis (Zacharias, 1898)** | x | x | x | x | x |     |     |     |     |     |     | 33.33 |
| Filinia terminalis (Plate, 1886)** | x | x | x | x | x |     |     |     |     |     |     | 33.33 |
| Sinantherina spinosa (Thorpe, 1893) | x |     |     |     |     |     |     |     |     |     |     | 6.67 |
| Gastropodidae |     |     |     |     |     |     |     |     |     |     |     |     |
| Gastropus hyptopus (Ehrenberg, 1938) | x |     |     |     |     |     |     |     |     |     |     | 6.67 |
| Hexarthridae Bartos, 1959 |     |     |     |     |     |     |     |     |     |     |     |     |
| Hexarthra intermedia brasiliensis Haue, 1953** | x | x | x | x | x |     |     |     |     |     |     | 33.33 |
| Hexarthra mira (Hudson, 1871) | x | x | x | x | x |     |     |     |     |     |     | 33.33 |
| Hexarthra fennica (Levander, 1892)** | x | x | x | x | x |     |     |     |     |     |     | 20.00 |
| Lecanidae Remane, 1933 |     |     |     |     |     |     |     |     |     |     |     |     |
| Lecane aquila Harring & Myers, 1926** | x | x | x | x | x | x |     |     |     |     |     | 46.67 |
| Lecane aculeata (Jakubski, 1912)** | x |     |     |     |     |     |     |     |     |     |     | 6.67 |
| Lecane arcuata (Bryce, 1981)** | x |     |     |     |     |     |     |     |     |     |     | 6.67 |
| Lecane braumi Koste, 1988** | x | x |     |     |     |     |     |     |     |     |     | 13.33 |
| Lecane bulla (Gosse, 1851) | x | x | x | x | x |     |     |     |     |     |     | 20.00 |
| Lecane bulla bulla (Gosse, 1851)** | x | x | x | x | x | x |     |     |     |     |     | 53.33 |
| Lecane closterocerca (Schmarda, 1859)** | x | x | x | x | x | x |     |     |     |     |     | 33.33 |
| Lecane cornuta (Müller, 1786)** | x | x | x | x | x |     |     |     |     |     |     | 20.00 |
| Lecane curvicornis (Murray, 1913) | x | x | x | x | x | x |     |     |     |     |     | 46.67 |
| Lecane clara (Bryce, 1892) | x |     |     |     |     |     |     |     |     |     |     | 6.67 |
### Table 2. Continued...

| Published studies | Sampling in this study |
|-------------------|------------------------|
|                   | PA | GL | CS | BR | XX | SD | RD | FS | VC | MC | CRB | FO (%) |
| Lecane elegans Harring, 1914** |   |   |   |   |   |   |   |   | x  |   |     | 13.33 |
| Lecane elsa Hauer, 1931 |   |   |   |   |   |   |   |   |     |   |     | 6.67  |
| Lecanidae Remane, 1933 |   |   |   |   |   |   |   |   |     |   |     |     |
| Lecane halichyta Harring & Myers, 1926 |   |   |   |   |   | x  |   |   |     |   |     | 6.67  |
| Lecane furcata (Murray, 1913) | x  |   | x  |   | x  | x  | x  | x  |     |   |     | 40.00 |
| Lecane hamata (Stokes, 1896)** |   |   |   |   |   |   |   | x  |     |   |     | 20.00 |
| Lecane hastata (Murray, 1913)** |   |   |   |   |   |   |   | x  |     |   |     | 13.33 |
| Lecane hornemanni (Ehrenberg, 1834)** |   | x  | x  |     |   |     |   |   |     |   |     | 13.33 |
| Lecane imbricata Carlin, 1939** |   | x  | x  |     |   |     |   |   |     |   |     | 13.33 |
| Lecane kuitkowa Koste, 1972** |   |   |   |   |   |   |   |   | x  |   |     | 6.67  |
| Lecane latissima Yamamoto, 1955** |   |   |   |   |   |   |   | x  |     |   |     | 6.67  |
| Lecane leontina (Turner, 1892) | x  |   | x  | x  | x  | x  | x  | x  |     |   |     | 60.00 |
| Lecane ludwigi (Eckstein, 1883)** | x  |   | x  | x  |   |     |   |   |     |   |     | 26.67 |
| Lecane luna (Müller, 1776) | x  | x  | x  | x  | x  | x  | x  | x  |     |   |     | 46.67 |
| Lecane lunaris (Ehrenberg, 1832) | x  | x  | x  | x  | x  | x  | x  | x  |     |   |     | 46.67 |
| Lecane lunaris crenata (Harring, 1913)** |   |   |   |   |   |   |   | x  |     |   |     | 6.67  |
| Lecane lunaris f. constricta (Murray 1913)** | x  | x  | x  | x  | x  | x  | x  | x  |     |   |     | 6.67  |
| Lecane minutut Segers, 1994** |   |   |   |   |   |   |   |   | x  |   |     | 6.67  |
| Lecane monostyla (Daday, 1897)** | x  |   | x  | x  | x  |   |     |   |     |   |     | 26.67 |
| Lecane nana (Murray, 1913)** |   |   |   |   |   |   |   | x  |     |   |     | 6.67  |
| Lecane nelesoni Segers, 1994** |   |   |   |   |   |   |   | x  |     |   |     | 6.67  |
| Lecane niothis Harring & Myers, 1926** | x  | x  | x  | x  | x  | x  | x  | x  |     |   |     | 6.67  |
| Lecane papuana (Murray, 1913)** | x  | x  | x  | x  | x  | x  | x  | x  |     |   |     | 46.67 |
| Lecane punctata (Murray,1913)** | x  | x  | x  | x  | x  |     |   |   |     |   |     | 20.00 |
| Lecane pyriformis (Daday, 1905) | x  | x  | x  | x  | x  |     |   |   |     |   |     | 13.33 |
| Lecane quadridentata (Ehrenberg, 1830)** | x  | x  | x  | x  | x  |     |   |   |     |   |     | 20.00 |
| Lecane rhytida Harring & Myers, 1926 | x  | x  | x  | x  | x  | x  | x  | x  |     |   |     | 6.67  |
| Lecane spinulifera (Edmondson, 1935) | x  | x  | x  | x  | x  | x  | x  | x  |     |   |     | 6.67  |
| Lecane crepida Harring, 1914** |   |   |   |   |   |   |   | x  |     |   |     | 6.67  |
| Lecanidae Remane, 1933 |   |   |   |   |   |   |   | x  |     |   |     | 6.67  |
| Lecane stenroosi (Meissner, 1908) | x  | x  | x  | x  | x  | x  | x  | x  |     |   |     | 6.67  |
| Lecane stichaeae Harring, 1913 |   |   |   |   |   |   |   | x  |     |   |     | 6.67  |
| Lecane subulata (Harring & Myers, 1926)** | x  |   |   |   |   |   |   | x  |     |   |     | 6.67  |
| Lecane tabida Harring & Myers, 1926** | x  | x  | x  | x  | x  | x  | x  | x  |     |   |     | 6.67  |
| Lecane thalera (Harring & Myers, 1926)** | x  | x  | x  | x  | x  | x  | x  | x  |     |   |     | 6.67  |
**Table 2.** Continued...

| Published studies                                                                 | Sampling in this study |
|----------------------------------------------------------------------------------|------------------------|
|                                                                                   | PA         | GL  | CS  | BR  | XX | SD  | RD  | FS  | VC  | MC  | CRB | FO (%) |
| **Lecane ungulata** (Gosse 1887)                                                | x          |     |     |     |    |     |     |     |     |     |     | 6.67   |
| Lepadellidae Harring, 1913                                                        |            |     |     |     |    |     |     |     |     |     |     |         |
| **Colurella adriatica** Ehrenberg, 1831**                                        |            |     |     |     |    |     |     |     | x   |     |     | 6.67   |
| **Colurella salina** Althaus, 1957**                                             |            |     |     | x   |    |     |     |     |     |     |     | 13.33  |
| **Colurella obtusa obtusa** (Gosse, 1856)**                                       |            |     |     |     |    |     |     | x   |     |     |     | 20.00  |
| **Lepadella patella patella** (Müller, 1786)**                                   |            |     | x   |     |    |     |     |     |     |     |     | 46.67  |
| Lepadella benjaminsi Harring, 1916                                                |            |     |     |     |    |     |     |     |     | x   |     | 6.67   |
| Lepadella ovalis (Muller,1786)                                                   |            |     |     |     |    |     |     |     |     |     | x   | 6.67   |
| †¤ Squatinella mutica (Ehrenberg, 1832)**                                        |            |     |     | x   |    |     |     |     |     |     |     | 13.33  |
| Mytilinidae Harring, 1913                                                        |            |     |     |     |    |     |     |     |     |     |     |         |
| **Mytilina mucronata** (Muller, 1773)                                            |            |     |     |     |    |     |     |     | x   |     |     | 6.67   |
| **Mytilina ventralis** (Ehrenberg, 1830)                                         |            |     |     |     |    |     |     | x   |     |     |     | 13.33  |
| Notommatidae Hudson & Gosse, 1886                                                |            |     |     |     |    |     |     |     |     |     |     |         |
| **Cephalodella gibba** (Ehrenberg, 1830)**                                       |            |     |     | x   |    |     |     |     |     |     |     | 13.33  |
| **Cephalodella tenuiseta** (Burn, 1890)                                          |            |     |     |     |    |     |     | x   |     |     |     | 6.67   |
| **Monommata actices** Myers, 1930**                                              |            |     |     |     |    |     |     |     | x   |     |     | 6.67   |
| **Notommata cerberus** (Gosse, 1886)                                             |            |     |     |     |    |     |     |     |     | x   |     | 6.67   |
| **Notommata copeus** Ehrenberg, 1834                                             |            |     |     |     |    |     |     |     |     |     | x   | 6.67   |
| Scaridiidae Manfredi, 1927                                                       |            |     |     |     |    |     |     |     |     |     |     |         |
| **Scaridium longicaudum** (Muller, 1786)                                         |            |     |     |     |    |     |     |     |     | x   |     | 6.67   |
| Synchaetidae Hudson & Gosse, 1886                                                |            |     |     |     |    |     |     |     |     |     |     |         |
| **Plosoma truncatum** (Levander, 1894)                                           |            |     | x   |     |    |     |     |     |     |     |     | 33.33  |
| **Polycarpa dolichoptera** Idelson, 1925                                          |            |     |     | x   |    |     |     |     |     |     |     | 60.00  |
| **Polycarpa vulgaris** Carin, 1943                                                |            |     |     |     |    |     |     | x   |     |     |     | 6.67   |
| **Synchaeta stylosa** Wierzejski, 1893                                           |            |     |     |     |    |     |     |     | x   |     |     | 6.67   |
| Testudinellidae Harring, 1913                                                    |            |     |     |     |    |     |     |     |     |     |     |         |
| **Pompholyx cf. sulcata** Hudson, 1885                                            |            |     |     |     |    |     |     |     |     | x   |     | 6.67   |
| †¤ Testudinella dendralena de Beauchamp, 1955**                                   |            |     | x   |     |    |     |     |     |     |     |     | 33.33  |
| **Testudinella patina** (Hermann, 1783)                                           |            |     |     |     |    |     |     |     | x   |     |     | 6.67   |
| Trichocercidae Harring, 1913                                                     |            |     |     |     |    |     |     |     |     |     |     |         |
| **Trichocerca bicristata** (Gosse, 1887)**                                       |            |     |     |     |    |     |     | x   |     |     |     | 13.33  |
| **Trichocerca bidens** (Lucks, 1912)                                             |            |     |     |     |    |     |     |     | x   |     |     | 6.67   |
### Table 2. Continued...

| Published studies                        | Sampling in this study |
|------------------------------------------|------------------------|
| **FO (%)**                               |                        |
| **TCT** BS BR XX SD RD FS VC MC CRB RPC LB RFBJ RT RP RS RCo RCa** |                        |
| Trichocerca capucina (Wierzejski e Zacharias, 1893) | x                      | 6.67                  |
| Trichocerca cf. lata (Jennings, 1894)    | x                      | 6.67                  |
| Trichocerca cylindrica (Imhof, 1891)     | x                      | 6.67                  |
| Trichocerca elongata (Gosse, 1886)**     | x                      | 6.67                  |
| †¤Trichocerca elongata braziliensis (Murray, 1913) | x                      | 6.67                  |
| Trichocerca heterodactula (Tschugunoff, 1921) | x                      | 6.67                  |
| Trichocerca insignis (Herrick, 1885)     | x                      | 6.67                  |
| Trichocerca intermedia (Stenroos, 1898)  | x                      | 6.67                  |
| †¤ Trichocerca fusiforme Gosse,1886**     | x                      | 6.67                  |
| Trichocerca marina (Daday, 1890)**       | x x                    | 13.33                 |
| Trichoceridae Harring, 1913              |                        |                       |
| Trichocerca pusilla (Jennings, 1903)     | x x                    | x x x x x x x x x     | 80.00                 |
| Trichocerca ruttneri Donner, 1953**      | x                      | 6.67                  |
| Trichocerca simulis grandis Hauer, 1965**| x x                    | 13.33                 |
| Trichocerca simulis similis (Wierzejski, 1893)** | x x                    | 13.33                 |
| Trichocerca temulens (Hauer, 1931)**     | x                      | 6.67                  |
| Trichocerca vernalis (Hauer, 1936)**     | x x                    | 13.33                 |
| Trichotriidae Harring, 1913              |                        |                       |
| Macruchaetaeus collinsi (Gosse, 1867)   | x                      | 6.67                  |
| Macruchaetaeus sericus (Thorpe, 1893)   | x                      | 6.67                  |
| Trichotria tetractis (Ehrenberg, 1830)  | x                      | 6.67                  |
| Trochosphaeridae Harring, 1913           |                        |                       |
| Horaella thomassoni Koste, 1973          | x                      | 6.67                  |

Sempre Vivas Municipal Park. High densities of *Brachionus angularis angularis* have been found to be associated with high nutrient concentrations (Branco and Senna, 1996; Sládeček, 1983), and that species was encountered in three rivers in the Cachoeira river basin (Table 2).

Oligotrophic lakes support large numbers of phytoplankton and zooplankton species, but usually have only small numbers of individuals; eutrophic lakes, on the other hand, support smaller numbers of plankton species but larger populations of each (Maitland, 1990). Therefore, to fully understand Rotifera diversity patterns in Bahia State, taxonomic and ecological studies will need to be combined.

The shortage of studies in Bahia, together with the lack of Rotifera specialist in northeastern Brazil have resulted in artificially lower established richness of that group as...
Figure 2. Rotifers from Bahia State, Brazil, sampled from 2010 to 2016. A. Anuraeopsis fissa Gosse, 1851. B. Brachionus calyciflorus Pallas, 1766. C. Brachionus caudatus f. austrogenitus Ahlstrom, 1940. D. Brachionus falcatus Zacharias, 1898. E. Brachionus quadridentatus quadridentatus Hermann, 1783. F. Brachionus urceolaris urceolaris Müller, 1773. G. Keratella cochlearis (Gosse, 1851). H. Platyias quadricornis (Ehrenberg, 1832). I. Dipleuchlanis propatula (Gosse, 1886). J. Testudinella dendradena de Beauchamp, 1955. K. Trichocerca pusilla (Jennings, 1903). L. Squatinella mutica (Ehrenberg, 1832). Species stained with bengal rose. Scale bars= 100 μm.

compared to the states Mato Grosso do Sul (Roche and Silva, 2017) and São Paulo (Souza-Soares et al., 2011). Nonetheless, 155 species were recorded here, including 68 new occurrences, and most freshwater environments in Bahia have not yet even been sampled. Many news sites will need to be surveyed and many aspects of the ecology and physiology of that group investigated (which will also contribute to our knowledge of New World biodiversity).

4.1. Limitations for taxonomic studies of Rotifera

The taxonomy of the Rotifera can be extremely complex due to wide morphological variations observed within the group, cyclomorphosis, their capacity for phenotypic plasticity (Segers and De Smet, 2008), and factors such as temperature and predation that can modify their morphological characteristics and make identifications much more difficult (Gilbert, 2011). As such, the complex morphological details of small metazoans and, in some cases, their polymorphic cycles, tend to inflate the numbers of species (Finlay et al., 1996).

Among the representatives of Rotifera (Monogononta, Bdelloidea, and Seisonacea), taxonomic difficulties are most evident among the Bdelloidea, one of the most sustained clades of ancient asexuals (Butlin, 2002). They reproduce only by parthenogenesis, as
Figure 3. Rotifers from Bahia State, Brazil, sampled from 2010 to 2016. M. *Hexarthra intermedia brasiliensis* Hauer, 1953. N. *Filibia opoliensis* (Zacharias, 1898). O. *Filibia terminalis* (Plate, 1886). P. *Lecane aquila* Harring & Myers, 1926. Q. *Lecane bulla bulla* (Gosse, 1851). R. *Lecane cornuta* (Müller, 1786). S. *Lecane quadridentata* (Ehrenberg, 1830). T. *Lecane monostyla* (Daday, 1897). U. *Lecane hornemannii* (Ehrenberg, 1834). V. *Lecane leontina* (Turner, 1892). W. *Lecane ludwigii* (Eckstein, 1883). X. *Lecane lunaris crenata* (Harring, 1913). Species stained with bengal rose. Scale bars= 100 μm.

Figure 4. Numbers of Rotifera species per family in Bahia State, Brazil.
scanning electron microscopy (SEM) allows a more detailed visualization of the ultrastructure of the trophos that cannot be obtained using light microscopy. A thorough examination of trophos using light and scanning electron microscopy should be part of all Rotifera taxonomic studies (De Smet, 1998), and their morphological taxonomy should be aligned with ecological and molecular taxonomic studies to increase the precision of the diagnoses (Roche and Silva, 2017).

The use of valid nomenclature, excluding synonyms, is also a recurrent problem, and recent research has addressed synonyms referred to as valid species or variant names of the subspecies (Souza-Soares et al., 2011). Synonyms are used in many Rotifera species based on morphological characters, such as in the genus Brachionus where Brachionus angularis orientalis (Sudzuki 1989) = B. angularis (Gosse 1851) (Segers, 2007).

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