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Inventory

Composition and richness of monogonont rotifers from La Plata River Basin, South America

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Abstract: We present here the first study that analyzed the composition and richness of rotifers of the entire La Plata River basin, the second largest in South America, based on simultaneous and standardized sampling. Fifteen large reservoirs and eight river stretches were selected in the upper, middle, and lower portions of the Paraná, Paraguay, and Uruguay Rivers, which are the major rivers of the La Plata basin. We took a total of 86 samples (open water habitats) in 2010. A mean of 27±11 species per sub-basin was found, with the highest richness in the Lower Paraná (41 species), followed by the Paranapanema (40 species) and Lower Uruguay (38 species). Low richness was observed in the Middle Uruguay and Middle Paraná. We found 106 species belonging to 21 families and two orders. The family with the highest number of species was Lecanidae (21), followed by Brachionidae (20), Trichocercidae (9), and Synchaetidae (8). The species with higher occurrences were *Conochilus dossuarius*, *Kellicottia bostoniensis*, *Keratella americana*, *Keratella cochlearis* and *Hexarthra mira*. New occurrences of rotifers were registered for Brazil (*Colurella adriatica*), São Paulo State (*Enteroplea lacustris*), and Argentina (*Gastropus hyptopus*, *Harringia rousseleti* and *Lecane thienemanni*). Spearman correlation between the number of species and physical and chemical variables demonstrated positive correlation with chlorophyll and temperature, and negative correlation with dissolved oxygen. We extend the distribution list for some native (*Lecane ludwigii*) and non-native species of rotifers (*K. bostoniensis*). We also list the monogonont rotifer species found at the sampling stations.
Keywords: *Biodiversity; Rotifera; Survey; New records; Lotic; Lentic environments.*

Composição e riqueza de rotíferos Monogononta da Bacia do Rio da Prata, América do Sul

Resumo: Apresentamos aqui o primeiro estudo que analisou a composição e riqueza de rotíferos de toda a bacia do Rio da Prata, a segunda maior da América do Sul, com amostragens simultâneas e padronizadas. Quinze grandes reservatórios e oito trechos lóticos foram selecionados nas porções alta, média e baixa dos rios Paraná, Paraguai e Uruguai, que atuam como os principais formadores da bacia do Prata. Coletamos um total de 86 amostras (habitats de águas abertas) em 2010. Foi encontrada uma média de 27 ± 11 espécies por sub-bacia, com maior riqueza no Baixo Paraná (41 espécies), seguido por Paranapanema (40 espécies) e Baixo Uruguai (38 espécies). Uma baixa riqueza foi observada no Médio Uruguai e no Médio Paraná. Encontramos 106 espécies pertencentes a 21 famílias e duas ordens. A família com maior número de espécies foi Lecanidae (21), seguida por Brachionidae (20), Trichocercidae (9) e Synchaetidae (8). As espécies com maior ocorrência foram *Conochilus dossuarius*, *Kellicottia bostoniensis*, *Keratella americana*, *Keratella cochlearis* e *Hexarthra mira*. Novas ocorrências de rotíferos foram registradas para o Brasil (*Colurella adriatica*), Estado de São Paulo (*Enteroplea lacustris*) e Argentina (*Gastropus hyptopus*, *Harringia rousseleti* e *Lecane thienemanni*). A correlação de Spearman entre o número de espécies e as variáveis físicas e químicas demonstrou correlação positiva com clorofila e temperatura, e correlação negativa com oxigênio dissolvido. Estendemos a lista de distribuição para algumas espécies nativas (*Lecane ludwigii*) e não-nativas de rotíferos (*K. bostoniensis*). Disponibilizamos também uma lista de espécies de rotíferos Monogononta encontrados nas estações amostradas.
Palavras-chave: *Biodiversidade; Rotifera; Levantamento; Novos Registros; Lótico; Ambientes lênticos.*

Introduction

Species inventories are important tools for conservation measures and management, especially in areas imperiled by human actions. It is also useful to show gaps in the scientific knowledge about zooplankton diversity and directions for future research.

There have been surveys of Rotifera diversity in the La Plata River basin, the second largest in South America. However, these surveys have focused on regions such as in the Upper Paraná floodplain (Lansac-Tôha et al. 2009), waterbodies of São Paulo State (Souza-Soares et al. 2011), and a few tributaries (Neschuk et al. 2002, Kuczynski 2017). There have been no basin-wide surveys that included all the countries drained by the basin.

The La Plata River basin has very distinct environments, with extensively dammed and undammed reaches. For example, there are reservoirs in more than half of the upper reaches in the Paraná River basin, leaving few truly lotic reaches; the opposite occurs in its middle and lower reaches (Agostinho et al. 2007). The situation is very similar for the Uruguay River. However, there are no reservoirs in the Paraguay River (Perbiche-Neves et al. 2016). This results in different habitats with distinct limnological features, which may favor differences in rotifer species composition among lotic and lentic regions.

There have been multiple studies of rotifer richness and distribution in Brazilian and Argentinian waters of the La Plata River basin. For example, Garraffoni & Lourenço (2012) surveyed rotifer species throughout Brazil. Other rotifer surveys were less extensive, such in Mato Grosso do Sul (Roche & Silva 2017), São Paulo (Souza-Soares et al. 2011), the Upper Tietê River basin (Lucinda et al. 2004), and Paranoá Reservoir (Padovesi & Andreoni 2011). Despite those surveys, the number of rotifer surveys are underrepresented (Souza et al. 2018), when compared to other groups of zooplankton such as copepods (Silva et al. 2009, Matsumura-Tundisi & Tundisi 2011, Perbiche-Neves et al. 2014).

For Argentina, José de Paggi (1990) listed 279 rotifer taxa. Most rotifer surveys have been in the Paraná River floodplains (Aoyagui & Bonecker 2004) and La Plata River tributaries (Macluf et al. 1998, Modenutti 1998, Bazzuri et al. 2020). Recently, Ferrando & Claps (2016) updated the checklist of Argentinian Rotifera, including a reporting 35 species of monogonont rotifers. According to the authors, "[...] the majority of reports were restricted to the provinces of Santa Fe (68% of the total records), Corrientes and Buenos Aires (50% of the total records), Río Negro and Formosa (30% of the total records)" (Ferrando & Claps 2016; p.2). The rotifer species which are more commonly found in Argentinian Paraná River reaches and La Plata River tributaries were *Keratella cochlearis* (Gosse, 1851), *K. americana* Carlin, 1943 and *Brachionus calyciflorus* Pallas, 1776 (Modenutti 1998, Bonetto & Wais 2006).

Knowledge of the diversity and distribution of rotifers in the Paraguay River basin is scarce and concentrated in Brazil and Argentina, including rivers in the Pantanal (Branco et al. 2018, Brito et al. 2020) and those joining the Paraná River (Frutos et al. 2006). Similarly, few rotifer surveys have been conducted in the Uruguay River basin (e.g., José de Paggi 1978; Picapedra et al. 2019).

Therefore, we provide for the first time a spatially extensive survey of Rotifera species found in the lentic and lotic stretches of the La Plata River basin to characterize its species diversity patterns. In addition, we have expanded the distribution of some Rotifera species not yet reported in the literature, thus contributing to the general knowledge of the diversity of the group in the region.

Materials and Methods

1. *Study area*

The La Plata River basin has an area of 3.1 million km^2 (Cuya et al. 2013) and drains portions of five countries: Brazil, Paraguay, Uruguay, Argentina, and Bolivia. The main sub-basins are the Paraná, Paraguay, and Uruguay River basins. The Paraná basin is the largest, covering 48.7% of the basin, followed by the Paraguay (35.3%) and Uruguay (11.8%) basins (Cuya et al. 2013).

2. *Sampling*

A total of 86 samples were collected at 43 stations, including 15 reservoirs (in dam and upriver zones) and 13 lotic stretches distributed in the three main sub-basins of La Plata River (Figure 1, Table 1). Sites (open water - littoral habitats were not included) were sampled in January (summer - wet season) and July (winter- dry season) 2010. Ten water quality variables were measured at each sampling station during each visit following Perbiche-Neves et al. (2016) and Pessotto & Nogueira (2018): total phosphorus and nitrogen, temperature, transparency, turbidity, conductivity, pH, dissolved oxygen, depth, and total chlorophyll.

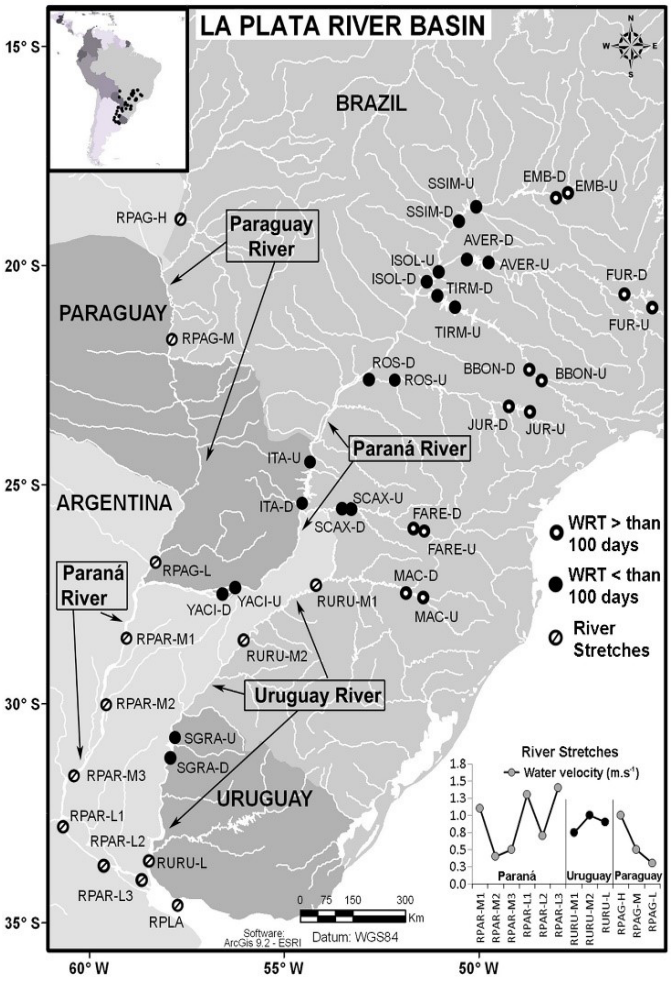

Figure 1. Locations of the 43 sites in La Plata River basin, with data of water retention time (WRT) and water velocity of the river stretches. For codes see Table 1. Adapted from Perbiche-Neves et al. (2016).

Table 1. Acronyms of the sites, sub-basin, geographical coordinates and habitat type sampled in the La Plata River basin. Number (n°) represents the sampling stations in the basin. Codes: ARG – Argentina, BRA – Brazil, PAR – Paraguay, URU – Uruguay.

Site	Sub-basin	Coordinates	Acronyms	N°	Habitat
Emborcação HPP – MG/GO – BRA	Paranaíba	18º26'28.43"S	EMB-U	1	Lentic
		47º58'59.59"W	EMB-D	2	Lentic
São Simão HPP – MG/GO – BRA	Paranaíba	19º00'04.51"S	SSIM-U	3	Lentic
		50º29'47.69"W	SSIM-D	4	Lentic
Furnas HPP – MG – BRA	Grande	20º39'38.30"S	FUR-U	5	Lentic
		46º18'01.65"W	FUR-D	6	Lentic
Água Vermelha HPP – MG/SP – BRA	Grande	19º51'58.67"S	AVER-U	7	Lentic
		50º19'11.62"W	AVER-D	8	Lentic
Ilha Solteira HPP – SP/MS – BRA	Upper Paraná	20º21'43.24"S	ISOL-U	9	Lentic
		51º21'14.53"W	ISOL-D	10	Lentic
Barra Bonita HPP – SP – BRA	Tietê	22º31'23.48"S	BBON-U	11	Lentic
		48º31'56.30"W	BBON-D	12	Lentic
Três Irmãos HPP – SP – BRA	Tietê	20º39'32.50"S	TIRM-U	13	Lentic
		51º16'56.16"W	TIRM-D	14	Lentic
Jurumirim HPP – SP - BRA	Paranapanema	23º13'02.15"S	JUR-U	15	Lentic
		49º13'26.89"W	JUR-D	16	Lentic
Rosana HPP – SP/PR - BRA	Paranapanema	22º36'02.03"S	ROS-U	17	Lentic
		52º51'07.39"W	ROS-D	18	Lentic
Itaipu HPP – BRA/PAR	Upper Paraná	25º24'21.09"S	ITA-U	19	Lentic
		54º34'02.38"W	ITA-D	20	Lentic
Foz do Areia HPP – PR – BRA	Iguaçu	26º00'23.84"S	FARE-U	21	Lentic
		51º39'45.76"W	FARE-D	22	Lentic
Salto Caxias HPP – PR - BRA	Iguaçu	25º32"25.00"S	SCAX-U	23	Lentic
		53º29'30.72"W	SCAX-D	24	Lentic
Yaciretá HPP – Ituzaingó - ARG	Middle Paraná	27º25'28.83"S	YACI-U	25	Lentic
		56º37'37.50"W	YACI-D	26	Lentic
Paraná River – Bella Vista - ARG	Middle Paraná	28º30'04.81"S	RPAR- M1	27	Lotic
		59º02'58.21"W	RPAR-M2	28	Lotic
			RPAR-M3	29	Lotic
La Plata River – Rosário - ARG	Lower Paraná	32°53'08.12"S	RPAR-L1	30	Lotic
		60°40'48.69"W	RPAR-L2	31	Lotic
			RPAR-L3	32	Lotic
La Plata River –- URU/ARG	Lower Paraná	34°00'51.25"S			Lotic
		58°19'21.84"W	RPLA	33	
Machadinho HPP – SC - BRA	Upper Uruguay	27°31'12.35"S	MAC-U	34	Lentic
		51°47'05.01"W	MAC-D	35	Lentic
Porto Xavier – RS - BRA	Middle Uruguay	27°'52'17.26"S	RURU-M1	36	Lotic
		55°07'25.49"W	RURU-M2	37	Lotic
Salto Grande HPP – URU	Middle Uruguay	31°15'44.17"S	SGRA-U	38	Lentic
		57°55'47.34"W	SGRA-D	39	Lentic
Uruguay River - Fray Bentos – URU	Lower Uruguay	33°21'02.20"S	RURU-L	40	Lotic
		58°25'49.97"W			
Paraguay River– Corumbá - BRA	Upper Paraguay	18°59'40.76"S	RPAG-H	41	Lotic
		57°39'12.53"W			
Paraguay River – Assunción - PAR	Middle Paraguay	25°28'24.65"S	RPAG-M	42	Lotic
		57°33'40.53"W			
Paraguay River – Paso de la Patria – PAR	Lower Paraguay	27°15'38.43"S	RPAG-L	43	Lotic
		58°35'39.79"W			

We sampled rotifers through vertical hauls by using a 50 µm mesh conical plankton net. In deep sites, the maximum depth hauled was 40 m (Perbiche-Neves et al. 2019). The sampled rotifers were subsequently packed, labeled, and fixed with 4% formalin solution. Identifications were conducted with an optical microscope (Zeiss Axio Imager.A2m) and by using species keys (Edmondson 1959, Koste 1978, Nogrady et al. 1995, Segers & Dumont 1995, Smet & Pourriot 1997, Nogrady 2002, Wallace et al. 2019). Voucher specimens were deposited in the Laboratory of Continental Waters Ecology, Institute of Biosciences of Botucatu at the Universidade Estadual Paulista Júlio de Mesquita Filho (UNESP), Brazil. The number of species was correlated with water quality variables by using non-parametric Spearman correlation and a logarithmic transformation in R Cran Project 3.3.0 (2016) using the Hmisc package of R.

Results

The mean rotifer richness was 27±11 species. The sub-basins with higher richness were the Lower Paraná (41 species), followed by the Paranapanema (40 species) and Tietê (35 species). The basins with lower richness were the Middle Paraná and Lower Uruguay (Figure 2A).

The Rotifera fauna of the La Plata River basin was composed of 106 species, distributed in 21 families and 37 genera (Table 2, Figure 2B). The most representative family in the basin is the Lecanidae (21 species), followed by the Brachionidae (20), Trichocercidae (9), and Synchaetidae (8) (Figure 2B). The most speciose genera are *Lecane* Nitzsch, 1827 and *Brachionus* Pallas, 1766 with 21 and 10 species, respectively. We found 44 rotifer species in summer and 17 in winter. These seasonal periods share a combined 45 rotifer species (Figure 3).

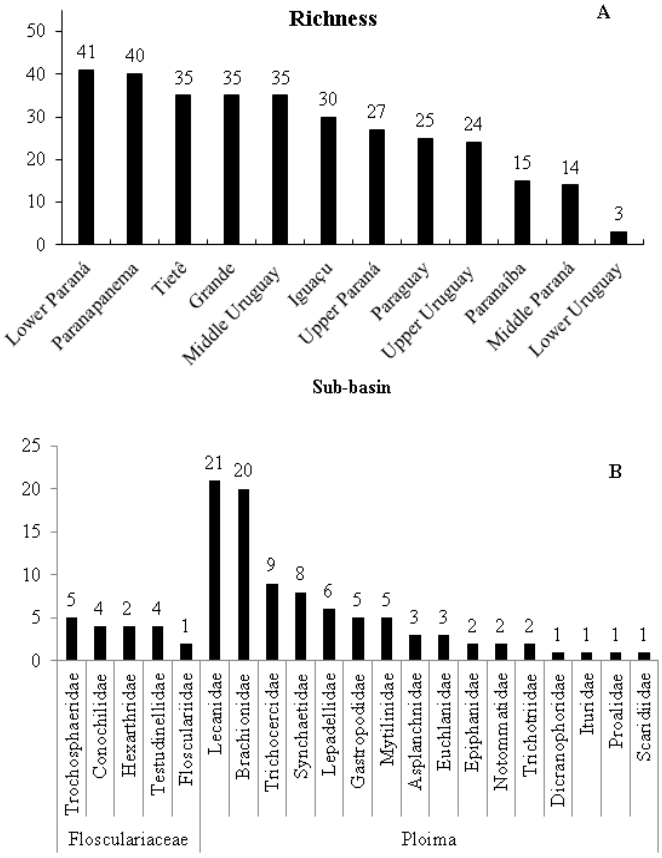

Figure 2. Rotifer richness per basin for species (A) and family (B).

Table 2. Rotifer species collected in lotic and lentic habitas in the La Plata River basin, South America.

Order/Family	Species	Sites	Frequency (%)
Order Floscullariaceae			
Family Conochilidae	*Conochilus coenobasis* (Skorikov, 1914)	4	2.32
	Conochilus dossuarius Hudson, 1885	1, 3, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 23, 24, 28, 29, 30, 31, 33, 34, 36, 43	65.11
	Conochilus natans (Seligo, 1900)	7, 8, 15, 34	9.3
	Conochilus unicornis Rousselet, 1892	1, 2, 3, 4, 6, 7, 8, 12, 14, 15, 18, 28, 30, 32, 33, 34, 35, 39	41.86
Family Flosculariidae	*Ptygura* sp. Ehrenberg, 1832	15	2.32
Family Hexarthridae	*Hexarthra intermedia* (Wiszniewski, 1929)	9, 16, 22	6.97
	Hexarthra mira (Hudson, 1871)	2, 5, 7, 8, 9, 10, 12, 15, 17, 21, 22, 23, 24, 27, 28, 30, 39, 43	41.86
Family Testudinellidae	*Pompholyx triloba* Pejler, 1957	16, 32	4.65
	Testudinella mucronata (Gosse, 1886)	15, 31, 32, 39, 41, 43	13.95
	Testudinella ohlei Koste, 1972	11	2.32
	Testudinella patina (Hermann, 1783)	12, 15, 18, 19, 28, 30, 32, 39, 40	20.93
Family Trochosphaeridae	*Filinia limnetica* (Zacharias, 1893)	21, 22	4.65
	Filinia longiseta (Ehrenberg, 1834)	7, 12, 21, 22, 30, 34	13.95
	Filinia opoliensis (Zacharias, 1898)	6, 7, 12, 16, 39, 43	13.95
	Filinia saltator (Gosse, 1886)	41	2.32
	Filinia terminalis (Plate, 1886)	5, 6, 7, 8, 11, 12, 13, 16, 21, 33, 34, 39	27.91
Order Ploima			

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Family Asplanchnidae	*Asplanchna priodonta* Gosse, 1850	12	2.32
	Asplanchna sieboldii (Leydig, 1854)	7, 12, 18, 22, 24, 25, 30, 34, 35, 39, 43	25.58
	Harringia rousseleti de Beauchamp, 1912	28	2.32
Family Brachionidae	*Anuraeopsis fissa* Gosse, 1851	12, 21	4.65
	Anuraeopsis navicula Rousselet, 1911	5, 15, 19	6.98
	Brachionus angularis Gosse, 1851	30	2.32
	Brachionus budapestinensis Daday, 1885	7	2.32
	Brachionus calyciflorus Pallas, 1766	2, 5, 7, 8, 11, 12, 13, 15, 16, 18, 30, 31, 33, 34, 35, 39	37.21
	Brachionus caudatus Barrois & Daday, 1894	29, 30, 31, 32, 37, 38, 39, 43	18.6
	Brachionus dolabratus Harring, 1914	5, 6, 8, 13, 16, 25, 34, 35, 37, 39	23.25
	Brachionus falcatus Zacharias, 1898	3, 5, 6, 7, 11, 12, 16, 23, 34, 35, 38, 39, 42, 43	32.56
	Brachionus mirus Daday, 1905	10, 11, 12, 14, 21, 30, 31, 34, 39, 42, 43	25.58
	Brachionus quadridentatus Hermann, 1783	32, 43	4.65
	Brachionus urceolaris Müller, 1773	11, 39	2.32
	Brachionus zahniseri Ahlstrom 1934	41	2.32
	Kellicottia bostoniensis (Rousselet, 1908)	4, 5, 6, 11, 12, 15, 16, 21, 22, 23, 24, 25, 29, 32, 33, 34, 35, 36, 38	44.19
	Keratella americana Carlin, 1943	1, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 21, 22, 24, 35, 36, 38, 39, 43	44.19
	Keratella cochlearis (Gosse, 1851)	3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 15, 16, 18, 21, 22, 26, 34, 35, 38, 39, 41, 42	51.16
	Keratella lenzi Hauer, 1053	5, 8, 10, 11, 12, 13, 15, 34	18.61
	Keratella tropica (Apstein, 1907)	3, 4, 5, 6, 11, 12, 13, 14, 15, 16, 17, 21, 22, 35, 37, 38	37.21
	Plationus patulus (Müller, 1786)	11, 12, 13, 17, 21, 25, 26, 30, 32, 38, 39, 40, 42, 43	32.56
	Platyias leloupi (Gillard, 1957)	12, 17, 19, 27, 29, 30, 31, 32, 42, 43	23.25
	Platyias quadricornis (Ehrenberg, 1832)	17, 28, 29, 30, 43	11.63
Family Dicranophoridae	*Dicranophoroides caudatus* (Ehrenberg, 1834)	10	2.32
Family Epiphanidae	*Epiphanes clavulata* (Ehrenberg, 1832)	1, 11, 12, 15, 30, 43	13.95
	Epiphanes macroura (Barrois & Daday, 1894)	35	2.32
Family Euchlanidae	*Beauchampiella eudactylota* (Gosse, 1886)	30	2.32
	Dipleuchlanis propatula (Gosse, 1886)	41	2.32
	Euchlanis dilatata Ehrenberg, 1832	11, 12, 19, 25, 27, 32, 37, 41	16.28
Family Gastropodidae	*Ascomorpha agilis* Zacharias, 1893	39	2.32
	Ascomorpha ovalis (Bergendal, 1892)	34	2.32
	Ascomorpha saltans Bartsch, 1870	5, 9, 11, 15, 17	11.63
	Gastropus hyptopus (Ehrenberg, 1838)	30, 39	4.65
	Gastropus stylifer (Imhof, 1891)	17	2.32
Family Ituridae	*Itura aurita* (Ehrenberg, 1830)	19	2.32

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Family Lecanidae	*Lecane amazonica* (Murray, 1913)	32	2.32
	Lecane bulla (Gosse, 1851)	12, 19, 21, 15, 30, 43	13.95
	Lecane cornuta (Müller, 1786)	43	2.32
	Lecane curvicornis (Murray, 1913)	11, 12, 17, 18, 19, 30, 32, 33, 39, 41, 42, 43	27.91
	Lecane elsa Hauer, 1931	40, 41	4.65
	Lecane haliclysta Harring & Myers, 1926	21, 41	2.32
	Lecane hornemanni (Ehrenberg, 1834)	7, 8, 15, 25, 34	11.63
	Lecane leontina (Turner, 1892)	30, 39	4.65
	Lecane ludwigii (Eckstein, 1883)	33	2.32
	Lecane luna (Müller, 1776)	7, 19, 29, 21, 24, 32, 35	16.28
	Lecane lunaris (Ehrenberg, 1832)	20, 30, 39	6.98
	Lecane obtusa (Murray, 1913)	2, 6, 15	4.65
	Lecane papuana (Murray, 1913)	7, 39, 42	6.98
	Lecane proiecta Hauer, 1956	5, 7, 8, 12, 19, 39	13.95
	Lecane quadridentata (Ehrenberg, 1830)	19, 30	2.32
	Lecane rhytida Harring & Myers, 1926	17	2.32
	Lecane robertsonae Segers, 1993	6	2.32
	Lecane stenroosi (Meissner, 1908)	8	2.32
	Lecane subtilis Harring & Myers, 1926	18	2.32
	Lecane thienemanni (Hauer, 1938)	19, 21, 28	4.65
	Lecane ungulata (Gosse, 1887)	5, 42	2.32
Family Lepadellidae	*Colurella adriatica* Ehrenberg, 1831	21	2.32
	Colurella obtusa (Gosse, 1886)	21, 30	2.32
	Lepadella cristata (Rousselet, 1893)	38	2.32
	Lepadella donneri Koste, 1972	18	2.32
	Lepadella ovalis (Müller, 1786)	42	2.32
	Lepadella patella (Müller, 1786)	41	2.32
Family Mytilinidae	*Lophocharis oxysternon* (Gosse, 1851)	5	2.32
	Mytilina acanthophora Hauer, 1938	7	2.32
	Mytilina bisulcata (Lucks, 1912)	27	2.32
	Mytilina mucronata (Müller, 1773)	5, 7, 14, 19, 29	11.63
	Mytilina ventralis (Ehrenberg, 1830)	7, 8, 9, 12, 15, 16, 22, 27, 32, 35, 39	25.58
Family Notommatidae	*Enteroplea lacustris* Ehrenberg, 1830	13	2.32
	Monommata maculata Harring & Myers, 1930	30	2.32
Family Proalidae	*Proalinopsis staurus* Harring & Myers, 1924	7	2.32
Family Scaridiidae	*Scaridium longicaudum* (Müller, 1786)	30	2.32
Family Synchaetidae	*Ploesoma lenticulare* Herrick, 1885	21, 22, 24, 30	9.3
	Ploesoma truncatum (Levander, 1894)	5, 9, 15, 20, 21, 22, 23, 24, 34, 39	23.25
	Polyarthra dolichoptera Idelson, 1925	5, 7, 8, 10, 11, 12, 13, 15, 16, 18, 21, 22	27.91
	Polyarthra remata Skorikov, 1896	2, 9, 15, 21, 22, 25, 29, 35	18.6
	Polyarthra vulgaris Carlin, 1943	10	2.32
	Synchaeta oblonga Ehrenberg, 1832	7, 9, 17, 18, 39	11.63
	Synchaeta pectinata Ehrenberg, 1832	5, 6, 7, 12, 15, 18, 30	16.28
	Synchaeta stylata Wierzejski, 1893	7, 26, 30, 34	9.3

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Family Trichocercidae	*Trichocerca bicristata* (Gosse, 1887)	19, 42	2.32
	Trichocerca capucina (Wierzejski & Zacharias, 1893)	1, 2, 6, 21, 8, 12, 15, 37, 39	20.93
	Trichocerca chattoni (de Beauchamp, 1907)	9, 21, 22, 23, 24, 34, 39	16.27
	Trichocerca cylindrica (Imhof, 1891)	5, 8, 12, 15	9.3
	Trichocerca elongata (Gosse, 1886)	30, 33	4.65
	Trichocerca gracilis (Tessin, 1890)	6, 12, 25	4.65
	Trichocerca heterodactyla (Tschugunoff, 1921)	39	2.32
	Trichocerca longiseta (Schrank, 1802)	22	2.32
	Trichocerca rattus (Müller, 1776)	27	2.32
Family Trichotriidae	*Trichotria tetractis* (Ehrenberg, 1830)	20, 42	4.65
	Macrochaetus collinsii (Gosse, 1867)	37, 42	4.65

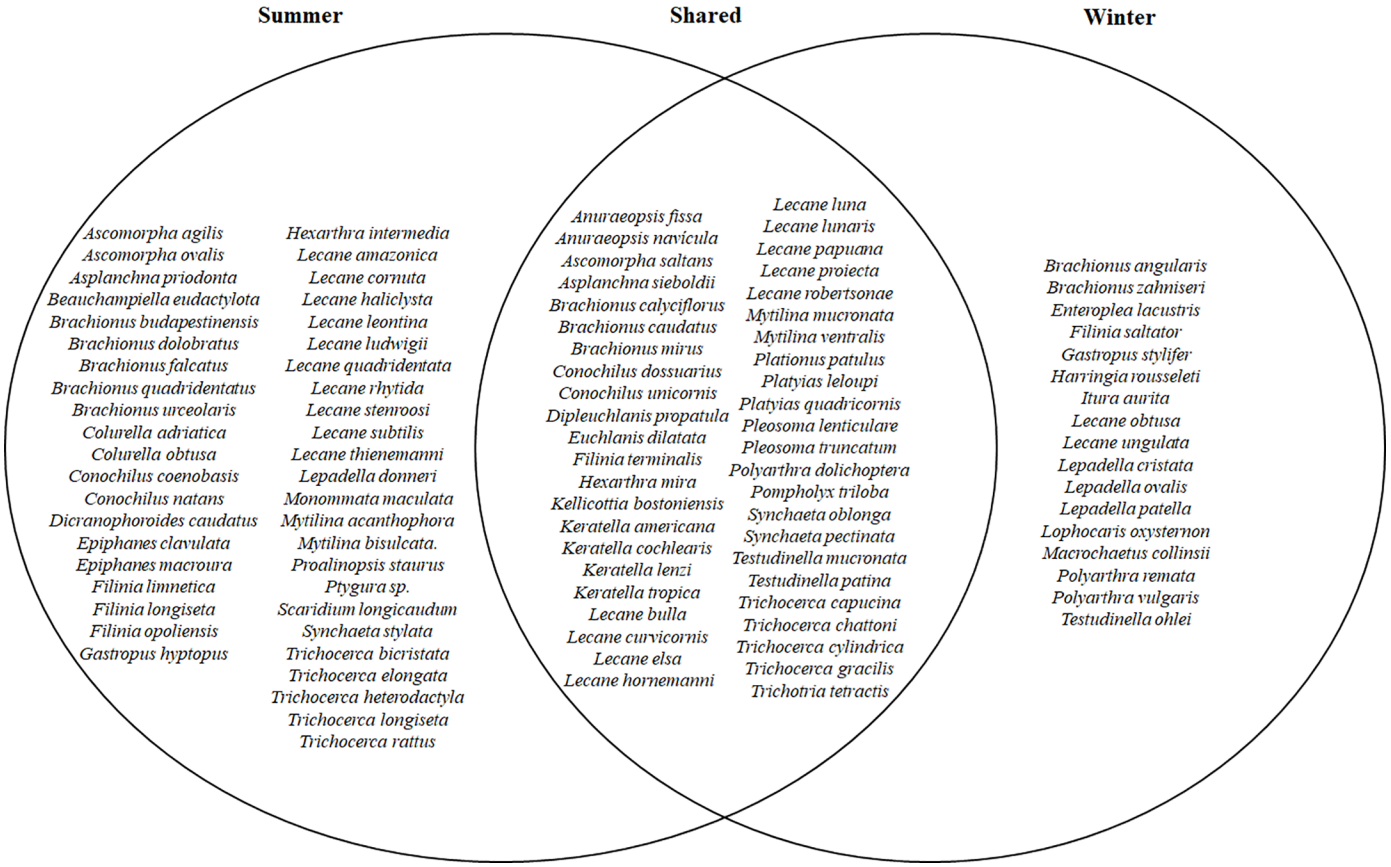

Figure 3. Species collected in the summer, winter and shared in both seasons.

Regarding individual sites, we found a wide range in species richness. Barra Bonita Reservoir (BBON-D; 12) in the Tietê River had the greatest species richness (22). The lowest richness was observed in the Lower (RURU-L; 40) and Middle (RURU-M1; 36) Uruguay River (3 species each; Table 2). The species occurring in >40% of the lotic and lentic sites evaluated were *Conochilus dossuarius* Hudson, 1885, *Kellicottia bostoniensis* (Rousselet, 1908), *Keratella americana* Carlin, 1943 *K. cochlearis* (Gosse, 1851) and *Hexarthra mira* (Hudson, 1871).

Our results indicate greater distribution ranges for several species. *Colurella adriatica* Ehrenberg, 1831, from the Foz do Areia Reservoir, is a new record for Brazil. *Gastropus hyptopus* (Ehrenberg, 1838) in the La Plata River and *Harringia rousseleti* de Beauchamp, 1912 and *Lecane thienemanni* (Hauer, 1938) in the Paraná River, are their first reports in Argentina. Finally, we expand the range of *Enteroplea lacustris* Ehrenberg, 1830, in São Paulo State (Brazil) and *Lecane ludwigii* (Eckstein, 1883) in Buenos Aires Province (Argentina).

Almost all the species are native, except *Kellicottia bostoniensis* which occurred in a new locality. Seven other species are Neotropical endemics (Table 2): *Brachionus dolabratus* Harring, 1914*, B. mirus* Daday, 1905*, B. zahniseri* Ahlstrom 1934*, K. americana, Lecane amazonica* (Murray, 1913), *L. proiecta* Hauer, 1956 and *Testudinella ohlei* Koste, 1972.

The mean ± standard deviations of water quality variables (Table 3) stratified by sub-basin reveals that the Tietê River has higher levels of total nitrogen, phosphorus, chlorophyll, and electrical conductivity.

The Lower Paraná River also demonstrates high values for these variables except for nitrogen. Higher temperatures were found in the Paraguay and Iguaçu Rivers. The lowest levels of dissolved oxygen occurred in the Paraguay River. Spearman correlations indicated that total chlorophyll and water temperature were positively correlated with species richness; dissolved oxygen demonstrated a negative correlation (Table 4).

Discussion

We found a total of 106 rotifer species in the La Plata basin. Our data represent 14% of the rotifer species richness known to Brazil (Garraffoni & Lourenço 2012), 37% of that for São Paulo State (Souza-Soares et al. 2011), 30% of that for the Upper Paraná (Lansac-Tôha et al. 2009), and 40% for the Upper Paraguay River (Branco et al. 2018). Data from other inventories show that the rotifer fauna in the La Plata River basin is richer than what was demonstrated in our study, possibly because we sampled in few Uruguay and Paraguay River stretches, and exclusively in open water habitats, not in littoral. Therefore, as recommended by Ferrando & Claps (2016), further investigations should be carried out to expand the distribution list of species in the La Plata River Basin.

The most diverse families were Lecanidae (21 spp.) and Brachionidae (20 spp.). These two families compose most rotifer species throughout Brazil and Argentina (Garraffoni & Lourenço, 2012; Ferrando & Claps, 2016), supporting our findings.

The higher summer (wet season) rotifer richness may be associated with the concentrated rainfall events that occur during this season.

Table 3. Means ± standard-deviations of water quality variables by sub-basin.

Sub-basin	Total Nitrogen (µg.L^{-1})	Total Phosphorus (µg.L^{-1})	Chlorophyll (µg.L^{-1})	Depth Max. (m)	Transparency (m)
Paranaíba	196.1±43.38	9.60±3.08	1.21±0.67	61.61±16.29	4.13±1.64
Grande	311.78±53.54	8.53±1.16	2.45±1.60	44.32±25.01	3.31±1.42
Tietê	2131.05±1373.24	58.19±45.73	7.19±6.54	25.93±6.85	2.70±1.45
Paranapanema	463.92±115.72	16.94±5.21	1.51±0.72	21.66±6.89	1.41±0.64
Iguaçu	325.38±37.98	15.40±4.67	1.26±0.63	57.75±24.13	1.45±0.34
Upper Paraná	622.30±126.81	15.40±4.19	1.52±0.80	41.14±23.40	2.75±1.50
Middle Paraná	468.12±47.37	34.33±6.48	3.17±1.30	9.85±3.40	0.42±0.08
Lower Paraná	415.29±79.69	54.60±13.93	3.74±1.63	11.8±5.80	0.56±0.09
Upper Uruguay	452.04±93.24	14.54±3.22	1.74±0.30	95.75±6.88	1.86±0.22
Middle Uruguay	780.90±70.22	22.07±5.80	3.12±1.96	22.67±15.43	0.66±0.11
Lower Uruguay	650.35±108.47	36.10±9.01	2.97±1.36	16.93±5.40	0.67±0.15
Paraguay	426.44±225.85	43.00±18.71	2.41±0.87	10.1±4.37	0.81±0.32
Sub-basin	**Temperature (°C)**	**pH**	**Conductivity (µS.cm^{-1})**	**DO (mg.L^{-1})**	**Turbidity (NTU)**
Paranaíba	24.35±1.81	7.21±0.19	41.82±4.32	6.26±0.97	8.64±3.38
Grande	24.10±2.8	7.20±0.33	38.45±7.07	7.16±1.16	11.58±6.70
Tietê	24.11±3.10	7.27±0.30	182.42±43.98	6.92±1.54	12.1±6.46
Paranapanema	23.01±3.16	7.25±0.27	55.10±6.56	7.91±0.96	24.2±11.41
Iguaçu	25.14±3.37	7.34±0.14	51.26±4.74	7.57±0.79	20.52±7.70
Upper Paraná	21.73±3.69	7.19±0.32	46.31±6.44	7.80±1.12	12.75±4.91
Middle Paraná	23.21±6.19	7.36±0.22	64.64±4.96	7.98±1.36	40.49±7.56
Lower Paraná	22.10±7.40	7.47±0.31	118.16±24.69	7.85±2.21	37.80±6.93
Upper Uruguay	17.71±1.77	6.86±0.13	32.26±2.13	8.68±0.46	14.51±2.12
Middle Uruguay	21.84±4.49	7.42±0.14	45.75±2.75	8.63±0.91	32.39±7.41
Lower Uruguay	22.22±6.75	7.44±0.21	59.24±20.58	8.69±1.22	31.30±5.68
Paraguay	26.40±3.87	6.75±0.24	67.84±15.33	5.17±1.28	27.40±13.22

Table 4. Spearman correlations between species richness and water quality variables. Bold = significant correlations.

Variables	R2	p	Variables	R2	p
Total Nitrogen	0.12	0.27	Temperature	0.27	**0.01**
Total Phosphorus	0.11	0.29	pH	-0.15	0.15
Chlorophyll	0.28	**0.00**	Conductivity	0.08	0.48
Depth	0.13	0.23	D.O.	-0.24	**0.02**
Transparency	0.02	0.87	Turbidity	-0.07	0.53

Summer rains can carry nutrients and organic matter from the margins of aquatic environments resulting in increased food concentration and a reduction in competition for resources. The same tendency was observed for the rainy season in a study performed on a tropical lake in Mexico (Jiménez-Contreras et al. 2018). Richness may also be related to the sediment mixture caused by intense rains. This process provides a favorable condition for hatching of dormant stages (i.e., resting eggs), resulting in an increase in rotifer species richness.

Greater rotifer species richness was observed in the Lower Paraná sub-basin. Rotifers have low locomotion capacity and are carried by drifting through the central channel of the river and consequently the species richness increase towards downstream.

Barra Bonita Reservoir in the Tietê River sub-basin was the site with the greatest richness. Despite being a reservoir with a high degree of anthropogenic disturbance, including eutrophication (Tundisi et al. 2008), many studies have shown high biodiversity for other groups, which include rotifers (Matsumura-Tundisi & Tundisi 2005, Rocha et al. 2006). In the Barra Bonita Reservoir, Matsumura-Tundisi & Tundisi (2005) found 32 species of rotifers. However, in our work we found 22 species. The Spearman correlation suggested a positive relation between richness and chlorophyll levels, with Barra Bonita Reservoir demonstrating the highest values of observed chlorophyll. Presumably, this higher richness is a result of greater numbers of tolerant rotifer species (Allen et al. 1999).

The commonest species in the La Plata basin were *Keratella americana, K. cochlearis*, and *Hexarthra mira*. Others have reported the occurrence these species in the Uruguay (Di Persia & Neiff 1986), Paraguay (Frutos et al. 2006, Branco et al. 2018) and Upper Paraná Rivers (Bonetto & Wais 2006), indicating the wide distribution of these rotifers in the study area.

Colurella has been found in several inland waters (Arroyo-Castro et al. 2019, Tasevska et al. 2019, Wei et al. 2019). In the La Plata Basin we found two species of this genus: *Colurella adriatica* Ehrenberg, 1831 and *C. obtusa* (Gosse, 1886). *Colurella adriatica* originates in the Adriatic Sea and has been described as endemic (Ehrenberg 1831), but it is now widely distributed, including in Neotropical regions (Segers 2007). We found it in Foz do Areia Reservoir, in the Iguaçu sub-basin, Paraná State, which is its first record in Brazil.

Enteroplea lacustris is widely distributed in the Australasia, Neoarctic, Neotropical, Oriental, and Paleoarctic regions (Segers 2007). In Brazil, it occurs in Mato Grosso do Sul (Roche & Silva 2017) and Paraná States in the Paranapanema River basin (Dias et al. 2011, Roche & Silva 2017). We found it in Três Irmãos Reservoir, Tietê sub-basin, São Paulo State, near the Paraná River, indicating a gap in previous studies of this region.

For Argentina, Ferrando & Claps (2016) recorded 351 species of monogonont rotifers from lotic and lentic environments. Among the species they recorded, we found 43 (12.2%). Three other species of rotifers (*Gastropus hyptopus*, *Harringia rousseleti*, and *Lecane thienemanni*) found in our study are new records for Argentina. *Gastropus hyptopus* was found in the La Plata River Basin, in Rosario, Argentina. In Brazil, it had been registered in several regions (Serafim Jr. et al. 2003, Bonecker et al. 2005, Serafim-Júnior et al. 2010, Souza-Soares et al. 2011). *Harringia rousseleti* and *L. thienemanni* were recorded for the first time in Argentine reaches of the Paraná River, in the Bella Vista municipality. A new locality was found for *L. ludwigii*, which had been recorded in Corrientes Province (José de Paggi 1996); however, there is no previous record in the La Plata River estuary where we collected it.

We found a non-native species in the La Plata River basin, *Kellicottia bostoniensis* (Rousselet, 1908), which is native to North America (Edmondson 1959). For Argentina, José de Paggi (2002) first recorded the species in the Iguaçu River and Salto Grande Reservoir. We found the species in the La Plata River (Uruguay and Argentina reach), where there were no prior records of it. We thus extended the known distribution of *K. bostoniensis*. It is possible that its occurrence in the La Plata basin is related to aquaculture activities as has occurred in other regions (Coelho & Henry 2017). In many reservoirs of the La Plata basin, there are aquaculture activities, mainly with non-native fish species (Azevedo-Santos et al. 2011, Nobile et al. 2018). This rotifer may be introduced from cage aquaculture in upstream rivers (e.g., Grande and Paranapanema Rivers) and reached downstream areas where we captured it.

Seven Neotropical endemic species (sensu José de Paggi 1996) were found in the La Plata River basin. Their presence highlights the importance of preserving the condition of these ecosystems. However, anthropogenic stressors imperil many areas where these seven species occur. For example, in the Barra Bonita and Três Irmãos Reservoirs, where *Brachionus dolobratus, B. mirus,* and *L. proiecta* were captured, waters are polluted (Rodgher et al. 2005, Favaro et al. 2018). Similarly, eutrophic tributaries in the Grande River sub-basin (Melo et al. 2017) may affect endemic rotifer species. Another example is the occurrence of *L. amazonica* in the La Plata River; which also receives water from these polluted river basins. Conservation policies must be discussed for the entire La Plata system because of fluvial connectivity (Azevedo-Santos et al. 2019).

In conclusion, surveys covering wide spatial extents, such as in our study, are important for increasing the knowledge of species diversity and distribution. Our findings may contribute to future monitoring studies as well as management and conservation programs for the La Plata River basin. Finally, we recommend that future rotifer surveys should be concentrated in Paraguay and Uruguay River reaches because of the scarcity of data from them.

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Author Contributions

Bárbara A. Martins: Contribution to data analysis, interpretation, Contribution to manuscript preparation.

Paula N. Coelho: Contribution to manuscript preparation, Contribution to critical revision, adding intellectual content.

Marcos G. Nogueira: Substantial contribution in the concept and design of the study, Contribution to data collection, Contribution to critical revision, adding intellectual content.

Gilmar Perbiche-Neves: Substantial contribution in the concept and design of the study, Contribution to data collection, Contribution to critical revision, adding intellectual content.

Conflicts of Interest

The author(s) declare(s) that they have no conflict of interest related to the publication of this manuscript.

Ethics

The data collection was complied with the guidelines established by the ethics committees of Universidade Estadual de São Paulo.

Data availability

The species were deposited in the Laboratory of Ecology and Continental Waters, Institute of Biosciences of Botucatu at the Universidade Estadual Paulista Júlio de Mesquita Filho (Unesp), Brazil. Lot 009, samplings 1 to 44.

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