Zooplankton diversity in freshwater environments of Parintins, Amazonas, Brazil

Diversidade do zooplâncton em ambientes de água doce de Parintins, Amazonas, Brasil

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Abstract: This study presents a taxonomic survey of the zooplankton community in Parintins, located on the right bank of the Amazon River, Amazonas State, Brazil. Sampling was carried out at ten sites encompassing lentic and lotic environments during the rainy (June–July 2022) and dry (October–November 2022) seasons. Zooplankton samples were collected through horizontal subsurface tows using a 64 μm plankton net and analyzed under light microscopy. A total of 118 taxa were identified, belonging to eight main groups: rotifera, protozoa, chromista, branchiopoda, copepoda, diptera, gastrotricha, and nematoda. Taxonomic richness was higher in lentic environments (99 taxa) and during the dry season (93 taxa). Rotifera and protozoa were the most representative groups, followed by chromista and branchiopoda. Seventy-nine taxa represent first records for the lower Amazonas region, highlighting the importance of taxonomic inventories in underexplored Amazonian areas and contributing to biodiversity knowledge and environmental monitoring in the context of urbanization and hydrological variability.

Keywords: Amazon Basin. Black water. Inventories. Plankton.

Resumo: Este estudo apresenta um levantamento taxonômico da comunidade zooplanctônica de Parintins, localizada na margem direita do rio Amazonas, estado do Amazonas, Brasil. As coletas foram realizadas em dez pontos abrangendo ambientes lênticos e lóticos, durante as estações chuvosa (junho-julho de 2022) e seca (outubro-novembro de 2022). As amostras foram obtidas por meio de arrastos horizontais em subsuperfície, utilizando uma rede de plâncton com malha de 64 μm, e analisadas em microscópio óptico. Foi identificado um total de 118 táxons pertencentes a oito grupos principais: rotifera, protozoa, chromista, branchiopoda, copepoda, diptera, gastrotricha e nematoda. Ambientes lênticos apresentaram maior riqueza de táxons (99 táxons) e durante o período seco (93 táxons). Os rotifera e protozoa foram os grupos mais representativos, seguidos por chromista e branchiopoda. Setenta e nove táxons representam registros inéditos para a região do baixo Amazonas, destacando a importância dos inventários taxonômicos em áreas amazônicas pouco exploradas e contribuindo para o conhecimento da biodiversidade e para o monitoramento ambiental associado à urbanização e à variação hidrológica.

Palavras-chave: Bacia amazônica. Águas pretas. Inventários. Plâncton.

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INTRODUCTION

Freshwater ecosystems hold highly diverse, endemic, and sensitive biota that provide and sustain a wide range of ecosystem services (Strayer & Dudgeon, 2010). Among freshwater fauna, zooplankton occur abundantly in virtually all types of aquatic habitats and play a key role in energy transfer, occupying an intermediate trophic level (Melo et al., 2006). Many zooplankton species feed on bacteria and algae and, in turn, serve as prey for numerous invertebrates, fish, and birds (Simões et al., 2008; Panpatil & Deshmukh, 2021).

Limnetic zooplankton communities are mainly composed of protozoa, rotifera, copepoda, and branchiopoda, whose distribution is regulated by environmental factors such as food availability, water flow, and turbidity (Simões et al., 2013). Studies on zooplankton diversity and ecology contribute to a better understanding of aquatic ecosystem functioning and have increasingly been used as indicators of water quality and hydrological fluctuations (Medeiros et al., 2011; Panpatil & Deshmukh, 2021).

Globally, freshwater ecosystems are estimated to harbor the following number of known species: 257 genera and 2,814 species of copepoda (Boxshall & Defaye, 2008), 128 genera and 1,949 species of rotifera (Segers, 2008), 95 genera and 620 species of branchiopoda (Forró et al., 2008). In Brazil, between 1900 and 2021, a total of 1,014 studies on freshwater zooplankton were published, most of them focusing on the ecology and taxonomy of branchiopoda, followed by copepoda and rotifera, whereas protozooplankton remain the least investigated group (Castilho-Noll et al., 2023). Despite this growing body of research, the freshwater zooplankton fauna of Brazil is still poorly known (Elmoor-Loureiro et al., 2022).

Although the Amazon Basin represents the world's largest river system in terms of both drainage area and freshwater discharge (Calléde et al., 2000), there is a gap of nearly four decades in zooplankton research for the region, particularly for the state of Amazonas (Brandorff et al., 1982; Hardy et al., 1984; Robertson & Hardy, 1984; Koste et al., 1984; Brito et al., 2015; Arrieira et al., 2016; Souza et al., 2021; Elmoor-Loureiro et al., 2022). Consequently, knowledge of zooplankton diversity in Amazonian ecosystems remains incomplete, with many areas still lacking adequate survey and taxonomic documentation (Souza et al., 2019; L. Santos et al., 2022).

Increasing anthropogenic pressures and land use changes throughout the Amazon Basin (Pacheco et al., 2015; Kimura et al., 2017) threaten species that have not yet been recorded, disrupting biological processes and altering zooplankton species distribution patterns, colonization dynamics, and life cycles (Simões et al., 2008; K. Santos et al., 2022). These impacts may ultimately lead to species loss and functional homogenization (Gadelha et al., 2022).

In this study, we present a taxonomic inventory of zooplankton species from lentic and lotic environments of white and black water systems in the Amazon basin and its tributaries in Parintins, lower Amazon region. This study contributes with new data on regional biodiversity and improves knowledge of the occurrence and distribution of zooplankton communities in Amazonian freshwater ecosystems.

MATERIAL AND METHODS

STUDY AREA

The study was conducted in the Parintins region (02° 37' 40" S; 56° 44' 09" W), the second most populous municipality in the state of Amazonas, Brazil, with approximately 110,000 inhabitants (Silva et al., 2016; IBGE, 2023). Parintins is a fluvial island located on the right bank of the Amazon River and comprises aquatic ecosystems influenced by both white-water and black-water systems.

White waters, originating mainly from Andean and sub-Andean drainages, are characterized by high loads of suspended sediments, neutral to slightly acidic pH, higher electrical conductivity, and relatively elevated concentrations of dissolved nutrients. These characteristics result in high primary and secondary productivity. In contrast, black waters drain highly weathered terrains and are characterized by low sediment loads, acidic pH, low ionic content, and high

concentrations of dissolved humic substances, which impart a dark coloration to the water and are associated with low nutrient availability and reduced productivity (Sioli, 1984; Junk et al., 2011).

The region has a humid tropical climate (Köppen, 1936), with four distinct phases in the regional hydrological cycle: an intense rainy season from December to April, a period of high water levels in May and June, a dry season from June to October, and the lowest water levels in November (Coêlho et al., 2024; Silva-Lehmkuhl et al., 2024).

Ten sampling sites were selected within and around Parintins Island and classified as lentic (P1–P6) and lotic (P7–P10) environments (Figure 1).

SAMPLING

Sampling was conducted during the high-water (June–July 2022) and low-water periods (October–November 2022). Water temperature (°C) and pH were measured *in situ* using a multiparameter probe (HANNA HI98194) (Table 1).

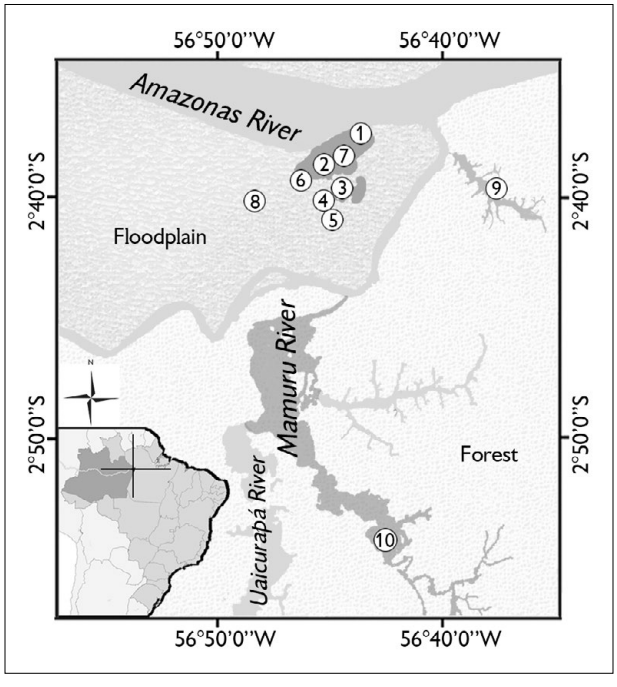

Figure 1. Location of the sampling sites in Parintins, Amazonas, Brazil. Site codes correspond to those listed in Table 1. Source: Author (2026).

Zooplankton samples were collected through horizontal subsurface tows (Anyanwu et al., 2020) using a conical plankton net with a 64 μm mesh size and 60 cm mouth diameter, towed for three minutes. The material retained in the net was transferred to 200 mL polyethylene bottles, properly labeled, and preserved in 70% ethanol (CETESB, 2014).

SPECIES ANALYSIS

Samples were homogenized, and 1.5 mL subsamples were withdrawn using a Hansen–Stempel pipette, following Bottrell et al. (1976). Analyses were performed in a Sedgewick–Rafter counting chamber (Koste, 1978) under a light microscope (Opton TNB-40T model) at 100× and 400× magnifications, equipped with a digital camera. Subsamples were examined following a species rarefaction criterion, whereby consecutive microscopic fields were analyzed until no additional taxa were observed. Whenever possible, organisms were identified to the species level based on Montú and Gloeden (1986), Loureiro (1996), Dahms et al. (2006), Tenebaum (2006), and Ezz et al. (2014). Taxa representing first record for Parintins are indicated by an asterisk (*) in Table 2.

RESULTS

A total of 118 taxa were recorded in the study area, comprising 48 rotifera (40.6%) (Figure 3), 38 protozoa (32.2%) (Figure 4), 16 chromista (13.5%), 10 branchiopoda (8.7%) (Figure 5), three copepoda (2.6%), and one taxon (0.8%) each of diptera, gastrotricha, and nematoda (Table 2). Of these, 79 taxa represent the first records for the lower Amazonas region.

Taxonomic richness ranged from 67 taxa in lotic environments to 99 in lentic environments. Species richness was also higher during the dry season (93 taxa) than during the rainy season (46 taxa) (Table 2, Figure 2). All zooplankton groups exhibited greater richness during the dry period and in lentic environments (Figure 2).

Table 1. Description of zooplankton sampling sites in Parintins, Amazonas, Brazil, including geographic coordinates, environment type, and mean temperature (T °C) and pH values during flood and drought periods. Sites P3–P6 are associated with groundwater discharge.

CODE	Sampling sites	Geographic coordinates	Environment type	T (°C)	pH
P1	Francesa Lagoon	2° 37' 31.8" S 56° 43' 22.2" W	Floodplain area with lentic conditions and white water, influenced by seasonal inundation pulses	33.4	6.8
P2	Lake Lagoa Azul	2° 38' 51" S 56° 44' 52" W	An urban lentic black-water lake	32.6	9.3
P3	Paraíso Resort Spring	2° 40' 11.9" S 56° 44' 52.5" W	Lentic black-water spring located in a recreational area	26.8	3.4
P4	Regaço Resort Spring	2° 39' 46" S 56° 44' 18" W	Lentic black-water spring located in a recreational area	26.5	4.6
P5	Luiz Viana Farm Spring	2° 40' 52.4" S 56° 44' 39.2" W	Lentic black-water spring located on a farm	30	6.3
P6	Areial Springs	2° 39' 32.2" S 56° 45' 50.4" W	Lentic black-water spring complex in a sandy area	31	5.2
P7	Amazonas-Macurany várzea	2° 38' 29" S 56° 44' 04" W	Floodplain area with lentic conditions and white water, influenced by seasonal inundation pulses	32	7
P8	Canta Galo	2° 40' 16" S 56° 47' 47" W	Floodplain area with lentic conditions and white water, influenced by seasonal inundation pulses	30.7	6.4
P9	Lake Lago do Zé Açu	2° 40' 12.7" S 56° 37' 36" W	Lake influenced by lotic black-water from tributaries	31.4	5.7
P10	Mamuru River	2° 55' 9.88" S 56° 42' 13.06" W	Lotic black-water	32	5.2

Table 2. Occurrence and distribution of zooplankton taxa across sampling sites in Parintins, Amazonas, Brazil. Taxa marked with an asterisk (*) indicate new records for Parintins. Site locations correspond to the codes presented in Table 1. (Continue)

Taxa	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
COPEPODA										
Order: Calanoida										
Family: Diaptomidae										
Diaptomus Westwood, 1836									X	
Order: Cyclopoida										
Family: Cyclopidae										
Microcyclops Claus, 1893		X				X			X	X
**Microcyclops varicans* (Sars G.O., 1863)	X	X							X	X
BRANCHIOPODA										
Order: Anomopoda										
Family: Chydoridae										
Alonella G.O. Sars, 1862						X	X			
Chydorus Leach, 1816			X							
**Chydorus sphaericus* (O.F. Müller, 1776)			X			X				
Leydigia Kurz, 1875				X						

Table 2. Taxa (Continue)

Taxa	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
**Monospilus dispar* G.O. Sars, 1862						X				
Family: Bosminidae										
Bosmina longirostris (O.F. Müller, 1785)	X								X	X
Bosminopsis deitersi Richard, 1895	X						X			X
Family: Macrothricidae										
**Macrothrix laticornis* (Jurine, 1820)						X				
Family: Moinidae										
**Moina micrura* Kurz, 1875	X	X				X	X		X	X
Order: Ctenopoda										
Family: Sididae										
Diaphanosoma Fischer, 1850							X			
ROTIFERA										
Subclass: Bdelloida										
Order: Adinetida										
Family: Adinetidae										
**Adineta vaga* (Davis, 1873)	X	X			X	X				
Family: Philodinidae										
Philodina Ehrenberg, 1830									X	
Subclass: Monogononta										
Order: Flosculariaceae										
Family: Conochilidae										
Conochilus Ehrenberg, 1834									X	
Family: Hexarthridae										
**Hexarthra mira* (Hudson, 1871)						X				
Family: Testudinellidae										
Testudinella patina (Hermann, 1783)	X					X	X			
Family: Trochosphaeridae										
Filinia opoliensis (Zacharias, 1898)							X			X
**Filinia terminalis* (Plate, 1886)							X		X	
Order: Ploima										
Family: Asplanchnidae										
Asplanchna priodonta Gosse, 1850						X	X			X
Family: Brachionidae										
Anuraeopsis fissa Gosse, 1851		X				X	X		X	X
**Brachionus angularis* Gosse, 1851		X								X
**Brachionus bidentatus* Anderson, 1889	X								X	
**Brachionus budapestinensis* Daday, 1885	X	X					X			
**Brachionus caudatus* Barrois & Daday, 1894							X			
**Brachionus diversicornis* (Daday, 1883)		X								

Table 2. (Continue)

Taxa	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Brachionus falcatus Zacharias, 1898		X								
**Brachionus forficula* Wierzejski, 1891		X					X			
Brachionus gessneri Hauer, 1956						X			X	X
**Brachionus havanaensis* Rousselet, 1911		X					X			X
**Brachionus plicatilis* Müller, 1786		X								X
Brachionus zahniseri Ahlstrom, 1934		X								
Keratella americana Carlin, 1943										X
Keratella cochlearis (Gosse, 1851)			X						X	X
**Keratella tropica* (Apstein, 1907)							X			
Plationus patulus var. *macracanthus* (Daday, 1905)							X			
Family: Euchlanidae										
**Euchlanis dilatata* Ehrenberg, 1830							X			
Family: Gastropidae										
Ascomorpha ovalis (Bergendal, 1892)						X				X
**Ascomorpha saltans* Bartsch, 1870		X				X			X	X
Gastropus Imhof, 1888		X				X			X	
Family: Lecanidae										
Lecane bulla (Gosse, 1851)	X	X	X			X	X			
Lecane closterocerca (Schmarda, 1859)						X				
Lecane luna (Müller, 1776)			X	X	X	X				
**Lecane mira* (Murray, 1913)						X			X	
Lecane papuana (Murray, 1913)	X						X			
**Lecane undulata* Hauer, 1938.	X									
Family: Lepadellidae										
Colurella adriatica Ehrenberg, 1831			X	X						
Family: Mytilinidae										
**Mytilina mucronata* (Müller, 1773)	X	X					X		X	X
Family: Notommatidae										
Cephalodella Bory de St. Vincent, 1826	X					X				X
Eosphora Ehrenberg, 1830							X			
**Monommata longiseta* (Müller, 1786)			X		X					X
Family: Proalidae										
**Proales daphnicola* Thompson, 1892		X								
Family: Trichocercidae										
**Trichocerca cylindrica* (Imhof, 1891)									X	X
**Trichocerca multicrinis* (Kellicott, 1897)		X				X				
Trichocerca pusilla (Jennings, 1903)		X				X	X		X	X
Family: Trichotriidae										
**Macrochaetus subquadratus* (Perty, 1850)										X
Family: Synchaetidae										

Table 2. Taxa (Continue)

Taxa	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Ploesoma lenticulare Herrick, 1885										X
**Polyarthra dolichoptera* Idelson, 1925	X					X	X		X	X
Polyarthra vulgaris Carlin, 1943	X	X					X			X
Synchaeta stylata Wierzejski, 1893							X			X
PROTOZOA										
AMEBOZOA										
Order: Arcellinida										
Family: Arcellidae										
**Arcella brasiliensis* A.M.Cunha, 1913		X			X					X
**Arcella conica* (Playfair, 1918)				X	X	X		X		
**Arcella costata* Ehrenberg, 1847						X				
**Arcella crenulata* Deflandre, 1928			X		X	X	X			X
**Arcella gandalfi* Féres, Porfírio-Sousa, Ribeiro, Rocha, Sterza, Souza, Soares and Lahr, 2016				X						
**Arcella gibbosa* Penard, 1890									X	X
**Arcella hemisphaerica* Perty, 1852		X	X	X	X		X			
**Arcella hemisphaerica* forma *undulata* Deflandre, 1928						X				
**Arcella mitrata* Leidy, 1876						X				
**Arcella vulgaris* Ehrenberg, 1830	X	X	X	X	X	X	X		X	X
**Galeripora discoides* (Ehrenberg, 1871) González-Miguéns et al. 2021						X				
**Galeripora megastoma* (Penard, 1902)				X						
Family: Centropyxidae										
**Centropyxis aculeata* (Ehrenberg, 1832) Stein, 1859	X		X	X	X	X				
**Centropyxis constricta* (Ehrenberg, 1841) Deflandre, 1929	X									
**Centropyxis sylvatica* (Deflandre, 1929) Bonnet and Thomas, 1955	X									
Family: Cylindriflugiidae										
**Cylindrifflugia acuminata* (Ehrenberg, 1838)	X				X					
**Cylindrifflugia elegans* (Penard, 1890)	X					X	X			
**Cylindrifflugia oblonga* (Ehrenberg, 1838)	X		X	X	X	X	X			
Family: Difflugiidae										
**Difflugia brevicolla* Cash & Hopkinson, 1909	X		X	X	X	X				
**Difflugia limnetica* (Levander, 1900) Penard, 1902	X									
**Difflugia lobostoma* (Leidy, 1879)			X						X	
**Difflugia nodosa* (Leidy, 1879)				X						
**Difflugia papillomata* Gauthier-Lièvre et Thomas, 1958						X				
**Lagenodifflugia vas* (Leidy, 1874) Medioli e Scott, 1983			X		X					
Lamtopyxis Bonnet, 1974						X				
**Protocucurbitella coroniformis* Gauthier-Lièvre & Thomas, 1960	X									
Family: Heleoperidae										
**Heleopera petricola* Leidy, 1879										X

Table 2. (Continue)

Taxa	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Family: Hyalospheniidae										
**Hyalosphenia nobilis* Cash, 1909			X							
**Hyalosphenia subflava* Cash, 1909	X		X	X						X
Family: Lesquereusiidae										
**Lesquereusia spiralis* Ehrenberg, 1840	X					X				
Family: Netzeliidae										
**Netzelia corona* (Wallich, 1864)						X				
**Netzelia oviformis* (Cash, 1909) Ogden,1979	X	X	X			X	X			X
Family: Plagiopyxidae										
Bullinularia Penard, 1911	X		X	X	X					X
**Plagiopyxis declivis* Bonnet, 1955	X									
Family: Trigonopyxidae										
**Cyclopyxis arcelloides* (Penard, 1902) Deflandre, 1929						X		X		
**Cyclopyxis impressa* (Daday, 1905) Da Cunha, 1913		X	X	X						
CHROMISTA										
CERCOZOA										
Order: Euglyphida										
Family: Euglyphidae										
**Euglypha filifera* Penard, 1890					X					
**Euglypha rotunda* Wailes & Penard, 1911	X						X			X
Family: Trinematidae										
**Trinema complanatum* Penard, 1890							X			
**Trinema enchelys* (Ehrenberg, 1838) Leidy, 1878	X								X	
CILIOPHORA										
Order: Choreotrichida										
Family: Codonellidae										
Codonaria Kofoid & Campbell, 1939					X					
Codonella Haeckel, 1873	X									
**Codonella nationalis* Brandt, 1906										X
**Tintinnopsis acuminata* Daday, 1887	X						X	X	X	X
**Tintinnopsis beroidea* Stein, 1867	X				X					
**Tintinnopsis campanula* (Ehrenberg, 1840)	X									
**Tintinnopsis fimbriata* Meunier, 1919									X	
**Tintinnopsis lobiancoi* Daday, 1887	X									
**Tintinnopsis radix* (Imhof, 1886)								X		
**Tintinnopsis rotundata* Kofoid & Campbell, 1929					X		X			
Family: Codonellopsidae										
**Codonellopsis morchella* (Cleve) Jörgensen, 1924	X									
Family: Tintinnidiidae										
**Leprotintinnus simplex* Schmidt, 1902	X				X					

Table 2. (Conclusion)

Taxa	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
**Tintinnidium fluviatile* Stein, 1863	X									
GASTROTRICHA										
Order: Chaetonotida										
Family: Chaetonotidae										
Chaetonotus Ehrenberg, 1830										X
Others (aloctone)										
NEMATODA										
Order: Dorylaimida										
Family: Dorylaimidae										
Prodorylaimus Andrássy, 1959			X			X				
INSECTA										
Order: Diptera										
Family: Dixidae										
Dixa Meigen, 1818				X						

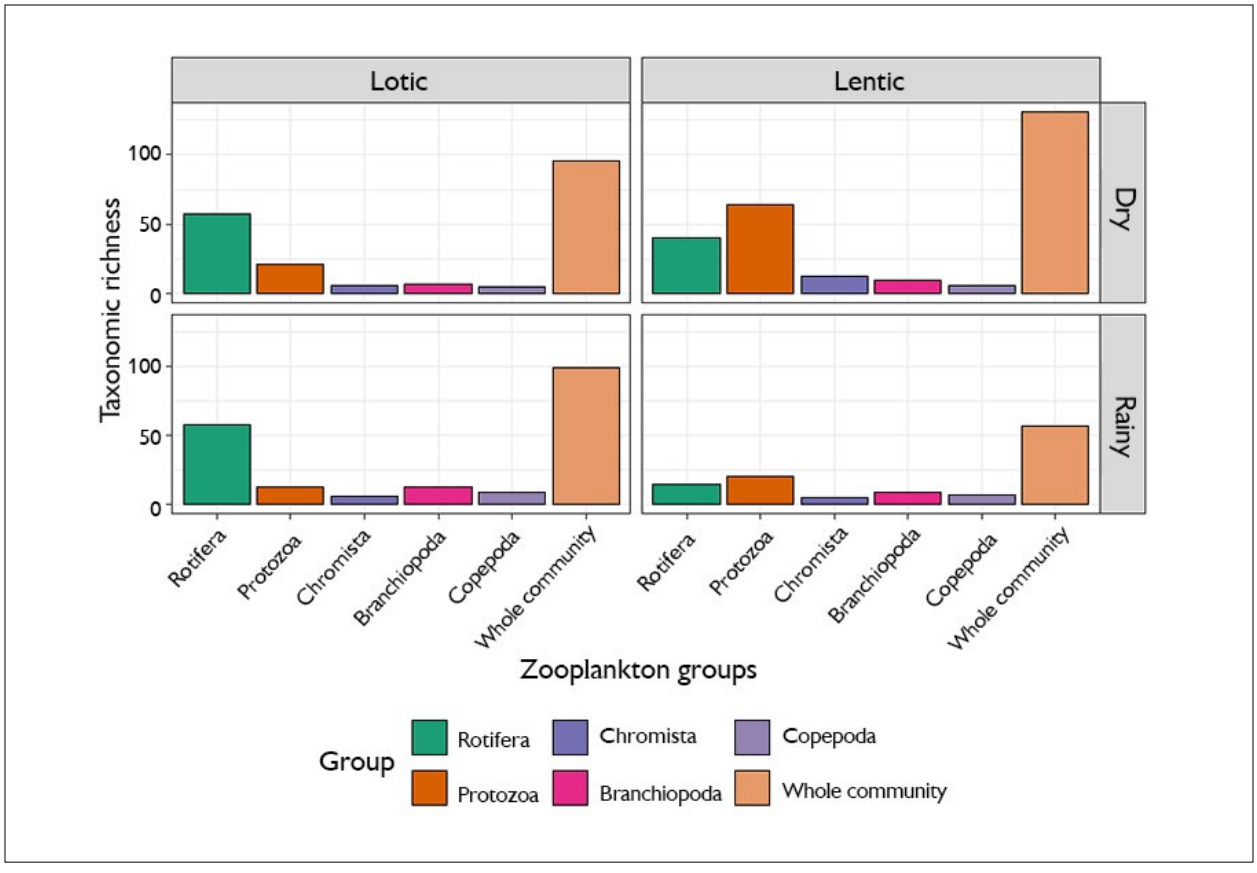

Figure 2. Difference in zooplankton group richness between lotic and lenticenvironments and between rainy and dry periods. On the X-axis, from left toright: Rotifera, Protozoa, Chromista, Branchiopoda, Copepoda and the whole community. Source: Author (2026).

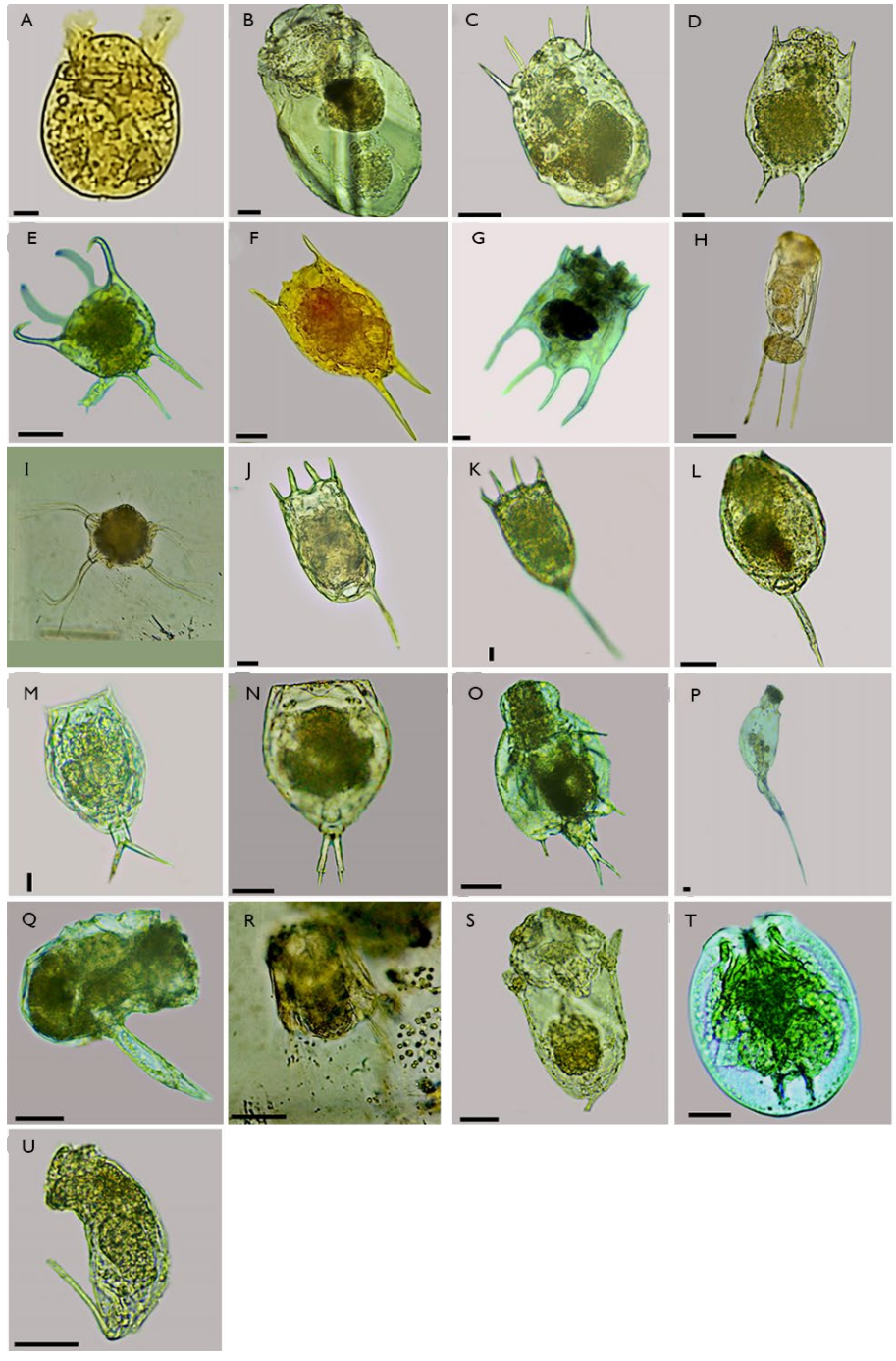

Figure 3. Rotifer taxa recorded in freshwater environments of Parintins, Amazonas, Brazil: A) *Ascomorpha saltans*, B) *Asplanchna priodonta*, C) *Brachionus budapestinensis*, D) *Brachionus forficula*, E) *Brachionus gessneri*, F) *Brachionus havanaensis*, G) *Plationus patulus* var. *macracanthus*, H) *Filinia opoliensis*, I) *Hexarthra mira*, J) *Keratella tropica*, K) *Keratella cochleares*, L) *Lecane bulla*, M) *Lecane mira*, N) *Lecane papuana*, O) *Macrochaetus subquadratus*, P) *Monommata longiseta*, Q) *Ploesoma lenticulare*, R) *Polyarthra dolichoptera*, S) *Synchaeta stylata*, T) *Testudinella patina*, U) *Trichocerca pusilla*. Scale bar: 2 mμ. Source: Author (2026).

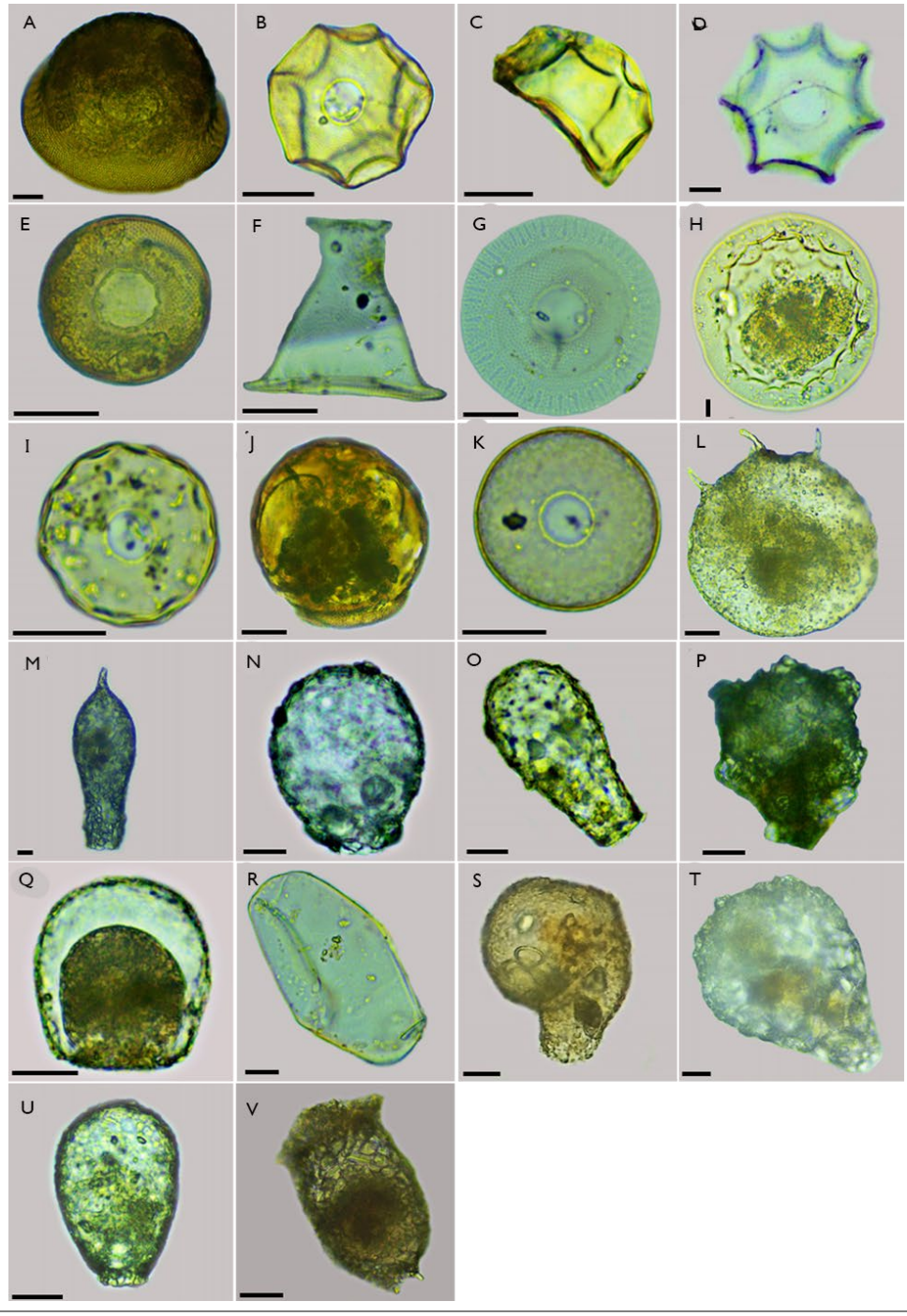

Figure 4. Protozoa taxa recorded in freshwater environments of Parintins, Amazonas, Brazil: A) *Arcella brasiliensis*, B) *Arcella conica* (basal view), C) *Arcella conica* (lateral view), D) *Arcella costata*, E) *Arcella crenulata*, F) *Arcella gandalfi*, G) *Arcella gandalfi* (basal view), H) *Arcella gibbosa*, I) *Arcella hemisphaerica*, J) *Arcella mitrata*, K) *Arcella vulgaris*, L) *Centropyxis aculeata*, M) *Cylindrifflugia acuminata*, N) *Difflugia brevicolla*, O) *Cylindrifflugia oblonga*, P) *Difflugia nodosa*, Q) *Heleopera petricola*, R) *Hyalosphenia subflava*, S) *Lesquereusia spiralis*, T) *Nebela*, U) *Netzelia oviformis*, V) *Protocucurbitella coroniformis.* Scale bar: 2 mμ. Source: Author (2026).

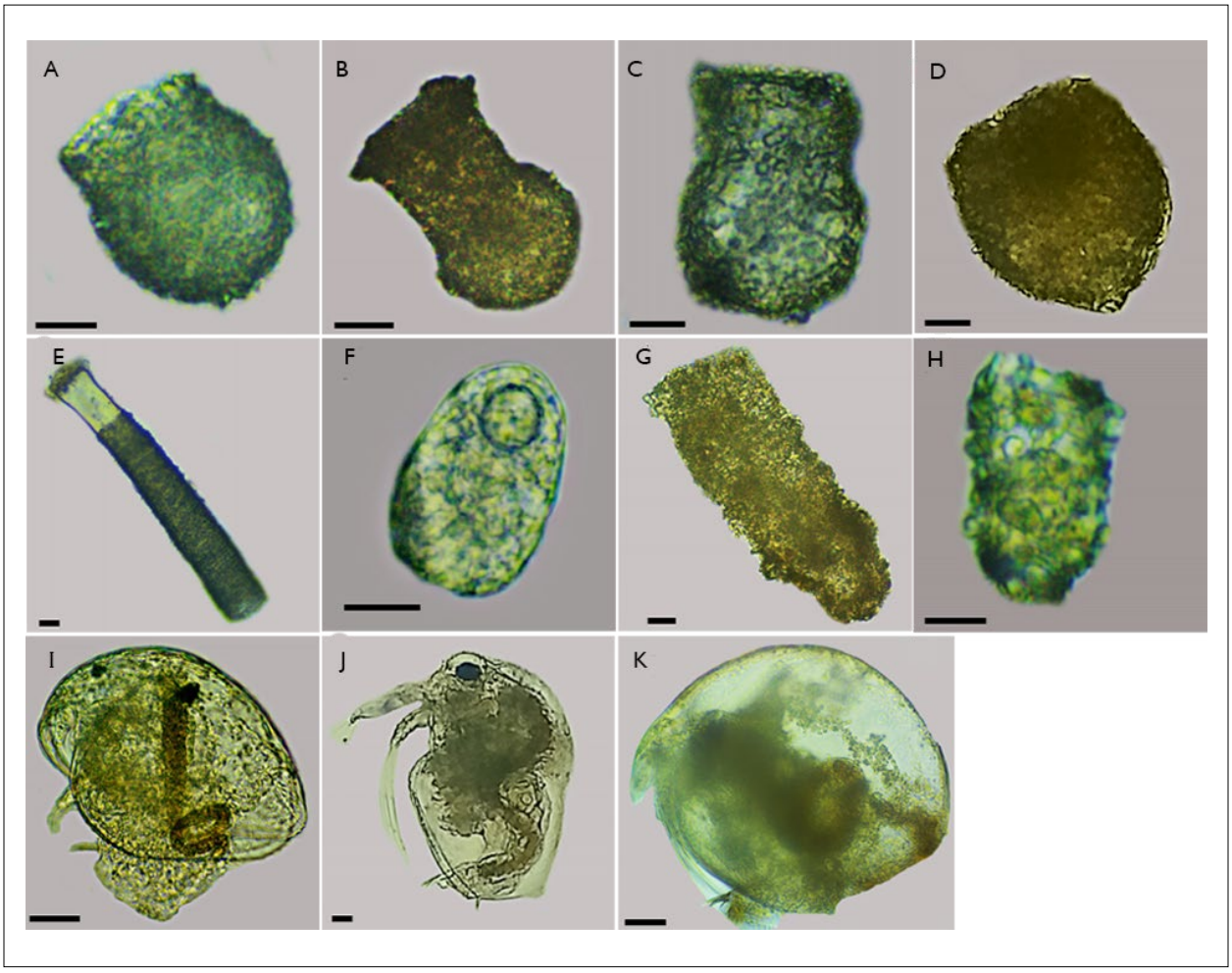

Figure 5. Chromista (A-H) and Diplostraca (I-K) taxa recorded in freshwater environments of Parintins, Amazonas, Brazil: A) *Codonaria*, B) *Codonella*, C) *Codonella nationalis*, D) *Codonellopsis morchella*, E) *Leprotintinnus simplex*, F) *Trinema complanatum*, G) *Tintinnopsis acuminata*, H) *Tintinnopsis beroidea*, I) *Alonella*, J) *Bosmina longirostris*, K) *Chydorus sphaericus.* Scale bar: 2 m*µ*. Source: Author (2026).

Rotifera, protozoa, chromista, and branchiopoda accounted for 26, 27, nine, and six species, respectively, occurring exclusively in lentic environments. In contrast, lotic environments harbored 13 rotifera, two protozoa, two chromista, and one branchiopoda species. With respect to seasonality, 11 rotifer taxa, two protozoan taxa, five chromista taxa, and three branchiopoda taxa were recorded exclusively during the rainy period, whereas 27 rotifer taxa, 49 protozoa taxa, 10 chromista taxa, and six branchiopoda taxa occurred only during the dry period (Appendix 1). *Arcella vulgaris* was the most frequent species in the samples.

DISCUSSION

Our study revealed a higher richness of rotifera, followed by protozoa, chromista, and branchiopoda, a pattern commonly reported for inland water environments in the Amazon Basin (Table 3; Robertson & Hardy, 1984; Keppeler, 2003; L. Santos et al., 2022; Brito et al., 2015; Costa et al., 2016a). The prevalence of rotifera is closely associated with their high reproductive rates, short life cycles, and efficient conversion of primary production into biomass, with this group accounting for up to 30% of total plankton biomass in some freshwater systems.

In addition, rotifera exhibit a broad feeding spectrum and high ecological resilience, allowing them to persist even in environments subject to elevated organic pollution (Oliveira et al., 2015; Gadelha et al., 2022).

Table 3. Occurrence of the main zooplankton groups in different Amazonian aquatic environments, indicating water type and supporting literature. Hydrographic basins and main river systems are indicated in bold. (Continue)

Environment	Water category	Rotifera	Branchiopoda	Copepoda	Protozoa	Chromista	Main source
Amazon-Solimões River System	White	110		17			Robertson and Hardy (1984)
Calado Lake	White		8				Robertson and Hardy (1984)
Camaleão Lake	White	175					Koste et al. (1984)
Castanho Lake	White		16				Robertson and Hardy (1984)
Jacaretinga Lake	White		12				Robertson and Hardy (1984)
Redondo Lake	White		5				Robertson and Hardy (1984)
Manacuri Lake	White		16				Robertson and Hardy (1984)
Branco River	White	11	1				Robertson and Hardy (1984)
Madeira River	White	60		7			Robertson and Hardy (1984)
		130	55	28	105		Souza et al. (2021)
Maracá-Roraima Island	White	159					Koste and Robertson (1990)
Cuiabá River marginal lakes	White	79	30	6			Neves et al. (2003)
Acre river							
Amapá Lake, Pirapora Lake	White	38	6	2			Keppeler (2003)
Amapá Lake	White	30	5	3			Keppeler and Hardy (2004)
Guamá River	White	30					Gadelha et al. (2022)
Juruá River							
Cigana Lake	White	37	2				L. Santos et al. (2022)
Novo Lake	White	49	2				L. Santos et al. (2022)
Verde Lake	White	48	3				L. Santos et al. (2022)
Moju Lake	White	41	2				L. Santos et al. (2022)

Table 3. (Continue)

Environment	Water category	Rotifera	Branchiopoda	Copepoda	Protozoa	Chromista	Main source
Santo Elias Lake	White	36	3				L. Santos et al. (2022)
Curuperê-Dendê River	White	37	8	8	27	11	Costa et al. (2016a)
Pará River	White	30	7	4	8	4	Costa et al. (2016b)
Amazonian floodplain lakes (Solimões and Amazon Rivers)	White				70	1	Arrieira et al. (2016)
Amazon Basin							
Pacu Lake	White	13	5	3			Ghidini et al. (2018)
Sucuriju Lake	White	6	4	7			Ghidini et al. (2018)
Itapaíuna Lake	White	3	2	7			Ghidini et al. (2018)
Araçazinho Lake	White	6	7	11			Ghidini et al. (2018)
Lagoa da Francesa	White	11	3	1	15	10	This is study
Lagoa Azul Lake	Black	18	1	2	5		This is study
Lago do Zé Açú Lake	Black	14	2	3	3	3	This is study
Amazonas-Macurany várzea	White	20	4		6	4	This is study
Canta Galo					2	2	This is study
Springs	Black	27	8		53	5	This is study
Mamuru River	Black	21	3	2	8	3	This is study
Negro River	Black	50	7	18			Robertson and Hardy (1984)
Cristalino Lake	Black		6				Robertson and Hardy (1984)
Tarumã-Mirim Lake	Black		12				Robertson and Hardy (1984)
Guedes Lake	Black		7				Robertson and Hardy (1984)
Caju Lake	Black		5				Robertson and Hardy (1984)
Prato Lake	Black		3				Robertson and Hardy (1984)
Utinga-Pará system Bolonha Lake	Black	30	19	7			Melo et al. (2006)
Tapajós River	Clear	127		8			Robertson and Hardy (1984)
Paroni Lake	Clear	76					Koste (1974)

Table 3. (Conclusion)

Environment	Water category	Rotifera	Branchiopoda	Copepoda	Protozoa	Chromista	Main source
Tocantins River	Clear	34	15	8			Espíndola et al. (2000)
Tocantins River	Clear	21	5-7	14			Robertson and Hardy (1984)
Tauá Lake	Clear	6					Robertson and Hardy (1984)
Paulo Pool	Clear	3					Robertson and Hardy (1984)
Lower Nhamundá River	Clear	145					Brandorff et al. (1982)
Trombetas River							
Macaco Lake	Clear	48					Koste (1989)
Batata Lake (impacted by bauxite waste)	Clear	98	10	7			Bozelli et al. (2000)
Xingu River (lentic/lotic)	Clear	55-87	10-16	1-2			Brito et al. (2015)
Ilha Grande Lake	Clear	56	6	3			Brito et al. (2015)
Pimental Lake	Clear	97	5	4			Brito et al. (2015)
Curuá-Una River (Reservoir)	Clear				51		Lansac-Tôha et al. (2008)
Amazon Region		397	107	88	159		Elmoor-Loureiro et al. (2022)

All zooplankton groups exhibited greater taxonomic richness in lentic environments and during the dry period. In lentic environments, increased richness during the dry period can be attributed to hydrological changes associated with water-level drawdown. As water levels decrease, lakes become shallower, leading to the concentration of organisms and increased availability of nutrients and seston in the water column, either through sediment resuspension or enhanced local inputs of organic matter (Roberto et al., 2009; Arrieira et al., 2016). These conditions promote higher primary productivity and favor the development of zooplankton communities (Bonecker et al., 2013). Furthermore, the greater hydrodynamic stability typically observed in lentic environments during the dry season provides favorable conditions for the establishment and persistence of planktonic species.

Lake margins, in particular, tend to support higher species richness than central areas due to increased environmental heterogeneity associated with aquatic macrophytes. Macrophyte stands enhance food availability, increase structural complexity, and provide refuge from predators, allowing the coexistence of planktonic and periphytic species (Buosi et al., 2011). During the rainy season, rising water levels and increased connectivity with flooded areas expand available habitats but promote organism dispersal and population dilution. As a result, local richness may decrease despite higher regional connectivity, in accordance with predictions of the flood pulse concept (Junk et al., 2011).

In lotic environments, the lower richness observed comparison to lentic systems primarily reflects less stable hydrodynamic conditions, characterized by higher current velocity and shorter water residence time. These conditions limit the development and persistence of typically planktonic organisms (Park et al., 2023). Increased current

velocity and turbulence shift environmental conditions from lentic to lotic, directly impairing zooplankton reproductive and feeding activities, such as predation and filtration (Ning et al., 2013; Park et al., 2023).

During the dry season, reduced river discharge may locally favor zooplankton accumulation in marginal zones and low-flow areas, allowing the occurrence of taxa exclusive to this period. In contrast, during the rainy season, increase discharge intensifies longitudinal transport and organism dilution, reducing local richness and favoring species with greater tolerance to hydraulic drift (Bonecker et al., 2013; Arrieira et al., 2016). In this context, the seasonal flood pulse of the Amazon plays a central role in structuring zooplankton communities by regulating the alternation between phases of concentration, dispersion, and connectivity among rivers, lakes, and floodplains, thereby shaping spatial and temporal patterns of diversity in both lotic and lentic environments (Melack & Forsberg, 2001; K. Santos et al., 2022).

Protozooplankton groups, including Chromista and Protozoa, remain among the least studied component of tropical freshwater ecosystems. In these environments, testate amoebae (Arcellinida and Difflugiidae) generally prevail, followed by ciliates, flagellates, and naked amoebae (Castilho-Noll et al., 2023). In the present study, species of the family Codonellidae (Ciliophora) were recorded, a group more commonly associated with brackish and marine environments. The occurrence of ciliates across diverse habitats reflects their high tolerance and adaptability to a wide range of physical and chemical conditions (Vilas-Boas et al., 2020). Studies conducted in the Guamá River, a tidal system under oceanic influence, indicate that such species can be transported from estuarine areas and persist in environments with very low salinity (Gadelha et al., 2023).

The order Arcellinida was the most diverse protozoan group in the studied environments, consistent with findings from other tropical freshwater systems. This order represents the most species-rich assemblage of testate amoebae, currently comprising approximately 687 described species (Castilho-Noll et al., 2023). Within Arcellinida, *Arcella* is one of the most extensively studied genera, exhibiting high morphological plasticity and a wide geographic distribution, particularly in tropical and subtropical regions (Zapata-Muñoz et al., 2021).

This study documents the first record of *Arcella gandalfi* Féres et al., for Parintins and for the state of Amazonas. This species was recently described and has so far been recorded in South America, where it may serve as a flagship species for the continent (Féres et al., 2016). Previous records have been identified in Brazil, specifically Minas Gerais (Gameleira River), Tocantins (*Vereda* Bomfim), Paraná (Paraná River), Amapá (Araguaia River), and Rio de Janeiro (Veiga Lagoon; Féres et al., 2016), and in Colombia (Caño Siete Vueltas and Caño Grande, Acacías River; Zapata-Muñoz et al., 2021).

Arcella gandalfi has been reported from freshwater systems and coastal lagoons, typically occurring in waters with temperatures above 21 °C and pH ranging from acid (4.4) to neutral (7.38), and showing tolerance to wide ranges of conductivity (16.1–941 μS/cm), total phosphorus (< 0.030–4.700 μg/L), and dissolved oxygen (0.37–9.31 mg/L) (Féres et al., 2016; Zapata-Muñoz et al., 2021). In thist study, the species was recorded in lentic environments characterized black, warm and acidic waters, in agreement with previous reports.

Although this record expands the known geographic distribution of *A. gandalfi* into the lower Amazonas region, its broader distribution along the Amazon River and its tributaries cannot be ruled out. The presence of this species suggests a broad ecological tolerance and potential connectivity among Amazonian aquatic habitats and other Neotropical regions. This finding represents an important contribution to the knowledge of testate amoebae diversity and biogeography in the Amazon Basin. Future studies should investigate whether *A. gandalfi* forms stable populations in the region or represents a sporadic occurrence associated with passive dispersal processes.

CONCLUSION

This study expands current knowledge of the composition and spatial distribution of zooplankton communities in Parintins, in the lower Amazonas region, by documenting 118 taxa across lentic and lotic environments. The identification of 79 taxa recorded for the first time in Parintins highlights the still-limited knowledge of zooplankton diversity in Amazonian freshwater ecosystems and emphasizes the importance of local-scale taxonomic inventories in underexplored areas. The observed patterns of richness, with higher diversity in lentic environments and during the dry season, reinforce the role of hydrological dynamics and habitat heterogeneity in structuring zooplankton communities in the Amazon Basin. In addition, the occurrence of taxa with broad ecological tolerances, including species typically associated with other aquatic systems, underscores the potential for dispersal, adaptability, and connectivity among the Amazonian freshwater habitats. Finally, our findings highlight the need to strengthen biodiversity research initiatives and to promote graduate-level training focused on the taxonomy and ecology of zooplankton in tropical regions.

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AUTHOR'S CONTRIBUTION

E. S. Gadelha contributed to conceptualization, methodology, data curation, data analysis and writing (original draft, revision and editing); J. M. S. Coêlho contributed to research and writing (revision and editing); M. R. Casartelli contributed to research and writing (revision and editing); E. A. Lehmkuhl contributed to research, formal analysis and writing (revision and editing); A. M. da Silva-Lehmkuhl contributed to ethodology, research, project management, funding acquisition, supervision and writing (original draft, revision and editing).

Appendix 1. List of zooplankton species found on Parintins Island by seasonal period. (Continue)

Groups	Season	
	Rainy	Dry
Copepode		
Order: Cyclopoida		
Family: Cyclopidae		
Microcyclops varicans varicans (Sars G.O., 1863)		X
Microcyclops rubellus (Lilljeborg, 1901)	X	X
Cladocera		
Order: Anomopoda		
Family: Chydoridae		
Alonella G.O. Sars, 1862		X
Chydorus Leach, 1816		X
Chydorus sphaericus (O.F. Müller, 1776)		X
Leydigia Kurz, 1875		X
Monospilus dispar G.O. Sars, 1862		X
Family: Bosminidae		
Bosmina (Bosmina) longirostris (O.F. Müller, 1785)	X	
Bosminopsis deitersi Richard, 1895	X	
Family: Macrothricidae		
Macrothrix laticornis (Jurine, 1820)		X
Family: Moinidae		
Moina micrura Kurz, 1875	X	X
Order: Ctenopoda		
Family: Sididae		
Diaphanosoma Fischer, 1850	X	
Nematoda		
Order: Dorylaimida		
Family: Dorylaimidae		
Prodorylaimus Andrássy, 1959		X
Gastrotricha		
Order: Chaetonotida		
Family: Chaetonotidae		
Chaetonotus Ehrenberg, 1830		X
Insecta		
Order: Diptera		
Family: Dixidae		
Dixa Meigen, 1818		X

Appendix 1. (Continue)

Groups	Season	
	Rainy	Dry
Rotifera		
Order: Adinetida		
Family: Adinetidae		
Adineta vaga (Davis, 1873)	X	X
Order: Flosculariaceae		
Family: Hexarthridae		
Hexarthra mira (Hudson, 1871)		X
Family: Testudinellidae		
Testudinella patina (Hermann, 1783)	X	X
Family: Trochosphaeridae		
Filinia opoliensis (Zacharias, 1898)	X	
Filinia terminalis (Plate, 1886)	X	
Order: Ploima		
Family: Asplanchnidae		
Asplanchna priodonta Gosse, 1850		X
Family: Brachionidae		
Anuraeopsis fissa Gosse, 1851		X
Brachionus angularis Gosse, 1851	X	
Brachionus bidentata Anderson, 1889		X
Brachionus budapestinensis Daday, 1885	X	
Brachionus caudatus Barrois & Daday, 1894		X
Brachionus diversicornis (Daday, 1883)	X	
Brachionus falcatus Zacharias, 1898		X
Brachionus forficula var. *inegalis* Rodewald, 1940	X	
Brachionus gessneri Hauer, 1956		X
Brachionus havanaensis Rousselet, 1911		X
Brachionus patulus var. *macracanthus* (Daday, 1905)		X
Brachionus plicatilis Müller, 1786	X	
Brachionus zahniseri Ahlstrom, 1934		X
Keratella americana Carlin, 1943		X
Keratella cochlearis (Gosse, 1851)		X
Keratella tropica (Apstein, 1907)	X	
Family: Euchlanidae		
Euchlanis dilatata Ehrenberg, 1832		X
Family: Gastropidae		
Ascomorpha ovalis (Bergendal, 1892)		X
Ascomorpha saltans Bartsch, 1870		X
Gastropus Imhof, 1898		X
Family: Lecanidae		

Appendix 1. (Continue)

Groups	Season	
	Rainy	Dry
Lecane bulla (Gosse, 1851)	X	X
Lecane luna (Müller, 1776)		X
Lecane mira (Murray, 1913)		X
Lecane papuana (Murray, 1913)		X
Lecane undulata Hauer, 1938.	X	
Monostyla closterocerca Schmarda, 1859		X
Family: Lepadellidae		
Colurella adriatica Ehrenberg, 1831		X
Family: Mytilinidae		
Mytilina mucronata (Müller, 1773)	X	
Family: Notommatidae		
Cephalodella Bory de St. Vincent, 1826		X
Eosphora Weber, 1918		X
Monommata Bartsch, 1870		X
Family: Proalidae		
Proales daphnicola Thompson, 1892	X	
Family: Trichocercidae		
Trichocerca cylindrica (Imhof, 1891)		X
Trichocerca multicrinis (Kellicott, 1897)	X	X
Trichocerca pusilla (Jennings, 1903)	X	X
Family: Trichotriidae		
Macrochaetus subquadratus (Perty, 1850)		X
Family: Synchaetidae		
Ploesoma lenticulare Herrick, 1885		X
Polyarthra dolichoptera Idelson, 1925	X	X
Polyarthra vulgaris Carlin, 1943	X	
Synchaeta stylata Wierzejski, 1893	X	X
Protozoa		
Order: Arcellinida		
Family: Arcellidae		
Arcella brasiliensis Cunha, 1913	X	X
Arcella conica (Playfair, 1918)	X	X
Arcella costata Ehrenberg, 1847		X
Arcella crenulata Deflandre, 1928		X
Arcella gandalfi Féres, Porfírio-Sousa, Ribeiro, Rocha, Sterza, Souza, Soares and Lahr, 2016		X
Arcella gibbosa Penard, 1890		X
Arcella hemisphaerica Perty, 1852		X
Arcella hemisphaerica undulata Deflandre, 1928		X
Arcella mitrata Leidy, 1876		X
Arcella vulgaris Ehrenberg, 1832	X	X

Appendix 1. (Continue)

Groups	Season	
	Rainy	Dry
Galeripora discoides (Ehrenberg, 1871) González-Miguéns et al., 2021		X
Galeripora megastoma (Penard, 1902)		X
Family: Centropyxidae		
Centropyxis aculeata (Ehrenberg, 1832) Stein, 1859		X
Centropyxis constricta (Ehrenberg, 1841) Deflandre, 1929		X
Centropyxis sylvatica (Deflandre, 1929 var.) Bonnet and Thomas, 1955	X	
Trigonopyxis arcula Penard, 1912		X
Family: Difflugiidae		
Difflugia acuminata Ehrenberg, 1838		X
Difflugia brevicolla Cash & Hopkinson, 1909		X
Difflugia elegans Penard, 1890		X
Difflugia limnetica (Levander, 1900) Penard, 1902		X
Difflugia lobostoma (Leidy, 1879)		X
Difflugia nodosa (Leidy, 1879)		X
Difflugia oblonga Ehrenberg, 1838	X	X
Difflugia papillomata Gauthier-Lièvre et Thomas, 1958		X
Lagenodifflugia vas (Leidy, 1874) Medioli and Scott, 1983	X	X
Protocucurbitella coroniformis Gauthier-Lièvre & Thomas, 1960		X
Family: Heleoperidae		
Heleopera petricola Leidy, 1879		X
Family: Hyalospheniidae		
Hyalosphenia nobilis Cash & Hopkinson, 1909		X
Hyalosphenia subflava Cash and Hopkinson, 1909	X	X
Family: Lamtopyxidae		
Lamtopyxis Bonnet, 1974		X
Family: Lesquereusiidae		
Lesquereusia spiralis Ehrenberg, 1840	X	X
Family: Nebelidae		
Nebela (Leidy, 1874)		X
Family: Netzeliidae		
Netzelia corona (Wallich, 1864)		X
Netzelia oviformis (Cash,1909) Ogden,1979		X
Family: Plagiopyxidae		
Bullinularia Penard, 1911	X	X
Plagiopyxis declivis Bonnet, 1955	X	
Family: Trigonopyxidae		
Cyclopyxis arcelloides (Penard, 1902)		X
Cyclopyxis impressa (Daday, 1905) Da Cunha, 1913	X	X

Appendix 1. (Conclusion)

Groups	Season	
	Rainy	Dry
Kingdom: Chromista		
Cercozoa		
Order: Euglyphida		
Family: Euglyphidae		
Euglypha filifera Penard, 1890		X
Euglypha rotunda Wailes & Penard, 1911	X	
Family: Trinematidae		
Trinema enchelys (Ehrenberg, 1938) Leidy, 1878	X	
Trinema complanatum Penard, 1890		X
Ciliophora		
Order: Choreotrichida		
Family: Codonellidae		
Codonaria Kofoid & Campbell, 1939	X	X
Codonella Haeckel, 1873		X
Codonella nationalis Brandt, 1906		X
Tintinnopsis acuminata Daday, 1887	X	
Tintinnopsis beroidea Stein, 1867	X	X
Tintinnopsis campanula Ehrenberg, 1840	X	
Tintinnopsis lobiancoi Daday, 1887		X
Tintinnopsis radix (Imhof, 1886)		X
Tintinnopsis rotundata Kofoid & Campbell, 1929		X
Family: Codonellopsidae		
Codonellopsis morchella (Cleve) Jörgensen, 1924		X
Family: Tintinnidiidae		
Leprotintinnus simplex Schmidt, 1902	X	X
Tintinnidium fluviatile Stein, 1863	X	