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Zooplankton community of Parnaíba River, Northeastern Brazil

Comunidade zooplanctônica do Rio Parnaíba, Nordeste, Brasil

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Abstract: Aim: The objective of the present work is to present a list of species of zooplankton (Rotifera, Cladocera and Copepoda) from the Parnaíba River. Additionally, we provide comments on their distribution along the river, and between dry and wet seasons. **Methods:** Zooplankton was collected with a plankton net (60 µm mesh) and concentrated into a volume of 80 mL for further analysis, during the dry (October 2010) and wet (April 2011) seasons. Sampling was restricted to the marginal areas at depths between 80 and 150 cm. **Results:** A total of 132 species was recorded among the three zooplankton groups studied. During the dry season a total of 82 species was registered and 102 species was registered for the wet season. Rotifera contributed with 66.7% of the species, followed by Cladocera (26.5%) and Copepoda (6.8%). **Conclusions:** The richness of species observed was high compared to other large rivers in Brazil. In the context of current policies for water management and river diversions in northeastern Brazil, the present study highlights the importance of this river system for biodiversity conservation.

Keywords: semiarid; large rivers; biodiversity; zooplankton; seasonality.

Resumo: Objetivo: O objetivo do presente estudo é apresentar uma lista de espécies de zooplâncton (Rotifera, Cladocera e Copepoda) do Rio Parnaíba, NE, Brasil, com comentários sobre a sua distribuição ao longo do rio e entre estações do ano. **Métodos:** O zooplâncton foi amostrado usando uma rede de plâncton (60 µm) e concentrado em um volume de 80 mL para ser levado ao laboratório. As amostragens ocorreram durante o período seco (Outubro 2010) e chuvoso (Abril 2011) e foram restritas a áreas marginais com profundidades entre 80 e 150 cm. **Resultados:** Um total de 132 espécies foi registrado, sendo que durante a estação seca foram registradas 82 espécies e durante a estação chuvosa foram registradas 102 espécies. Rotifera representou 66,7% das espécies coletadas, seguido por Cladocera com 26,5% e Copepoda com 6,8%. **Conclusões:** A riqueza de espécies coletada foi alta quando comparada com outros sistemas lóticos brasileiros. No contexto atual de transposição de águas e manejo de fluxo hidrológico nos rios do Nordeste, o presente estudo ressalta a importância do Rio Parnaíba e sua variação sazonal para a conservação da biodiversidade do semiárido brasileiro.

Palavras-chave: semiárido; grandes rios; biodiversidade; zooplâncton; sazonalidade.

1. Introduction

Large rivers support an important portion of the world´s diversity, in some cases surpassing traditionally diverse systems such as coral reefs (Arthington et al., 2004). A range of characteristics are used to define large rivers, such as drainage basin size, river length, volume of sediment transported and water discharge (Potter, 1978). In South America, the Amazon River (catchment size of 6112000 km^2 and 6868 km in length) and the Paraná River (2600000 km^2 basin area and some 5000 km in length) are the most studied large rivers. Other less studied large rivers are the São

Francisco River (drainage area of 640000 km^2 and 2700 km in length) and the Parnaíba River (344112 km^2 drainage area and 1432 km in length). The latter systems (São Francisco and Parnaiba) partially flow through the Brazilian Caatinga and Cerrado; drylands that present complex climatic patterns that lead to scarce and irregularly distributed rainfall, as well as low thermal amplitudes mostly in the Caatinga (monthly air temperatures between 25 and 30 °C). As a consequence, many of the tributaries of the São Francisco and Parnaiba rivers present intermittent water flow, which contributes to a high degree of spatial and temporal flow variability (see Medeiros et al., 2011).

In large river systems, flooding usually extends to the floodplain dispersing sediment laterally, booming production and increasing organic matter and nutrient inputs (Arthington et al., 2004). The annual cycle of pulse inundation connects the range of lateral habitats to the main river channel enhancing diversity of organisms and ecological processes (Schiemer et al., 2004).

Zooplankton communities in large rivers show marked spatial and temporal variation in association with physical and chemical variables and river hierarchy (Latrubesse & Stevaux, 2002; Bonecker et al., 2005). Furthermore, these organisms contribute with significant biomass to consumers, linking primary production to higher trophic levels (Cardoso et al., 2008; Medeiros & Arthington, 2011). Another important role of the zooplankton in large rivers is their ability to recycle nutrients which in turn makes them sensitive to environmental changes that affect production and decomposition. This makes the group an important biological indicator of environmental change.

Despite the high diversity of other groups of organisms (Ramos, et al., 2014), surveys and ecological studies on the plankton fauna along the entire channel of the Parnaíba River are scarce. The survey across several spatial scales has been argued to increase efficiency in estimates of species richness (Magurran, 1996), most importantly so in large river systems. Species list generated from such sampling schemes contribute to the understanding on geographical distribution and macro-ecological traits along large river systems (see Ramos et al., 2014) and helps decision-makers on conservation efforts. In this context, a species list of zooplankton is an important tool in impact assessments, given the present state of knowledge on northeastern Brazil large rivers.

The objective of the present work is, therefore, to present a list of species of zooplankton (Rotifera, Cladocera and Copepoda) from the Parnaíba River. Additionally, we provide comments on their distribution along the river, and between dry and wet seasons.

2. Material and Methods

2.1. Study area

The Parnaíba River is located in the border between the states of Maranhão and Piauí (NE Brazil) (Figure 1). It has 1432 km in length and drains an area of approximately 344112 km^2. Its location in a transitional area between the semi-arid (*BSh*) and tropical (*Aw*) climates (classification of Köeppen-Geiger modified by Peel et al., 2007) makes this river an important divisor between the perennial (to the west) and intermittent (to the east) water courses (CODEVASF, 2010; EPE, 2005). Most of the affluents on the middle and lower portions of the river are perennial, whereas the small rivers and streams in the upper Parnaíba River are intermittent (Rosa et al., 2003; EPE, 2005). Precipitation in the area ranges from 600 to 1800 mm per year and temperature varies from 24 to 38° C (CODEVASF, 2010).

The Parnaíba River is divided into the upper, middle and lower portion, the former being characterized by accentuated declivity and deeper

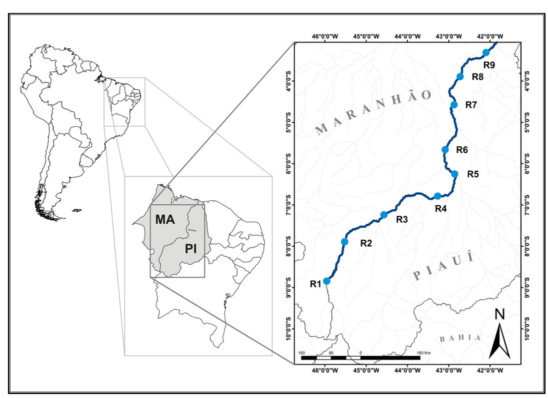

Figure 1. Study area in the Parnaíba River and location of each sampling site along the three stretches (upper, middle and lower). R1. 09°08'04.2"S 045°55'45.2"W; R2. 07°33'24.6"S 045°14'58.2"W; R3. 07°14'43.5"S 044°34'16.4"W; R4. 06°47'44.1"S 043°16'39.5"W; R5. 06°15'55.90"S 042°51'21.5"W; R6. 05°41'12.8"S 043°05'01.9"W; R7. 04°34'52.3"S 042°52'31.3"W; R8. 03°54'06.9"S 042°43'27.8"W; R9. 03°18'24.8"S 042°05'36.0"W.

valleys, the middle portion presents uneven terrain with some waterfalls and the lower portion shows more gradual declivity and wider valleys (Brasil, 2006; EPE, 2005). Vegetal cover in the basin is diverse, consisting of dense and sparse vegetal formations, associated with the Caatinga and Cerrado (CODEVASF, 2010).

2.2. Sampling design and data collection

Nine river reaches were surveyed along the three study portions of the Parnaíba River. In each river reach, collections were performed in three sampling points. At each sampling point three samples were performed, resulting in a total of 81 samples. This design allowed for the calculation of the curves of accumulation of species for this study. Distance between sampling points were approximately 1 km and distances between reaches varied between 92 and 217 km (Figure 1). This design was performed once during the dry season (October 2010) and once during the wet season (April 2011) in order to account for temporal variation in species occurrence. Species accumulation curves and Bray-Curtis distance curves (and their standard deviation) were calculated on PC-ORD 4.2 (McCune & Mefford, 1999) to evaluate the adequacy of sample size for the present study. The distance curve represents the distance between the centroid of a sample and the centroid of the data set. That means that the more representative is a sample the lower the distance between it and the dataset (McCune & Grace, 2002).

Each sample consisted of a volume of 120 liters filtered in a plankton net (60 µm mesh) and concentrated into a volume of 80 mL for posterior analysis. Sampling was restricted to the marginal areas at depths between 80 and 150 cm. The zooplankton samples were anesthetized with commercial sparkling water before preservation in 4% formalin and sucrose was added to the preserved sample. This procedure prevents female cladocerans from losing eggs and minimizes zooplankton carapace distortion (Haney & Hall, 1973). In the laboratory, two subsamples of 1.5 mL were taken from the concentrated sample and had their organisms identified. Only adult stages of rotifers, cladocerans and copepods were considered in the present study. Identifications were based on Koste (1978), Shiel (1995), Nogrady et al. (1993), Segers (1995), Reid (1985), Suárez-Morales et al. (1996), Rocha & Matsumura-Tundisi (1976) and Elmoor-Loureiro (1997).

3. Results

During the present study a total of 132 species were recorded among the three zooplankton groups studied (Table 1). Copepoda Harpacticoida were identified only to order and are not referred to henceforth, unless mentioned. Rotifera contributed with 66.7% of the species, followed by Cladocera (26.5%) and Copepoda (6.8%). The same pattern was observed for both seasons, with rotifers dominating in number of species and Copepoda with lower richness (Figure 2).

During the dry season a total of 82 species was registered across the 9 reaches sampled, being 56 of Rotifera, 19 of Cladocera and 7 of Copepoda. The most representative Rotifera were Brachionidae (16 species) and Lecanidae (14 species). The rotifers observed only during the dry season were *Asplanchna herrickii*, *Cephalodella biungulata, Conochilus* sp., *Brachionus bidentatus, B. plicatilis, B. urceolaris, Keratella cochlearis, Filinia saltator, Hexarthra mira, Lecane closterocerca, L. crepida, L. hornemanni, L. imbricata, L. obtusa, L. proiecta, L. signifera, Lepadella donneri, Testudinella tridentata, Trichocerca cylindrica, T. gracilis, T. elongata* and *T. insignis*. Among the Cladocera, Sididae (4 species), Chydoridae (4 species) and Bosminidae (4 species) were the richest families. The Cladocera observed only during the dry season were *Daphnia* sp., *Alona rectangula, Ephemeroporus tridentatus, Bosmina freyi* and *B. tubicen*. Among the Copepoda, the Diaptomidae (4 species) and Cyclopidae (3 species) were the only families observed. The Copepoda present only during the dry season were *Notodiaptomus* sp., *N. iheringi,* and *N. dubius* (Table 1). During the dry season the order Harpacticoida was present only at the R4 reach.

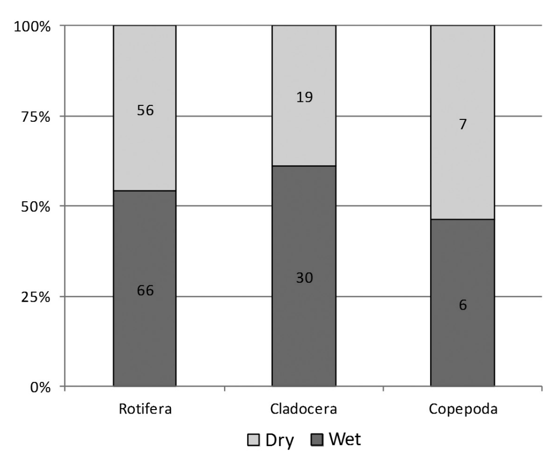

Figure 2. Number of species of Rotifera, Cladocera and Copepoda during the dry and wet seasons in the Parnaíba River.

Table 1. Species list and density (ind./L) of zooplankton in the nine sampled reaches (from R1 to R9) of the Parnaíba River (NE Brazil).

	R1	R2	R3	R4	R5	R6	R7	R8	R9
Rotifera									
Philodinidae									
Dissotrocha macrostyla (Ehrenberg, 1838)							0.0247		
Rotaria neptunia (Ehrenberg, 1839)							0.0247		0.0247
Asplanchnidae									
Asplanchna brightwelli Gosse, 1850							0.0247	0.0247	0.1235
*Asplanchna herrickii*de Guerne, 1888								0.0247	
Asplanchna priodonta Gosse, 1850								0.0494	0.0247
Notommatidae									
Cephalodella sp.									0.0494
Cephalodella biungulata Wulfert, 1937								0.1235	
Cephalodella forficata (Ehrenberg, 1832)						0.0247		0.0741	
Cephalodella mucronata Myers, 1924							0.0988	0.0494	0.1235
Conochilidae									
Conochilus sp.							0.0247	0.0247	0.0247
Conochilus dossuarius Hudson, 1885									0.0494
Flosculariide									
Ptygura pectinifera (Murray, 1913)									0.0741
Brachionidae									
Brachionus bidentatus Hauer, 1963							0.0247		0.0741
Brachionus plicatilis Müller, 1786			0.0247						0.3457
Brachionus havanaensis Rousselet, 1911			0.0247			0.2222	2.2963	0.3704	0.4444
Brachionus falcatus Zacharias, 1898			0.0247			0.1235	0.7407	0.0741	1.1358
Brachionus caudatus Barrois & Daday, 1894						0.0247	0.2222	0.3951	2.3951
Brachionus angularis Gosse, 1851				0.0247			4.7160	2.0741	9.0123
Brachionus calyciflorus Pallas, 1766							3.4815	1.4321	0.5926
Brachionus rubens Ehrenberg, 1838							0.0494		
Brachionus quadridentatus Hermann, 1783				0.0494	0.0494	0.4938	0.0988	0.0494	0.3457
Brachionus mirus Daday, 1905								0.0494	
Brachionus dolabratus Harring, 1914							0.0247		0.1481
Brachionus mirabilis Daday 1897				0.0494					
Brachionus urceolaris Müller, 1773							0.0247	0.0988	0.1975
Brachionus zahniseri Ahlstrom, 1934								0.0247	0.1975

Table 1. Continued...

	R1	R2	R3	R4	R5	R6	R7	R8	R9
Plationus patulus (Müller, 1786)			0.0494	0.1235	0.1235	0.0247	1.0370	0.2716	2.4198
Platyias quadricornis (Ehrenberg, 1832)				0.3457	0.0988	0.0494	0.0988	0.1975	0.0494
Keratella americana Carlin, 1943			0.0247	0.3210	0.2222	0.3210	2.4691	5.3580	26.5432
Keratella tropica (Apstein, 1907)					0.0247	0.0494	10.2222	0.0741	8.9136
Keratella cochlearis (Gosse, 1851)				0.0741	0.0494	8.8889	5.6790	2.7160	2.3704
Epiphanidae									
Epiphanes macroura (Barrois & Daday, 1894)			0.0247				3.0370	1.0370	2.8642
Euchlanidae									
Beauchampiella eudactylota (Gosse, 1886)				0.0988	0.0247				
Euchlanis dilatata Ehrenberg, 1832			0.0247	0.1728			0.0988	0.3210	0.3210
Dipleuchlanis propatula (Gosse, 1886)		0.0247	0.0247	0.0000	0.0988		0.1481	0.0247	
Trochosphaeridae									
Filinia camasecla Myers, 1938									0.0494
Filinia longiseta (Ehrenberg, 1834)				0.0741		23.5556	0.8395	0.7654	3.4074
Filinia opoliensis (Zacharias, 1898)				0.1975	0.0247	0.0741	0.3951	0.4691	0.4444
Filinia terminalis (Plate, 1886)				0.0494		5.2346	0.1235	0.1481	1.8272
Filinia saltator (Gosse, 1886)						4.1481			
Hexarthridae									
Hexarthra intermedia (Wiszniewski, 1929)							0.0494	0.0741	0.2716
Hexarthra mira (Hudson, 1871)						0.0247			
Lecanidae									
Lecane leontina (Turner, 1892)	0.0494	0.0247	0.0247	0.0494			0.0247	0.0247	0.0247
Lecane curvicornis (Murray, 1913)	0.0741	0.0247	0.0247	0.8889	0.2716	0.1481	0.0494	0.2963	0.1975
Lecane clara (Bryce, 1892)									0.0247
Lecane cornuta (Müller, 1786)				0.1481	0.0988	0.0247	0.0494	0.1728	
Lecane decipiens (Murray, 1913)	0.0247								
Lecane hastata (Murray, 1913)	0.0000					0.0247		0.0494	0.3210
Lecane lunaris (Ehrenberg, 1832)	0.0741		0.1235	0.1235	0.1728	0.0988	0.0494	0.0247	0.0494
Lecane papuana (Murray, 1913)		0.0741	0.0494	0.0741	0.1235	0.0741	0.1235	0.4198	1.3333
Lecane luna (Müller, 1776)				0.9136	0.4444	0.2469	0.1235	0.1235	0.3210
Lecane copeis (Harring & Myers, 1926)				0.0247		0.0247	0.0741	0.0247	
Lecane bulla (Gosse, 1851)	0.0494	0.0247	0.0741	1.4568	0.3457	0.2469	0.3704	0.5432	0.4691

Table 1. Continued...

	R1	R2	R3	R4	R5	R6	R7	R8	R9
Lecane quadridentata (Ehrenberg, 1830)				0.0494			0.0494	0.0000	0.0247
Lecane rhenana Hauer, 1929								0.0247	
Lecane ungulata (Gosse, 1887)								0.0494	
Lecane proiecta Hauer, 1956						0.0247			
Lecane hornemanni (Ehrenberg, 1834)									0.0988
Lecane obtusa (Murray, 1913)									0.0247
Lecane closterocerca (Schmarda, 1859)								0.0247	
Lecane imbricata Carlin, 1939								0.0741	0.0494
Lecane signifera (Jennings, 1896)	0.0247								
Lecane crepida Harring, 1914						0.0247		0.0247	0.0247
Lepadellidae									
Lepadella sp.	0.0741								
Lepadella donneri Koste, 1972		0.0741	0.0494						
Lepadella cristata (Rousselet, 1893)		0.0741	0.1235						
Lepadella ovalis (Müller, 1786)				0.0247				0.0494	
Mytilinidae									
Mytilina unguipes (Lucks, 1912)							0.0247		
Mytilina ventralis (Ehrenberg, 1830)				0.0247					0.0247
Mytilina acanthophora Hauer, 1938				0.0247	0.0247		0.0247		0.0247
Synchaetidae									
Polyarthra dolichoptera Idelson, 1925							1.2840	0.0494	0.0741
Polyarthra vulgaris Carlin, 1943						3.0370	0.2222		0.1235
Synchaeta pectinata Ehrenberg, 1832									0.0247
Synchaeta stylata Wierzejski, 1893									0.0247
Testudinellidae									
Testudinella tridentata Smirnov, 1931			0.0494						
Testudinella patina (Hermann, 1783)				0.1728	0.2469	0.2469	0.3210	0.1481	0.0988
Testudinella mucronata (Gosse, 1886)				0.1481	0.0247	0.0247	0.0494	0.1235	0.1481
Trichocercidae									
Trichocerca cylindrica (Imhof, 1891)				0.0247	0.0247	0.0247	0.1728		
Trichocerca pusilla (Jennings, 1903)						0.0988	0.1728		0.2963
Trichocerca similis (Wierzejski, 1893)			0.0247		0.0494		4.4198	0.2469	0.3210

Table 1. Continued...

	R1	R2	R3	R4	R5	R6	R7	R8	R9
Trichocerca bicristata (Gosse, 1887)							0.0494		
Trichocerca collaris (Rousselet, 1896)									0.0247
Trichocerca tenuior Gosse, 1886			0.0247						
Trichocerca gracilis (Tessin, 1890)							0.2222		
Trichocerca elongata (Gosse, 1886)							0.0247		0.0741
Trichocerca insignis (Herrick, 1885)									0.0247
Trichotriidae									
Macrochaetus altamirai (Arévalo, 1918)									0.1481
Trichotria sp.								0.0494	
Cladocera									
Daphniidae									
Daphnia sp.				0.0494					
Daphnia gessneri Herbst, 1967				0.0247					
Ceriodaphnia cornuta Sars, 1885				0.6667			0.2716	0.2222	0.0988
Ceriodaphnia cornuta rigaudi Richard, 1886				0.0494	0.0494		0.3210	0.0741	0.2222
Sididae									
Diaphanosoma birgei Korinek, 1981				0.2716	0.0247			0.0247	0.0988
Diaphanosoma brevireme Sars, 1901							0.0247		0.1235
Diaphanosoma fluviatile Hansen, 1899				0.0247			0.0247		0.0494
Diaphanosoma spinulosum Herbst, 1975				1.3333			0.0494	0.0247	0.0494
Diaphanosoma polyspina Korovchinsky 1982				0.0494				0.0247	
Chydoridae									
Acroperus harpae Baird 1843	0.0247								
Alona dentifera (Says, 1901)								0.0247	
Alona verrucosa Sars, 1901		0.0494							0.0247
Alona rectangula Sars, 1861	0.0247	0.0247							
Alonella clathratula Sars, 1896	0.0247								
Chydorus dentifer Daday, 1905								0.0247	
Coronatella poppei (Richard, 1897)	0.0247		0.0247		0.0494		0.0741	0.0247	0.1728
Coronatella sp.					0.0494				
Ephemeroporus tridentatus (Bergamin, 1931)								0.0494	0.0000
Euryalona brasiliensis Brehm & Thomsen, 1936								0.0247	
Kurzia polyspina Hudec, 2000				0.0247					0.0247

Table 1. Continued...

	R1	R2	R3	R4	R5	R6	R7	R8	R9
Nicsmirnovius sp.	0.0247								
Moinidae									
Moina minuta Hansen, 1899	0.0247			0.0741	0.0247	0.1235	1.3086	0.6914	4.0741
Moinodaphnia macleayi (King, 1853)							0.0494		
Bosminidae									
Bosmina freyi De Melo & Hebert 1994				0.2716					
Bosmina tubicen Brehm, 1953									0.3210
Bosmina hagmanni Stingelin, 1904				0.8642	0.3704	0.0247	0.0988	0.1481	0.4938
Bosminopsis deitersi Richard, 1895			0.0247			0.0247	0.0741	0.5926	4.2963
Ilyocryptidae									
Ilyocryptus spinifer Herrick, 1882					0.0494				0.5679
Macrothricidae									
Grimaldina brazzai Richard, 1892								0.0247	
Macrothrix sp.								0.0247	
Macrothrix superaculeata (Smirnov, 1982)								0.0494	
Macrothrix laticornis (Jurine 1820)					0.0247				0.0741
Macrothrix mira Smirnov 1982						0.0494			
Macrothrix elegans Sars, 1901								0.0988	
Macrothrix squamosa Sars, 1901				0.0247			0.0741		0.0988
Copepoda									
Calanoida									
Diaptomidae									
Notodiaptomus sp.				0.1235	0.0494		0.0988	0.1728	
Notodiaptomus dubius Dussart, 1986				0.0494				0.0247	
Notodiaptomus iheringi Wright, 1935				0.1235					
Notodiaptomus oliveirai Matsumura-Tundisi, 2010				0.6914	0.0247		0.0988		
Cyclopoida									
Cyclopidae									
Thermocyclops minutus (Lowndes, 1934)				2.9877	0.0494		0.0988		0.0494
Thermocyclops decipiens (Kiefer, 1929)				0.1975	0.1235	0.0494	1.2593	0.0988	0.1481
Mesocyclops sp.				0.0247					
Microcyclops anceps (Richard, 1897)							0.0494	0.0988	0.0247
Paracyclops cf. *fimbriatus* (Fischer, 1853)				0.0247			0.0494		
Harpacticoida	0.0247	0.0494	0.0247	0.0494	0.0494	0.0247	0.2469	0.0247	

During the wet season, it was registered a total of 102 species, being 66 of Rotifera, 30 of Cladocera and 6 of Copepoda. The most diverse families among the Rotifera were Brachionidae (15 species) and Lecanidae (14 species). The rotiferans recorded only during the wet season were *Asplanchna priodonta, Cephalodella* sp., *C. forficata, C. mucronata, Conochilus dossuarius,* *Ptygura pectinifera, Dissotrocha macrostyla, Rotaria neptunia, Brachionus dolabratus, B. mirabilis, B. zahniseri, Beauchampiella eudactylota, Filinia camasecla, Lecane clara, L. cornuta, L. decipiens, L. hastata, L. quadridentata, L. rhenana, L. ungulata, Lepadella* sp., *L. cristata, L. ovalis, Mytilinia acantophora, M. unguipes, Synchaeta pectinata, S. stylata, Trichocerca bicristata, T. collaris, T. tenuior, Macrochaetus altamirai* and *Trichotria* sp. Among the Cladocera, Chydoridae (10 species) and Macrothricidae (7 species) were the richest families. The cladocerans present only during the wet season were *Daphnia gessneri, Diaphanosoma brevireme, Acroperus harpae, Alonella clathratula, Alona dentifera, Coronatella* sp., *Euryalona brasiliensis, Chydorus dentifer*, *Nicsmirnovius* sp., *Kurzia polyspina, Moinodaphnia macleari, Grimaldina brazzai, Macrothrix* sp., *M. laticornis, M. mira* and *M. superaculeata.* Among the Copepoda, the Cyclopidae (5 species) and Diaptomidae (1 species) were the only families observed. Copepoda observed only during the wet season were *Mesocyclops* sp. and *Paracyclops fimbriatus* (Table 1). During the wet season the order Harpacticoida was considerably frequent, being observed at all reaches except for the R9 reach.

An increase in number of species was observed from the upper to the lower reaches during both dry and wet seasons (Figure 3). This increase was greater at the reach R4, which is located after the Boa Esperança reservoir (24 and 22 species during the wet and dry seasons, respectively).

Species accumulation and distance curves (Figure 4) showed that 60 samples will yield over 94 species for the dry season samples (90% of the season), with more samples yielding relatively small increases in the number of species. Similarly, 60 samples will yield a Bray-Curtis distance of 0.08 (<10%), measured between the centroid of the dry season sample and the centroid of the whole dry season dataset. That means that, further increases in samples render the sample only slightly more similar to the whole dry season dataset. The same was observed for the wet season samples, where 60 samples yielded over 77 species (93% of the season) and a Bray-Curtis distance of 0.08 (<10%). These results indicate that sampling effort during the present study was representative, with at least 90% of the species being captured at 74% of the effort employed.

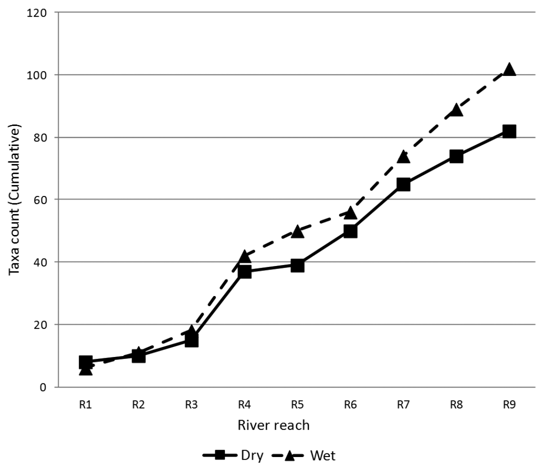

Figure 3. Cumulative species richness across study stretches during the dry and wet seasons in the Parnaíba River.

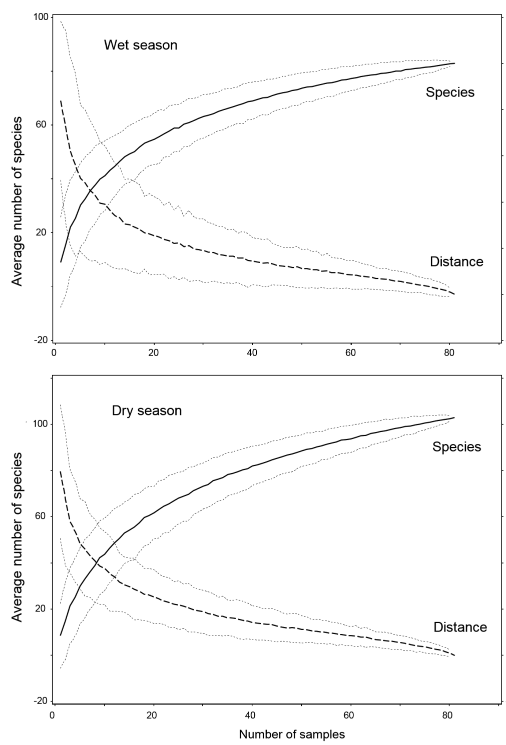

Figure 4. Accumulation and distance curves (±SD) used to assess sample adequacy for the 81 wet and dry season samples in the Parnaíba River.

4. Discussion

Among the zooplankton studied, Rotifera was the richest. This is a common feature in many studies on zooplankton communities (Lansac-Tôha et al., 2009; Melo et al., 2014) since this group is generally regarded as encompassing opportunistic organisms, with high adaptive capacity, fast colonization and broad niche (Pourriot, 1977; Medeiros et al., 2011). These characteristics lead to large numbers of species in most aquatic systems. Furthermore, their large numbers and diverse feeding habits enable this group to participate in the nutrient cycling, contributing to the overall productivity of riverine systems (Rocha et al., 1995; Gosselain et al., 1998; Reckendorfer et al., 1999).

The Rotifera families with most species were Brachionidae and Lecanidae. Brachionidae is considered to be one of the most important taxa of freshwater zooplankton, whose species usually have planktonic habit, while Lecanidae is related to the benthos and periphyton, especially in places rich in vegetation, occurring in plankton only as occasional migrants (Almeida et al., 2009). The relatively large numbers of species in some taxa (e.g. Lecanidae, Brachionidade, Chydoridae) is typical for littoral areas, where the presence of aquatic macrophytes and other underwater structures provide refuge from predation (Lansac-Tôha et al., 2004).

The increase in species richness during the wet season observed in the present study, despite high water levels and discharges, is likely to be the result of increased organic matter content in the water and consequently greater nutrient availability for the zooplankton (Matsumura-Tundisi et al., 2002). Furthermore, the lateral expansion of the river during the wet season increases the degree of connectivity and the exchange of nutrient and species across river and flooded areas. Thus, aquatic organisms including zooplankton would migrate from previously isolated areas and exploit the newly available habitats and their resources.

An increase in species numbers was observed from the upper to the lower reaches during both dry and wet seasons. This increase being greater after the Boa Esperança reservoir. Reservoirs tend to accumulate nutrients which, associated with greater water residence time, is favorable to a greater number of zooplankton species (Almeida et al., 2009). Additionally, upper river reaches are generally more running and/or less nutritive, so the plankton communities should be less representative. The greater variations in water flow expected at upper reaches associated with the intermittent stream affluents may also explain the higher paucity of plankton at these reaches (Sedell et al., 1989).

The present study provides a list of zooplankton species for the Parnaíba River, a large and relatively unknown river system with regard to the plankton fauna. It takes account for spatio-temporal variation in species occurrence largely improving knowledge on this system. The richness of species observed in the Parnaíba River is high compared to other large rivers in Brazil (e.g. Bonecker et al., 2005). In the context of current policies of water management and river diversions for the northeast of Brazil, the present study highlights the importance of large river systems for biodiversity conservation. This is importantly so in the Parnaíba River, since conservation of dryland rivers is arguably enhanced given the dry nature of the environment.

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