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Distribution of planktonic microcrustaceans (Cladocera and Copepoda) in lentic and lotic environments from the semiarid region in northeastern Brazil

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ABSTRACT. The present study aimed to inventory the biodiversity of planktonic microcrustaceans (Cladocera and Copepoda) in 44 environments from the semiarid region of Brazil, increasing the knowledge about zooplankton community, including phytophilous species. Between 2011 and 2017, organisms were collected in a non - systematic way in the states of Rio Grande do Norte, Pernambuco, Ceará and Paraíba. A total of 60 species of planktonic microcrustaceans were identified, of which 52 were cladocerans and eight were copepods. The basin that presented the highest richness was Pajeú River with 41 species. Nevertheless, the extrapolated number of species shows an increasing tendency for this basin. The genus composition was different between the basins, with Moxotó basin (Pernambuco) being isolated from the others, probably since lagoons were the only type of environment sampled in this basin. Richness and abundance patterns were higher for the basins where sampling was mainly performed in lentic environments, such as Pajeú and Moxotó. Microcrustacean inventories and long-term studies need to be conducted more frequently to better understand the biodiversity of continental aquatic ecosystems in the semiarid region of Brazil.

KEYWORDS. Zooplankton, Neotropical, shallow lakes, Caatinga.

RESUMO. **Distribuição de microcrustáceos planctônicos (Cladocera e Copepoda) em ambientes lênticos e lóticos do semiárido brasileiro.** O presente estudo objetivou inventariar a biodiversidade de microcrustáceos planctônicos (Cladocera e Copepoda) em 44 mananciais da região semiárida do Brazil, ampliando o conhecimento da comunidade zooplanctônica desta região, incluindo as espécies fitófilas. Os organismos foram coletados de modo não sistemático entre 2011 e 2017, nos estados do Rio Grande do Norte, Pernambuco, Ceará e Paraíba. Um total de 60 espécies de microcrustáceos planctônicos foram identificadas, sendo 52 de cladóceros e oito de copépodes. A bacia que apresentou maior riqueza foi a do rio Pajeú com 41 espécies. Mesmo assim, o número extrapolado de espécies mostra uma tendência de aumento para essa bacia. A composição dos gêneros foi diferente entre as bacias hidrográficas, sendo a bacia do Moxotó (Pernambuco) isolada das demais, talvez porque nesta bacia as lagoas foram o único tipo de ambiente amostrado. Os padrões de riqueza e de abundância se mostraram mais elevados para as bacias ondem a amostragem foi realizada principalmente em ambientes lênticos, como a do Pajeú e do Moxotó. Inventários de microcrustáceos e estudos de longa duração precisam ser maximizados para ampliação do conhecimento da biodiversidade dos ecossistemas aquáticos continentais da região semiárida brasileira.

PALAVRAS-CHAVE. Zooplâncton, Neotropical, lagos rasos, Caatinga.

Ecosystems in the semiarid region of Brazil encompass artificial reservoirs and natural shallow lakes, as well as streams and rivers. These systems present peculiarities in semiarid landscapes, characterized by complex climatic patterns and irregular rainfall indices (Medeiros & Maltchik, 2001; Maltchik & Medeiros, 2006). Organisms that inhabit these habitats are prone to strong changes in their composition and dynamics (Cardoso *et al.*, 2012). Nevertheless, these environments hold high species biodiversity, since the stresses caused by irregular seasonality tend to favor higher microcrustacean diversity (Güntzel *et al.*, 2010).

Planktonic microcrustaceans, including phytophilous species, that inhabit plankton in the shallow littoral zone play a special role in energy transfer (Melão *et al.*, 2005) as they provide nutrients for deeper/bottom layers of continental aquatic ecosystems through their fecal pellets (Shatova *et al.*, 2012) and carcasses. Although there are several surveys about microcrustaceans from continental waters around the world, much remains to be understood regarding their biodiversity patterns. The last global survey of cladocerans comprised 620 species recorded in freshwater ecosystems around the world, with 186 species found in the Neotropical region (Forró *et al.*, 2008). For freshwater copepods, 2,814 species have been recorded worldwide, with the Neotropical region presenting the second highest richness with 561 species (Boxshall & Defaye, 2008).

Zooplankton studies in the Brazilian northeastern region began with the works of Wright (1935), Brehm & Thomsen (1936), Brehm (1937, 1938), and Ahlstrom (1938). A few decades after these pioneering studies, new studies s were carried out in Paraíba (Nordi & Watanabe, 1978) and Maranhão (Reid & Turner, 1988). In Pernambuco the first studies of zooplankton were implemented by Schubart (1938, 1942), followed by Neumann-Leitão & Souza (1987) and Neumann-Leitão *et al.*, (1989). After that, other researchers collected and reviewed works from the region (Reid, 1989). Although the number of studies about planktonic microcrustaceans from continental waters in the semiarid region have increased in recent years (Almeida *et al.*, 2009; Soares & Elmoor-Loureiro, 2011; Diniz *et al.*, 2013; Melo *et al.*, 2014; Sousa *et al.*, 2015a,b; Medeiros & Melo-Júnior, 2016; Diniz & Melo-Júnior, 2017; Cabral *et al.*, 2019), many are still difficult to find and access, being found in particular libraries and collections (Melo-Júnior *et al.*, 2007; Paranhos *et al.*, 2013). According to Silva & Perbiche-Neves (2017), 45% of studies about microcrustaceans in Brazil encompasses only three of the most populous Brazilian states (São Paulo, Minas Gerais and Paraná).

Indeed, the knowledge concentrates around a few research centers, with focus on particular localities, limiting the taxonomic and biogeographic knowledge of the species (Debastiani-Júnior *et al.*, 2015). The small amount of research about the semiarid biodiversity has led to the misperception of poor aquatic biota with little endemism (Maltchik & Medeiros, 2006). Further research is needed focusing on the taxonomy and ecology of microcrustaceans of more regions in order to reduce biodiversity loss and improve conservation measures in continental aquatic habitats. In addition, as microcrustaceans can be used in environmental biomonitoring and ecotoxicological studies (Silva, 2011; Moreira *et al.*, 2014), increasing the number of biodiversity studies could further improve this field of knowledge.

Therefore, the goal of the present study was to inventory the planktonic microcrustaceans (Cladocera and Copepoda) in 44 lentic and lotic habitats in the Brazilian semiarid. We also aimed to increase knowledge about zooplankton, including phytophilous species. This is one of the largest studies about freshwater zooplankton fauna in the northeastern region, encompassing different states and hydrographic basins with the highest number of sampled waterbodies.

MATERIAL AND METHODS

Study area. Our study was carried out in 44 environments from the semiarid region in northeastern Brazil (lentic, lotic, natural and artificial), distributed among the states of Rio Grande do Norte, Pernambuco, Ceará and Paraíba. The environments belong to eight different sub-basins, distributed into two hydrographic regions: the Eastern Northeastern Atlantic region and the São Francisco region (Appendix, Fig. 1) (MMA, 2006a).

The Eastern Northeastern Atlantic region includes the states of Ceará (CE), Rio Grande do Norte (RN), Paraíba (PB) and the coastal part of the states of Pernambuco (PE) and Alagoas (AL). We sampled 10 environments in the Piranhas-Apodi sub-basin (RN-PB), with an area of 59,701.22 km², and one environment in the Jaguaribe basin - Salgado subdivision (CE), which occupies an area of 12,882.48 km².

The São Francisco region includes the states of Minas Gerais (MG), Bahia (BA), Pernambuco (PE) and some

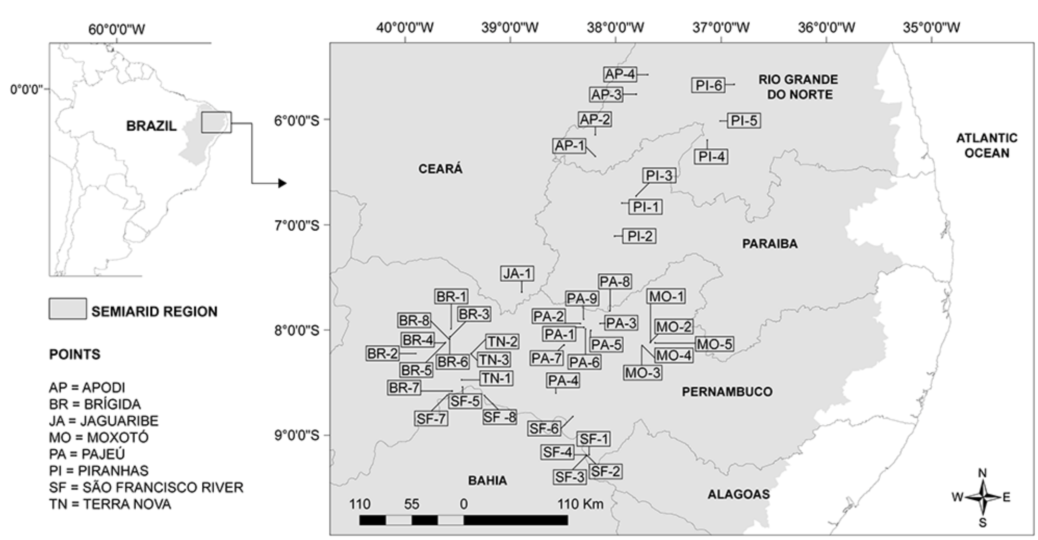

Fig. 1. Location of the 44 environments studied in the semiarid region of northeastern Brazil. A1 to A4, Apodi basin; B1 to B8, Brígida basin; J1, Jaguaribe basin; M1 to M5, Moxotó basin; P1 to P9, Pajeú basin; R1 to R6, Piranha basin; S1 to S8, São Francisco basin; T1 to T3, Terra Nova basin.

regions near the river in the states of Alagoas and Sergipe (SE). Most of the studied environments were distributed in the fraction of the São Francisco sub-basin, located in Pernambuco state, comprising a total area of 114,375.61 km². Eight environments were sampled in the Brígida River sub-basin; five in the Moxotó sub-basin; nine in the Pajeú sub-basin, and 11 points in stretches of the São Francisco River. Three reservoirs were sampled in the Terra Nova sub-basin (MMA, 2006b).

Procedures for sampling and analyzing biological material. Zooplankton samples were carried out in a non-systematic manner between January 2011 and May 2016, with some samples collected in littoral zone and others in pelagic zone of the environments. Samples were obtained using a plankton net with 45 µm size mesh and graduated container. The amount of filtered water varied in each environment (Appendix). The organisms were fixed with 4% neutral formalin. Samples were registered and deposited in the Zooplankton Collection at the UFRPE (CZ-UFRPE).

In the laboratory, cladocerans and copepods were studied under optical microscope and stereomicroscope and were identified using usual dissection methods for microcrustaceans and specialized bibliography (e.g. Reid, 1985; Matsumura-Tundisi, 1986; Smirnov, 1996; Elmoor-Loureiro, 1997; Perbiche-Neves *et al.*, 2015). For each sample, three 2 mL replicates were placed in a Sedgwick-Rafter-type chamber, prepared specifically for this volume. For each replicate, a minimum of 100 individuals should be counted, totaling at least 300 individuals per sample, which maintains high chances of detecting rare species. Samples with a low number of specimens (< 100 individuals per subsample) were completely analyzed.

Data analysis. Data was initially treated as frequency of occurrence (%), abundance of individuals (ind.m^{-3}), and species richness. After this, we plotted a rarefaction curve based on the number of individuals, which was extrapolated to estimate and compare species richness among different river basins. Each basin was represented by one curve, with confidence intervals (95%) generated by the bootstrap method with 100 replications (Chao & Jost, 2012). For this analysis, we used the iNEXT package in R (Hsieh *et al.*, 2016; R Core Team, 2016).

To verify possible similarities between basins, a Cluster Analysis was used through the Bray-Curtis dissimilarity index obtained using the Proxy package for R (Meyer & Buchta, 2018). In addition, to verify differences in genus composition between basins, the Permutational multivariate analysis of variance (PERMANOVA, "Adonis" function, see Anderson *et al.*, 2001) was used, with distance matrix calculated using the Bray-Curtis method and visualized with Non-Metric Multidimensional Scaling (NMDS), performed in the Vegan package (Oksanen *et al.*, 2018). All analyses were performed in software R (R Core Team, 2016).

RESULTS

We identified 60 species of planktonic microcrustaceans: 52 Cladocera and eight Copepoda. Cladocerans were distributed among the families Sididae (6 species) Bosminidae (3), Moinidae (2), Daphniidae (6) Macrothricidae (5), Ilyocryptidae (1) and Chydoridae (30). Copepods were distributed among Diaptomidae (3) and Cyclopidae (5) (Tab. I).

The most frequently found species were: *Ceriodaphnia cornuta* Sars, 1885 (43.18%), *Diaphanosoma spinulosum* Herbst, 1975 (36.36%), *Macrothrix elegans* Sars, 1901 (34.09%), and *Notodiaptomus cearensis* (Wright, 1936) (31.82%). The naupliar forms reached 95.45%. The other species had frequencies less than 30% (Tab. I).

The Pajeú River basin had the highest richness with 41 species, followed by the Brígida River (31), while the lowest richness was found in the Apodi River basin (1) (Tab. I). Most river basins reached the asymptote for the number of species, through collected individuals. However, the greatest richness was found in the Pajeú River basin, where the extrapolated number shows an increasing trend (Fig. 2).

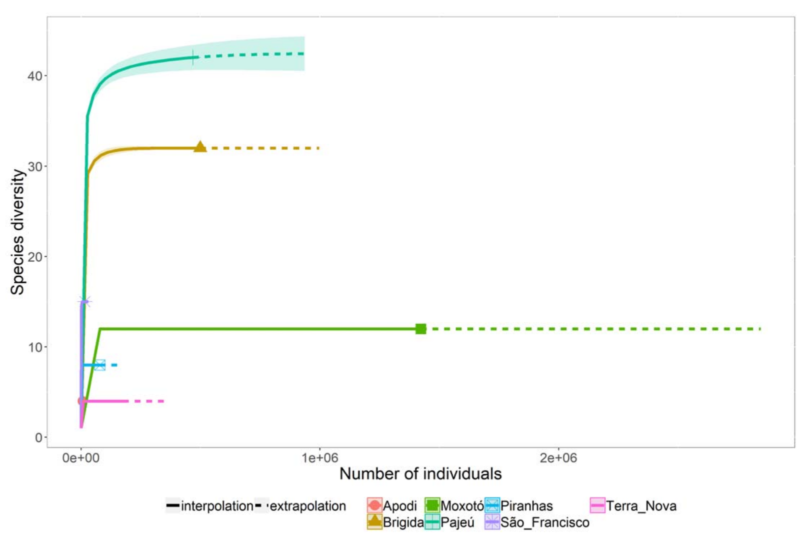

Fig. 2. Rarefaction and extrapolation curves based on the number of microcrustaceans collected from seven basins in the semiarid region of northeastern Brazil. The shaded area represents the 95% confidence interval.

Tab. I. List of microcrustaceans (Cladocera and Copepoda) species collected in the semiarid ecosystems, Brazil (F.O., frequency of occurrence; ANT, Antarctic; AU, Australasian; AT, Afrotropical; NA, Nearctic; NT, Neotropical; OL, Oriental; PA, Palearctic; PAC, Pacific ocean).

Species	Basins								F.O.	Global distribution
	Apodi	Brígida	Jaguaribe	Moxotó	Pajeú	Piranhas	São Francisco	Terra Nova		
CLADOCERA										
SIDIDAE										
Diaphanosoma fluviatile Hansen, 1899					X				2.27	NT
Diaphanosoma polyspinum Korovchinsky, 1982					X				2.27	NT
Diaphanosoma spinulosum Herbst, 1975	X	X		X	X	X			36.36	NT
Latonopsis australis Sars, 1888					X				4.55	AT; AU; NA; NT; OL; PAC; PA
Pseudosida bidentata Herrick, 1884		X			X				4.55	NT
Sarsilatona serricaudata (Sars, 1901)		X							2.27	NA; NT
BOSMINIDAE										
Bosminopsis deitersi Richard, 1895							X		2.27	AU; AT; NA; NT; OL; PA
Bosmina freyi De Melo & Hebert, 1994					X		X	X	13.64	AT; ANT; AU; NA; NT OL; PAC; PA
Bosmina hagmanni Stingelin, 1904								X	2.27	NA; NT
MOINIDAE										
Moina micrura Kurz, 1875		X		X	X			X	29.55	AT; AU; NA; NT; OL; PAC; PA
Moina reticulata (Daday, 1905)		X							4.55	AT; NT
DAPHNIIDAE										
Ceriodaphnia cornuta Sars, 1885		X		X	X		X	X	43.18	AT; AU; NA; NT; OL; PAC; PA
Daphnia gessneri Herbst, 1967					X		X		13.64	NT
Simocephalus acutirostris (King, 1853)					X				4.55	AU; OL; PAC
Simocephalus latirostris Stingelin, 1906					X				2.27	NT
Simocephalus serrulatus (Koch, 1841)					X				2.27	AT; AU; NA; NT; OL; PAC; PA
Simocephalus sp.						X			2.27	
MACROTHRICIDAE										
Grimaldina brazzai Richard, 1892		X			X				6.82	AT; AU; NT; OL
Macrothrix elegans Sars, 1901		X		X	X				34.09	NT
Macrothrix superaculeata (Smirnov, 1982)					X				2.27	NT
Macrothrix sp.							X		2.27	
ILYOCRYPTIDAE										
Ilyocryptus spinifer Herrick, 1882		X		X	X				13.64	AT; AU; NA; NT; OL; PAC; PA
CHYDORIDAE										
CHYDORINAE										
Alonella dadayi Birge, 1910		X							2.27	NT
Alonella sp.							X		2.27	
Chydorus eurynotus Sars, 1901					X				2.27	AT; AU; NT; OL; PAC
Chydorus nitidulus (Sars, 1901)		X							2.27	NT
Chydorus pubescens Sars, 1901				X	X				9.09	AT; AU; NT; OL
Chydorus sp.						X	X		6.82	
Dadaya macrops (Daday, 1898)		X							2.27	AT; AU; NT; OL; PAC
Dunhevedia odontoplax Sars, 1901		X							4.55	NT

Tab. I. Cont

Species	Basins								F.O.	Global distribution
	Apodi	Brígida	Jaguaribe	Moxotó	Pajeú	Piranhas	São Francisco	Terra Nova		
Ephemeroporus hybridus (Daday, 1905)		X			X				18.18	NT; OL
Ephemeroporus tridentatus (Bergamin, 1939)		X			X				4.55	NT; OL
ALONINAE										
Magnospina dentifera (Sars, 1901)		X			X				11.36	NT
Ovalona glabra Sars, 1901		X			X		X		15.91	NT
Alona guttata Sars, 1862					X				6.82	AT; AU; NA; NT; OL; PA
Flavalona margipluma Sousa, Santos, Güntzel, Diniz, Melo Junior & Elmoor-Loureiro, 2015					X				2.27	-
Alona ossiani Sinev, 1998					X				4.55	NT
Alona sp.							X		4.55	
Anthalona verrucosa (Sars, 1901)		X		X	X				20.45	NT
Celsinotum laticaudatum Smirnov & Santos-Silva, 1995					X				2.27	NT
Coronatella monacantha (Sars, 1901)					X				2.27	NT
Coronatella serratalhadensis Sousa, Elmoor-Loureiro & Santos, 2015				X	X		X		15.91	NT
Euryalona orientalis (Daday, 1898)		X			X				11.36	AT; AU; NT; OL
Flavalona iheringula (Kotov & Sinev, 2004)					X				2.27	NT
Karualona muelleri (Richard, 1897)		X		X	X		X		25.00	NT
Kurzia polyspina Hudec, 2000		X			X				11.36	NT
Leberis davidi (Richard, 1895)					X				11.36	NT
Leygidia sp.							X		6.82	NT
Leydigiopsis curvirostris Sars, 1901		X			X				2.27	NT
Leydigiopsis ornata Daday, 1905					X				4.55	NT
Notoalona sculpta (Sars, 1901)		X			X				4.55	NT
Oxyurella longicaudis (Birge, 1910)		X		X					2.27	
COPEPODA										
Nauplii	X	X	X	X	X	X	X	X	95.45	
CALANOIDA					X				4.55	
DIAPTOMIDAE										
Argyrodiaptomus sp.	X					X	X		9.09	
Notodiaptomus cearensis (Wright, 1936)	X			X	X	X	X		31.82	NT
Notodiaptomus iheringi (Wright, 1935)		X							4.55	NT
CYCLOPOIDA				X	X		X		34.09	
CYCLOPIDAE										
Thermocyclops decipiens (Kiefer, 1929)	X	X				X			11.36	NT
Thermocyclops sp.		X							11.36	
Eucyclops neumani (Pesta, 1927)		X							11.36	NT
Ectocyclops herbstii Dussart, 1984		X							11.36	NT
Paracyclops sp.						X			2.27	
HARPACTICOIDA		X				X			6.82	
Total richness	5	31	1	13	41	9	16	5		

The genus composition was different among hydrographic basins (F = 1.88; p = 0.0051) (Fig. 3). The Cluster analysis, considering hydrographic basins, indicated three major groups: Group 1- Terra Nova (Pernambuco) and Piranhas (Paraíba and Rio Grande do Norte), group 2- Pajeú and Brígida (both in Pernambuco) and group 3- São Francisco (Pernambuco), and Apodi (Rio Grande do Norte). The Moxotó River basin (Pernambuco) was isolated from the rest (Fig. 4).

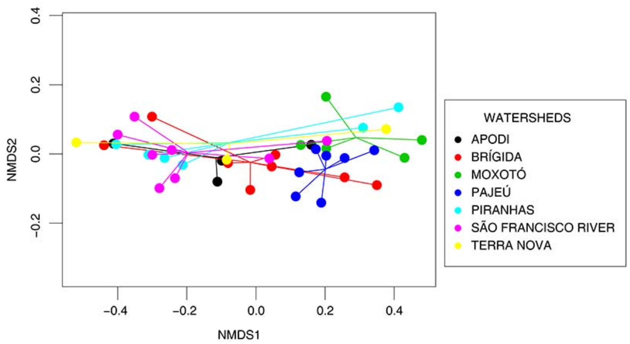

Fig. 3. Non-metric multidimensional scaling considering the composition data of the microcrustaceans from seven basins in the semiarid region of northeastern Brazil.

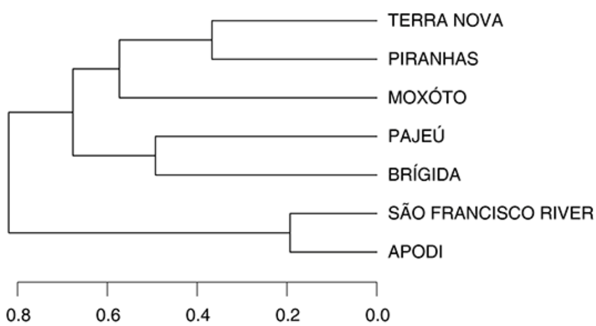

Fig. 4. Cluster analysis of samples from the seven basins of the semiarid region in northeastern Brazil.

The greatest density values for cladocerans were recorded in the Terra Nova River basin (58,524.2 ± 101,366.8 ind. m^3), Moxotó (50,495.2 ± 70,015.9 ind. m^3) and Brígida (43,353.7 ± 99,886.6 ind. m^3). For copepods, the Moxotó River basin presented the highest density (426,076.2 ± 505,754.2 ind. m^3), followed by Piranhas (190,529.98 ± 270,111.2 ind. m^3) and Jaguaribe (single sample with 155,2162.85 ind. m^3) (Fig. 5).

DISCUSSION

Richness and abundance patterns were higher in basins where sampling was performed mainly in lentic environments, such as Pajeú and Moxotó. However, a clear species distribution pattern was not found among the studied basins. This could reflect the non-systematic collection method used. In addition, there are considerable differences regarding endemism between the basins, with Pajeú presenting the highest number of exclusive species, probably because the highest number of environments was sampled from this basin.

The knowledge of limnic microcrustaceans from 18 years ago was considered insufficient in Brazil (Elmoor-Loureiro, 2000), and currently, even with new research, little progress has been made to fill this gap, especially when considering the Northeastern region (Silva & Perbiche-Neves, 2017). According to Silva (2008), the endemism record per region is related to the number of specialists in each area, which makes it difficult, or even impossible, to compare results between regions. Primary studies like biological inventories are considered one of the most important tools for management and conservation measures in a given area (Silveira *et al.*, 2010).

Considering recent surveys of cladoceran fauna in Pernambuco (Soares & Elmoor-Loureiro, 2011; Diniz *et al.*, 2013; Sousa *et al.*, 2015a,b), 55 species were verified in the state. With this study, we add seven new species to Pernambuco's list of cladoceran species. Thus, these new occurrences (*Celsinotum laticaudatum* Smirnov & Santos-Silva, 1995, *Diaphanosoma fluviatile* Hansen, 1899, *D. polyspinum* Korovchinsky, 1982, *Flavalona iheringula* (Kotov & Sinev, 2004), *Moina reticulata* (Daday, 1905), *Pseudosida bidentata* Herrick, 1884 and *Simocephalus serrulatus* (Koch, 1841) increase the total number of known species to 62 for the state. Such increase in species for Pernambuco shows the importance of biodiversity inventories and reiterates that further research is still needed to determine the true biodiversity of aquatic invertebrates, especially for the semiarid region.

The cladocerans *Ceriodaphnia cornuta*, *Diaphanosoma spinulosum* and *Moina micrura* occurred in most of the studied environments. In the Brazilian Northeastern region, aquatic environments are generally

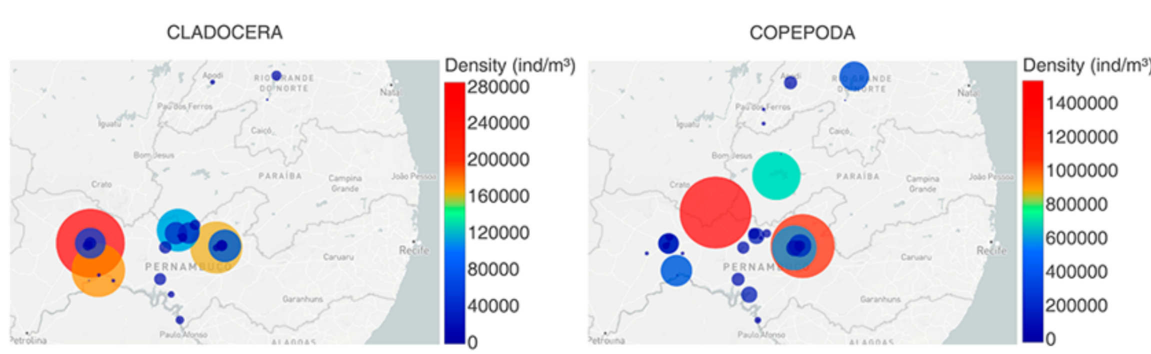

Fig. 5. Density of microcrustaceans (cladocerans and copepods) distributed in the eight basins of the semiarid region in northeastern Brazil.

dominated by these species, mainly in reservoirs from Pernambuco (Medeiros & Melo-Júnior, 2016), Rio Grande do Norte (Eskinazi-Sant'Anna *et al*., 2007), Bahia (Santos *et al*., 2018), and Piauí (Paranhos *et al*., 2013). The presence of *Karualona muelleri* (Richard, 1897) in half of the studied ecosystems (all in Pernambuco) reinforces the importance of studying aquatic environments such as ponds, river stretches and temporary pools, since this species has never been reported after 34 years of studying Pernambuco reservoirs (Medeiros & Melo-Júnior, 2016).

Calanoida and Cyclopoida are the most common orders in these environments, with dominance of the families Diaptomidae and Cyclopidae in South America; the former endemic to the Neotropical region (Boxshall & Dafaye, 2008). In the Brazilian northeastern region, the species *Notodiaptomus cearensis* (Diaptomidae) and *Thermocyclops decipiens* (Kiefer, 1929) (Cyclopidae) were reported from several reservoirs in Pernambuco (Medeiros & Melo Júnior, 2016), Bahia (Santos *et al*., 2018), Piauí (Paranhos *et al*., 2013) and Rio Grande do Norte (Eskinazi-Sant'Anna *et al*., 2007). In general, these species are associated with the trophic state of the environment, with Cyclopoida being dominant in eutrophic environments (Pinto-Coelho *et al*., 2005). However, for the state of Rio Grande do Norte, the predominance of Calanoida in impacted environments has also been reported (Panosso *et al*., 2007; Eskinazi-Sant'Anna *et al*., 2007). *Notodiaptomus*, for example, may consume small cyanobacterial colonies, favoring them in eutrophic environments (Panosso *et al*., 2007). In our study, *Notodiaptomus cearensis* was the most common species. Although we did not measure the trophic state of the waterbodies, most of them suffer from eutrophication (Bouvy *et al*., 2001; Eskinazi-Sant'Anna *et al*., 2013; Diniz & Melo-Júnior, 2017), which could explain the dominance of this calanoid copepod.

We did not find a clear distribution pattern for the species. However, concerning endemism, there were considerable differences between the basins, in which the Pajeú presented the highest number of exclusive species (17). Several factors may be responsible for endemism, such as the presence of aquatic macrophytes (Perbiche-Neves *et al*., 2014). Since we did not measure the physicochemical variables of water, nor have detailed information about the littoral zone of the areas, it is difficult to establish patterns. However, the highest number of studied environments come from this basin, which may explain the highest number of exclusive species recorded (Silva, 2008). While some species were recorded in certain basins, others were widely distributed (see Tab. II). For example, *N. cearensis* occurred in almost all basins. This is expected since members of Diaptomidae are distributed almost everywhere in the world, being even more diverse in the Neotropical region (Dussart & Defaye, 2002).

Sampling in a non-systematic way, regarding periodicity, as well as the occasional sampling events, could have possibly hindered the real estimation of microcrustacean taxonomic composition, since some rare species might not have been sampled (Paranhos *et al*., 2013). This

Tab. II. List of water bodies in the semiarid ecosystems, Brazil where microcrustaceans have already been studied (*indicate articles that did not study certain groups - Cladocera or Copepoda).

Reference	State	Basins	Environment type	Number of environments	Cladocera richness	Copepoda richness
Crispim & Watanabe, 2000	CE	River Jaguaribe	Reservoir, river	3	4	5
Present study	*CE*	*River Jaguaribe*	*Reservoir*	*1*	*	*1*
Present study	*RN*	*River Apodi*	*Reservoir, river*	*4*	*1*	*3*
Eskinazi-Sant'Anna *et al*., 2007	RN	River Piranhas-assu	Reservoir	6	9	9
Medeiros *et al*., 2011	RN, PB	River Piranhas-assu	River, stream and reservoir	3	4	2
Crispim & Watanabe, 2000	RN, PB	River Piranhas-assu	Reservoir, river	4	8	3
Present study	*RN, PB*	*River Piranhas-assu*	*River, stream and reservoir*	*6*	*3*	*5*
Melo & Medeiros, 2013	PB	River Paraíba	River	3	6	4
Crispim & Freitas, 2005	PB	River Paraíba	Lagoon	1	9	*
Vieira *et al*., 2009	PB	River Paraíba	Reservoir	1	9	*
Crispim *et al*., 2006	PB	River Paraíba	Reservoir	5	12	*
Present study	*PE*	*River Moxotó*	*Reservoir*	*4*	*10*	*2*
Medeiros *et al*., 2011	PE	River Moxotó	Stream	1	0	2
Medeiros *et al*., 2011	PE	River Ipanema	Reservoir	1	4	2
Melo *et al*., 2014	PE	River Ipanema	Reservoir, stream	4	3	2
Medeiros *et al*., 2011	PE	River Una	Reservoir	1	3	3
Present study	*PE*	*River Pajeú*	*Reservoir*	*9*	*37*	*3*
Present study	*PE*	*River Brígida*	*Reservoir*	*8*	*24*	*6*
Present study	*PE*	*River São Francisco*	*River, stream and reservoir*	*8*	*12*	*3*
Present study	*PE*	*River Terra Nova*	*River*	*3*	*4*	*1*

may justify the fact that, although the Pajeú River basin presented the highest richness and largest sample effort, the extrapolated number of species still shows an increasing tendency. Moreover, most of the samples were collected from reservoirs and small ponds in this basin. Sharma *et al.* (2012), studying lakes in India, concluded that the depth of the spring, commonly shallow waters, combined with other factors, such as homogeneous distribution of light incidence, contribute the most to the higher richness and composition of these invertebrates.

The Moxotó basin, in Pernambuco, presented the highest abundance of cladocerans and copepods. All samplings in this area were only carried out in lentic environments which could favour their development (Takahashi *et al.*, 2009). Their eating habits, reproductive and morphological strategies could also explain the great temporal and even spatial variation of their community structure. Besides being characterized as lentic environments, the studied environments in this basin are also temporary. Thus, another possible reason for greater zooplankton abundance may be the reduction or even absence of fish in temporary environments. For example, Drenner *et al.* (2009) found a predominance of larger sized zooplankton organisms in the absence of fish in temporary ponds.

The species composition was different among river basins, which was already expected since sampling events were carried out in environments with distinct features (lotic and lentic stretches - reservoirs and temporary ponds). Merrix-Jones *et al.* (2013), who studied natural and artificial ponds from various parts of the world, have observed that the composition of zooplanktonic organisms differs between natural and artificial systems on a global scale. In fact, several factors may be responsible for structuring communities, including environmental heterogeneity, intensity of disturbances, connectivity and dispersion (Vellend, 2010; Lopes *et al.*, 2014). In addition, solar radiation may be a predictor responsible for variation in species composition (Pinel-Alloul *et al.*, 2013).

Comparing the richness values between the studied environments and other works from adjacent basins, we did not find a clear pattern of distribution and diversity in Northeastern basins (see Tab. II). Although average richness of cladocerans was intermediate in the Paraíba river basin, the region still lacks studies about copepod diversity (see Tab. II). Pernambuco basins showed higher average richness of cladocerans, with decreasing tendency towards the northern portion of the Northeastern region (RN and CE). On the other hand, we found an opposite pattern for copepods, with the highest average richness found in Rio Grande do Norte and Ceará basins.

The multiple uses of aquatic environments in the Brazilian semiarid (Eskinazi-Sant'Anna *et al.*, 2007) may lead to eutrophication. Traditional metrics have shown that modifications in a naturally lotic system, transforming it into a lentic one (dam construction, for example), cause changes in species richness, density and composition of the community. Therefore, studies that aim to catalogue the biodiversity of this area are fundamental for conservation of the aquatic biota. In addition, the São Francisco River has a great socioeconomic importance for the states of Pernambuco, Alagoas, Sergipe and Bahia, but its biodiversity is still poorly known and there is a clear need for studies about zooplankton species diversity due to the deterioration of the environmental quality. We also emphasize that future studies and inventories, in the semiarid region should consider the different seasonal periods to maximize understanding of microcrustacean dynamics.

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Appendix. Codes and coordinates of the studied springs, city/state, type of environment, filtered volume (in liters), amount of sample collected in each spring (quant.) and sampling period (month/year) in semiarid ecosystems, Brazil (RN, Rio Grande do Norte; PE, Pernambuco; CE, Ceará; PB, Paraíba).

Springs/ codes	Coordinates	City/state	Type of environment	L	Quant.	Month/year
Basins						
Apodi						
A1	06°21’12”S, 38°11’41”W	Pau dos Ferros/RN	River	393	1	04/2016
A2	06°08’50”S, 38°11’37”W	Pau dos Ferros/RN	Reservoir	393	1	04/2016
A3	05°45’37”S, 37°48’08”W	Apodi/RN	Reservoir	393	1	04/2016
A4	05°34’36”S, 37°41’47”W	Apodi/RN	River	393	1	04/16
Brígida						
B1	07°59’34”S, 39°33’55”W	Parnamirim/PE	Reservoir	393	1	04/16
B2	08°13’43”S, 39°53’42”W	Parnamirim/PE	Reservoir	393	1	04/16
B3	08° 04.097’S, 39°34.403’W	Parnamirim/PE	Reservoir	100	2	05/13
B4	08°05.183’S, 39°34.694’W	Parnamirim/PE	Reservoir	4-30	4	05/11
B5	08°07.296’S, 39°37.074’W	Parnamirim/PE	Reservoir	100	2	05/13
B6	08°05.169’S, 39°34.648’W	Parnamirim/PE	Reservoir	10	1	04/13
B7	08°34’53”S, 39°33’12”W	Orocó/PE	River	393	1	05/16
B8	08°05.126’S, 39°34.819’W	Parnamirim/PE	Reservoir	70-150	2	04/13
Jaguaribe						
J1	07°38’26”S, 38°53’34”W	Brejo Santo/CE	Reservoir	393	1	04/16
Moxotó						
M1	08°07’13.3”S, 37°40’12.6”W	Custódia/PE	Lagoon	2	1	02/11
M2	08°06’59.3”S, 37°39’55.2”W	Custódia/PE	Lagoon	14	1	07/11
M3	08°08’56.5”S, 37°44’53.8”W	Custódia/PE	Lagoon	2	1	01/11
M4	08°09’08.3”S, 37°44’55.0”W	Custódia/PE	Lagoon	2	1	01/11
M5	08°07’27.3”S, 37°37’34.2”W	Custódia/PE	Lagoon	2	1	02/12
Pajeú						
P1	07°58’41”S, 38°17’59”W	Serra Talhada/PE	Reservoir	30-50	3	02 a 05/11
P2	07°56’35”S, 38°20’07”W	Serra Talhada/PE	Reservoir	75-100	6	04/11 a 05/14
P3	07°56’30.8”S, 38°08’55.0”W	Calumbi/PE	River	42-110	6	12/11 a 06/12
P4	08°36’09.0”S, 38°33’56.7”W	Floresta/PE	River	30-40	3	05 a 06/12
P5	08°00’18.6”S, 38°14’10.0”W	Serra Talhada/PE	Reservoir	40-100	16	09/11 a 11/12
P6	07°59’31”S, 38°17’05”W	Serra Talhada/PE	Reservoir	75-100	14	10/11 a 01/12
P7	08°08’43”S, 38°29’23”W	Serrinha/PE	Reservoir	66-110	20	09/11 a 11/12
P8	07°49’22.59”S, 38°3’22.31”W	Triunfo/PE	Lagoon	2,5	2	07/11
P9	07°53’58.2”S, 38°18’09.6”W	Serra Talhada/PE	Lagoon	14-60	3	05/12 a 01/14
Piranhas						
R1	06°47’41”S, 37°56’26”W	Souza/PB	River	393	1	04/16
R2	07°06’33”S, 38°00’32”W	Coremas/PB	Reservoir	393	1	04/16
R3	06°43’49”S, 37°48’12”W	Pombal/PB	River	393	1	04/16
R4	06°11’57”S, 37°07’47”W	Coremas/RN	River	393	1	04/16
R5	06°00’58”S, 37°00’31”W	Açu/RN	Reservoir	393	1	04/16
R6	05°40’03”S, 36°52’29” W	Açu/RN	Reservoir	393	3	04/16
São Francisco						
S1	09°11’17.4”S, 38°15’08.6”W	Jatobá/PE	River	50	1	08/12
S2	09°11’46.1”S, 38°16’26.0”W	Jatobá/PE	River	100	1	08/12
S3	09°11’31.1”S, 38°16’38.3”W	Jatobá/PE	River	100	1	08/12
S4	09°11’23.7”S, 38°16’42.2”W	Jatobá/PE	River	200	1	11/12
S5	08°32’40”S, 39°27’16”W	Cabrobó/PE	River	393	1	05/16

Appendix. Cont.

Springs/ codes	Coordinates	City/state	Type of environment	L	Quant.	Month/year
S6	08°49’25”S, 38°24’11”W	Petrolândia/PE	Reservoir	393	1	05/16
S7	08°37’23”S, 39°35”W	Orocó/PE	River	393	1	05/16
S8	08°37’28”S, 39°14’43”W	Ibó	River	393	1	05/16
Terra Nova						
T1	08°28’35.4”S 39°27’45.4”W	Terra Nova/PE	Reservoir	393	1	04/16
T2	08°13’45”S, 39°22’25”W	Terra Nova/PE	Reservoir	393	1	04/16
T3	08°13’36”S, 39°22’23”W	Terra Nova/PE	Reservoir	393	1	04/16