Biota Neotropica 21(2): e20201079, 2021
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
Article

Composition and diversity of phytophilous cladocerans of oxbow lakes of Southwest Amazonian, Acre state, Brazil

Guilherme Sampaio Cabral[1,3]*, *Ronaldo Souza da Silva*[2], *Ronnilda Maria Gonçalves Araujo*[3] & *André Ricardo Ghidini*[1,3,4]

[1]*Universidade Federal do Acre, Programa de Pós-Graduação em Ecologia e Manejo de Recursos Naturais, Rio Branco, AC, Brasil.*
[2]*Universidade Federal do Pará, Programa de Pós-graduação em Zoologia, Belém, PA, Brasil.*
[3]*Universidade Federal do Acre, Laboratório de Pesquisa em Limnologia e Plâncton, Rio Branco, AC, Brasil.*
[4]*Universidade Federal do Acre, Centro de Ciências Biológicas e da Natureza, Rio Branco, AC, Brasil.*
**Corresponding author: Guilherme Sampaio Cabral, e-mail: oguilhermecabral@gmail.com*

CABRAL, G.S., DA SILVA, R.S., ARAUJO, R.M.G., GHIDINI, A.R. **. Composition and diversity of phytophilous cladocerans of oxbow lakes of Southwest Amazonian, Acre state, Brazil.** Biota Neotropica 21(2): e20201079. https://doi.org/10.1590/1676-0611-BN-2020-1079

Abstract: The objective of this study was to inventory the community of cladocerans associated with macrophytes in oxbow lakes of the Chandless River, located within the Chandless State Park, during the local dry season. In three lakes covered with macrophytes, 90 sample units were collected, arranged over nine transects. Twenty species of cladocerans were found, which 16 are new records for the state of Acre. Mascote Lake had the largest abundance and richness, while São João Lake had the lowest indexes. The Shannon-Wiener index points to an average diversity within the work area, probably due to the difference in richness and abundance between the lakes.
Keywords: *Cladocera; Freshwater; Macrophytes; Species Inventory.*

Composição e diversidade de cladóceros fitófilos de lagos de meandro do sudoeste da Amazônia, estado do Acre, Brasil

Resumo: O objetivo desse estudo foi inventariar a comunidade de cladóceros associados às macrófitas aquáticas em três lagos de meandro do rio Chandless, dentro do Parque Estadual Chandless, no período da estação seca local. Em três lagos com cobertura de macrófitas foram amostradas noventa unidades amostrais, dispostas ao longo de nove transectos. Foram encontradas vinte espécies de cladóceros, sendo que dessas dezesseis são novos registros para o estado do Acre. O lago Mascote foi o que apresentou maior abundância e riqueza, enquanto o lago São João foi o que apresentou as menores. O índice de Shannon-Wiener aponta para uma diversidade dentro de valores locais conhecidos, provavelmente por conta da diferença da riqueza e da abundância entre os lagos.
Palavras-chave: *Cladocera; Água Doce; Macrófitas; Inventário De Espécies.*

Introduction

Tropical varzea Amazon ecosystems undergo regular changes in water level, whose fluctuation can exceed 10 meters (Correa & Winemiller 2014, Junk et al. 2014). These flood pulses are reflected in all local fauna and flora, even those of oxbow lakes, which are formed due to the process of sedimentation and erosion of the river beds (Junk et al. 2014, Esteves, 1998). To aquatic plants, the flood pulse promotes an homogenizer effect (Thomaz et al. 2007). These local flood pulses are extremely important for the local diversity of cladocerans (Guntzel et al. 2010), including those that interact with aquatic plants, the phytophilous cladocerans.

Aquatic plants confer important habitat heterogeneity in aquatic environments, and the unique spatial structure of plants is important for the growth and survival of the other aquatic organisms (Dibble & Thomaz 2006, Suçuarana et al. 2016), such as phytophilous cladocerans. The high ecological plasticity of the macrophytes make these plants potential colonizers of a huge variety of aquatic ecosystems (Pompêo 2008). In contrast, several taxa of cladocerans are specialized in colonizing these environments, presenting evolutionary adaptations for this way of life (Fryer 1995).

The scarcity of data on phytophilous cladocerans makes it difficult to understand the relationship of this group with macrophytes, although more than two-thirds of the known cladocerans are associated with this group of plants (Elmoor-Loureiro 2000). However, Forró (2008) estimated that the fauna of freshwater cladocerans is two to four times richer than what is currently known, which indicates that this number may be even higher. The author also pointed out that half of the most common species in Brazil are from typically coastal families. In general, the cladocerans reach their largest diversity in lentic environments (Rocha et al. 2011), because they present better conditions for this type of organism, specially when we consider that most of the species are not effective swimmers (Bolduc et al. 2020).

Another contribution to the scarcity of phytophilous cladocerans data is the frequency of most studies in the limnetic zone. Ghidini et al. (2017) focused his study on the cladocerans associated with *Eichhornia azurea* (Pontederiaceae) in the central Amazon and already warned about the scarcity of similar studies in the region. Despite this, there is a recent effort to increase knowledge about the group (eg Guntzel et al. 2010, Souza et al. 2013, Ghidini et al. 2017). However, the group continues to be scarcely sampled in the Amazon.

When analyzing the species of cladocerans registered for Acre state, we found only 17 records. These records were made in studies that covered zooplankton as a whole group (Sendacz & Melo-Costa 1991, Keppeler & Hardy 2002, Keppeler 2003a, Keppeler 2003b, Keppeler & Hardy 2004, Oliveira et al. 2010, Silva et al. 2012, Santos et al. 2013, Silva et al. 2014, Nascimento & Keppeler 2017a, Nascimento & Keppeler 2017b), but most of them were focused on rotifers. One species of the Eurycercidae family, one species of Ilyocryptidae, two species of Bosminidae, two species of Moinidae, three species of Sididae, four species of Chydoridae and four species of Daphnidae are registered. However, it is worth pointing out that almost all of these records came from studies carried out in the limnetic zone, which probably resulted in a species composition quite different from what could be collected in the coastal zone.

Studying phytophilous cladocerans becomes relevant, especially because of their great bioindicator potential, and a greater understanding of this group should help in understanding their contribution to the stability and maintenance of aquatic systems (De Eyto et al. 2002). In addition to the aforementioned little knowledge of the group, the importance of these studies is reinforced when it is considered that the diversity of cladocerans increases as the available vegetation abounds to be used as their ecological niches (Bolduc et al. 2020). Therefore, the objective of this study was to evaluate the composition and abundance of cladocerans associated with macrophyte beds in oxbow lakes in the southwestern Amazon and make new records for the group in the state of Acre. We theorize that local diversity would be high, given the seemingly favorable conditions for this.

Material and Methods

1. *Study area*

This study was carried out in three oxbow lakes from the Chandless River, located in the municipality of Manoel Urbano-AC, within the geographical limits of the Chandless State Park. Chandless State Park (Parque Estadual Chandless- PEC) is an Integral Protection Conservation Unit (IPCU) and it was created by decree 10.670, of September 2, 2004, with 695,303 ha, which also cover part of the municipalities of Sena Madureira and Santa Rosa do Purus (Acre 2010).

Located in the center-south of the state of Acre (Figure 1), bordering the Brazilian border with Peru, the Chandless State Park is the largest conservation unit in the state, with an open rainforest as dominant vegetation, in addition to the dominance of bamboos (Mielke et al. 2010), which is typical of the region. The local climate at PEC is hot and humid, with an average temperature above 18ºC (Acre 2010). A monsoon climate is a main characteristic of the region, with a moderate dry season and an average monthly rainfall of less than 60 mm (SEMA 2010). In this part of the state, the dry season runs from June to September, considering the previous and subsequent months as transition months (Acre 2012).

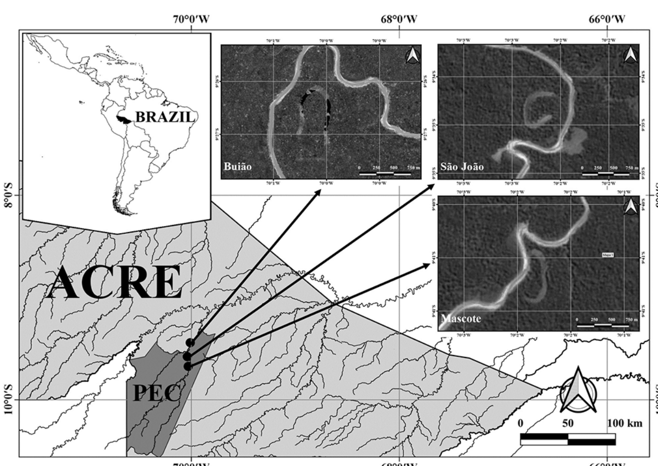

Figure 1. Map indicating the location of Chandless State Park (Parque Estadual Chandless- PEC) and the lakes available for the study (Buião lake, Mascote lake and São João lake).

According to the Sioli classification (1984), the lakes, created by the river as well, have white waters, that are subjected to the annual flood pulse of the river, which carries nutrients into the lakes. They vary in length, but all are at least 1,000 meters long. The study was carried out only in the dry season (July 2019), due to the reduction of lake area that occurs at that time, increasing the chances of finding individuals in abundance.

The region has lakes along the Chandless River, at the north end of the park. Of these lakes, only three were able to carry out the study, due to the size of the macrophyte beds. Still, the beds had different successional stages on the lakes.

2. *Data collection and analysis*

In each lake, three transects of 200 m were sampled, two of them at the lakes ends and the third at the center of the lake. Within each transect, ten sample units were made, with a distance of 20 m between them. In each sample unit, 50 cm X 50 cm, two samples of cladocerans were collected, a quantitative sample and a qualitative sample.The quantitative samples were taken with the aid of bucket and filtered through a 100 µm mesh zooplankton conical net, 100 L of water in total was filtered to sample the macrophytes. For qualitative samples, macrophytes were collected inside the sample unit with the D grid, also with 100 µm mesh. The macrophytes and collected water were poured into a polyethylene container, where the macrophytes were washed and returned. The resulting water was also filtered through the 100 µm conical zooplankton mesh.

All samples were labeled and stored in 100 mL bottles. The collected micro-crustaceans were anesthetized with carbonated water (25 mL) and subsequently fixed in alcohol (final concentration at 70%), according to the methodology of Pinto-Coelho (2004). Analyses of the samples of phytophilous cladocerans were set at the Limnology Laboratory of the Federal University of Acre - UFAC, with the aid of an optical microscope. Due to the low number of organisms found in the pilot collection, the samples were analyzed in their entirety. The identification keys of Smirnov (1971), Smirnov (1976), Korovchinsky (1992) and Orlova-Bienkowskaja (2001) were used.

A multiparameter probe (model Akron AK87) estimated the temperature, pH, dissolved oxygen and electrical conductivity, while turbidity was determined with an Instrutherm turbidimeter and depth and transparency were measured using a Secchi disk. These measurements were carried out close to the macrophyte beds of the transect to be collected in at a standardized time, totaling nine collections of physical-chemical parameters. In addition, we checked the macrophyte species composition to provide an improved differentiate of the lakes.

The importance of limnological variables for cladoceran community occurrence and abundance was quantified through a Redundancy Analysis (RDA), preceded by standardization (Legendre & Legendre 2012). Limnological variables were standardized (method: standardization) with mean = 0 and standard deviation = 1. The abundance data were also transformed by Hellinger (Legendre & Gallagher 2001) before the analysis, as this procedure produces precise estimates of the percentage of variation explained by the predictor variables (Peres-Neto et al. 2006), reproducing a species matrix (Hellinger) as a function of abiotic variables. The significance of the influence was obtained from 999 permutations, defining the significance for the axes together (Legendre & Legendre 2012). To determine whether the variables were significantly correlated with each other, Pearson's correlation was performed. If there was a correlation between them, one of the correlated variables would be discarded.

The frequency of occurrence and the Dajoz Index (Dajoz 1973) was used to classify the cladocerans species as accidental (occurrence below 25%), accessory (occurrence between 25 to 50%) and constant (occurrence in more than 50% of the samples), calculated from the formula c = p x 100/P, where p is the number of samples containing the species and P is the total number of samples. For the analysis of diversity of phytophilous cladocerans, we used the Shannon-Wiener index, whose formula is where pi is the relative abundance of each species and Inpi is the Neperian logarithm of relative abundance.

The analysis were performed with the aid of the Vegan (Oksanen et al. 2013) and Psych (Revelle 2020) packages in the RStudio software (R Core Team, 2020), considering the 5% significance level.

Results

Regarding macrophytes, the three lakes showed dominance of different species, despite having the common characteristic of the abundance of macrophytes. At Buião Lake, which had well-established beds all through its surface, in addition to some loose beds, the species *Oxycaryum cubense* (Poepp. & Kunth) Palla and *Salvinia minima* Baker predominated. In Mascote Lake, the predominant species were *S. minima* and *Ricciocarpus natans* (L.) Corda, which are pioneer species in the colonization of macrophytes beds; moreover, the beds were small and always on the margins of the lake. Finally, at São João Lake there was no longer any surface water free of macrophytes. The dominant species were *Pistia stratiotes* L and *Utricularia gibba* L. The water lettuce (*P. stratiotes*) organisms almost completely cover the water surface, and the few vacant spaces are filled by *U. gibba* individuals, who intertwine among the roots of water lettuce, forming a continuous network, making navigation within the lake difficult, which shows an advanced stage of colonization of macrophytes in the lake.

Besides the difference in the composition of the species of macrophytes in the lakes, their dissimilarity in limnological variables was also notable (see Table 1). Buião Lake is the deepest ($\bar{X}$ = 1.65 m deep in the vicinity of the macrophyte beds), the least turbid and with the largest transparency ($\bar{X}$ = 7.08 UNT and 55 cm, respectively) and the most alkaline, evidenced by means of DO and pH ($\bar{X}$DO = 9.93 and $\bar{X}$pH = 7.28, respectively). Mascote Lake is shallower ($\bar{X}$ = 0.58 m) and most acidic, with an average of 26.3ºC, 4.63 DO mg L^{-1}, 66.3 µS cm^{-1} of electrical conductivity and a pH of 6.75. São João Lake also showed a tendency toward acidity, despite presenting the lowest average temperature ($\bar{X}$ = 24.2ºC), which can be explained by the total vegetation cover of the lake.

During the investigation we found 2,529 individuals of cladocerans among the macrophytes, among them were 20 species, 16 genera and six families (Chydoridae, Daphnidae, Ilyocryptidae, Macrothricidae, Moinidae and Sididae). The Chydoridae family was the most represented in variety (12 species) and abundance (1,641 individuals). The species *Ephemeroporus hybridus* Daday, 1905 was the most abundant species, with 1,109 individuals, while the most frequent species was *Oxyurella ciliata* Bergamin, 1939, which occurred in 44 of the 90 sample units. Among all the registered species, only four of them (*Alonella dadayi, Diaphanosoma spinulosum, Ovalona glabra* and *Simocephalus latirostris*) had previous records for the state of Acre, thus 15 new records were established for the state (Table 2).

The Macrothricidae family was the second most representative, with three species, followed by the Sididae family, with two species. The families Daphnidae, Ilyocryptidae and Moinidae registered only one species and that was in the Buião Lake. In addition to *D. spinulosum*, two other taxa occurred strictly in one lake. The species *Leydigiopsis*

Table 1. Limnological variables measured in the lakes. T1 (Transect one); T2 (Transect two); T3 (Transect three); Dep (Depth); Tran (Transparency); Temp (Temperature); DO (Dissolved oxygen); EC (Electrical conductivity); Turb (Turbidity).

Lakes	Depth (m)	Tran (m)	Temp (°C)	DO (mg L^{-1})	EC (µS cm^{-1})	pH	Turb (UNT)
Buião T1	1.20	0.60	25.8	13.6	133.1	7.3	6.67
Buião T2	1.97	0.45	25.3	6.7	137.8	7.3	6.28
Buião T3	1.80	0.60	25.3	9.5	137.1	7.3	8.29
Mascote T1	0.55	0.15	27.6	6.0	104.8	6.7	13.03
Mascote T2	0.45	0.15	25.6	2.3	48.3	6.8	17.00
Mascote T3	0.75	0.45	25.6	5.6	45.7	6.8	16.04
São João T1	0.50	0.30	24.1	5.8	139.7	6.7	19.31
São João T2	1.50	0.50	24.1	1.2	132.8	6.8	17.55
São João T3	0.15	0.15	24.3	7.3	146.8	6.8	16.55

Table 2. Taxon registered in each studied oxbow lakes with their abundance and species richness. Species with (*) are new records for the Acre state

Taxon	Lakes		
	Buião	Mascote	São João
Chydoridae			
**Acroperus tupinamba* Sinev & Elmoor-Loureiro, 2010	16	82	4
Alonella dadayi Birge, 1910	2	12	1
**Anthalona verrucosa* (Sars, 1901)	6	33	4
**Chydorus eurynotus* Sars, 1901		43	3
**Chydorus pubescens* Sars, 1901	1	3	
**Coronatella cf. monacantha* (Sars, 1901)	3	10	
**Ephemeroporus hybridus*(Sars,1901)		1106	3
Kurzia polyspina Hudec, 2000	44	9	
**Leydigiopsis curvirostris* Sars, 1901		6	
**Leydigiopsis ornata* Daday, 1905	14	61	22
Ovalona glabra (Sars, 1901)		32	
**Oxyurella ciliata* Bergamin, 1939	48	69	4
Daphnidae			
Simocephalus latirostris Stingelin,1906	7	26	
Ilyocryptidae			
Ilyocryptus spinifer Herrick, 1882	16	176	1
Macrothricidae			
**Macrothrix elegans* Sars, 1901		5	5
**Macrothrix paulensis* (Sars, 1900)		15	4
**Streblocerus pigmaeus Sars, 1901*	2	53	14
Moinidae			
**Moina micrura* Kurz, 1874		9	7
Sididae			
**Diaphanosoma birgei* Korineck, 1981	32	510	5
Diaphanosoma spinulosum Herbst, 1967	1		
Total	192	2260	77

curvirostris and *O. glabra* occurred exclusively in Mascote Lake. São João Lake did not present an exclusive record.

Analyzing the rates of occurrence according to the Dajoz Index (Table 3), it is evident that Mascote Lake showed a higher frequency of occurrence in general. In this lake, four species were classified as accessory and four as constant, compared to three accessory and one constant in Buião Lake and only one constant in São João Lake, which did not present accessory species.

As for the influence of limnological variables, it was found that those that did not show correlation were conductivity, dissolved oxygen, temperature and turbidity. The variation in the community composition was significant ($p = 0.024$; $R^2 = 0.32$). The RDA ordered the collection sites according to the environmental variables, which allowed us to verify how the variables were related to the species composition (Figure 2), according to the direction of the axis.

The RDA results showed that approximately 66% of this observed variation can be explained by the environmental variables selected for the model. The first axis showed that 30.34% of the variation in total abundance is related to electrical conductivity, dissolved oxygen and turbidity, while the second axis indicates that temperature explains 20.41% of the variation in total species abundance.

The Buião lake transects have the largest amplitude of dissolved oxygen than the other lakes. The turbidity variable showed the largest amplitude in the São João lake transects. The species *Leydigiopsis ornata* presented a relationship with the electrical conductivity variable. The species *Oxyurella ciliata* and *Kurzia polyspina*, however, were related to dissolved oxygen. All species of the Macrothricidae family showed correlation with turbidity.

The Shannon-Wiener index pointed to a diversity of 1.89 for phytophilous cladocerans.

Discussion

The limnological variables of the lakes were within the average fluctuation described by Salimon et al. (2013) for the Purus basin. Despite the strong differences between the lentic environment of the lake and the lotic of the river, the averages found were very similar to that described for the dry season. Ríos-Villamizar et al. (2011) corroborates by adding data for the lakes, where the physical-chemical characteristics were compatible with those found, except for the average transparency (120 cm).

The abundance of phytophilous cladocerans was much larger in Mascote Lake than in the other two lakes. Therefore, it is deducible that this community prefers shallow, turbid waters with a tendency to acidity. When addressing the phytophilous zooplankton of the Paraná River, Chaparro et al. (2016) also found a tendency toward larger abundance in the community when the waters were warmer and with low electrical

Table 3. Absolute frequency and frequency of occurrence (F.O.) of species of cladocerans per lake. The frequencies of occurrence were classified according to the Dajoz Occurrence Index as accidental (until 25% occurrence, in white), accessory (from 25 to 50% occurrence, in light gray) and constant (more than 50% occurrence, in dark gray).

Family	Species	Buião	F.O.	Mascote	F.O.	São João	F.O.	Total
Chydoridae	**Acroperus tupinamba*	7	23.3	6	20	3	10	16
	Alonella dadayi	1	3.3	8	26.6	1	3.3	10
	**Anthalona verrucosa*	5	16.6	7	23.3	4	13.3	16
	**Chydorus eurynotus*	0	0	10	33.3	2	6.6	12
	**Chydorus pubescens*	1	3.3	3	10	0	0	4
	**Coronatella cf. monocantha*	3	10	5	16.6	0	0	8
	**Ephemeroporus hybridus*	0	0	20	66.6	2	6.6	22
	**Kurzia polyspina*	11	36.6	4	13.3	0	0	15
	**Leydigiopsis curvirostris*	0	0	4	13.3	0	0	4
	**Leydigiopsis ornata*	9	30	16	53.3	18	60	43
	Ovalona glabra	0	0	7	23.3	0	0	7
	**Oxyurella ciliata*	19	63.3	21	70	4	13.3	44
Daphnidae	*Simocephalus latirostris*	7	23.3	9	30	0	0	16
Ilyocryptidae	**Ilyocryptus spinifer*	5	16.6	19	63.3	1	3.3	25
Macrothricidae	**Macrothrix elegans*	0	0	2	6.6	3	10	5
	**Macrothrix paulensis*	0	0	8	26.6	1	3.3	9
	**Streblocerus pigmaeus*	2	6.6	9	30	5	16.6	16
Moinidae	**Moina micrura*	7	23.3	0	0	3	10	10
Sididae	**Diaphanosoma birgei*	13	43.3	24	80	3	10	40
	Diaphanosoma spinulosum	1	3.3	0	0	0	0	1

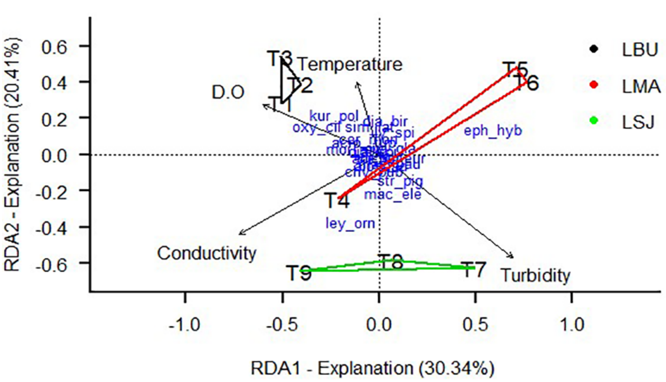

Figure 2. Biplot of the RDA showing the collection sites (LBU corresponding to Buião Lake, LMA corresponding to Mascote Lake, LSJ corresponding to São João Lake) and the relationship of the variables with the species.

conductivity, characteristics that tend to be similar to those found in Mascote Lake. Although the Buião Lake had a higher correlation with temperature by the RDA, the lake with the highest average temperature was Mascote (Buião $\overline{X}$= 25.5ºC; Mascote $\overline{X}$= 26.3ºC). Choedchim et al. (2017), when working on a lake, noticed that the shallower regions concentrated a larger abundance of phytophilous cladocerans, which were also the most acidic waters, thus corroborating with our theory.

Melão (1999) pointed to temperature as one of the two main factors for the development and reproduction of cladocerans (food being the second factor). According to the author, waters with higher temperatures positively influence the metabolism of cladocerans. These data describe an environment more similar to that found at Mascote Lake. Another factor that may also justify the predilection of cladocerans in this lake is the low biomass produced by the most common macrophyte species in the lake (*S. minima* and *R. natans*), which relates less with the reduction of oxygen levels by decomposition (Bianchini Jr. et al. 2008), since oxygenation is also an important factor for the greater abundance of phytophilous cladocerans (Takeda et al. 2003).

The RDA showed a preference of the Sididae, as well as the species *Simocephalus latirostris*, for higher temperatures. This trend had already been described by Zhao et al. (2020). Macrothricidae, however, seem to have a correlation with low levels of turbidity, which can complement the data of Guntzel et al. (2002), who found individuals of this family in abundance in high transparency lakes. The species *Moina minuta*, on the other hand, appears to have a correlation with lower levels of dissolved oxygen (DO), since it appeared at the base of the arrow of this variable in the RDA.

The Chydoridae family, being the largest in number of species in the study, did not present a common pattern of distribution. *Kurzia polyspina* and *Oxyurella ciliata* showed positive correlation with DO; in contrast, the species *Acroperus tupinamba* and *Coronatella* cf. *monacantha* was correlated with lower DO rates. Similarly, the species *Leydigiopsis ornata* showed a correlation with higher rates of electrical conductivity, in contrast to the species *Chydorus pubescens*, which demonstrated to prefer areas with low electrical conductivity.

The low number of species previously registered for the state of Acre corroborates the idea that the species composition differs largely from the limnetic zone to the littoral zone, even more if the collection in the latter is carried out among the aquatic vegetation, although the majority of the species found are not considered constant by the Dajoz

Index. Furthermore, even if the other studies in the state have all been carried out in the limnetic zone, the sampling effort for cladocerans is still considerably low, since in a space of 26 years, only 11 studies on zooplankton (including cladocerans) have been published.

Despite being considered a benthic species, *Ilyocryptus spinifer* Herick, 1882 was a constant species in Mascote Lake. This probably happened because it is the shallowest of the three lakes with an average depth of 0.58 m in the transects. Another factor that may have contributed to the incidence of this species in the study is the abundance of the large grass *Panicum aquaticum* Poir., which was sometimes fixed or very close to being fixed to the substrate, which may have contributed to this high constancy. The same can be considered for the registration of species of the genus *Chydorus*, which are also considered benthic.

The Chydoridae, Macrothricidae and the species *Simocephalus latirostris* Stingelin, 1906 frequently appear in association with macrophytes (e.g., Guntzel et al. 2010 and Sousa et al. 2013) and are referred to as typically limnetic. However, in our study they were mostly found at an accessory frequency (except for *Ephemeroporus hybridus* and *Leydigiopsis ornata*). It is likely that these cladocerans were in the process of colonizing the macrophytes of the sampled lakes.

The species *Diaphanosoma birgei* Korineck, 1981 appeared as an accessory in Buião Lake and as a constant in Mascote Lake. This species is considered common (Santos-Wisniewski et al. 2011, Maia-Barbosa et al. 2014) and appears frequently among phytophilous cladocerans records (Sipaúba-Tavares & Dias 2014, Souza et al. 2017), possibly because of foraging among the macrophytes, since it is considered limnetic.

Although 14 of the 20 species are new records for the state of Acre, all of them have previous records for the Amazon. Santos et al. (2014) reports the occurrence of three species on the list for the Madeira River basin, in Rondônia. These are *Chydorus pubescens*, *D. birgei* and *I. spinifer*. More recently, Souza et al. (2019) included the species *Anthalona verrucosa*, *Chydorus eurynotus* and *Macrothrix elegans* among the records for the Madeira basin. Thus, the records of these species closest to the state of Acre were more than 700 km away.

For the other species considered new records, the closest records are from the state of Amazonas. Rocha et al. (2017) recorded the species *Oxyurella ciliata* and *L. ornata* in the Amazon river Basin, more than 1,200 km from the points collected in this study. The other taxa were previously registered in the Negro River basin, with Brandorff et al. (1982) those responsible for the registration of *Macrothrix paulensis*, Ghidini & Santos-Silva (2011) those responsible for the registration of *Streblocerus pigmaeus*, Ghidini et al. (2017) those responsible for the registration of *Acroperus tupinamba*, and finally Carvalho-Pereira et al. (2015) confirmed the presence of *Coronatella monacantha, E. hybridus, Kurzia polyspina, Leydigiopsis curvirostris* and *Moina micrura* in this basin.

The Shannon-Wiener Index pointed to an intermediate diversity (1.89), being higher than that found by Neves (2003), which was a diversity of 1.62. It was also shown to be higher than what was found by Zanatta et al. (2010), who found rates below 1.85. However, it is still lower than most values registered by Guntzel et al. (2010) and Simões & Sonoda (2009). It is worth noting that the work of Zanatta et al. (2010) and Simões & Sonoda (2009) are related to samplings in the limnetic zone. A possible explanation for this number is the advanced stage of colonization of the macrophytes of São João Lake, which had inferior richness and abundance than the other lakes. Lakes with an advanced stage of ecological succession of macrophytes, to the point that they completely cover the water surface, hinder local oxygenation, which contributes to the low local diversity of cladocerans (Coutinho et al. 2017, Takeda et al. 2003).

In summary, the lakes vary in their physical-chemical characteristics and in the dominance of macrophyte species, which is sufficient to cause large differences in the abundance and composition of phytophilous cladoceran species, corroborating the idea of an environmental heterogeneity from one lake to the other. The RDA showed a preference of the Macrothricidae family for points of largest turbidity. The value found by the Shannon-Wiener diversity index is similar to that found in Brazilian vegetated aquatic environments, but below the value we had theorized. Finally, the maintenance of the preservation of the lakes in Chandless State Park is indicated in this study, so the largest diversity can be protected.

Acknowledgments

The authors are grateful for the assistance of the Federal University of Acre for the materials provided and SEMA for the logistical and financial support, for this study to take place in the Chandless State Park. The first author also thanks the CNPq grant given during his master's period.

Author Contrubutions

Guilherme Sampaio Cabral: Contribution in the concept of the study; data collection; data analysis and interpretation; manuscript preparation; contribution to critical revision, adding intellectual content.

Ronaldo Souza da Silva: Contribution in data analysis and interpretation; manuscript preparation; contribution to critical revision, adding intellectual content.

Ronnilda Maria Gonçalves Araujo: Contribution in data analysis and interpretation; manuscript preparation; contribution to critical revision, adding intellectual content.

André Ricardo Ghidini: Contribution in the concept of the study; data collection; data analysis and interpretation; manuscript preparation; contribution to critical revision, adding intellectual content.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

References

1. Acre. 2010. Governo do Estado do Acre. Zoneamento Ecológico-Econômico do Estado do Acre, Fase II – Escala 1:250.000: Documento Síntese. Rio Branco: SEMA.
2. Acre. 2012. Plano estadual de recursos hídricos do Acre. Rio Branco: SEMA, Rio Branco.
3. Bianchini Jr, I., Cunha-Santino, M.B. & Peret, A.M. 2008. Oxygen demand during mineralization of aquatic macrophytes from an oxbow lake. Braz. J. Biol., 68(1):61-67.
4. Bolduc, P., Bertolo, A., Hudon, C., Pinel-Alloul, B., 2020. Submerged aquatic vegetation cover and complexity drive crustacean zooplankton community structure in a large fluvial lake: An in situ approach. J. Great Lakes Res., 46:767-779.
5. Brandorff, G.O., Koste, W. & Smirnov, N.N. 1982. The composition and structure of rotiferan and crustacean communities of the lower Rio Nhamundá, Amazonas, Brazil. Stud Neotrop Fauna E, 17:69-121.

6. Carvalho-Pereira, T.S.A., Santos, T.S., Pestana, E.M.S., Souza, F.N., Lage, V.M.G.B., Nunesmaia, B.J.B., Sena, P.T.S., Mariano-Neto, E. & Da Silva, E.M. 2015. Natural humic substances effects on the life history traits of Latonopsis australis Sars (1888) (Cladocera-Crustacea). Chemosphere, 120:165-170.
7. Chaparro, G., Fontanarrosa, M.S. & O'Farrel, I. 2016. Colonization and succession of zooplankton after a droght: Influence of hydrology and free-floating plant dynamics in a floodplain lake. Wetlands, 36:85-100.
8. Choedchim, W., Van Damme, K. & Maiphae, S. 2017. Spatial and temporal variation of of Cladocera in a tropical shallow lake. Ann. Limnol. – I. J. Lim., 53:233-252.
9. Correa, S.B. & Winemiller, K.O. 2014. Niche partitioning among frugivorous fishes in response to flutuacting resources in the Amazonian floodplain forest. Ecology, 95(1):210-224.
10. Coutinho, B.A., Pott, V.J., Arrua, B.A., Aoki, C., & Pott, A. 2017. Ecological succession of aquatic macrophytes on floating meadows in the Pantanal wetland. Braz. J. Bot., 41(1): 65–75.
11. Dajoz, R. 1973. Ecologia geral. 3º ed. Petrópolis: Vozes. 471 p.
12. Dibble, E.D. & Thomaz, S.M. 2006. A simple method to estimate spatial complexity in aquatic plants. Braz. Arch. Biol. Technol., 49:421– 428.
13. Elmoor-Loureiro, L.M.A. 2000. Brazilian cladoceran studies: where do we stand? Nauplius, 8(1):117-131.
14. Esteves, F.A. 1998. Fundamentos de Limnologia. 2º Ed. Rio de Janeiro: Interciência. 602 p.
15. Forró, L., Korovichinsky, N.M., Kotov, A.A. & Petrusek, A. 2008. Global diversity of cladocerans (Cladocera; Crustacea) in freshwater. Hydrobiologia, 595:177-184.
16. Fryer, G. 1995. Phenology and adaptive radiation within the Anomopoda: a preliminary exploration. In: Cladocera as Model Organisms in Biology. Developments in Hydrobiology. [s.l.] Springer, Dordrecht, p. 57–68.
17. Ghidini, A.R., Calixto, L.S.F. & Bandeira, M.G.S. 2017. Riqueza e composição de cladóceros (Crustacea: Ctenopoda e Anemopoda) associados à Eichhornia azurea na área do complexo do lago Catalão, Amazonas, Brasil. Ens. Ciênc. Ciênc. Biol. Agrár. Saúde, 21(1):8-14.
18. Ghidini, A.R. & Santos-Silva, E.N. 2011. Ocorrência de cladóceros (Crustacea: Anomopoda) associados à esponjas (Porifera: Demospongiae: Metaniidae) no lago Tupé, AM, Brasil. In: Santos-Silva, E.N., Scudeller, V.V. & Cavalcanti, M.J. Biotupé: meio físico, diversidade biológica e sociocultural no baixo rio Negro, Amazônia Central. Vol 3, Rizoma Editorial, Manaus, p. 235-240.
19. Guntzel, A.M., Panarelli, E.A., da Silva, W.M. & Roche, K.F. 2010. Influence of connectivity on Cladocera diversity in oxbow lakes in the Taquari River floodplain (MS, Brazil). Acta Limnol. Bras., 22:93-101.
20. Guntzel, A.M., Rocha, O., Santos-Whisniewski, M.J. & Matsumura-Tundisi, T. 2002. Diversity of littoral Cladocera (Macrothricidae and Ilyocryptidae) from Brazilian lakes and reservoirs, with some remarks on the life cycles of Macrothrix flabelligera, Smirnov, 1992. Verh. lnternat. Verein. Limnol., 28(2):1070-1075.
21. Junk, W.J., Piedade, M.T.F., Lourival, R., Wittmann, F., Kandus, P., Lacerda, L.D. & Schöngart, J. 2014. Brazilian wetlands: their definition, delineation, and classification for research, sustainable management, and protection. Aquatic Conserv: Mar Freshw Ecosyst, 24:5-22.
22. Keppeler, E.C. & Hardy, E.R. 2002. Estimativa do tamanho das fêmeas com ovos de Moina minuta Hansen, 1899 (Cladocera, Crustacea) no lago Amapá, Rio Branco, Estado do Acre, Brasil. Acta Sci- Biol. Sci, 24:321-328.
23. Keppeler, E.C. 2003A. Abundance of zooplankton for different zones (pelagic and littoral) and time periods (morning and night) in two Amazonian meandering lakes. Acta Sci- Biol. Sci, 25:287-297.
24. Keppeler, E.C. 2003B. Comparative study of the zooplankton composition of two lacustrine ecosystems in Southwestern Amazonia. Acta Sci- Biol. Sci, 25:467-477.
25. Keppeler, E.C. & Hardy, E.R. 2004.Vertical distribution of zooplankton in the water column of Lago Amapá, Rio Branco, Acre, Brasil. Rev. Bras. Zool., 21:169-177.
26. Korovchinsky, N.M. 1992. Sididae & Holopedidae. Guides to the identification of the microinvertebrates of the continental waters of the world 3. SPB Academic Publishing, The Hague, The Netherlands, 82 p.
27. Legendre, P. & Gallagher E.D. 2001. Ecologically meaningful transformations for ordination of species data. Oecologia, 129:271–280.
28. Legendre, P. & Legendre, L. 2012. Numerical ecology. (2ª ed. Em inglês). Amsterdam, Holanda, Elsevier.
29. Maia-Barbosa, P.M., Menendez, R.M., Pujoni, D.G.F., Brito, S.L., Aoki, A. & Barbosa, F.A.R. 2014. Zooplankton (Copepoda, Rotifera, Cladocera and Protozoa: Amoeba Testacea) from natural lakes of the middle Rio Doce basin, Minas Gerais, Brazil. Biota Neotrop., 14:1-20 https://www.biotaneotropica.org.br/v14n1/pt/fullpaper?bn00414012014+en (último acesso em 25/05/2020).
30. Mielke, O.H.H., Carneiro, E. & Casagrande, M.M. 2010. Lepidopterofauna (Papilionoidea e Hesperioidea) do Parque Estadual do Chandless e arredores, Acre, Brasil. Biota Neotrop., 10(4):285-300 https://www.biotaneotropica.org.br/v10n4/pt/fullpaper?bn03210042010+pt (último acesso em 22/03/2020).
31. Melão, M.G.G. 1999. Desenvolvimento e aspectos reprodutivos de cladóceros e copépodos de águas continentais brasileiras. In: Pompêo, M.L.M. Perspectivas da limnologia no Brasil. São Luiz (ed.), 45-57.
32. Nascimento, S.O. & Keppeler, E.C. 2017B. Zooplâncton com ênfase em rotífera no balneário canhoto (igarapé sacado de Brasília) localizado na sub-bacia hidrográfica do rio Juruá, Cruzeiro do Sul, Acre. Ver. Bras. Zoociências, 18(1):91-102.
33. Nascimento, T.S. & Keppeler, E.C. 2017A. Diversidade e riqueza de rotíferos de um lago meandrico da planície de inundação do Rio Juruá, Acre. Braz. J. Aquat. Sci. Technol., 21(1):28-36.
34. Neves, I.F., Rocha, O., Roche, K.F. & Pinto, A.A. 2003. Zooplankton community structure of two marginal lakes of the river Cuiabá (Mato Grosso, Brazil) with analysis of Rotifera and Cladocera diversity. Braz. J. Biol., 63(2):329-343.
35. Oksanen, F. J., G. Blanchet, R. Kindt, P. Legendre, P. R. Minchin, R. B. O'Hara, G. L. Simpson, P. Solymos, M. H. H. Stevens, and H. Wagner, 2013. Vegan: community ecology package. R Package Version 2.0-10.
36. Oliveira, E.A., Freitas, J.S., Keppeler, E.C., Gomes, C.G., Nascimento, A.M., Serrano, R.O.P., Medalha, J.A. & Silva, A.J.A. 2010. Zooplâncton de dois ecossistemas aquáticos rasos, em áreas de incidência do Anopheles darlingi, no noroeste do estado do Acre. Ens. Ciênc. Ciênc. Biol. Agrár. Saúde, 14(2):1-12.
37. Orlova-Bienkowskaja, M.Y. 2001. Cladocera: Anomopoda, Daphniidae: genus Simocephalus. In: Dumont, H.J.F. Guides to the identification of the microinverterbates of the continental waters of the world. Leiden: Blackhuys Publishers, 130p.
38. Peres-Neto, P. 2006. A unified strategy for estimating and controlling spatial, temporal and phylogenetic autocorrelation in ecological models. Oecol. Bras, 10:105-119.
39. Pinto-Coelho, R. M., 2004. Métodos de coleta, preservação, contagem e determinação de biomassa em zooplâncton de águas epicontinentais. In: Bicudo, C.E.M. & Bicudo, D.C. Amostragem em limnologia. Eds. São Carlos: Rima. 351p.
40. Pompêo, M. 2008. Monitoramento e manejo de macrófitas aquáticas. Oecol. Bras., 12(3):406-424.
41. R Development Core Team, 2020. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna.
42. Revelle, W. 2020. Psych: Procedures for Psychological, Psychometric, and Personality Research. Northwestern University, Evanston, Illinois. R package version 2.0.9.
43. Ríos-Villamizar, E.A., Martins Junior, A.F. & Waichman, A.V. 2011. Caracterização físico-química das águas e desmatamento na bacia do rio Purus, Amazônia Brasileira Ocidental. Rev. Geogr. Acad., 5(2):64-75.
44. Rocha, O., Santos-Wisniewski, M.J. & Matsumura-Tundisi, T. 2011. Checklist dos Cladocera de água doce do Estado de São Paulo, Brasil. Biota Neotrop., 11(1a):1-22 https://www.biotaneotropica.org.br/v11n1a/pt/fullpaper?bn0271101a2011+pt (último acesso em 15/04/2020).
45. Rocha, M.P., Heino, J., Velho, L.F.M., Lansac-Tôha, F.M. & Lansac-Tôha, F.A. 2017. Fine spatial grain, large spatial extent and biogeography of macrophyte-associated cladoceran communities across Neotropical floodplains. Freshw. Biol., 62:559-569.
46. Salimon, C., Sousa, E.D.S., Alin, S.R., Krusche, A.V. & Ballester, M.V. 2013. Seasonal variation in dissolved carbon concentrations and fluxes in the upper Purus River, southwestern Amazon. Biogeochesmitry, 114:245-254.
47. Santos, M.J.A., Keppeler, E.C., Vieira, L.J.S., Serra, A.J. & Ferraudo, A.S. 2013. Zooplankton composition in five oxbow lakes from the Upper Juruá River, Acre State, Brazil. Ver. Peru. Biol., 20:137-144.

48. Santos, R.M., Negreiros, N.F. & Silva, L.C. 2014. Composição e biomassa da comunidade zooplanctônica no Canal Cuniã, Bacia do rio Madeira, Amazônia. Periódico Eletrônico Fórum Ambiental da Alta Paulista, 10(3):188-201.

49. Santos-Wisniewski, M.J., Matsumura-Tundisi, T., Negreiros, N.F., Silva, L.C.S., Santos, R.M. & Rocha, O. 2011. O estado atual do conhecimento da diversidade de Cladocera (Crustacea, Branchiopoda) nas águas doces do estado de Minas Gerais. Biota Neotrop., 11(3):287-301 https://www.biotaneotropica.org.br/v11n3/pt/fullpaper?bn01511032011+pt (último acesso em 18/04/2020).

50. Sendacz, S. & Melo-Costa, S.S. 1991. Caracterização do zooplâncton do Rio Acre e lagos Lua Nova, Novo Andirá e Amapá (Amazônia, Brasil). Ver. Bras. Biol., 51:455-462.

51. Silva, E.S., Keppeler, E.C. & Silverio, J.F. 2012. Composição do zooplâncton do Igarapé Jesumira, localizado numa área desmatada no Parque Nacional da Serra do Divisor, Acre, Brasil. Semina ciênc. biol. saúde, 33:201-2012.

52. Silva, E.S., Keppeler, E.C. & Silvério, J.F. 2014. Composition of zooplankton at the small rivers Pedernal and Anil, Serra do Divisor National Park, Acre, Brazil. Ver. Saúde Biol., 9:86-94.

53. Smirnov, N.N. 1971. Chydoridae of the world fauna. Fauna SSSR. Rakoobraznie. Vol.1. Nº 2. 531 p.

54. Smirnov, N.N. 1976. Macrothricidae and Moinidae of the World fauna. Fauna SSSR, novaya seriya. Rakoobraznye, 1(3). 237 p.

55. Simões, N.R. & Sonoda, S.L. 2009. Estrutura da assembleia de microcrustáceos (Cladocera e Copepoda) em um reservatório do semi-árido Neotropical, Barragem de Pedra, Estado da Bahia, Brasil. Acta Scien. Biol. Sci., 31:89-95.

56. Sioli, H. 1984. The Amazon and its main affluents: Hydrography, morphology of the river courses, and river types, p. 127–165. In: Sioli, H. (ed.). The Amazon: Limnology and Landscape Ecology of a Mighty Tropical River and its Basin. Dr. W. Junk Publisher, Dordrecht, The Netherlands.

57. Sipaúba-Tavares, L.H. & Dias, S.G. 2014. Water quality and communities associated with macrophytes in a shallow water-supply reservoir on an aquaculture farm. Braz. J. Biol., 74:420-428.

58. Sousa, F.D.R., Elmoor-Loureiro, L.M.A. & Mendonça-Galvão, L. 2013. Cladocerans (Crustacea, Anomopoda and Ctenopoda) from Cerrado of Central Brazil: inventory of phytophylous community in natural wetlands. Biota Neotrop., 13:222-229 https://www.biotaneotropica.org.br/v13n3/pt/fullpaper?bn00413032013+en (último acesso em 07/04/2020).

59. Souza, B.B., Arcifa, M.S., Ferreira, T.C.S., da Silva, L.H.S., Fileto, C. & Domingos, A.R. 2017. Are the littoral zone conditions suitable for tropical planktonic microcrustaceans? Ann. Limnol., 53:281-291.

60. Souza, C.A., Vieira, L.C.G., Legendre, P., Carvalho, P., Velho, L.F.M. & Beisner, B.E. 2019. Damming interacts with the flood pulse to alter zooplankton communities in na Amazonian river. Freshw. Biol., 64:1040-1063.

61. Suçuarana, M.S., Virgílio, L.R. & Vieira, L.J.S. 2016. Trophic structure of fish assemblages associated with macrophytes in lakes of an abandoned meander on the middle river Purus, Brazilian Amazon. Acta Scien. Biol. Sci., 38(1):37-46.

62. Takeda, A.M., Souza-Franco, G.M., Melo, S.M. & Monkolski, A. 2003. Invertebrados associados às macrófitas aquáticas da planície de inundação do alto rio Paraná (Brasil). In: Thomaz, S.M. & Bini, L.M. Ecologia e Manejo de Macrófitas Aquáticas. Ed. Maringá: Eduem, 243-260.

63. Ter Braak, C.J.F. & Verdonschot, P.F.M. 1995. Canonical correspondence analysis and related multivariate methods in aquatic ecology. Aquat. Sci., 57:255-289.

64. Thomaz, S.M., Bini, L.M. & Bozelli, R.L. 2007. Floods increase similarity among aquatic habitats in river-floodplain systems. Hydrobiologia, 579:1-13.

65. Zanatta, A.S., Perbiche-Neves, G., Ventura, R., Ramos, I.P. & Carvalho, E.D. 2010. Effects of a small fish cage farm on zooplankton assemblages (Cladocera and Copepoda: Crustacea) in a sub-tropical reservoir (SE Brazil). Pam-Am. J. Aquat. Sci., 5:530-539.

66. Zhao, F., Yu, H.X., Ma, C.X., Sun, X., Liu, D., Shang, L.D., Liu, J.M., Li, X.Y., Li, S., Li, X.C., Yu, T.Y., Shabani, I.E., Wang, Y.Z., Su, L.J., Zhang, L.M., Mu, Y.Y., Xiao, L., Tian, Z., Pan, C., Sun, B., Pan, H.F., Shang, G.Y.Q., Chai, F.Y. & Meng, Y. 2020. Characteristics of zooplankton functional groups and their environmental factors in the Harbin Section of the Songhua River, China. Appl. Ecol. Env. Res., 18(5):7457:7471.

Received: 06/07/2020

Revised: 19/01/2021

Accepted: 16/02/2021

Published online: 26/03/2021