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Cladocerans (Crustacea, Anomopoda and Ctenopoda) from Cerrado of Central Brazil: Inventory of phytophilous community in natural wetlands

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***Abstract**:* The aim of this study was to inventory the cladoceran fauna in wetlands located in two large areas that protect fragments of Cerrado. Located in the Brasília National Park-DF and Campo de Instrução de Formosa-GO, these wetlands are formed by upwelling groundwater, with extensive vegetation cover. We found 24 species in the Brasília National Park and 30 in the Campo de Instrução de Formosa. The observed richness reached approximately 80% of the estimated values for both protected areas. Moreover, the community of cladocerans in the kind of environment studied appears to be influenced by depth, with higher values of richness and similarity in wetlands of higher average depths. However, shallow wetlands contributed to the total richness with exclusive species, which shows the importance of these habitats for species richness.
***Keywords**: High Paraná River Basin, High São Francisco River Basin, protected areas, richness, shallow wetlands.*

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Resumo: O objetivo deste estudo foi inventariar a fauna de Cladocera em zonas úmidas localizadas em duas grandes áreas que protegem fragmentos de Cerrado. Estas estão localizadas no Parque Nacional de Brasília, DF, e Campo de Instrução de Formosa, Goiás, e são formadas pelo afloramento de lençol freático, com extensa cobertura vegetal. Foram encontradas 24 espécies no Parque Nacional de Brasília e 30 no Campo de Instrução de Formosa. A riqueza observada alcançou, aproximadamente, 80% dos valores estimados para ambas as áreas protegidas. Além disto, a comunidade de Cladocera no tipo de ambiente estudado parece ser influenciada pela profundidade, com maiores valores de riqueza e similaridade para áreas com maiores médias de profundidade. Contudo, as zonas úmidas mais rasas contribuíram para a riqueza total com espécies exclusivas, o que mostra a importância desses ambientes para a riqueza de espécies.
Palavras-chave: *Bacia do Alto Rio Paraná, Bacia do Alto Rio São Francisco, áreas protegidas, riqueza, zonas úmidas rasas.*

Introduction

Wetlands are ecosystems widely distributed across the planet and include habitats that range from continental coastlines to inland aquatic systems, namely ecotone areas along rivers and lakes, ponds, swamps, flooded forests, among others (Moore 2007). These environments are characterized mainly by the intrinsic relationship with terrestrial systems as well as the dependence on fluctuations in water availability.

Currently, two approaches have taken hold of the debate about wetlands. The first is related to social issues and sustains that the environmental services provided by these ecosystems – e.g. flood control, retention of large loads of nutrients and sediment, and mainly the supply of food (fish, crustaceans et cetera) – making these wetlands environments extremely vulnerable to anthropogenic activities (Clare et al. 2011). The second approach emphasizes on biodiversity, since these areas are of extreme importance, harboring large numbers of organisms of different taxonomic groups, from microscopic species, such as algae and protozoa, to invertebrates (crustaceans, insects), to vertebrates (reptiles, amphibians, birds), and many plant species. A whole host of organisms makes use of wetlands to establish populations, forage and disperse, which implies that ecological interactions in such environments are extremely complex and important (Gibbs 2000).

Wetlands appear as shallow and highly heterogeneous environments due to the diversification of habitats and ecological niches provided by macrophytes (Van Der Valk 2006). Among other factors, such as the absence of top-level predators in shallow environments (Scheffer et al. 2006), the presence of macrophytes has been recognized as one of the main community-structuring factors (Thomaz & Cunha 2010), with a bearing on the diversity patterns and spatial distribution of biota associated with aquatic vegetation (Balayla & Moss 2003, Sakuma et al. 2004).

Among the different groups of organisms that live in association with macrophytes, cladocerans have been extensively studied in various regions of the world, both from a taxonomic perspective (e.g Kotov et al. 2004, Elmoor-Loureiro et al. 2009, Sinev & Elmoor-Loureiro 2010), and in ecological studies (Hann 1995, Hann & Zrum 1997, Laurindsen et al. 1996, Blindow et al. 2000).

Although Cladocera fauna associated with macrophytes corresponds to about 70% of known species for that group (Elmoor-Loureiro 2000, Forró et al. 2008), in Brazil's wetlands data available on these microcrustaceans refer primarily to those found in the floodplains of the Paraná River and the Pantanal (e.g. Rossa et al. 2001, Lima et al. 2003, Hollwedel et al. 2003, Serafim et al. 2003, Choueri et al. 2005, Palazzo et al. 2008, Lansac-Tôha et al. 2009, Güntzel et al. 2010), which are areas covering large tracts. This evinces a major gap in the knowledge of Cladocera fauna in wetlands that are smaller, shallow (<5 m maximum depth), located in highlands, with seasonal fluctuation of the water level and broad occupation by macrophytes, such as moist grasslands, earth mounds (*murundus*) and shallow ponds. These types of environments comprise much of the aquatic ecosystems in the Cerrado (Padovesi-Fonseca 2005), in addition to potentially harboring a high diversity of species (Leibowitz 2003).

The aim of this study was to evaluate the composition and abundance of Cladocera fauna in natural wetlands, located in preserved fragments of the Cerrado in Central Brazil.

Material and Methods

1. *Area of the study*

This study was conducted in two areas that protect large fragments of Cerrado: the Brasília National Park (*PNB*), in the Federal District, and the Campo de Instrução de Formosa *(CIF)*, in Goiás (Figure 1). According to the Köppen system, these two areas are subject to a tropical savanna climate (Aw), characterized by a dry season - with lower temperatures and occurring between the months of May and September - and a rainy season - a warmer period which concentrates more than 80% of the annual rainfall, from October to April. For this biome, the average annual rainfall is 1,500 mm and average temperatures range between 18 °C and 27 °C.

The *PNB* has a total area of 42,389 hectares, the largest Full Protection Conservation Unit in the Federal District. The *PNB*'s aquatic ecosystems belong to the Upper Paraná watershed and consist mostly of small lotic systems, but also several natural wetlands formed by upwelling groundwater, commonly referred to as marshes. These palustrine environments are represented by moist grasslands, earth mounds (*murundus*) and shallow ponds. Five among these were the object of this study (Table 1) (Figure 2a-e).

The *CIF* is an area under the management of the Brazilian Army since 1972, and maintains a large fragment of Cerrado along the eastern boundary between the states of Goiás, Minas Gerais and the Federal District. A number of lotic systems and large natural wetlands outcropping from groundwater also occur inside the *CIF*, and these water bodies belong to the São Francisco River watershed. In total, four wetlands were studied in the *CIF* (Table 1) (Figure 2f-i).

The wetlands studied are classified as inland wetlands featuring a relatively stable water level (Source: National Institute of Science and Technology on Wetlands), but these wetlands are subject to fluctuations in water level between seasons. Fluctuations in water

Table 1. Geographical location, mean depth and number of samples collected in the wetlands studied in Brasília National Park (PNB) and Campo de Instrução de Formosa (CIF).

Protected Area	Wetland	Geographic Coordinates	Mean depth (m)			Number of samples	
			Dry Season	Rainy Season	Overall	Dry Season	Rainy Season
CIF	Lagoa Grande	15°49’35,70” S and 47°13’49,40” W	0.60	0.83	0.71	4	4
	Lagoa Cabocla I	15°48’15,00” S and 47°14’57,50” W	0.32	0.46	0.39	4	4
	Lagoa Cabocla II	15°48’21,00” S and 47°14’09,20” W	0.50	0.65	0.58	5	5
	Lagoa dos Veados	15°36’19,40” S and 47°16’32,70” W	-	0.31	0.31	-	3
PNB	Lagoinha Meandros	15°43’29,80” S and 47°58’08,90” W	0.06*	0.17	0.13	1	1
	Murundus	15°46’48,10” S and 47°58’42,20” W	0.05*	0.05	0.05	1	2
	Peito de Moça	15°45’05,08” S and 48°01’33,20” W	0.05	0.05	0.05	3	3
	Lagoa do Henrique	15°41’18,00” S and 47°56’26,10” W	0.58	0.73	0.66	4	4
	Lagoa do Exército	15°44’44,30” S and 47°58’49,10” W	0.19	0.33	0.26	5	5

Figure 1. Location of the Brasília National Park – DF (PNB), Campo de Instrução de Formosa – GO (CIF) and wetlands sampled.

level in some of these wetlands are related mainly to complete dryness (dry season) and overflows from the water table (rainy season).

The wetlands sampled showed high diversity of macrophytes with about 25 families recorded: Apiaceae, Asteraceae, Characeae, Cornaceae, Cyperaceae, Droseraceae, Euriocaulaceae, Fabaceae, Gentianaceae, Lamiaceae, Lentibulariaceae, Lycopodiaceae, Lythraceae Mayacaceae, Melastomataceae, Menyanthaceae, Ochnaceae, Onagraceae, Plantaginaceae, Poaceae, Polygalaceae, Rubiaceae, Sterculiaceae, Verbenaceae and Xyridaceae (unpublished data).

Characterized as pristine, the wetlands studied featured pH values between 3.89 and 7.04, electrical conductivity levels below 18.9 μS/cm^{-1}, dissolved oxygen levels between 2.7 and 7 mg/L, total nitrogen concentrations between 33.4 and 412.2 μg/L and total phosphorus concentrations between 1.0 and 120.0 μ /L.

1.1. Collection, identification and data analysis

Samplings were conducted in the dry (August-September, 2009) and rainy (December, 2009) seasons. Depth was taken for each site (Table 1). The Cladocera fauna was collected with plankton net of 80 μm mesh size dragged across the aquatic vegetation. The samples collected were anesthetized in sparkling water, and then fixed in ethanol with final proportion of 70%.

For each sample collected sub-samples of 4 mL in volume were screened under a stereomicroscope until the number of 50 individuals was reached. Then, five sub-samples were analyzed for the occurrence of species that had not yet been identified. With the addition of new species, new sub-samples were analyzed until stabilization of species richness was observed.

All individuals were counted and identified based on taxonomic references (Smirnov 1992, 1996; Elmoor-Loureiro 1997, Kotov et al. 2004, Kotov & Štifter 2006, Sinev & Elmoor-Loureiro 2010, Van Damme et al. 2010, 2011). The specimens found in this study are deposited in the collection of the Laboratory of Aquatic Biodiversity at the Catholic University of Brasilia.

Rarefactions were based on samples to compare richness between the *PNB* and *CIF*. The total richness for these two areas was obtained using the nonparametric estimator based on Jackknife1 incidence data (formula in Gotelli & Colwell 2010). The scores for the construction of species accumulation curves and estimated richness values were obtained through the EstimateS 8.2 software (Colwell 2009).

The faunal similarity between the wetlands studied was obtained using the Jaccard index. A cluster analysis based on mean depth values was also employed for each wetland to assess whether there was a clustering pattern. These analyses were performed in the PAST software (Hammer et al. 2001). In order to check whether there was a relationship between depth and Cladocera species composition the Mantel test was employed with 999 randomizations. The Jaccard dissimilarity matrices and Euclidean distance were used for the Cladocera fauna and mean depth data between seasons, respectively.

Results

Thirty-three species were found, considering all the areas analyzed. The species are distributed in five families (Sididae, Daphniidae, Ilyocryptidae, Macrothricidae and Chydoridae), and the Chydoridae had the greatest number of species (Table 2).

The comparison of species richness between the two areas studied showed greater richness in the *CIF* (Figure 3). Although there was a difference in richness, no stabilization for the rarefaction curves was

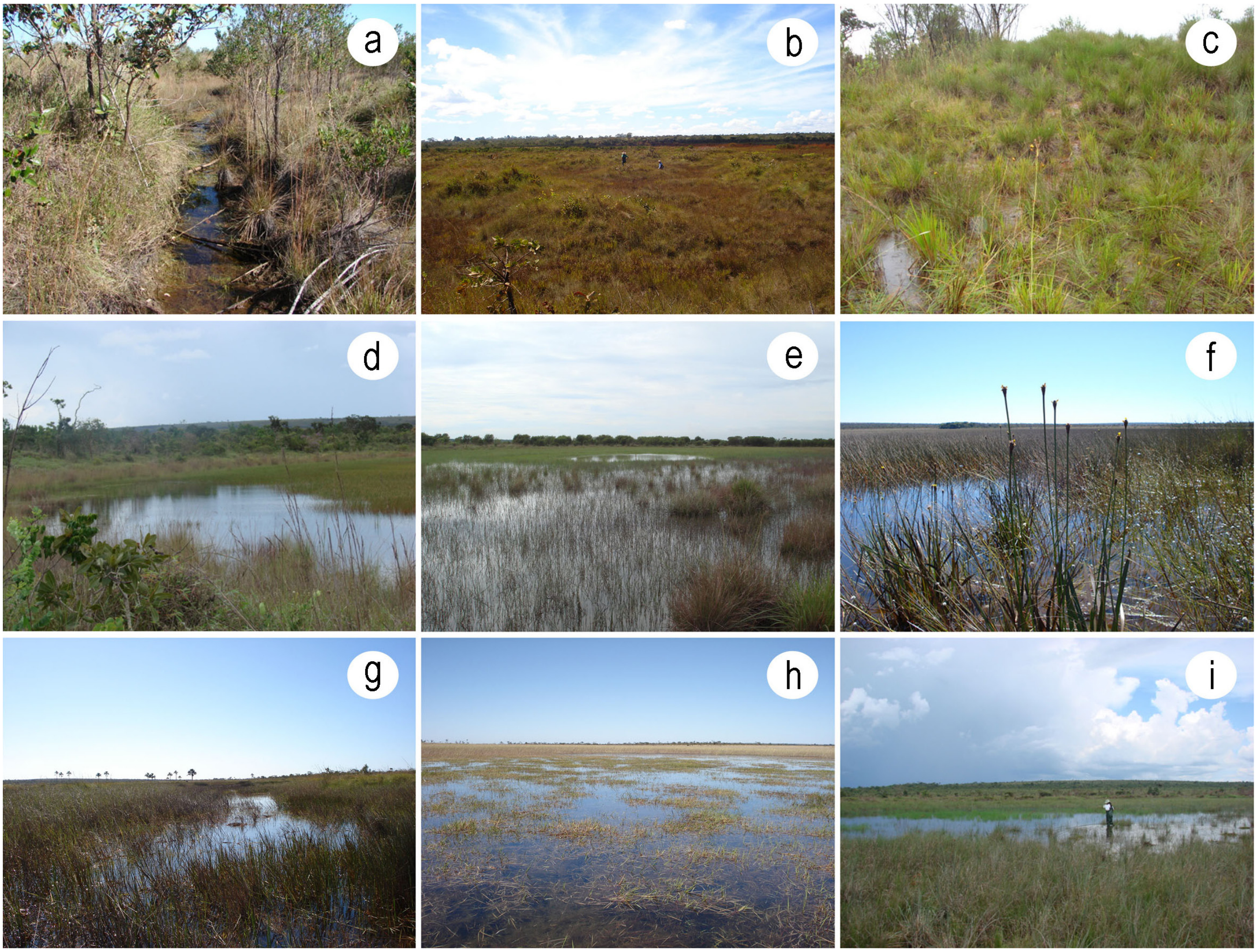

Figure 2. General aspects of the wetlands sampled in the Brasília National Park (PNB) and Campo de Instrução de Formosa (CIF). a) Lagoinha Meandros; b) Murundus; c) Peito de Moça; d) Lagoa do Henrique; e) Lagoa do Exército; f) Lagoa Grande; g) Lagoa Cabocla I; h) Lagoa Cabocla II; i) Lagoa dos Veados.

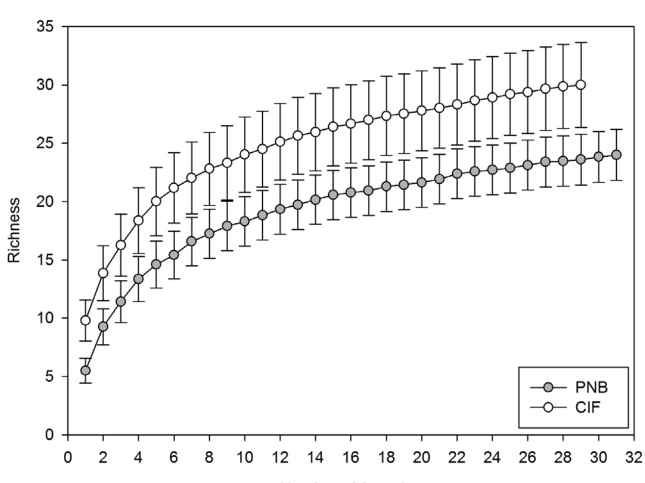

Figure 3. Rarefaction curve based on the number of samples collected for the Brasília National Park (PNB) and Campo de Instrução de Formosa (CIF).

observed in either of the areas studied, indicating there is a chance that new species may be collected with increased sampling efforts. This result is supported by the values of estimated richness, which extrapolated the richness observed in the *PNB* and *CIF* (Table 3).

Table 3. Total richness and average percentage of overestimation of species richness for Brasília National Park (PNB) and Campo de Instrução de Formosa (CIF).

Number of samples	PNB	CIF
	31	**29**
Richness observed	24	30
Estimated richness (Jackk1)	28.28 ± 2.82	36.76 ± 2.66
Overestimation of richness (%)	16.78	18.38

In the *CIF*, 30 species were identified (Figure 3), and *Lagoa Cabocla II* had the greatest number (22 species), followed by *L. Grande* (19 species), *L. Cabocla I* (14 species) and *L. dos Veados* (ten species). The greatest similarity identified by the Jaccard index was between *L. Cabocla II* and *L. Grande* (0.57), while both of these areas had little similarity with *L. dos Veados*, showing a Jaccard index value below 0.30 (Table 4).

In the *PNB*, 24 species were found, with representatives from the five families as well. The environment that proved to have the greatest number of species was *Lagoa do Henrique* (21 species), followed by *L. do Exército* (16 species), *Murundus* (eight species), *L. Meandros* (seven species) and *Peito de Moça* (six species). According to the

Table 2. Occurrence of cladoceran species in wetlands of Brasília National Park (PNB) and Campo de Instrução de Formosa (CIF). GR – Lagoa Grande; CBI – Lagoa Cabocla I; CBII – Lagoa Cabocla II; LV – Lagoa dos Veados; ME – Lagoinha Meandros; MU – Murundus; PM – Peito de Moça; HE – Lagoa do Henrique; EX – Lagoa do Exército.

Taxa	CIF				PNB				
	GR	CBI	CBII	LV	ME	MU	PM	HE	EX
Sididae Baird, 1850									
Latonopsis australis-group	x		x					x	
Daphniidae Straus, 1829									
Ceriodaphnia cornuta Sars, 1886			x	x				x	
Ceriodaphnia sp1			x						
Ceriodaphnia sp2			x						
Ilyocryptidae Smirnov, 1992									
Ilyocryptus spinifer Herrick, 1882	x	x	x	x	x		x	x	x
Macrothricidae Norman & Brady, 1867									
Macrothrix elegans Sars, 1901	x			x					
Macrothrix paulensis (Sars, 1900)	x	x	x					x	x
Streblocerus pygmaeus Sars, 1901	x		x			x			x
Chydoridae Stebbing, 1902									
Acroperus tupinamba Sinev & Elmoor-Loureiro, 2010		x					x		
Alona dentifera (Sars, 1901)			x					x	
Alona glabra Sars, 1901			x						
Alona setigera Brehm, 1931		x	x			x	x	x	x
Alona iheringula Sars, 1901	x	x	x		x	x	x	x	x
Alona intermedia Sars, 1862	x		x					x	x
Alona ossiani Sinev, 1998	x	x	x		x	x	x	x	x
Alona sp.							x		
Alonella clathratula Sars, 1896	x	x	x		x	x		x	x
Alonella dadayi Birge, 1910	x	x	x		x	x		x	x
Anthalona verrucosa (Sars, 1901)	x	x	x		x			x	x
Celsinotum candango Sinev & Elmoor-Loureiro, 2010								x	x
Chydorus dentifer Daday, 1905	x								
Chydorus eurynotus Sars, 1901	x	x	x	x				x	x
Chydorus pubescens Sars, 1901	x	x	x	x				x	
Disparalona leptorhyncha Smirnov, 1996	x								
Dunnhevedia odontoplax (Sars, 1901)		x		x					
Ephemeroporus barroisi (Richard, 1984)	x	x	x	x	x	x		x	x
Ephemeroporus tridentatus (Bergamin, 1931)				x					
Ephemeroporus sp.	x		x					x	x
Euryalona orientalis (Daday, 1898)				x					
Graptoleberis occidentalis (Sars, 1901)	x	x	x					x	x
Karualona muelleri (Richard, 1897)	x			x		x		x	x
Leydigiopsis curvirostris Sars, 1901			x					x	
Notoalona sculpta (Sars, 1901)								x	
Total	19	14	22	10	7	8	6	21	16

Jaccard index, the faunal composition in the PNB wetlands had the greatest similarity between *L. Henrique* and *L. do Exército* (0.68), with low similarity between these and the others (Table 4).

A comparison of the faunal composition between all the wetlands studied showed greater similarity between the *L. do Henrique*, *L. Grande*, *L. Cabocla II* and *L. do Exército*, with similarity values above 0.50 (Table 4). The other areas studied also showed low overlap in faunal composition among each other, as well as the areas mentioned above. The evaluation of the relationship between the depth showed that *L. do Henrique*, *L. Grande* and *L. Cabocla II* fell under the same group because of their higher mean depths (Figure 4). The Mantel test showed no relationship between mean depth and the composition of Cladocera fauna (R = 0.235, p = 0.07).

Table 4. Faunal similarity based on Jaccard index for wetlands of the Brasília National Park and Campo de Instrução de Formosa. GR – Lagoa Grande; CBI – Lagoa Cabocla I; CBII – Lagoa Cabocla II; LV – Lagoa dos Veados; ME – Lagoinha Meandros; MU – Murundus; PM – Peito de Moça; HE – Lagoa do Henrique; EX – Lagoa do Exército.

	CBI	CBII	LV	ME	MU	PM	LH	LE
LG	0.50	0.57	0.26	0.36	0.35	0.13	0.60	0.66
CBI	-	0.50	0.26	0.50	0.37	0.33	0.52	0.57
CBII		-	0.18	0.31	0.30	0.16	0.72	0.58
LV			-	0.13	0.12	0.06	0.24	0.18
ME				-	0.50	0.30	0.33	0.43
UM					-	0.27	0.31	0.50
PM						-	0.17	0.22
LH							-	0.68

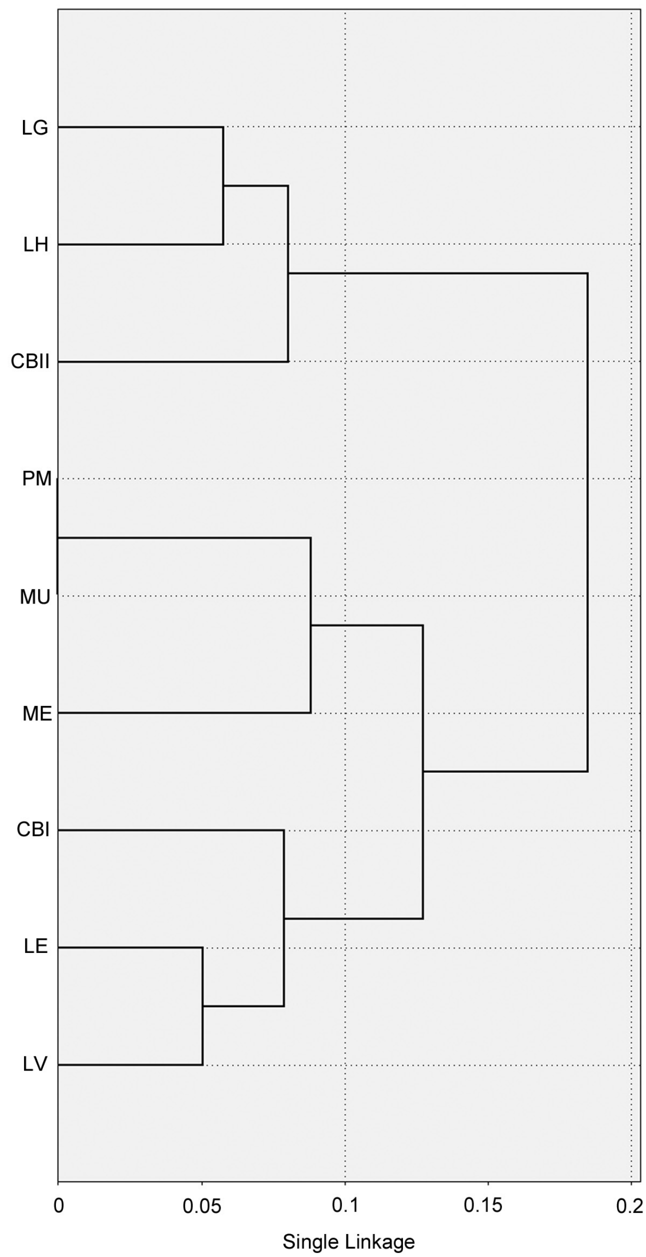

Figure 4. Cluster analysis resulting of the grouping of the wetlands studied according to mean depth. GR – Lagoa Grande; CBI – Lagoa Cabocla I; CBII – Lagoa Cabocla II; LV – Lagoa dos Veados; ME – Lagoinha Meandros; MU – Murundus; PM – Peito de Moça; HE – Lagoa do Henrique; EX – Lagoa do Exército. Cophenetic correlation = 0.829.

Discussion

The number of Cladocera species found in the wetlands studied is very similar to other studies conducted in Brazil for the littoral zone of inland water ecosystems or environments colonized by macrophytes (Santos-Wisniewski et al. 2002, Lima et al. 2003, Sousa et al. 2009, Elmoor-Loureiro 2007, Maia-Barbosa et al. 2008, Soares & Elmoor-Loureiro 2011). In all these studies, a greater contribution of the Chydoridae family was verified in the number of species, which was also observed in the wetlands sampled here, and this seems to be a pattern of faunal composition that is very common in studies of the littoral zone of water systems. Representatives of Chydoridae are highly specialized in exploiting microenvironments provided by vegetation, in addition to featuring greater diversity within the Superorder Cladocera (Forró et al. 2008).

For other families, the species composition pattern was quite similar to that found in the studies cited above, with contributions from other taxa that are typically from environments dominated by aquatic macrophytes, such as representatives of the family Macrothricidae and the species *Latonopsis australis* and *Ilyocryptus spinifer*.

Among Daphniidae, the genus *Ceriodaphnia* forms one of the major groups of plankton-filtering microcrustaceans in inland waters, and some forms of *C. cornuta* have been found mainly in large lakes and reservoirs (Alonso 1991, Dumont, 1994, Espindola et al. 2000, Eskinazi-Sant'Anna et al. 2005, Matsumura-Tundisi & Tundisi 2005). However, *C. cornuta* is also commonly found in samples collected in aquatic vegetation (Berner 1985, Elmoor-Loureiro 2007). This is a filtering species (Fryer 1991), unlike the species Chydoridae and Macrothricidae, which predominantly scrape the surface biofilm of macrophytes or are specialized sediment-food collectors (Fryer, 1968, 1974, Kotov 2006).

The occurrence of *Celsinotum candango* confirms indication that this genus has an ecological preference for shallow environments dominated by macrophytes, and that its species have a restricted geographical distribution. For example, *C. laticaudatum* is restricted to the northern Brazilian Amazon (Smirnov & Santos-Silva 1995), and on the Australian continent some species of this genus show an environment preference for shallow and saline ecosystems (Frey1991, 1993). To date, *C. candango* was recorded only in Cerrado wetlands, specifically in the *L. do Henrique* (Sinev & Elmoor-Loureiro 2010) and now also recorded in *L. do Exército*. Likewise, *Ephemeroporus* sp. also appears to inhabit exclusively this type of environment, constituting a new taxon (Elmoor-Loureiro, unplublished). Our data indicate that *C. candango* and *Ephemeroporus* sp. are species endemic to shallow wetlands found in the Cerrado, which supports the idea that such environments are important for the specific diversity of this biome. However, it is essential to expand investigations into similar systems in the Cerrado and in Brazil so as to better assess the issue of possible endemism pointed out in this study.

The findings show a trend of increasing richness and changes in the faunal composition related to the depth of wetlands, although this trend did not obtain statistical support ($R = 0.235$, $p = 0.07$). It was observed that wetlands with an average depth above 0.55 m, considered more stable in terms of water depth for not undergoing drastic reductions during the dry season - namely *L. do Henrique*, *L. Cabocla II* and *L. Grande* - showed the greatest richness, between 19 and 22 species. As for faunal composition, these three areas showed higher similarity (Table 4), which may be related to a host of environmental similarities, including depth. Although *L. do Exército* showed an average depth below 0.30 m, this wetland featured high richness (16 species) and was similar in faunal composition to *L. do Henrique*, *L. Cabocla II* and *L. Grande*, possibly as a result of other factors, such different macrophyte species.

These results show that in shallow wetlands, Cladocera species richness and composition may be related to depth and permanence of wetlands, as suggested by Eitam et al. (2004). It is quite likely that, for the types of environments studied, greater depth favors higher richness because this feature provides greater stability presenting less hydric stress. This was not the case of wetlands of reduced depth such as *Peito de Moça*, *Murundus* and *Lagoinha Meandros* in the *PNB*, as well as the case of *L. dos Veados*, which became completely dry at the height of the dry season. These environments, however, contributed with unique species such as *D. odontoplax*, which occurred exclusively in *L. Cabocla I* and *L. dos Veados*, as well as

E. tridentatus and *E. oryentalis*, which occurred in *L. dos Veados*, thus expanding total richness.

The colonization strategies of Cladocera fauna in unstable environments, such as those with drastic reduction of water depth, relate to resistance strategies (Santangelo 2009). According to Cáceres & Soluk (2002), many species of aquatic invertebrates decrease their chances of local extinction by resorting to forms of dormancy. However, there is a trade-off here, since animals that have the ability to become dormant for a long time are not good dispersers. It is likely that the species occurring exclusively in wetlands subject to droughts studied herein employ strategies such as those mentioned by Cáceres & Soluk (2002), which would also account for the restriction on their distribution across the remaining wetlands.

In conclusion, this study provides an inventory of species that inhabit moist palustrine environments in two large conserved areas of the Cerrado, as well as some ecological considerations. According to the criteria of Heck et al. (1975), the inventory for the *PNB* and *CIF* can be considered satisfactory since more than 80% of the values found by the richness estimator (Table 3) were accessed. Thus, these findings will hopefully contribute to future studies aiming to determine the biodiversity of these unique ecosystems that are widely distributed in the Cerrado.

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