Oecologia Australis
23(4):940-950, 2019
https://doi.org/10.4257/oeco.2019.2304.17

CHARACTERIZATION OF THE BIOTIC (MACROPHYTES AND MACROINVERTEBRATES) AND ABIOTIC FACTORS OF PANTANAL PONDS IN THE MIRANDA RIVER FLOODPLAIN

Emerson Machado de Carvalho[1], Nathaskia Silva Pereira[2], Mônica Ansilago[2], Ana Paula Lemke[3] & Jelly Makoto Nakagaki[3]*

[1] Universidade Federal do Sul da Bahia, Centro de Formação em Tecno-Ciências e Inovação, IHAC, Campus Jorge Amado, Rodovia Itabuna, Km 39, Ferradas, CEP 45613-204, Itabuna, BA, Brazil.

[2] Universidade Federal da Grande Dourados, Faculdade de Ciências Biológicas e Ambientais, Programa de Pós-Graduação em Ciência e Tecnologia Ambiental, Rod. Dourados-Itahum, Km 12, Cidade Universitária, CEP 79804-970, Dourados, MS, Brazil.

[3] Universidade Estadual do Mato Grosso do Sul, Centro de Pesquisa em Biodiversidade, Rod. Dourados–Itahum, Km 12, Cidade Universitária, CEP 79804-970, Dourados, MS, Brazil.

E-mails: carvalho.em@gmail.com (*corresponding author); nathaskia.spn@gmail.com; monica_ansilago@hotmail.com; anapaulalemke@yahoo.com.br; jellyuems@gmail.com

Abstract: The Pantanal has an exuberant biodiversity that is constantly regulated by the dynamics of the climate and by the flood pulses. The objective of this work was to characterize and evaluate the biotic (macrophytes and macroinvertebrates) and abiotic factors (pH, temperature, dissolved oxygen, conductivity, total dissolved solids, water turbidity, chlorophyll a and pheophytin-a) of Pantanal ponds depending on the dry or rainy season. Therefore, five ponds with different characteristics were analyzed and five samples of water were collected during the dry and rainy season. For sampling of the macrophytes and collection of the macroinvertebrates we used hand nets (area of 0,09m^2, opening of 5000 μm). This was done in order to observe seasonal difference in pH, chlorophyll-a and pheophytin-a and spatial differences between dissolved oxygen, electrical conductivity, turbidity, chlorophyll a and pheophytin-a was observed. The aquatic macrophyte *Eichornia azurea* (Commelinales, Ponteridaceae) showed high dominance and relative vegetation cover in at least three ponds, which was also related to higher values of macroinvertebrate biomass. On the other hand, the ponds that presented low dominance or absence of *E. azurea* presented high diversity of aquatic macrophytes. However, these intrinsic biological characteristics of the ponds altogether with the abiotic parameters demonstrated that there are distinct patterns in the dynamics of these ecosystems during the drought and flood regimes.

Keywords: biodiversity; environmental characterization; hydrology; Neotropical flora; wetlands.

INTRODUCTION

Considered one of the largest floodplains in Latin America, the Pantanal complex, or simply the Pantanal is placed in the center of South America, in Upper Paraguay basin, occupying Brazilian territory and a small part of the Bolivian and Paraguayan territory (Silva *et al.* 2009). Its area corresponds to about 140 thousand km^2, with 65% of its territory in the state of Mato Grosso do Sul and 35% in Mato Grosso (Pott 2004, Marengo *et al.* 2015). Pantanal is an area of great scenic beauty and a showcase for exuberant fauna and flora that are constantly regulated by the dynamics of the climate and by the flood pulses of the adjacent areas of its main rivers. About 88% of the native vegetation cover is still preserved, while about 12% has anthropic use (Marengo *et al.* 2015).

Pantanal is considered by UNESCO as a World Natural Heritage and Biosphere Reserve (Silio-Calzada *et al.* 2017) and has become an ecosystem of national and international reference due to its intrinsic characteristics that combine a mosaic of different environments that shelter a rich terrestrial and aquatic biota (MMA 2007). The region is a floodplain influenced by rivers that drain the Upper Paraguay basin, with a great diversity of fauna and flora, being influenced by four adjacent biomes: Amazonia, Cerrado, Chaco and Atlantic forest (Alho & Gonçalves 2005).

Hydrological variability over seasonal and multi-annual timescales strongly shapes the ecological structure and functioning of floodplain ecosystems (Silio-Calzada *et al.* 2017). Pantanal works as a large reservoir, storing the water of the surrounding plateaus during the rainy season and then slowly draining to the lower sections of Paraguay River (Marengo *et al.* 2015). They are key hydrological characteristics for shallow ponds and floodplain wetlands which are subject to periodic annual flooding from adjacent rivers.

Many ponds that are originated during flood periods remain during the dry season. These are shelter for a great diversity of aquatic vegetation, which contributes considerably to the occurrence of a wide range of aquatic and terrestrial fauna. The ponds are open environments, depositional, and subject to water level fluctuations, influx and outflow of organic matter and lotic ecosystem organisms, interconnected with the main channels of the drainage basin (Catian *et al.* 2012). Because of the standing and shallow water, the most common species in these habitats are emergent macrophytes (Pott & Pott 2000).

Aquatic macrophytes are vital components of the Pantanal complex. They promote changes and evolution of natural landscapes, as well as providing the occurrence of a diverse fauna. Macrophytes contribute to a considerable increase of the available area in a pond allowing colonization by invertebrates. They also provide habitat for associations of periphytic algae and nitrogen-fixing bacteria (Diniz *et al.* 2018). In this aquatic environment, invertebrates play a role in the flow of energy and matter, participating in the process of decomposition of organic matter, reducing the size of the particles and serving as food for several species of fish and other animals (Eaton 2006, Silva *et al.* 2009, Oliveira-Junior *et al.* 2013, Diniz *et al.* 2018).

Despite the great importance of the Pantanal complex for the diversity of fauna and flora, basic ecological information for most invertebrates is still incipient (Eaton 2006). Information on hydrological changes and invertebrates are valuable to understand the structure and dynamics of limnic communities and for records of ecological processes resulting from changes caused by flood (Oliveira-Junior *et al.* 2013). The lack of studies aiming the conservation of invertebrates in Pantanal occurs part due to the extremely high species richness, the enormous abundance of some groups, the taxonomic difficulties mainly of the hyperdiver groups, the anthropic alterations of the habitat as well as due to the lack of resources for conservation programs (MMA 2007).

In the Pantanal of Mato Grosso do Sul, Miranda subregion, is "Pantanal Portal", represented by a plain with several aquatic habitats influenced by the flood pulse of the Miranda River. Despite the environmental changes in the landscape associated with agriculture, fishing and tourism (Pott & Pott 2000, 2003), it is still possible to observe a dense area with several vegetation units, forming a mosaic with different communities, with frequent abrupt changes. Thus, it is common to find vegetation types of *cerradão* woodland, seasonal forest and riparian forest wthin only 100 meters of ancient levee or earth mound (Pott & Pott 2000).

In view of the above, the aim of this study was: (1) to classify aquatic habitats under the influence of the Miranda River; (2) to describe the composition and relative coverage of aquatic macrophyte species present in the sampled habitats; (3) to evaluate the distribution of invertebrates associated with aquatic macrophytes; (4) to analyze the effect of flood pulse on the structure of macrophyte-associated invertebrate communities; (5) to evaluate the correspondence of the physical and chemical parameters on the aquatic habitats and the relative coverage of macrophytes. It is expected that this research may bring important contributions to the understanding of the dynamics of aquatic communities under effects of flooding in Mato Grosso do Sul Pantanal.

MATERIAL AND METHODS

The selected tract for the study corresponds to a fluvial plain, distributed in a floodable area of the Miranda River (Miranda, Mato Grosso do Sul, Brazil). Five ponds were selected under the influence of the Miranda River flood flow, located on BR-262 highway between the municipalities of Miranda and Corumbá (State of Mato Grosso do Sul, Brazil). The ponds selected for sampling were classified according to Pott & Pott (2000) and are distinguished as: Pond 1 "Rice field"; Pond 2 "Borrow pit/low water"; Pond 3 "Permanent flooded grassland"; Pond 4 "Permanent flooded grassland/ low water"; Pond 5 "Borrow pit" (Figure 1).

In order to reach the objectives of this study, the following methodological steps were adopted: (1) photograph the ponds and describe the coverage of the macrophytes; (2) measure the physical and chemical parameters of ponds; (3) filter water samples for further analysis of chlorophyll-a and pheophytin-a; (4) weigh macrophyte samples using scale and hand net and collect associated invertebrates; (5) identify and prepare exsicates of the sampled macrophytes in the ponds; (6) collect and identify the macrophyte-associated invertebrate biomass.

The collections were conducted semiannually between May 2010 and April 2011, two in the dry season and two in the rainy season. Five water samples were collected in each pond using a Van Dorn bottle. Water temperature (ºC), pH, electrical conductivity (μS.cm^{-1}), dissolved oxygen (mg.L^{-1}), total dissolved solids (mg.L^{-1}) and turbidity (FTU) were measured *in loco* with multiparameter Horiba U-50, and chlorophyll-a (μg.L^{-1}) and pheophytin-a (μg.L^{-1}) were analyzed in the laboratory by the spectrophotometric method (CETESB 2014).

To measure the relative coverage of macrophytes ($RCM_{\%}$), a DJI (Mavic Air Fly model) drone was used

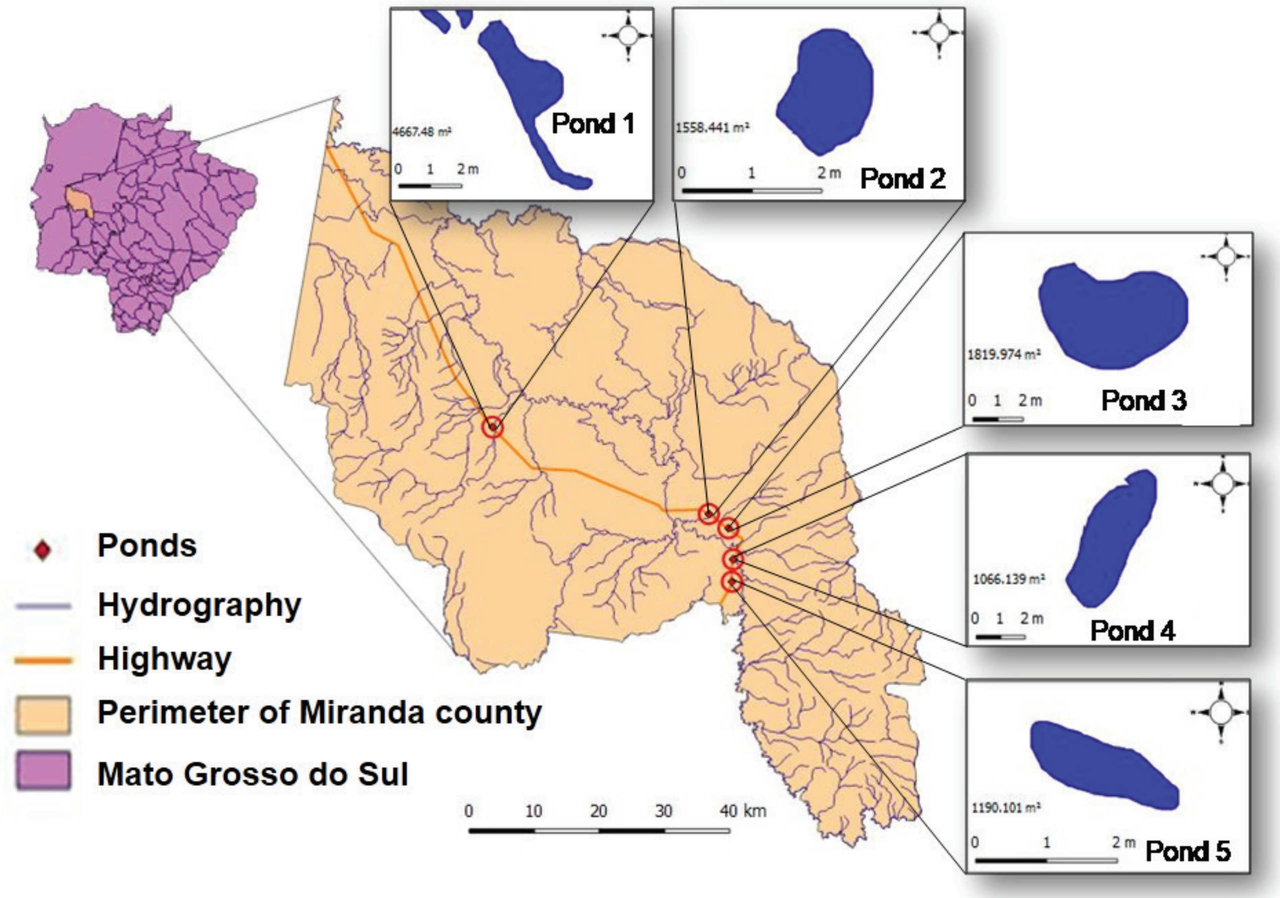

Figure 1. Location, position and aspect of the ponds in the perimeter of Pantanal, municipality of Miranda, state of Mato Grosso do Sul, Brazil.

to obtain aerial images of each pond. Afterwards the images were selected and superimposed on a millimeter grid to estimate the relative surface coverage of each species by the formula (e_i/E)*100, where e_i = sum of the coverage projection of all individuals of species *i* under the surface area of the pond; E = total extent of sampling in square meters (adapted from Santos-Junior & Costacurta 2011).

Macrophytes and macroinvertebrates were collected only in the coastal zone, obtaining five samples per pond. Sampling was performed with a 30 x 30 cm opening and depth of 30 cm (0.09 m^2 area, 500 μm opening) square hand net. The macrophytes were weighed and inspected for separation of macroinvertebrates. The macrophytes were returned to the ponds after their inspection. Only a sample of the macrophytes was collected to preparet the exsicates. The aquatic macrophytes were identified with assistance of a specific dichotomous key (Pott & Pott 2000, Flora do Brasil 2020 2019). The macrophytes collected in the hand net were weighed in the field to obtain their biomass ($g^{-1}.m^2$), then washed in the net to separate the macroinvertebrates. In the lab, the macroinvertebrates were screened under stereomicroscope and weighed to obtain their fresh biomass ($g^{-1}.m^2$). Chemical physical parameters of the water were analyzed using Kruskal-Wallis non-parametric test and the fresh biomass of macrophytes and macroinvertebrates were analyzed using Spearman correlation test (StatSoft 1996).

The physical and chemical parameters and the relative surface cover of macrophytes per pond and per station were submitted to Principal Component Analysis (PCA) in order to simplify the environmental variability in a few interpretable axes. This analysis was performed through the routine "rda" using the vegan package (Oksanen *et al.* 2018) using the R environment (R Development Core Team 2018).

The process of ecological succession has been studied quantitatively considering the changes in the abundance of microalgae throughout the colonization process. This analysis was applied to the 7 most abundant species of each pond and period, having a graphical representation of the relative abundance for each day of sampling.

The density was also analyzed by density-dominance curves of macroinvertebrates taxa, which were constructed by plotting on the ordinate the $\log_{10}$ (x + 1) of the abundance of each taxon and on the abscissa the importance number of each taxon (ranking), in order of decreasing abundance (Brower & Zar 1984).

RESULTS

The minimum and maximum values for each physical and chemical parameter measured in the ponds. Significant differences ($p < 0.05$) were observed only for pH values between dry and rainy seasons, dissolved oxygen and conductivity between the ponds (Table 1).

The highest percentage of macrophyte surface cover was observed for the rainy season, mainly for ponds 1 and 3, followed by ponds 2 and 4. On the other hand, pond 5 presented the highest diversity of macrophytes (Table 2).

The highest abundance of invertebrates

Table 1. Descriptive statistics of the minimum and maximum values for each physical and chemical parameters of the water of Pantanal ponds in the Miranda river floodplain (municipality of Miranda, state of Mato Grosso do Sul, Brazil). Qui Square (X^2) and probability (p) estimates of Kruskal-Wallis non-parametric analysis.

Parameters	Mean	Min.	Max.	Seasons		Ponds	
				X^2	p	X^2	p
Temperature ºC	28.7	20.8	33.8	0.90	0.34	2.40	0.66
pH	6.9	6.4	7.4	19.60	< 0.05	9.00	0.06
Dissolved oxygen ($mg.L^{-1}$)	2.0	0.4	3.6	0.00	1.00	10.00	< 0.05
Conductivity ($\mu S.cm^{-1}$)	164	80	210	0.40	0.53	17.00	< 0.05
Turbidity (FTU)	36	6	157	0.00	1.00	5.00	0.29
Chlorophyll-a ($\mu g.L^{-1}$)	31.6	11.9	72.4	16.78	< 0.05	10.30	< 0.05
Pheophytin-a ($\mu g.L^{-1}$)	28.9	7.3	67.9	12.32	< 0.05	9.80	< 0.05

Table 2. Composition, biological form and relative coverage of macrophytes (RCM $_{\%}$) sampled in ponds in dry (DS) and rainy (RS) season of Pantanal ponds in the Miranda river floodplain (municipality of Miranda, state of Mato Grosso do Sul, Brazil). Legends of the ponds: 1- "Rice field"; 2- " Borrow pit/low water "; 3- "Permanent flooded grassland"; 4- "Permanent flooded /low water"; 5 - "Borrow pit". Legend: Abundance: + between 1 to 5%; ++ from 6 to 20%; +++ from 21 to 60% and > 61%. Absence of macrophytes (-). Biological form (BF): (1) Free-floating; (2) Rooted-floating; (3) Fixed-submerged; (4) Emergent; (5) Amphibious; (6) Epiphyte.

Species		**Pond 1**		**Pond 2**		**Pond 3**		**Pond 4**		**Pond 5**	
	BF	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**
Salvinia auriculata Aubl.	1	-	++	+++	+	+++	++	++	-	-	-
Hygrophila costata Nees	4	-	-	-	-	-	-	-	-	+	+++
Echinodorus paniculatus Micheli.	4	-	-	-	-	-	-	-	-	+	++
Echinodorus glaucus Rataj	4	-	-	-	-	-	-	-	-	-	+++
Pistia stratiotes L.	1	-	+	-	+	-	-	+++	++	-	-
Cyperus blepharoleptos Steud.	6	-	-	-	-	-	-	+	-	-	-
Rotala ramosior (L.) Koehne	4	-	-	-	-	-	-	-	-	++	-
Thalia geniculata L.	4	+	+	-	-	-	-	-	-	-	-
Nymphaea amazonum Mart. & Zucc.	2	+	+	-	-	-	+	-	+	+	++
Ludwigia helminthorrhiza (Mart.) H.Hara	2	++	+++	-	-	-	-	-	-	-	-
Ludwigia inclinata (L.f.) M.Gómez	3	-	-	-	-	-	-	-	-	++	-
Echinochloa polystachya (Kunth) Hitchc.	5	-	-	++	+	-	-	-	-	-	
Hymenachne amplexicaulis (Rudge) Nees	5	-	-	-	-	-	++	-	-	-	++
Polygonum punctatum Elliott	4	-	-	-	-	-	-	-	+++	-	-
Eichhornia azurea (Sw.) Kunth	2	O	O	+++	O	+++	O	++	+++	-	+
Pontederia cordata L.	4	+	-	-	-	-	-	-	-	+	-
RCM$_{\%}$		66	93	61	87	73	90	70	86	30	41

associated with aquatic macrophytes was observed for pond 1 during the rainy season (Table 3). We also observed for the rainy season a high correlation (Spearman correlation = 0.908; $p < 0.05$) between the biomass of the macrophytes and the biomass of the associated invertebrates; in the dry season a low correlation (Spearman correlation = 0.199; $p = 0.11$) was observed (Figure 2). When the curve of density and dominance of taxa is analyzed, it can be observed that pond 1 showed the highest species dominance in both dry and rainy season (Figure 3).

The Principal Component Analysis (PCA) performed with the limnological parameters and the relative coverage of macrophytes in the ponds during the dry season showed that the first two axes explained 82.75% of the data variation (Figure 4a). The variables considered most important to explain the relative coverage of macrophytes were Pheophytin-a and Chlorophyll-a. Regarding data from the rainy season, the first two axes explained 80.23% of the data variation (Figure 4b). The variables considered most important for the relative

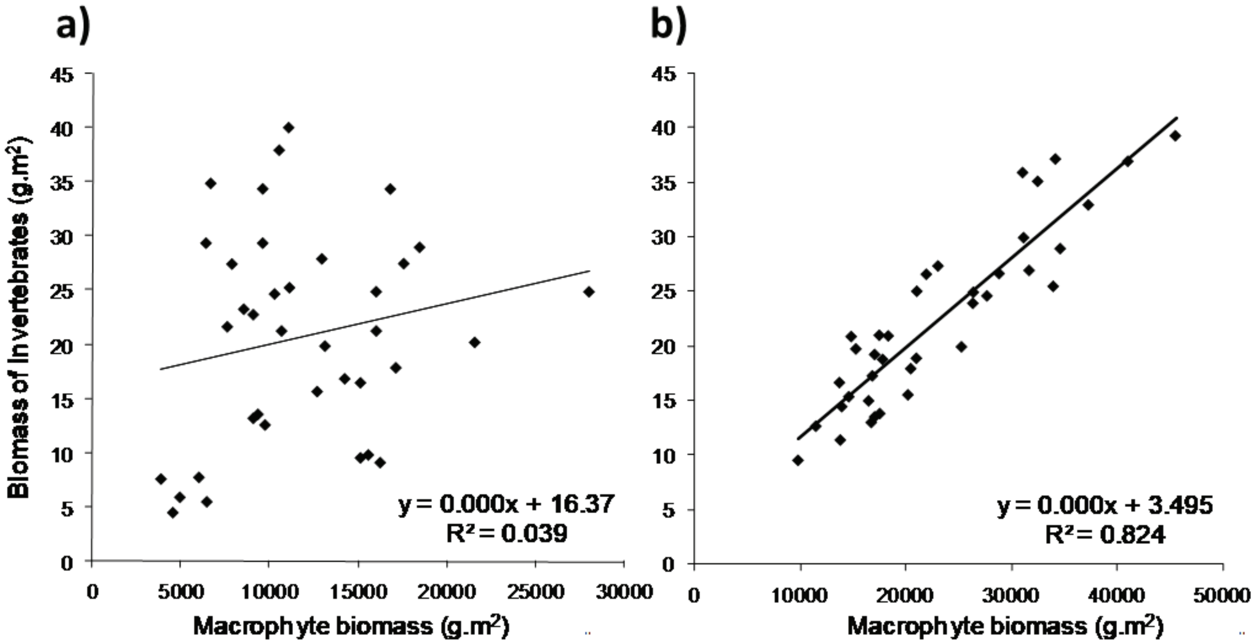

Figure 2. Spearman correlation estimates between the macrophyte and macroinvertebrate biomass collected in Pantanal ponds, municipality of Miranda, state of Mato Grosso do Sul, Brazil, in the dry (a) and rainy season (b).

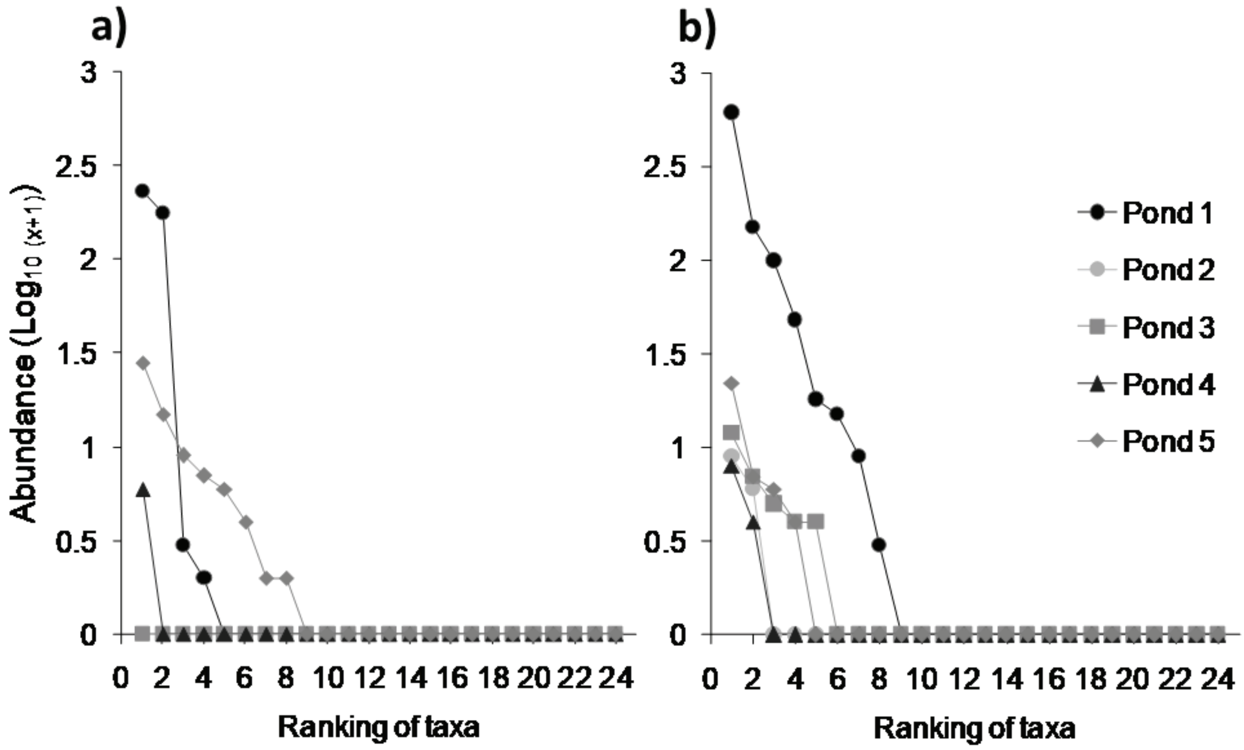

Figure 3. Curve of density and dominance of taxa in dry (a) and rainy (b) seasons in each pond in the Pantanal, municipality of Miranda, state of Mato Grosso do Sul, Brazil. For legends of the ponds see Table 2.

Table 3. Abundance, richness and diversity of Shannon Wiener (H') of aquatic invertebrate taxa sampled in the five Pantanal ponds in dry (DS) and rainy (RS) season of Pantanal ponds in the Miranda river floodplain (municipality of Miranda, state of Mato Grosso do Sul, Brazil). Legends of the ponds: 1- "Rice field"; 2- " Borrow pit/low water "; 3- "Permanent flooded grassland"; 4- "Permanent flooded /low water"; 5 - "Borrow pit". * In this season the pond was dry.

Taxa	Pond 1		Pond 2		Pond 3		Pond 4		Pond 5	
	DS	RS	DS	RS	DS*	RS	DS	RS	DS	RS
Hemiptera										
Belostomatidae	-	-	-	-	-	-	-	-	1	1
Mesovelidae	-	-	-	-	-	-	-	-	-	7
Lepidoptera										
Pyralidae	-	-	-	-	-	-	-	-	7	-
Diptera										
Chaoboridae	-	-	-	-	-	-	-	-	2	-
Chironomidae	176	612	-	9	-	12	-	8	15	6
Culicidae	-	-	-	-	-	-	6	-	-	-
Ceratopogonidae	-	150	1	1	-	7	-	1	28	-
Odonata										
Dicteriadidae	-	-	-	-	-	-	-	-	2	-
Libellulidae	1	-	-	-	-	1	-	-	6	-
Aeshnidae	2	-	1	-	-	-	-	1	-	-
Gomphidae	-	-	-	-	-	-	-	1	-	-
Coleoptera										
Hidrophylidae	-	-	-	-	-	-	-	-	1	-
Elmidae	-	9	-	-	-	-	1	1	-	-
Gyrinidae	-	-	-	-	-	1	-	-	-	-
Noteridae	-	-	-	-	-	-	-	-	-	1
Haliplidae	-	-	-	-	-	1	-	-	-	-
Dytiscidae	-	3	-	1	-	-	-	-	-	-
Megaloptera										
Corydalidae	3	-	-	1	-	-	-	-	-	-
Ephemeroptera										
Leptohyphidae	-	-	-	1	-	1	-	-	-	-
Leptophlebiidae	-	-	-	-	-	-	-	-	9	-
Bivalvia	-	99	-	-	-	-	-	-	-	-
Gastropoda	-	18	-	6		5	-	4	4	4
Hirudinea	-	15	-	1	-	4	-	-	-	22
Oligochaeta	231	48	-	-	-	4	1	-	-	1
Abundance	413	954	2	20	-	35	8	16	75	42
Richness	5	8	2	7	-	9	3	6	10	7
Diversity (H')	0.76	1.16	0.69	1.46	-	1.47	0.73	1.38	1.8	1.40

coverage of macrophytes were water temperature, turbidity and chlorophyll-a.

DISCUSSION

The observed results for the survey of the biotic *versus* the abiotic factors of the ponds of the Miranda floodplain in the Pantanal suggest a complex relation of factors, such as the dispersal capacity of the invertebrates associated to the macrophytes, intrinsic characteristics of the habitats, physical and chemical parameters of the water and flood from overflow of the Miranda river. Although they

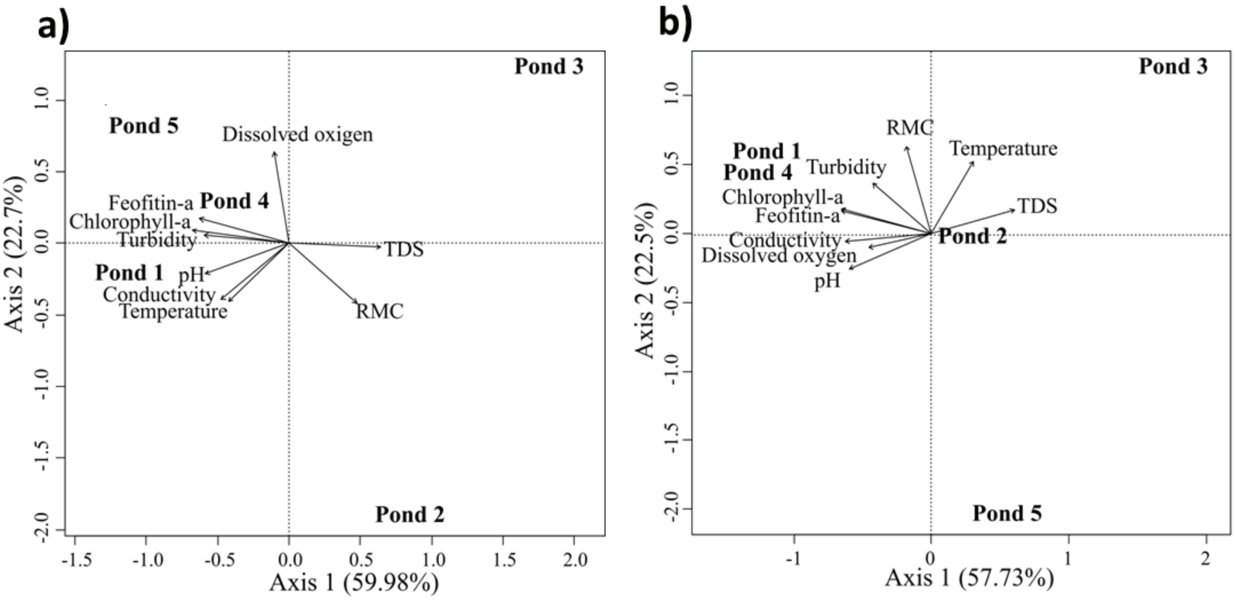

Figure 4. Principal Components Analysis (PCA) of individual influence of the limnological variables and relative macrophyte coverage (RMC) in ponds of the Pantanal, municipality of Miranda, state of Mato Grosso do Sul, Brazil, in the dry (a) and rainy season (b). For legends of the ponds see Table 2.

are present in our results, these factors are not easily disentangled.

The physical and chemical parameters indicated important seasonal and spatial characteristics in pond dynamics. The seasonal difference observed in the pH may be related to a higher concentration of organic matter during the dry season, which brought more acidity to the water (Esteves 1998). These variations in pH can be explained mainly by a natural phenomenon known as "decoada" or "dequada" (Esteves 1998). This event is characterized by the natural alteration of water quality during the hydrologic phase of flood, whose intensity varies according to the climate and the annual flood patterns (Oliveira-Junior *et al.* 2013). Besides, water losses due to evapotranspiration of macrophytes must exceed the intakes, especially during the dry season, leading to an increase in pH and alkalinity (Eaton 2006).

However, the variations observed for Chlorophyll-a and pheophytin-a may be the result of the availability of mineral salts through the complete decomposition of the organic matter leading to a significant increase in the development of microalgae. The high values of electrical conductivity of the water also indicated the concentration of mineral salts.

The variation of the physical and chemical parameters observed between the ponds, mainly between the values of dissolved oxygen, electrical conductivity, water turbidity, chlorophyll a and pheophytin-a can be explained both by the permanent and intermittent characteristics of the ponds (Silva & Carniello 2007) and by the concentration of organic matter at the bottom, which led to the depletion of dissolved oxygen in the benthic zone. Besides the senescence of many aquatic macrophytes (Oliveira-Junior *et al.* 2013), the leaching of the terrestrial litter raises the organic material inside the system. However, many Pantanal fauna and flora communities are adapted to such seasonal and temporal variations, which ultimately determine many biological patterns.

The composition and biological forms of the aquatic macrophytes may determine intrinsic characteristics on the aquatic fauna and, consequently, on the environmental parameters. The rooted floating macrophyte *Eichornia azurea* (anchored water hyacynth) was dominant in at least three of the five analyzed ponds and with the free floating macrophytes *Salvinia auriculata* (Salviniales, Salvinaceae) (eared watermoss) and *Pistia stratiotes* (Alismatale, Araceae) (water lettuce), comprised between 70 and 90% of vegetation cover in the ponds. Both biological forms of macrophytes contribute with a large surface area that support the colonization of a great diversity and density of invertebrates, offering habitats for refuge, reproduction and feeding. In addition, macrophytes provide a transitional environment between the aquatic and terrestrial environments (ecotone), allowing the occurrence of ecological communities of both environments.

On the other hand, pond 5 that presented the highest diversity of macrophytes species also presented the lowest vegetation cover. This pond was characterized by a great diversity of emerging and or amphibious biological forms. The invertebrates Belostomatidae, Mesovelidae, Pyralidae and Leptophlobiidae occurred only in this pond, while the dominant groups Chironomidae and Oligochaeta were absent. Such differences in invertebrate composition may be related to the architecture of the macrophytes, which present a smaller horizontal surface area, making it impossible to retain organic matter and the colonization of invertebrates with little mobility. Studies have shown that the richness and density of invertebrate species vary depending on the architecture and aquatic macrophyte biomass (Moretti *et al.* 2003, Peiró & Alves 2006).

The biomass of invertebrates showed significant correlation estimates with the biomass of aquatic macrophytes (only in the rainy season). Moretti *et al.* (2003) found higher density of macroinvertebrates in macrophytes with floating biological forms. Also, our results suggest that the dominance of the floating *E. azurea* macrophyte in ponds 1, 2 and 3 had a significant relation with the density of invertebrates. This species of macrophyte presents a larger surface area in contact with water, giving greater area for colonization by invertebrates. Besides, data from the literature indicate that the dimensions of *E. azurea* roots may play an important ecological role as a shelter and place of food accumulation for invertebrates in ponds (Saulino & Trivinho-Strixino 2014). This fact explains the dominance of Chironomidae and Oligochaeta in ponds under the dominance of *E. azurea, S. auriculata* and *P. stratiotes*.

Another important characteristic in floating macrophytes is their ability to spread during the flooding. This allows the colonization of different invertebrate communities resulting from adjacent areas connected by rising water levels. In lotic environments many aquatic invertebrates use the water current to colonize new areas, either for food or shelter (Carvalho & Uieda 2004). In lentic environments the macrophytes must contribute significantly to the dispersion of the invertebrates. This shows the influence of flood flow on the distribution of macrophytes and consequently on invertebrate colonization. Data from the literature confirm that the composition and abundance of invertebrates present in the macrophyte stands are determined by the amplitude of the flood pulse (Eaton 2006, Oliveira-Junior *et al.* 2013).

Summing up, the Principal Component Analysis indicated that there are seasonal and spatial differences between the limnological variables that possibly influenced the superficial coverage of macrophytes in the ponds of the Miranda River floodplain in the Pantanal. In the dry season Pheophytin-a pheopigment and the chlorophyll-a pigment indicated high replacement rates in phytoplankton biomass. Chlorophyll molecules are not stable and depending on the conditions of the environment, such as changes in pH, temperature or excessive light, they can be degraded, causing pheopigment (pheophytin-a), which are products of chlorophyll-a degradation (CETESB 2014).

In the rainy season, the limnological variables that best explained the surface cover of macrophytes in the ponds were water temperature, dissolved oxygen, turbidity and Chlorophyll-a. As discussed previously, these indicators are directly related to the entry and decomposition of organic matter, which in turn is indirectly related to the flood from overflow of the Miranda River.

Finally, permanent and intermittent Pantanal ponds present high dominance and vegetation coverage by anchored water yacynth (*E. azurea*), which was also related with higher values of macroinvertebrate biomass. On the other hand, the ponds that presented low dominance or absence of *E. azurea* presented high diversity of aquatic macrophytes. However, these intrinsic biological characteristics of the ponds altogether with the abiotic parameters demonstrated the distinct patterns in the dynamics of these ecosystems in accordance to flood regime.

ACKNOWLEDGMENTS

To Conselho Nacional de Desenvolvimento Cientifico e Tecnológico for the scholarship granted to Nathaskia Silva Pereira. To Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado de Mato Grosso do Sul (FUNDECT) for the assistance in the research (process 23 / 200,187 / 2010) and in the Regional Scientific Development project (DCR - FUNDECT / CNPq).

REFERENCES

Alho, C. J. R., & Gonçalves. H. C. 2005. Biodiversidade do Pantanal – Ecologia & Conservação. Campo Grande: Editora UNIDERP: p. 135.

Brower, J. E., & Zar, J. H. 1984. Field & laboratory methods for general ecology. Boston: W.C. Brown Publishers: p. 226.

Carvalho, E. M., & Uieda, V. S. 2004. Colonização por macroinvertebrados bentônicos em substrato artificial e natural em um riacho da serra de Itatinga, São Paulo, Brasil. Revista Brasileira de Zoologia, 21(2), 287–293. DOI: 10.1590/S0101-81752004000200021

Catian, G., Leme, F. M., Francener, A., Carvalho, F. S., Galletti, V. S., Pott, A., Pott, V. J., Scremin-Dias, E., & Damasceno-Junior, G. 2012. Macrophyte structure in lotic-lentic habitats from Brazilian Pantanal. Oecologia Australis, 16(4), 782–796. DOI: 10.4257/oeco.2012.1604.05

CETESB - Companhia Ambiental do Estado de São Paulo. 2014. Determinação de clorofila a e feofitina a: método espectrofotométrico. Norma Técnica L5.306. 3º ed. p. 14.

Diniz, F. M., Santos, M. O., & Melo, S. M. 2018. Levantamento da fauna de macroinvertebrados associados à macrófitas aquáticas. Journal of Environmental Analysis and Progress, 3(1), 86–91. DOI: 10.24221/jeap.3.1.2018.1693.086-091

Eaton, D. P. 2006. Contribuição para conservação de macroinvertebrados, peixes e habitats de água doce no Pantanal de Nhecolândia e do Rio Negro, Mato Grosso Do Sul. Ensaios e Ciência: Ciências Biológicas, Agrárias e da Saúde, 10(1), 99–118.

Esteves, F. A. 1998. Fundamentos de limnologia. Rio de Janeiro: Interciência: p. 602.

Flora do Brasil 2020 em construção. Jardim Botânico do Rio de Janeiro. Retrieved on 12 September, 2019, from http://floradobrasil.jbrj.gov.br/

Marengo, J. A., Alves, L. M., & Torres, R. R. 2015. Regional climate change scenarios in the Brazilian Pantanal watershed. Climate Research, 68(2), 201–213. DOI: 10.3354/cr01324

MMA – Ministério do Meio Ambiente. 2007. Biodiversidade do Cerrado e Pantanal: áreas e ações prioritárias para conservação da biodiversidade. Série Biodiversidade 17. Brasília: MMA.

Moretti, M. S., Goulart, M. D. C., & Callisto, M. 2003. Avaliação rápida da macrofauna associada a *Eichhornia azurea* (Swartz) Kunth, 1843 e *Pontederia lanceolata* Nutt., 1818 (Pontederiaceae) na Baía do Coqueiro, Pantanal de Poconé (MT/Brasil). Revista Brasileira de Zoociências, 5(1), 7–21.

Oliveira-Junior, E., Butakka, C. M. M., Silva, C. J., & Muniz, C. 2013. A influência do pulso de inundação na ecolimnologia de baías pantaneiras: um estudo na dinâmica de invertebrados aquáticos. Holos Environment, 13(2), 188–199. DOI: 10.14295/holos.v13i2.6688

Oksanen, J., Blanchet, F. G., Friendly, R., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O'hara, R. B., Simpson, G. L., Solymos, P., Stevens, M. H. H., Szoecs, E., & Wagner, H. 2018. Vegan: Community Ecology Package. R package version 2.0–10. Retrieved on July 20, 2018, from http://CRAN.R-project.org/package=vegan

Peiró, D. F., & Alves, R. G. 2006. Insetos aquáticos associados a macrófitas da região litoral da represa do Ribeirão das Anhumas (município de Américo Brasiliense, São Paulo, Brasil). Biota Neotropica, 6(2), 1–9. DOI: 10.1590/S1676-06032006000200017

Pott, V. J., & Pott, A. 2000. Plantas aquáticas do Pantanal. Brasília: Embrapa: p. 404.

Pott, V. J., & Pott, A. 2003. Dinâmica da vegetação aquática do Pantanal. In: S. T. Thomaz, & Bini, M. B. Ecologia e manejo de macrófitas aquáticas. pp.143–162. Maringá: EDUEM.

Pott, A., & Pott, V. J. 2004. Features and conservation of the Brazilian Pantanal. Wetlands Ecology and Management, 12(6), 547–552. DOI: 10.1007/s11273-005-1754-1

R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved on July 20, 2018, from http://www.R-project.org/

Santos-Junior, A., & Costacurta, M. B. 2011. Dinâmica da composição e cobertura de espécies de macrófitas aquáticas e a escolha de indicadores de impacto ambiental em um rio com ecoturismo. Ambiência Guarapuava, 7(3), 535–550. DOI: 10.5777/ambiencia.2011.03.10

Saulino, H. L., & Trivinho-Strixino S. 2014. Macroinvertebrados aquáticos associados às raízes de *Eichhornia azuera* (Swarts) Kunth (Pontederiaceae) em uma lagoa marginal no Pantanal, MS. Biotemas, 27 (3), 65–72. DOI:10.5007/2175-7925.2014v27n3p65

Silio-Calzada, A., Barquín, J., Huszar, V. L. M., Mazzeo, N., Méndez, F., & Álvarez-Martínez, J. M. 2017. Long-term dynamics of a floodplain shallow lake in the Pantanal wetland: Is it all about climate? Science of the Total Environment, 605(606), 527–640. DOI: 10.1016/j.scitotenv.2017.06.183

Silva, F. H., Favero, S., Sabino, J., & Garnés, S. J. A. 2009. Distribuição da entomofauna associada às macrófitas aquáticas na vazante do rio Correntoso, Pantanal do Negro, Estado do Mato Grosso do Sul, Brasil. Acta Scientiarum, Biological Sciences, 31(2), 127–134. DOI: 10.4025/actascibiolsci.v31i2.1182

Silva, R. M. M., & Carniello, M. A. 2007. Ocorrência de macrófitas em lagoas intermitentes e permanentes em Porto Limão Cáceres-MT. Revista Brasileira de Biociências, 5(2), 519–521.

StatSoft. 1996. Statistica 5.1 for Windows. Tulsa, USA.

Submitted: 15 September 2018
Accepted: 11 April 2019
Published online: 16 December 2019
Associate Editors: Camila Aoki, Gudryan J. Barônio & Arnildo Pott