Oecologia Australis
23(4):846-855, 2019
https://doi.org/10.4257/oeco.2019.2304.10

AQUATIC VEGETATION OF NEARSHORE AND FLOATING MEADOW OF A LARGE OXBOW LAKE IN THE BRAZILIAN PANTANAL

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Abstract: The objective of this study was to characterize the floristic and phytosociological composition of aquatic macrophytes occurring on the nearshore and on floating meadows of a large oxbow lake in the Pantanal wetland, in order to identify the degree of similarity between these biological compartments. Therefore, we sampled 100 plots of 0.5 x 0.5 m on floating meadows and 100 nearshore. We recorded 42 species, being 30 nearshore and 38 on floating meadows. The richness observed on floating meadows was little superior to the recorded nearshore, and the similarity between the compartments was relatively high (Jaccard = 61.90). Four species occurred exclusively nearshore, while 12 species were restricted to floating meadows. The outstanding species for their frequency and a high percentage of cover nearshore were *Ludwigia helminthorrhiza* (Mart.) H.Hara and *Eichhornia azurea* (Sw.) Kunth. On floating meadows, *Cyperus blepharoleptos* Steud. presented the highest importance value (61.3). The emergent and amphibious life forms were the most common in both compartments. The similarity between both formations is an expected outcome, once the floating meadows can develop from nearshore plants and contact them during displacements within the lake. We highlight the high number of exclusive species recorded on floating meadows, which can be explained by environmental (related to the interaction between species and environmental characteristics) or spatial factors (dispersal capacity) that favor the colonization of the floating meadows by species absent nearshore.

Keywords: aquatic macrophyte; floating island; phytosociology; wetland.

INTRODUCTION

The Pantanal is one of the largest continuous wetlands of the planet, encompassing *ca.* 140,000 km² plain of low elevation of the Upper Paraguay River (Harris *et al.* 2005). For being floodable, it is a favorable area to the development of many aquatic plants (Pott & Pott 1997), which are associated with the diversity of habitats, to the wide Neotropical distribution of species and to the flood pulse (Junk

et al. 1989, Wantzen *et al.* 2005). This vegetation is of great importance in the trophic chain of aquatic ecosystems, serving as shelter and food for fish, aquatic insects, mollusks, birds and mammals, besides configuring substrate for the periphyton (Pott & Pott 1997). In spite of its importance, the species richness in wetlands of South America is far from being adequately known (Ferreira *et al.* 2011).

The aquatic macrophytes present wide physiological and morphological plasticity, making them capable to colonize diverse habitats with a variety of physical and chemical characteristics (Pierini & Thomaz 2004). Growth and expansion of these plants in floodable and permanently flooded areas can culminate in the formation of wide green floating mats rich in organic matter originated from their decomposition and its buildup starts the formation of a floating island (Neiff 1982), regionally known as *baceiro* (Pott & Pott 2000), a floating meadow. The number of floating islands varies between lakes and their succession stage is variable even inside the same lake (C. Aoki, unpublished data). The floating islands can be displaced, mainly by winds and the generated waves, often colliding with the lakeshore. Especially during pronounced droughts, these floating islands may anchor on the shores of lakes (Pott & Pott 2003). For this reason, it must bear a certain floristic resemblance to this biological compartment. However, the process of formation is not yet fully understood. It is known, however, that floating meadows have succession stages with various species of aquatic macrophytes related to histosol thickness, but species composition regarding succession stages differs from other water bodies in the Pantanal wetland (Coutinho *et al.* 2017). Recognizing the similarity between these two compartments will help to understand how much the nearshore influences the floristic composition of these floating meadows and how much diversity comes from other mechanisms (*e.g.*, dispersal by animals that land on these islands).

The objective of the present study was to characterize the floristic and phytosociological composition of aquatic macrophytes occurring in the nearshore and on floating meadows of a large oxbow lake located in the Pantanal wetland, in order to identify the degree of similarity between both biological compartments. Thus, we intend to contribute to the knowledge about aquatic plants in the region and to understand the distribution pattern of species and dynamics of formation of a biological compartment of this ecosystem, what is important for the development of management plans and conservation of the habitats required for numerous species.

MATERIAL AND METHODS

The study was carried out in Baía Grande lake (20°18'05" S and 55°51'52" W, altitude *ca.* 140 m a.s.l.), in the municipality of Aquidauana, Mato Grosso do Sul, Brazil (Figure 1), Aquidauana subregion, in the southeast of the Brazilian Pantanal plain (Abdon & Silva 2006). It is an oxbow lake, *ca.* 3 km x 1.7 km, average depth of 2 m, connected to the Aquidauana river at high floods (Coutinho *et al.* 2017).

The region is characterized by a humid tropical climate presenting seasonal rainfall, with the summer rainy season from November to March and the drier winter from April to September (Marengo *et al.* 2015), and an annual rainfall of 1,200 mm and maximum and minimum temperatures of 33 and 19°C, respectively (Peel *et al.* 2007, Schiavo *et al.* 2010).

Aquatic macrophyte sampling was done throughout the Baía Grande lake on a motorboat, in December 2012 and April 2013. We sampled 200 plots of 0.5 x 0.5 m, 100 on floating meadows and 100 on the nearshore (inside the lake). The plots were randomly distributed, in each unit, we identified the species and estimated their percentage cover. The structure of the plant community was analyzed by means of calculating frequency, cover, as well as importance value, according to Damasceno-Junior & Pott (2011). In addition, we made the floristic survey collecting all species in reproductive phase or not, as well as those observed in the lake outside the plots.

The exsiccates were incorporated into the Herbarium CGMS of the Universidade Federal do Mato Grosso do Sul. The species were identified with pertinent bibliography, comparison with herbarium vouchers and assistance from specialists. The botanical nomenclature follows Flora do Brasil 2020 (The Brazil Flora Group 2018), according to APG IV (2016) for Angiosperms and Smith *et al.* (2006) for Pteridophytes. We considered the life forms according to the classification of Irgang *et*

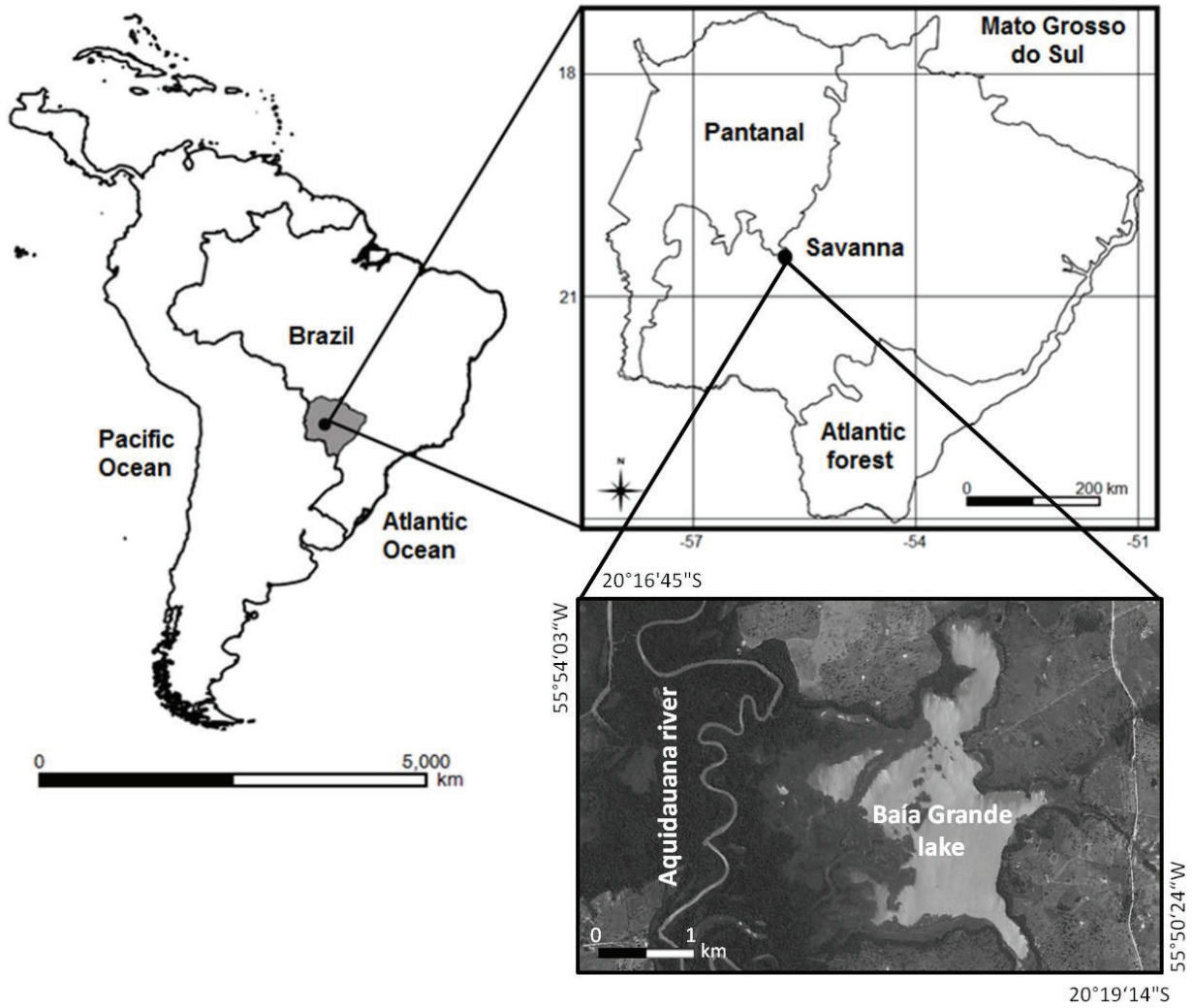

Figure 1. Location of the Baía Grande lake, Pantanal, in the municipality of Aquidauana, Mato Grosso do Sul state, Brazil.

al. (1984). The similarity between both biological compartments (nearshore and floating meadows) was compared by the index of Jaccard, utilizing the program Biodiversity Pro.

RESULTS

We recorded 42 species of aquatic macrophytes in the Baía Grande lake, distributed in 34 genera and 18 families (Table 1). Only two families are pteridophytes (Salviniaceae and Thelypteridaceae), one is bryophyte (Ricciaceae) and all others are Angiosperms. The richest families were Fabaceae, Poaceae (5 species each), Onagraceae and Lentibulariaceae (3 species each). Among the recorded genera, *Ludwigia* and *Utricularia* stood out with three species each (Table 1).

The species richness observed on the floating meadows (38 species, 31 genera, 16 families) was a little higher than on the nearshore (30 species, 24 genera and 18 families) (Table 1). There was a high number of species in common between biological compartments, resulting in high similarity (Jaccard = 61,9). Regarding families, Fabaceae (5 species) and Poaceae (4 species) stood out on the floating meadows, while Onagraceae, Poaceae and Lentibulariaceae (3 species each) on the nearshore. Four species occurred exclusively on the nearshore, the flood-tolerant riparian shrubs *Alchornea castaneifolia* (Willd.) A. Juss., *Cephalanthus glabratus* (Spreng.) K. Schum., and *Combretum lanceolatum* Pohl *ex* Eichler and the tussock grass *Hymenachne pernambucensis* (Spreng.) Zuloaga, while 12 species were restricted to the floating meadows.

Table 1. List of recorded species of aquatic macrophytes with their respective life forms and biological compartments of record in the Baía Grande lake, Aquidauana, Pantanal, Mato Grosso do Sul state, Brazil. Voucher number in the Herbarium CGMS. FF = Free floating; RF = Rooted floating; FS = Free submerged; RS = Rooted submerged; A = Amphibious; E = Emergent; EP = Epiphytic.

Family	Species	Life form	Nearshore	Floating meadow	Voucher
APOCYNACEAE	*Funastrum clausum* (Jacq.) Schltr.	E	X	X	59146
	Rhabdadenia madida (Vell.) Miers	E	X	X	59868
	Tassadia berteroana (Spreng.) W.D.Stevens	E		X	59858
ARACEAE	*Lemna aequinoctialis* Welw.	FF	X	X	59867
	Pistia stratiotes L.	FF	X	X	59149
	Wolffiella lingulata (Hegelm.) Hegelm.	FF		X	57925
ASTERACEAE	*Barrosoa candolleana* (Hook. & Arn.) R.M.King & H.Rob	E		X	59145
	Eclipta prostrata (L.) L.	A		X	59849
	Enydra radicans (Willd.) Lack	A	X	X	59850
COMBRETACEAE	*Combretum lanceolatum* Pohl ex Eichler	E	X		59853
CONVOLVULACEAE	*Ipomoea asarifolia* (Desr.) Roem. & Schult.	E	X	X	59844
	Ipomoea subrevoluta Choisy	A	X	X	59847
CYPERACEAE	*Cyperus blepharoleptos* Steud.	Ep	X	X	57933
	Cyperus odoratus L.	A		X	59851
	Rhynchospora corymbosa (L.) Britton	Ep		X	59855
EUPHORBIACEAE	*Alchornea castaneifolia* (Willd.) A.Juss.	A	X		59859
FABACEAE	*Aeschynomene americana* L.	E		X	59857
	Mimosa pigra L.	A	X	X	59846
	Mimosa polycarpa Kunth	A		X	59856
	Sesbania exasperata Kunth	E		X	59866
	Vigna longifolia (Benth.) Verdc.	E	X	X	59854
HYDROCHARITACEAE	*Limnobium laevigatum* (Humb. & Bonpl. ex Willd.) Heine	FF/Ep	X	X	59848
LENTIBULARIACEAE	*Utricularia breviscapa* Wright ex Griseb.	FS	X	X	57923
	Utricularia gibba L.	Ep	X	X	57967
	Utricularia foliosa L.	FS	X	X	59147

Table 1. Continued on next page...

Table 1. ...Continued

Family	Species	Life form	Nearshore	Floating meadow	Voucher
ONAGRACEAE	*Ludwigia helminthorrhiza* (Mart.) H.Hara	RF	X	X	59861
	Ludwigia lagunae (Morong) H.Hara	E	X	X	59862
	Ludwigia leptocarpa (Nutt.) H.Hara	A	X	X	59863
POACEAE	*Andropogon bicornis* L.	A		X	59144
	Hymenachne amplexicaulis (Rudge) Nees	E		X	59845
	Hymenachne pernambucensis (Spreng.) Zuloaga	E	X		59860
	Leersia hexandra Sw.	E	X	X	57963
	Paspalum repens P.J. Bergius	E	X	X	59143
POLYGONACEAE	*Polygonum acuminatum* Kunth	E	X	X	59150
	Polygonum punctatum Elliott	E	X	X	59864
PONTEDERIACEAE	*Eichhornia azurea* (Sw.) Kunth	RF	X	X	57957
RICCIACEAE	*Ricciocarpos natans* (L.) Corda	FF	X	X	59865
RUBIACEAE	*Cephalanthus glabratus* (Spreng.) K.Schum	A	X		59843
SALVINIACEAE	*Azolla filiculoides* Lam.	FF	X	X	59148
	Salvinia auriculata Aubl.	FF	X	X	57961
THELYPTERIDACEAE	*Cyclosorus interruptus* (Willd.) H. Ito	E		X	57960
VITACEAE	*Cissus spinosa* Cambess.	E	X	X	59842

Four species stood out for their frequency and high percentage cover on the nearshore of the Baía Grande lake: *Ludwigia helminthorrhiza* (Mart.) H.Hara (RF = 11.8; RC = 21.9), *Eichhornia azurea* (Sw.) Kunth (RF = 9.2; RC = 14.6), *Salvinia auriculata* Aubl. (RF = 12.6; RC = 10) and *Cyperus blepharoleptos* Steud. (RF = 8.4; RC = 11.1), consequently, these were the species with highest importance values, with highlight for *L. helminthorrhiza* with little more than 33 (Figure 2). *Azolla filiculoides* Lam. showed high RF (9.8%), but low cover values (a little over 2%), that resulted in 11.9 of IV.

On floating meadows, two species stood out in frequency and cover, *C. blepharoleptos* (RF = 16.1; RC = 45.2) and *L. helminthorrhiza* (RF = 12.4; RC = 18.3), consequently, presented the highest importance values (Figure 2). *Azolla filiculoides* and *S. auriculata* also presented high importance values, nevertheless, they did not present high cover (4.5% and 2.5%, respectively).

The emergent (40% on the nearshore and 44% on floating meadows) and amphibious life forms (20% on the nearshore and 21% on floating meadows) were the most common, followed by the free-floating forms (20% on the nearshore and 18% on floating meadows), epiphytic (7% on the nearshore and 8% on floating meadows), free

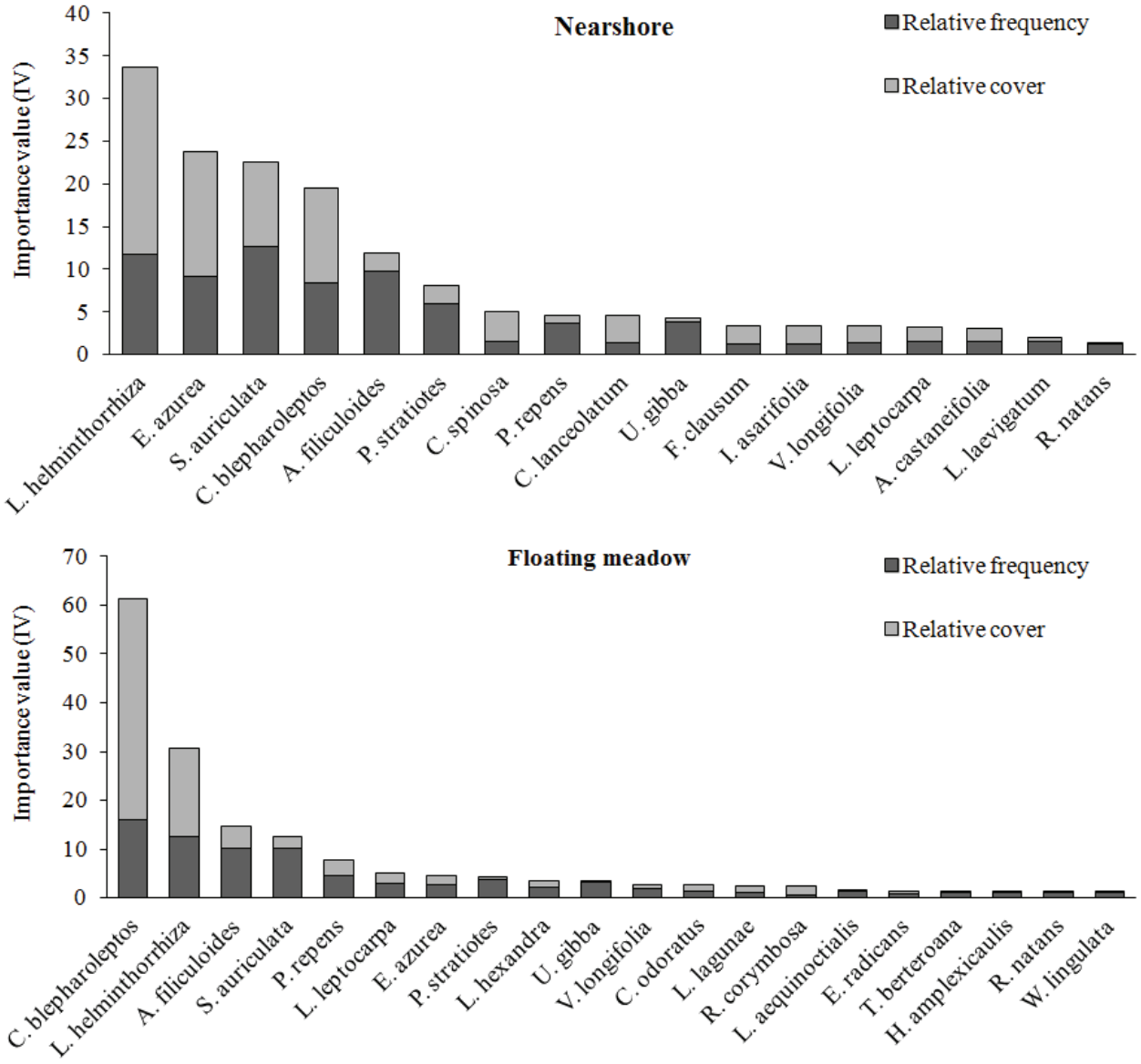

Figure 2. Importance Values (IV > 1) of the main species of aquatic macrophytes recorded on the nearshore and on floating meadows of Baía Grande lake, Aquidauana, Pantanal, Mato Grosso do Sul state, Brazil.

submerged (7% found in the nearshore and 5% on floating meadows) and rooted floating (7% on the nearshore and 5% on floating meadows).

DISCUSSION

The number of recorded species is intermediate if compared with other surveys conducted in the sub-region of Aquidauana. Rocha *et al.* (2007) recorded 89 species of aquatic macrophytes in a floristic survey in five ponds and two seasonal streams and Gomes & Aoki (2015) found 21 species probably because the study was held inside phytosociological plots in just one small urban pond.

Likewise we observed in this study, the richest families (Poaceae, Fabaceae, Onagraceae and Lentibulariaceae) are also well represented in surveys on aquatic macrophytes in the Pantanal (Rocha *et al.* 2007, Silva & Carniello 2007, Pivari *et al.* 2008, Pott *et al.* 2011, Aoki *et al.* 2017) and other wetlands in Brazil (Meyer & Franceschinelli 2011, Aona *et al.* 2015, Moura-Júnior *et al.* 2015, Pivari *et al.* 2019).

At the generic level, species richness varies among studies. Besides the common predominance of some genera of Cyperaceae (*Cyperus*, *Eleocharis* and *Rhynchospora*) (Lima *et al.* 2011, Meyer & Franceschinelli 2011, Rocha *et al.* 2015), several reports showed an elevated species richness of *Ludwigia* (Onagraceae) (Pivari *et al.* 2011, Cunha *et al.* 2012, Aoki *et al.* 2017). *Ludwigia* is among the most represented genera of aquatic plants in the Pantanal (Pott *et al.* 2011) and was also cited by Pivari *et al.* (2008) as the most representative genus for floating meadows in the Pantanal in the sub-regions of Abobral and Miranda. Such richness can be explained by the capacity of the species of *Ludwigia* to explore different habitats (Pott & Pott 2000) and to present different life forms (here represented by rooted floating, amphibious and emergent species), increasing the distribution amplitude in wetlands.

Different stages of formation of floating meadows were observed, since floating mats of macrophytes until floating meadows with histosol thicker than 26 cm, with high capacity of mechanical support, indicated by the main presence of *Ludwigia lagunae* (Morong) H. Hara and other shrubs recorded by Coutinho *et al.* (2017).

Ludwigia helminthorrhiza, species with the highest importance value in the nearshore and second in importance on floating meadows, increases with eutrophication and disturbance, being one of the species present in pioneer stages in the succession of floating meadows, decreasing with the advance of age and thickness of the floating layer (Pott & Pott 2000, Coutinho *et al.* 2017). *Cyperus blepharoleptos* is considered colonizer of floating species, acting as epiphytic during the formation of floating meadows (Pott & Pott 2000), becoming dominant over the vegetation, allowing the thickening of the floating layer by deposition of organic matter (Coutinho *et al.* 2017) and thereby had a high importance value in the sampled floating meadows.

Emergent and amphibious species are commonly representative in phytosociological surveys (Pott *et al.* 1989, Pott & Pott 1997), whilst epiphytic were the most abundant in surveys on floating meadows (Pivari *et al.* 2008). Although one of the most abundant life forms recorded in our work had been free floating, in another study on floating meadows, some of the same species, such as *Limnobium laevigatum* and *Utricularia gibba* can be considered "casual epiphytes" for showing to be adapted to the conditions of the histosol (floating organic soil layer), occurring rooted on it (Pivari *et al.* 2008).

The similarity between both formations is an expected outcome, once the floating meadows can develop from nearshore plants and contact them during displacements within the lake. We highlight the great number of exclusive species recorded on floating meadows, such result can be explained as much by environmental factors (*i.e.*, related to the interaction between species and characteristics of the environment and of the histosol), as by spatial (*i.e.*, dispersal capacity), that favor the colonization of the floating meadows by species absent on nearshore. Considering that the floating meadows need a number of years to develop, they can serve to estimate, for example, how long a lake or pond has not dried out or if there are surface nesting sites.

The total number of species recorded specifically on floating meadows (38 species) was intermediate compared with other surveys in the Pantanal (66 species by Pivari *et al.* 2008; 37 spp. by Catian *et al.* 2012; 47 spp. by Cunha *et al.* 2012; 44 spp. by Rocha *et al.* 2015; 58 spp. by Coutinho *et al.* 2017; the latter was conducted in the same oxbow lake but

for a longer period of time). The species richness recorded on floating meadows in this oxbow lake represents 13.5% of the total estimated number of aquatic macrophytes for the entire Pantanal (Pott *et al.* 2011). These results indicate that this biological compartment is of great importance for the understanding of ecological processes associated with this aquatic environment, once there is a direct relationship between species richness and its ecosystem functionality (Maestre *et al.* 2012).

In addition to expanding our knowledge on the floristic composition of aquatic environments, our study also generates information about the structure and colonization dynamics of these different formations in freshwater ponds and lakes, essential parameters for the conservation and maintenance of these biological compartments and associated biodiversity.

ACKNOWLEDGEMENTS

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. We thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (Process No. 303191/2017-1) for the research grant to A. Pott. To the Federal University of Mato Grosso do Sul (Campus de Aquidauana) for the support and Dr. Ricardo Henrique Gentil Pereira for the coordination of the project in which this subproject was inserted. We thank the anonymous reviewers whose comments/ suggestions helped to improve the manuscript.

REFERENCES

Abdon, M. M., & Silva, J. S.V. 2006. Fisionomias da vegetação nas sub-regiões do Pantanal Brasileiro. São José dos Campos: INPE: Embrapa Informática Agropecuária. CD-ROM.

Aoki, C., Teixeira-Gamarra, M. C., Gamarra, R. M., Medeiros, S. C. H., Pott, V. J., Damasceno-Junior, G. A., Pott, A., & Scremin-Dias, E. 2017. Abiotic factors drive the structure of aquatic plant assemblages in riverine habitats of the Brazilian "Pantanal". Brazilian Journal of Botany, 40(2), 405–415. DOI: /10.1007/s40415-016-0345-0

Aona, L. Y. S., Costa, G. M., Amaral, M. C. E., Faria, A. D., Duarte, E. F., & Brittrich, V. 2015. Aquatic and marsh plants from the Recôncavo basin of Bahia state, Brazil: checklist and life forms. Check List, 11(6), 1–10. DOI: 10.15560/11.6.1806

APG IV - Angiosperm Phylogeny Group. 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society, 181(1), 1–20. DOI: 10.1111/boj.12385

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

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. Brazilian Journal of Botany, 41(1), 65–75. DOI: 10.1007/s40415-017-0425-9

Cunha, N. L., Delatorre, M., Rodrigues, R. B., Vidotto, C., Gonçalves, F., Scremin-Dias, E., Damasceno-Junior, G. A., Pott, V. J., & Pott, A. 2012. Structure of aquatic vegetation of a large lake, western border of the Brazilian Pantanal. Brazilian Journal of Biology, 72(3), 1–13. DOI: 10.1590/S1519-69842012000300015

Damasceno-Junior, G. A., & Pott, A. 2011. Métodos de amostragem em estudos fitossociológicos sugeridos para o Pantanal. In: J. M. Felfili, P. V. Eisenlohr, M. M. R. F. Melo, L. A. Andrade, & J. A. A. Meira-Neto (Eds.), Fitossociologia no Brasil: Métodos e estudos de caso. pp. 295–323. Viçosa: Editora UFV.

Ferreira, F. A., Mormul, R. P., Thomaz, S. M., Pott, A., & Pott, V. J. 2011. Macrophytes in the upper Paraná river floodplain: checklist and comparison with other large South American wetlands. Revista de Biologia Tropical, 59(2), 541–556.

Gomes, A. C., & Aoki, C. 2015. Efeito da sazonalidade hídrica sobre a fitossociologia de macrófitas aquáticas em uma lagoa no Pantanal, Brasil. Revista de Biologia Neotropical, 12(1), 1–7. DOI: 10.5216/rbn.v1i1.33966

Harris, M. B., Tomas, W., Mourão, G., Silva, C. J., Guimarães, E., Sonoda, F., & Fachim, E. 2005. Safeguarding the Pantanal wetlands: Threats and conservation initiatives. Conservation Biology, 19(3), 714–720. DOI: 10.1111/j.1523-1739.2005.00708.x

Irgang, B. E., Pedralli, G., & Waechter, J. L. 1984. Macrófitos aquáticos da Estação Ecológica do Taim, Rio Grande do Sul, Brasil. Roessléria, 6, 395–404.

Junk, W. J., Bayley, P. B., & Sparks, R. E. 1989. The Flood Pulse concept in River-Floodplain-Systems. Canadian Journal of Fisheries and Aquatic Sciences, 106, 110–127.

Lima, L. F., Silva, S. S. L., & Zickel, C. S. 2011. Composição florística e chave de identificação das macrófitas aquáticas ocorrentes em reservatórios do estado de Pernambuco. Rodriguésia, 62(4), 771–783. DOI: 10.1590/S2175-78602011000400006

Maestre, F. T., Quero, J. L., Gotelli, N. J., Escudero, A., Ochoa, V., Delgado-Baquerizo, M., García-Gómez, M., Bowker, M., Soliveres, S., Escolar, C., García-Palacios, P., Berdugo, M., Valencia, E., Gozalo, B., Gallardo, A., Aguilera, L., Arredondo, T., Blones, J., Boeken, B., Bran, D., Conceição, A. A, Cabrera, O., Chaieb, M., Derak, M., Eldridge, D. J., Espinosa, C. I., Florentino, A., Gaitán, J., Gatica, M. G., Ghiloufi, W., Gómez-González, S., Gutiérrez, J. R., Hernández, R. M., Huang, X., Huber-Sannwald, E., Jankju, M., Miriti, M., Monerris, J., Mau, R. L., Morici, E., Naseri, K., Ospina, A., Polo, V., Prina, A., Pucheta, E., Ramírez-Collantes, D. A., Romão, R., Tighe, M., Torres-Díaz, C., Val, J., Veiga, J. P., Wang, D., & Zaady, E. 2012. Plant species richness and ecosystem multifunctionality in global drylands. Science, 335(6065), 214–218. DOI: 10.1126/science.1215442

Marengo, J. A., Alves, L. M., & Torres, R. R. 2015. Regional climate change scenarios in the Brazilian Pantanal watershed. Climate Research, 68(2-3), 201–213. DOI: 10.3354/cr01324

Meyer, S. T., & Franceschinelli, E. V. 2011. Influência de variáveis limnológicas sobre a comunidade das macrófitas aquáticas em rios e lagoas da Cadeia do Espinhaço, Minas Gerais, Brasil. Rodriguésia, 62(4), 743–758. DOI: 10.1590/S2175-78602011000400004

Moura-Júnior, E. G., Paiva, R. M. S., Ferreira, A. C., Pacopahyba, L. D., Tavares, A. S., Ferreira, F. A., & Pott, A. 2015. Updated checklist of aquatic macrophytes from Northern Brazil. Acta Amazonica, 45(2), 111–132. DOI: 10.1590/1809-4392201402662

Neiff, J. J. 1982. Esquema sucesional de la vegetacion en islas flotantes del chaco argentino. Boletin de la Sociedad Argentina de Botanica, 21, 325–341.

Peel, M. C., Finlayson, B. L., & McMahon, T. A. 2007. Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences, 11(5), 1633–1644. DOI: 10.5194/hess-11-1633-2007

Pierini, S. A., & Thomaz, S. M. 2004. Adaptações de plantas submersas à absorção do carbono inorgânico. Acta Botanica Brasilica, 18(3), 629–641. DOI: 10.1590/S0102-33062004000300020

Pivari, M. O. D., Pott, V. J., & Pott, A. 2008. Macrófitas aquáticas de ilhas flutuantes (baceiros) nas sub-regiões do Abobral e Miranda, MS, Brasil. Acta Botanica Brasilica, 22(2), 559–567. DOI: 10.1590/S0102-33062008000200023

Pivari, M. O. D., Oliveira, V. B., Costa, F. M., Ferreira, R. M., & Salino, A. 2011. Macrófitas aquáticas do sistema lacustre do Vale do Rio Doce, Minas Gerais, Brasil. Rodriguésia, 62(4), 759–770. DOI: 10.1590/S2175-78602011000400005

Pivari, M. O. D., Melo, P. H. A., Souza, F. S., Stehmann, J. R., Moura-Júnior, E. G., Moreira, S. N., Pott, V. J., Pott, A., Lopes, A., Moço, M. C. C., Oliveira, L. S., Lins, A. L. A., Arruda, R., Morais, I. L., Silva, G. S., & Ferreira, R. M. 2019. New initiatives for Brazilian aquatic plant data management. Acta Botanica Brasilica, 33(1), 78–87. DOI: 10.1590/0102-33062018abb0280

Pott, V. J., Bueno, N. C., Pereira, R. A. C., Sales, S. M., & Vieira, N. L. 1989. Distribuição de macrófitas aquáticas numa lagoa na fazenda Nhumirim, Nhecolândia, Pantanal, MS. Acta Botanica Brasilica, 3(2), 135–168. DOI: 10.1590/S0102-33061989000300015

Pott, V. J., & Pott, A. 1997. Checklist das macrófitas aquáticas do Pantanal, Brasil. Acta Botanica Brasilica, 11(2), 215–227. DOI: 10.1590/S0102-33061997000200010

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. M. Thomaz & L. M. Bini (Eds.), Ecologia e manejo de macrófitas aquáticas. pp. 145–162. Maringá: Editora da Universidade Estadual de Maringá.

Pott, V. J., Pott, A., Lima, L. C. P., Moreira, S. N., & Oliveira, A. K. M. 2011. Aquatic macrophyte diversity of the Pantanal wetland and upper basin. Brazilian Journal of Biology, 71(1), 255–

263. DOI: 10.1590/S1519-69842011000200004

Rocha, C. G., Resende, U. M., & Lugnani, J. S. 2007. Diversidade de macrófitas em ambientes aquáticos do IPPAN na Fazenda Santa Emília, Aquidauana, MS. Revista Brasileira de Biociências, 5(2), 456–458.

Rocha, M., Santos-Júnior, C. C., Damasceno-Junior, G. A., Pott, V. J., & Pott, A. 2015. Effect of fire on a monodominant floating mat of *Cyperus giganteus* Vahl in a neotropical wetland. Brazilian Journal of Biology ,75(1), 114–124. DOI: 10.1590/1519-6984.08613

Schiavo, J. A., Pereira, M. G., Miranda, L. P. M., Dias Neto, A. H., & Fontana, A. 2010. Caracterização e classificação de solos desenvolvidos de arenitos da formação Aquidauana-MS. Revista Brasileira de Ciência do Solo, 34(3), 881–889. DOI: 10.1590/S0100-06832010000300029

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.

Smith, A. R., Pryer, K. M., Schuettpelz, E., Korall, P., Schneider, H., & Wolf, P. G. 2006. A classification for extant ferns. Taxon, 55(3), 705–731. DOI: 10.2307/25065646

The Brazil Flora Group. 2018. Lista de espécies da flora do Brasil. Retrieved from http://floradobrasil.jbrj.gov.br/2017

Wantzen, K. M., Drago, E., & Silva, C. J. S. 2005. Aquatic habitats of Upper Paraguay river floodplain-system and parts of the Pantanal (Brazil). Ecohydrology & Hydrobiology, 6(2), 107–126.

Submitted: 10 October 2018
Accepted: 10 August 2019
Published online: 16 December 2019
Associate Editor: Gudryan J. Barônio