Aquatic macrophytes in Paraguay River branches in the Brazilian *Pantanal*, Mato Grosso do Sul, Brazil

Macrófitas aquáticas em braços do rio Paraguai, no Pantanal brasileiro, Mato Grosso do Sul, Brasil

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Abstract: Our objective was to inventory the flora of aquatic macrophytes and their life forms, and to determine the species similarity in different water bodies. Sampling of the vegetation was carried out in 333 plots of 0.5 x 0.5 m along ten transect lines on a boat to best cover the studied areas. Poaceae (18.9%), Cyperaceae (9.4%), Fabaceae, Onagraceae, and Pontederiaceae (7.5% each) were the most represented families. Emergent (56.6%), free floating (20.8%), rooted floating (18.9%), and amphibious (13.2%) were the most common life forms. We observed dissimilarity between most sampled points. We conclude from the inventory of aquatic macrophytes that the most prevalent species are common to other similar physiognomies in the *Pantanal* and the prevalent life forms corroborate the importance of flood in this environment, since they are typical of plants adapted to the flooded and dry transition. Even though the species richness is comparable to other areas, the plant communities inventoried separately are heterogeneous and respond in distinct ways to local environmental conditions.

Keywords: Floristic similarity. Herbaceous flora. Life forms. Species richness.

Resumo: O objetivo do presente estudo foi inventariar a flora de macrófitas aquáticas e as suas formas de vida em diferentes corpos hídricos, bem como determinar a similaridade de espécies. A amostragem da vegetação foi realizada em 333 parcelas, com 0,5 x 0,5 m, em dez transecções, utilizando-se barco a motor de modo a melhor cobrir as áreas estudadas. Poaceae (18,9%), Cyperaceae (9,4%), Fabaceae, Onagraceae e Pontederiaceae (7,5% cada) foram as famílias mais representativas. Entre as formas de vida registradas, emergente (56,6%), flutuante livre (20,8%) e flutuante fixa (18,9%) foram as mais expressivas. Com os resultados obtidos, observamos dissimilaridade entre a maioria dos pontos amostrados. Com isso, concluímos que as espécies prevalentes no inventário da riqueza de macrófitas aquáticas são comuns a outras fitofisionomias similares no Pantanal, e as formas de vida prevalentes corroboraram a importância da inundação para o ambiente, pois são típicas de espécies que se adaptam bem em transição de ambiente seco e alagado. Note-se que, mesmo a riqueza total de espécies sendo comum a outras áreas, as comunidades vegetais inventariadas separadamente são variáveis e respondem de maneira distinta às condições ambientais locais.

Palavras-chave: Similaridade florística. Flora herbácea. Formas de vida. Riqueza de espécies.

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INTRODUCTION

Aquatic macrophytes, according to Cook (1996), are plants visible to the naked eye whose actively photosynthesizing parts are permanently, or for several months every year, totally or partially submerged in fresh or brackish water, and that occur in great abundance in water bodies of different depths. These plants evolved various life forms (Irgang & Gastal Jr., 1996) that respond directly to abiotic factors such as water depth (Matias *et al.*, 2003). Pott *et al*. (2011) estimate that *c.* 280 species with distinct life forms occur in the *Pantanal*. these species perform important environmental (ecological and economical) services, especially in shallow water ecosystems such as floodplains where conditions are ideal for the colonization of large areas and high rates of primary production (Hamilton, 1993; Esteves, 2012).

Because it presents an extensive territory (Pereira *et al*., 2006) surrounded by different phytogeographic provinces, such as the Cerrado, Atlantic Forest, Amazonia and Chaco (Adámoli, 1982), under direct influence of flood pulse (Junk & Da Silva, 1999), the *Pantanal* wetland displays a peculiar heterogeneous mosaic of environments and consequently favors the establishment of typical aquatic plant communities and a highly diversified flora (Pott & Pott, 2000; Alho & Sabino, 2012).

Considering the importance of the aquatic macrophyte communities of the *Pantanal*, our objective was to inventory the aquatic plants and their life forms in different water bodies in the Paraguay River and to determine the species similarity.

MATERIAL AND METHODS

STUDY AREA

The inventoried areas are located in the sub-region of the Paraguay River: point 1 (P1) – 'underwater garden' (18° 29' 58" S, 57° 18' 17" W); point 2 (P2) – wild rice (18° 29' 49" S, 57° 20' 24" W); point 3 (P3) – *Thalia* stand ('Caetezal') (18° 30' 08" S, 57° 18' 26" W); point 4 (P4) – floating meadow ('Baceiro') (18° 29' 41" S, 57° 19' 29" W); and point 5 (P5) – wild rice/*Thalia* stand (18° 28' 50" S, 57° 20' 16" W), in the upper Paraguay River basin (Figure 1). The predominant regional climate is type Awa (Köppen, 1948), with an average annual rainfall of 1,100 mm and mean temperature of 25.1 °C. The studied sites, rivers Paraguay, Paraguai Mirim, and Negrinho, are the main

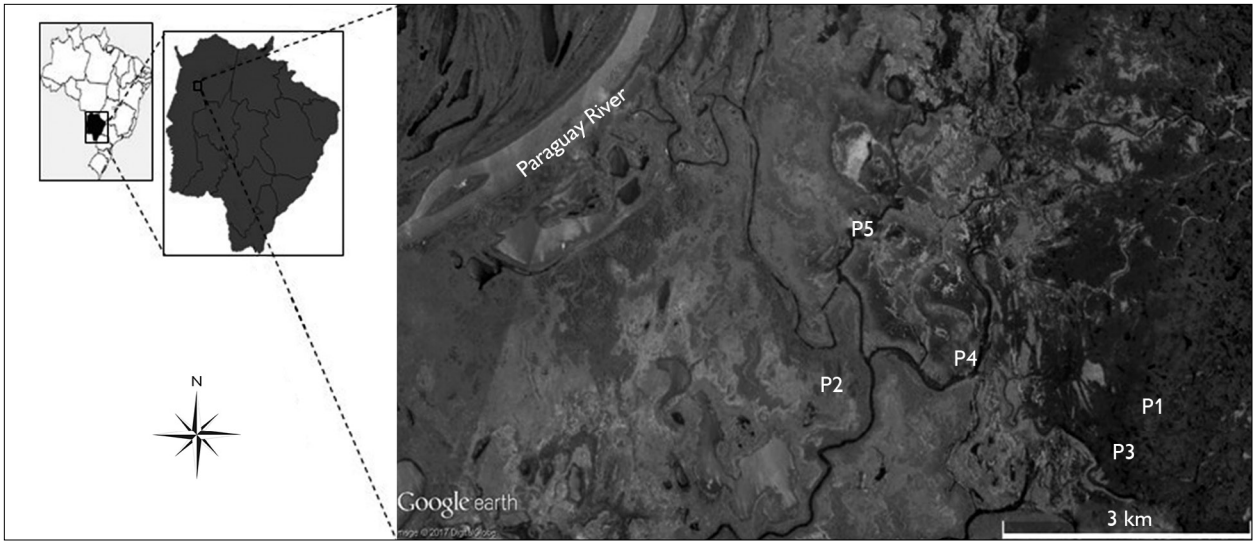

Figure 1. Location of the sampling points (P1 to P5) in the floodplains and branches of the rivers Paraguay, Paraguai Mirim, and Negrinho, in the sub-region of the Paraguay River, *Pantanal*, Mato Grosso do Sul, Brazil.

water courses of this sub-region (Galdino *et al*., 2006). The branches Paraguai Mirim and Negrinho, resulting from avulsion of the Taquari River, present waters with high transparency, compared with the turbid Paraguay River (Pott *et al*., 1997; Tucci *et al*., 1997; Mercante *et al*., 2007).

DATA COLLECTION

The study was carried out during the flood season, at five distinct points – point 1/'underwater garden'; point 2/ wild rice; point 3/*Thalia* stand ('Caetezal'); point 4/floating meadow ('Baceiro' – islands of floating vegetation; Pivari *et al*., 2008); and point 5/wild rice/*Thalia* stand – distributed in the rivers Paraguay, Paraguai Mirim, and Rio Negrinho (Figure 1). Point 1 is located further away from the river, on a small branch with slow water flow and more submerged species. All other points (P2, P3, P4, and P5) are located on the Paraguay River margin, under direct influence of its overflow. The sampling points were named according to the characteristics of the vegetation or its predominant species. The points were chosen according to their representativity of different physiognomies.

The aquatic macrophyte community was inventoried along ten straight transect lines, on board a motor boat. On both sides of the boat, at 2 m intervals, we placed polyvinyl chloride (PVC) quadrats of 0.5 x 0.5 m and recorded all species, considering their presence and absence inside the frame. We sampled at total 333 plots. Transect length varied between 30 and 90 m, corresponding to the difficulty to access the sample.

Fertile specimens were collected and identified with assistance from taxonomists and aquatic plant guides (*e.g.*, Pott & Pott, 2000). Vouchers were deposited (only plants with reproductive material were included) in the Campo Grande Mato Grosso do Sul Herbarium (CGMS) of the Universidade Federal de Mato Grosso do Sul. For the classification of Bryophytes, we followed Crandall-Stotler *et al*. (2009), for Pteridophytes we utilized the Pteridophyte Phylogeny Group (PPG I, 2016), and for Angiosperms, the Angiosperm Phylogeny Group (APG, 2016).

Life forms were determined following Irgang & Gastal Jr. (1996): emergent, amphibious, free floating, rooted floating, free submerged, rooted submerged, and epiphyte. Some species displayed more than one life form, but we considered only the life form observed at the moment of sampling. For the calculation of floristic similarity between points with data on the presence and absence of species, we utilized Jaccard's Index of Similarity (Müller-Dombois & Ellenberg, 1974). We used the grouping Unweighted Pair-Group Method (UPGMA) to build a dendrogram (Sneath & Sokal, 1973).

RESULTS

In the five sampling points we recorded 23 families, 38 genera, and 53 species of aquatic macrophytes. Bryophytes were represented by a single family (Ricciaceae), Pteridophytes by four families (Azollaceae, Marsileaceae, Pteridaceae, and Salviniaceae), and Angiosperms, the great majority, by 18 families. The ten richest families of Angiosperms were: Poaceae (18.9%), Cyperaceae (9.4%), Fabaceae, Onagraceae, and Pontederiaceae (7.5% each), Araceae, Convolvulaceae, and Lentibulariaceae (5.7% each), and Alismataceae and Polygonaceae (3.8% each). The other families had a single species each (1.9%). These ten most speciose families contributed with 75.4% of the species richness of the sampled areas (see Appendix). The richest genera were *Ludwigia* and *Utricularia* with three species each.

The species richness varied among points. The richest point was P3 (37 species), represented mainly by the monodominant *Thalia* stand ('Caetezal'), followed by P2 (34 species), in vegetation of wild rice (*Oryza* spp.). The points with the lowest species richness were the 'underwater garden' (21 species) and P4 (23 species), a very peculiar vegetation type of the *Pantanal*, the floating meadows.

Emergent (56.6%), free floating (20.7%), and rooted floating (17%) were the most abundant life forms (Appendix and Figure 2). The emergent form was the most representative in all points, following by the free floating form. All seven life forms were observed only at P3 (Appendix and Figure 2).

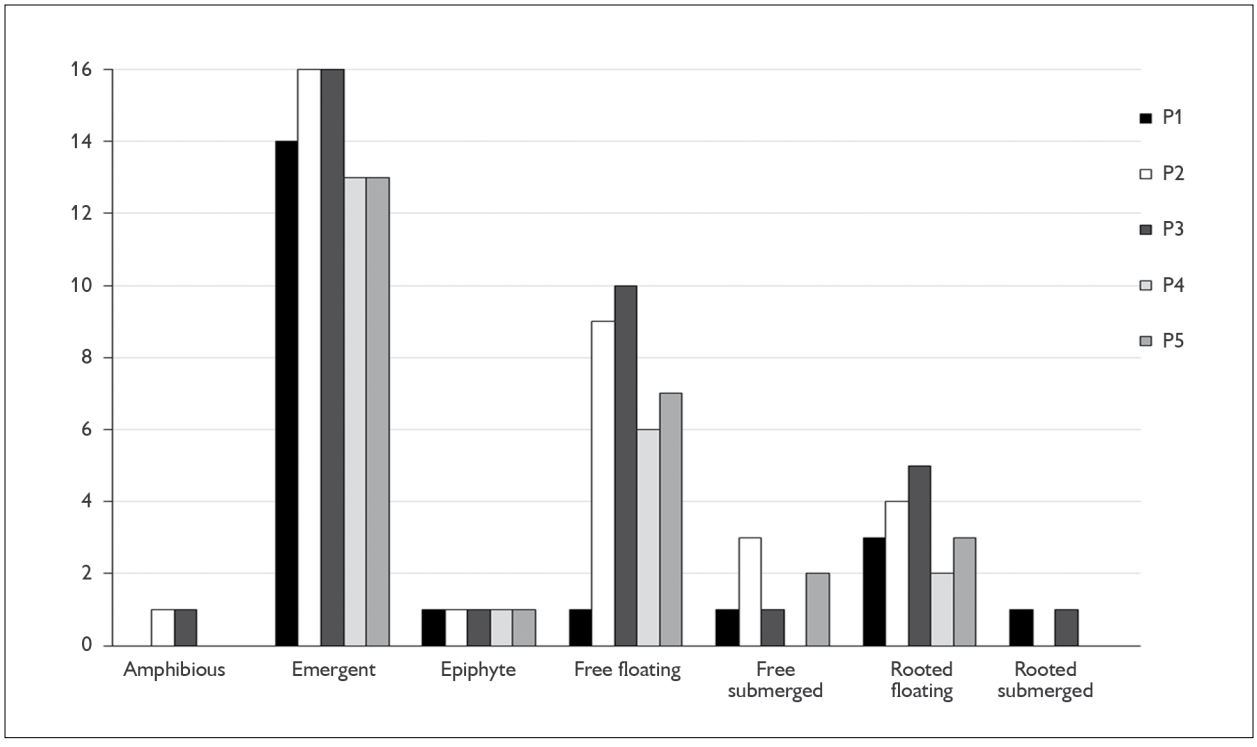

Figure 2. Number of species per life form, inventoried in the sub-region of the Paraguay River, *Pantanal* wetland, Mato Grosso do Sul, Brazil. Legends: point 1 (P1) = 'underwater garden'; point 2 (P2) = wild rice; point 3 (P3) = *Thalia* stand ('Caetezal'); point 4 (P4) = floating meadow ('Baceiro'); and point 5 (P5) = wild rice/*Thalia* stand.

According to the cluster analysis for species composition of the aquatic macrophyte communities in the five sampling points, the floristic similarity between points P2 and P5 was higher than in relation to points P3, P4 and P1 (Figure 3). Independently of their similarities, practically all points presented species of exclusive occurrence: P2 (*Aeschynomene sensitiva*, *Ipomoea alba*, *I. chiliantha*, and *Panicum dichotomiflorum*), P3 (*Ceratopteris pteridoides*, *Hymenachne donacifolia*, *Ludwigia sedoides*, *Mikania micrantha*, *Scleria variegata*, and *Wolffiella lingulata*), P4 (*Cyperus esculentus*, *Echinochloa polystachya*, *Echinodorus lanceolatus*, *Marsilea crotophora*, and *Utricularia hydrocarpa*), while P5 did not have any exclusive species. Seven species were common to all five points: *Eichhornia azurea*, *Hymenachne amplexicaulis*, *Leersia hexandra*, *Oxycaryum cubense*, *Polygonum acuminatum*, *Salvinia auriculata,* and *Vigna lasiocarpa*.

DISCUSSION

The floristic inventory showed that the most representative families also were the most common in other areas with similar physiognomies along the Paraguay River (Pott & Pott, 2000; Pivari *et al*., 2008; Catian *et al*., 2012; Cunha *et al*., 2012). Such large representativity is explained by Poaceae and Cyperaceae having genera with 30% and 9% of aquatic species, respectively (Cook, 1999).

Irgang & Gastal Jr. (1996) reported that generally the amphibious (seventh position in this work) and emergent (first) life forms are more representative than the other forms. This is justified by the fact that amphibious species colonize habitats functioning as ecotones between wet and dry zones. They have adequate morphological traits for either terrestrial or aquatic environments. On the other hand, emergent plants, found in littoral zones, benefit from high primary productivity, consequently with highest concentrations of

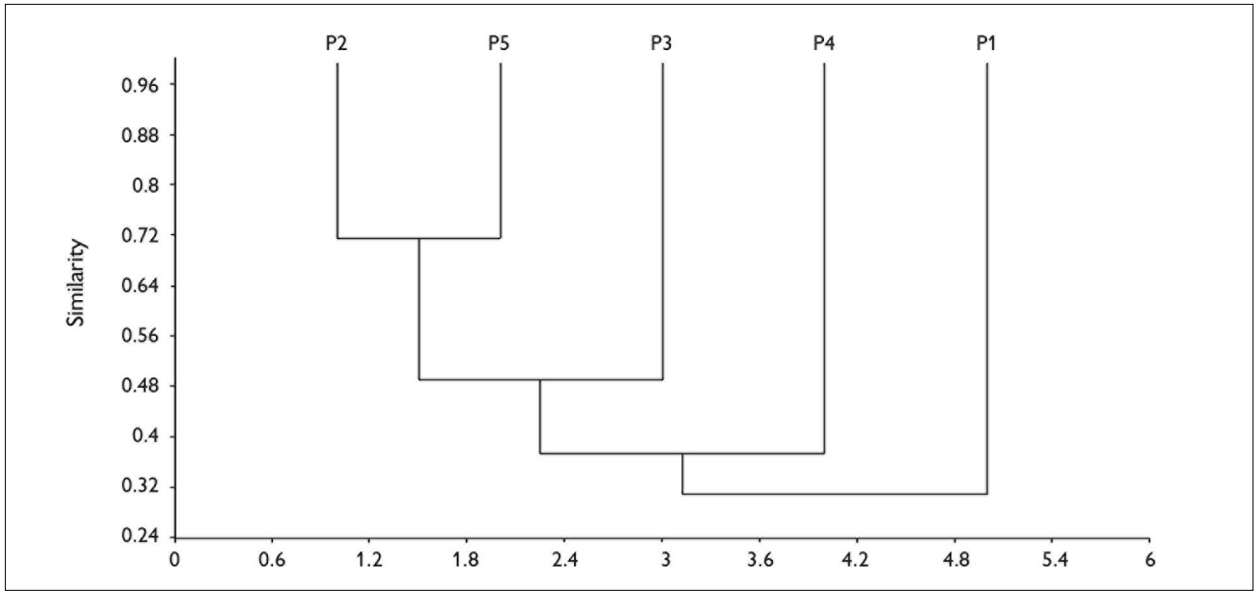

Figure 3. Dendrogram of similarity (Jaccard's index) with UPGMA ordination applied to species of communities of aquatic macrophytes in five sampling points in the sub-region of the Paraguay River, in the *Pantanal* wetland, Mato Grosso do Sul, Brazil. Cophenetic correlation: 0.97. Legends: point 1 (P1) = 'underwater garden'; point 2 (P2) = wild rice; point 3 (P3) = *Thalia* stand ('Caetezal'); point 4 (P4) = floating meadow ('Baceiro'); and point 5 (P5) = wild rice/*Thalia* stand.

nutrients, and high species diversity (Esteves, 2012), in both environments of the *Pantanal* (Ferreira *et al*., 2010; Catian *et al*., 2012), as well as in temporarily and permanently flooded sites (Cervi *et al*., 2009).

In our study, beside the emergent life form, the free floating form was the second most common form. Catian *et al*. (2012) reported a large number of floating species in the Paraguay River: *Eichhornia azurea*, *Lemna aequinoctialis*, *Limnobium laevigatum*, *Phyllanthus fluitans,* and *Ricciocarpus natans*. We recorded an additional seven free floating species: *Azolla filiculoides*, *Ceratopteris pteridoides*, *Eichhornia crassipes*, *Ludwigia helminthorrhiza*, *Pistia stratiotes*, *Salvinia auriculata,* and *Wolffiella lingulata*. Free floating plants are easily displaced by wind and by water currents (Pitelli *et al*., 2008), a reason for why we found them along aquatic habitats where they grow intermingled with other life forms. Also, the environments are very large and open, subject to variation in wind exposition and water speed. This creates different conditions for floating species, increasing the possibilities of colonization.

The analysis of similarity among points reflects the dissimilarity present in the aquatic environments of the *Pantanal* (Esteves & Camargo, 1986; Nakatani *et al*., 1997; Weaver *et al*., 1997; Catian *et al*., 2012). Probably what differs point 1 from the others is the occurrence of subaquatic vegetation – 'underwater garden', with three exclusive species: *Echinodorus paniculatus*, *Pontederia parviflora,* and *Scleria melaleuca*, highlighting the importance of water transparency for the occurrence of certain species (Esteves, 2012).

The lack of exclusive species in P5 is probably due to its downstream location in relation to the other points (Figure 1), where wild rice and *Thalia* stands predominated, already sampled in the previous points. Several species of Poaceae and Cyperaceae that occur upstream to point 5 present various types of propagation, such as rhizomes, stolons, and seeds (Pott & Pott, 2000). This feature explains their high capacity of propagation and colonization of differentiated habitats. The highest similarity between point 2 and point 5 is attributed to their spatial proximity, as observed on the map. Some authors (*e.g.*, Baattrup-Pedersen

et al., 2006; Chambers *et al*., 2008) argued that rivers are hierarchically structured and the composition of the macrophyte communities they support is influenced by a combination of local variables and environmental factors.

CONCLUSIONS

We conclude from the inventory of aquatic macrophyte species richness that the most representative species are common to other similar physiognomies in the *Pantanal* and the prevalent life forms demonstrate the importance of flooding in this environment, since they are typical of plants well adapted to the dry and flooded transition. Even though the species richness is comparable to other areas, the plant communities inventoried separately are heterogeneous and respond in distinct ways to local environmental conditions. Our work is a preliminary contribution, and we expect to encourage further studies to evaluate environmental parameters in order to better understand the aquatic macrophyte communities of the Pantanal.

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Appendix. List of families and species of aquatic macrophytes recorded in the sub-region of the Paraguay River, Mato Grosso do Sul, Brazil. Number 1 represents presence and (-) means absence of the species at the sampling point (P1 to P5). Legends: E = emergent; A = amphibious; FF = free floating; RF = rooted floating; FS = free submerged; RS = rooted submerged; Ep = epiphyte; CGMS = herbarium number. (Continue)

Family	Specie	Life form	P1	P2	P3	P4	P5	CGMS
Acanthaceae	*Justicia laevilinguis* (Nees) Lindau	E	-	1	1	-	-	27257
Alismataceae	*Echinodorus lanceolatus* Rataj	E	-	1	-	-	-	-
	Echinodorus paniculatus Micheli	E	1	-	-	-	-	29027
Apocynaceae	*Rhabdadenia madida* (Vell.) Miers	E	1	-	-	1	-	27229
Araceae	*Lemna aequinoctialis* Welw.	FF	-	1	1	1	1	27271
	Pistia stratiotes L.	FF	-	1	1	-	1	-
	Wolffiella lingulata (Hegelm.) Hegelm.	FF	-	-	1	1	-	-
Asteraceae	*Mikania micrantha* Kunth	E	-	-	1	-	-	27262
Azollaceae	*Azolla filiculoides* Lam.	FF	-	1	1	-	1	27256
Convolvulaceae	*Aniseia martinicensis* (Jacq.) Choisy	E	1	-	1	-	1	27270
	Ipomoea alba L.	E	-	-	-	1	-	27222
	Ipomoea chiliantha Hallier f.	E	-	-	-	1	-	27265
Cyperaceae	*Cyperus esculentus* L.	A	-	1	-	-	-	-
	Eleocharis minima Kunth	E	1	-	1	-	-	48000
	Oxycaryum cubense (Poepp. & Kunth) Palla	Ep	1	1	1	1	1	-
	Scleria melaleuca Rchb. ex Schltr. & Cham.	E	1	-	-	-	-	27274
	Scleria variegata Steud.	A	-	-	1	-	-	36093
Euphorbiaceae	*Caperonia castaneifolia* (L.) A. St.-Hil.	E	-	1	-	-	1	27227
Fabaceae	*Aeschynomene rudis* Benth.	E	-	1	-	-	1	27231
	Aeschynomene sensitiva Sw.	E	-	1	-	1	-	27278
	Sesbania exasperata Kunth	E	1	-	1	-1	-	27277
	Vigna lasiocarpa (Mart. ex Benth.) Verdc.	E	1	1	1	1	1	27226
Hydrocharitaceae	*Limnobium laevigatum* (Humb. & Bonpl. ex Willd.) Hein	FF	-	1	1	1	-	27236
Lentibulariaceae	*Utricularia breviscapa* Wright ex Griseb.	FS	-	1	-	-	1	27240
	Utricularia gibba L.	FS	1	1	1	-	1	-
	Utricularia hydrocarpa Vahl	FS	-	1	-	-	-	27239
Marantaceae	*Thalia geniculata* L.	E	1	1	1	-	1	27252
Marsileaceae	*Marsilea crotophora* D.M. Johnson	FF	-	1	-	-	-	-
Onagraceae	*Ludwigia grandiflora* (Michx.) Greuter & Burdet	E	-	1	1	-	1	27245
	Ludwigia helminthorrhiza (Mart.) H. Hara	RF	-	1	1	-	1	27246
	Ludwigia inclinata (L.f.) M. Gómez	RS	1	-	1	-	-	25811
	Ludwigia sedoides (Bonpl.) H. Hara	RF	1	-	1	-	-	25745
Phyllanthaceae	*Phyllanthus fluitans* Benth. ex Müll. Arg.	FF	-	1	1	-	1	27272
Poaceae	*Echinochloa polystachya* (Kunth) Hitchc.	E	-	1	-	-	-	27243
	Hymenachne amplexicaulis (Rudge) Nees	E	1	1	1	1	1	27235

Appendix. (Conclusion)

Family	Specie	Life form	P1	P2	P3	P4	P5	CGMS
Poaceae	*Hymenachne donacifolia* (Raddi) Chase	E	-	-	1	-	-	-
	Leersia hexandra Sw.	E	1	1	1	1	1	27258
	Oryza glumaepatula Steud.	E	-	1	1	-	1	27233
	Oryza latifolia Desv.	E	1	1	-	1	1	27238
	Panicum dichotomiflorum Michx.	E	-	-	-	1	-	27232
	Louisiella elephantipes (Nees ex Trin.) Zuloaga	E	-	1	1	1	1	27247
	Paspalum wrightii (Hitchc.) Chase	E	-	1	-	-	1	27254
	Paspalum repens P.J. Bergius	RF	-	1	1	1	1	-
Polygonaceae	*Polygonum acuminatum* Kunth	E	1	1	1	1	1	-
	Polygonum ferrugineum Wedd.	E	-	-	1	1	-	-
Pontederiaceae	*Eichhornia azurea* (Sw.) Kunth	RF	1	1	1	1	1	36098
	Eichhornia crassipes (Mart.) Solms	FF	-	1	1	1	1	-
	Pontederia parviflora Alexander	E	1	-	-	-	-	28498
	Pontederia rotundifolia L. f.	RF	1	1	1	-	-	28484
Pteridaceae	*Ceratopteris pteridoides* (Hook.) Hieron.	FF	-	-	1	-	-	36090
Ricciaceae	*Ricciocarpos natans* (L.) Corda	FF	-	1	1	1	1	27242
Salviniaceae	*Salvinia auriculata* Aubl.	FF	1	1	1	1	1	-
Vitaceae	*Cissus spinosa* Cambess.	E	1	-	1	1	-	27260