

The Aquatic Macrophyte Flora of the Pandeiros River Wildlife Sanctuary, Minas Gerais, Brazil

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ABSTRACT: The São Francisco River forms one of the main Brazilian hydrographic basins of ca. 645,000 km². The Pandeiros River is a tributary situated on the left margin of the São Francisco and is considered a strategic component for conservation of biodiversity of that hydrographic basin. An inventory of the aquatic macrophyte flora of the Pandeiros River Wildlife Sanctuary was carried out, using collections of botanical samples and examination of specimens at the BHC Herbarium. Aquatic environments in the study area were classified as follows: the Pandeiros riverbed, floodplains, oxbow lakes, and swamps. A total of 101 species was inventoried, distributed in 37 families (1 charophytes, 1 liverworts, 3 ferns and 32 angiosperms) and 71 genera. The species were classified into seven life forms, with the amphibian and rafted plants the more representative. The area shows a high diversity in its aquatic macrophytes and has an important role in the conservation of biodiversity of the region.

INTRODUCTION

Aquatic environments correspond to approximately 11% of the continental area of tropical regions (Rebouças *et al.* 1999). Brazil, with its largest hydrographic network in the world, has a high degree of habitat diversification, representing ecosystems that make up its natural landscape (Bove *et al.* 2003). However, several aquatic environments have been drained or eliminated in the last decades as a result of the expansion of agricultural activities, industrial development, urbanization, establishment of hydroelectric power reservoirs, and by attempts to eliminate breeding sites of disease vectors (Esteves 1988). These factors have been responsible for the disappearance of numerous habitats and, therefore, the plant diversity associated with them, potentially influencing fundamental ecologic processes, such as the nutrient cycling and primary productivity of water bodies.

The São Francisco forms one of the main Brazilian hydrographic basins with ca. 645,000 km² (7.5% of the country's area), of great social, economic, cultural, and biological relevance (Kohler 2003). Severe anthropic pressure of the last decades, such as the elimination of riparian forests and the transposition of its waters (a project carried out by the National Integration Ministry of the Brazilian Government) have had a negative impact on its biota that can be readily observed at several of its stretches.

The São Francisco rises in Minas Gerais, where several of its medium to large tributaries are found, accounting for more than 70% of its water (Kohler 2003). Some of those are located in the northern part of the state, an ecotonal area between the two important Brazilian biogeographic domains, the Caatinga and the Cerrado. A mosaic of different phyto-physiognomies is found in the region (Lombardi *et al.* 2005), composed of savannas, deciduous forests (associated with limestone outcrops), riparian

forests, and several aquatic macrophyte environments, associated with watercourses (Barbosa and Maillard 2010).

Even though the need for special attention to preserve the biodiversity in northern Minas Gerais is strongly felt, very few efforts focusing on documenting its floristic diversity have been made so far. The present study aims to contribute to the knowledge of its regional flora, and more specifically, to the study of aquatic macrophytes of the Pandeiros River Wildlife Sanctuary.

MATERIALS AND METHODS

Study site

The Pandeiros River is a tributary situated on the left margin of the São Francisco and is considered a strategic component in the conservation of biodiversity of that hydrographic basin, particularly with respect to its ichthyofauna (Sato and Godinho 2003). The Pandeiros encompasses the most expressive swamp (known locally as *pântano*) in the state, extending to up to 5,000 ha during the rainy season (Nunes *et al.* 2009) and highly favorable to the establishment of aquatic macrophytes. This unique ecosystem is regarded as a priority area for the biodiversity conservation of the Cerrado domain (Conservação Internacional 1999) in the state (Drummond *et al.* 2005) and has two conservation units: the Pandeiros River Wildlife Sanctuary (with full protection) and the Environmental Protection Area of the Pandeiros River (with sustainable use).

The Pandeiros River Wildlife Sanctuary is located in the municipality of Januária, Minas Gerais, and is delimited by the coordinates of 15°30' to 15°42' S and 44°35' to 44°46' W, occupying a total area of 6,102.75 ha (Figure 1). In accordance with Köppen's (1931) classification, the climate of the region is classified as Aw, moist tropical climate with a dry season during the winter. Temperatures

range from 16°C to 34°C (with the annual mean around 24°C), while precipitation varies from 850 to 950 mm, with occasional long dry periods (Ratter *et al.* 1978). The aquatic environments in the study area can be classified as: the Pandeiros riverbed (PAN), floodplains (FLP), oxbow lakes (OXL), and swamps (SWP). Table 1 summarizes some features of these environments.

Data collection

The inventory of aquatic macrophytes of the Pandeiros River Wildlife Sanctuary was carried out during the beginning of the rainy season (September 2007) and the dry season (June 2008) in the area. Transportation for the collection of samples in the environments cited in Table 1 was done by motorboat. Fertile material was prepared in accordance with the usual techniques for collecting aquatic macrophytes (Haynes 1984; Ceska *et al.* 1986) and the specimens were deposited at the BHCN herbarium (acronym follows Thiers 2012). Additional specimens from the study area previously deposited at the BHCN were also included in the compilation.

For species identification, pertinent literature was studied, including taxonomic treatments and guides, as well as comparison with the BHCN herbarium specimens previously determined by experts. Additionally, duplicates were sent to experts for confirmation and/or identification of some species. The classification of the angiosperm families follows APG III (2009); for ferns, Kramer and Green's (1990) classification is adopted; and for charophytes and liverworts, Raven *et al.* (1990) is followed. Nomenclatural terminology and author abbreviations are

TABLE 1. Aquatic environments of the Pandeiros River Wildlife Sanctuary and their principal features.

SITES	ACRONYM	FLOODABLE	WATERFLOW
Pandeiros riverbed	PAN	Perennial	Lotic
Floodplains	FLP	Seasonal	Intermediate
Oxbow lakes	OXL	Perennial	Lentic
Swamps	SWP	Perennial	Intermediate

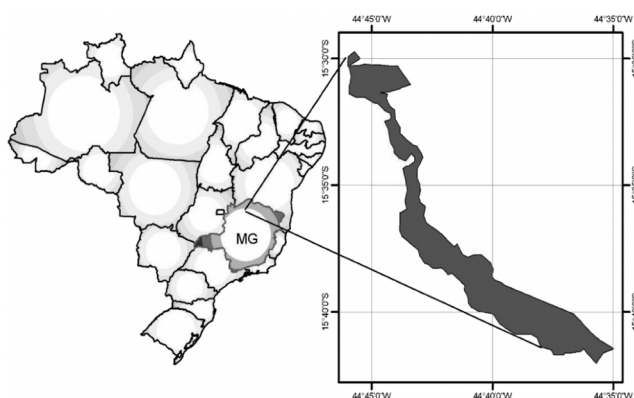


FIGURE 1. Location of the Pandeiros River Wildlife Sanctuary in Minas Gerais (MG), Brazil (extracted from Barbosa and Maillard 2010).

according to Brummit and Powell (1992). The life forms names were adopted in accordance with the classification proposed by Irgang *et al.* (1984), except for plants growing on organic soil (histosol) of floating meadows, which are classified as rafted plants, as suggested by Pivari *et al.* (2011). Data for the type of habitat for each species were obtained from exsiccate labels.

RESULTS AND DISCUSSION

A total of 101 aquatic macrophyte species was inventoried (Figures 2-6). The species are distributed in 37 families: 1 charophytes (2 spp.), 1 liverworts (1 spp.), 3 ferns (7 spp.) and 32 angiosperms (91 spp.), and 71 genera. The most represented families were Cyperaceae (10 spp.), Poaceae (9 spp.), Asteraceae (7 spp.), Fabaceae, Plantaginaceae and Pontederiaceae (with 6 spp. each), Alismataceae, Onagraceae and Rubiaceae (with 5 spp. each). The more speciose genera were *Bacopa*, *Cyperus* and *Ludwigia* (with 5 spp., each), followed by *Borreria*, *Echinodorus* and *Polygonum* (with 3 spp. each).

The inventoried species were classified into seven life forms (Table 2), with the prevalence of the amphibians (42 spp.) and rafted plants (27 spp.). The amphibian species were mostly associated with floodplains and borders of oxbow lakes, where the soil is transitional from dry to flooded during the annual hydrological cycle. The species classified as rafted plants were recorded exclusively in oxbow lakes, environments that gather adequate conditions for the establishment of floating meadows (Duzer 2004) as a result of succession of aquatic plants (Pivari *et al.* 2008) that accumulate large amounts of floating mulch and culminating in the histosol formation. Such substrate accounts for the occurrence of several aquatic macrophyte species (Pivari *et al.* 2008; Pivari *et al.* 2011). Other life forms sampled in the study were characterized as emerging (12 spp.), fixed submerged (7 spp.), free floating (6 spp.), fixed floating (5 spp.) and free submerged (2 spp., each), as in other Brazilian wetlands (Pott and Pott 2000; Pivari *et al.* 2011).

In the swamps of the Pandeiros River Wildlife Sanctuary were recorded 14 species distributed into all life forms (except rafted plants, since no floating meadows are found in that environment). Some species, such as *Azolla filiculoides*, *Ceratophyllum demersum*, *Egeria najas*, *Ludwigia inclinata*, and *Nymphaea rudgeana*, were observed exclusively in the swamps. Different life forms provide for higher heterogeneity of niches in the establishment and maintenance of aquatic fauna by creating refuges for spawning, nesting, and other specific conditions. The floodplains, on the other hand, accounted for 42% of the inventoried aquatic macrophyte species. Parts of these areas are significantly affected by cattle grazing, a common farming activity in the region. Therefore, some typical species of disturbed areas were also sampled, such as *Eclipta prostrata*, *Fuirena umbellata* and *Ludwigia octovalvis* (Lorenzi 2000).



FIGURE 2. Aquatic macrophyte species photographed at the Pandeiros River Wildlife Sanctuary: Liverworts and ferns. A. *Ricciocarpus natans* (Ricciaceae), B. *Ceratopteris pteridoides* (Pteridaceae), C. *Salvinia auriculata* (Salviniaceae), D. *Thelypteris interrupta* (Thelypteridaceae), E. *Salvinia oblongifolia* (Salviniaceae).

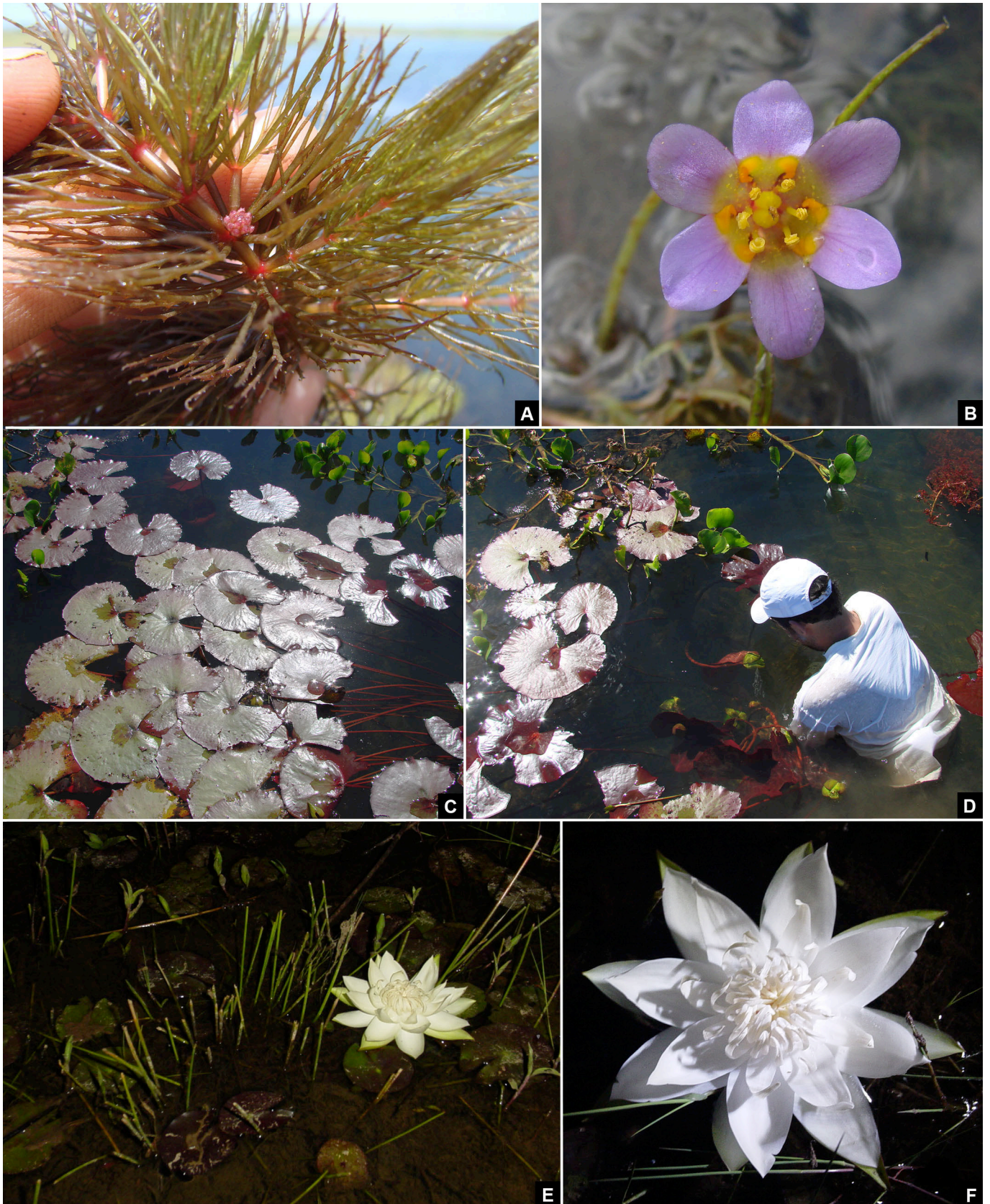


FIGURE 3. Aquatic macrophyte species photographed at the Pandeiros River Wildlife Sanctuary: Nymphaeales e Ceratophyllales. A. *Ceratophyllum demersum* (Ceratophyllaceae), B. *Cabomba furcata* (Cabombaceae), C-D. *Nymphaea rudgeana* (Nymphaeaceae), E-F. *Nymphaea lingulata* (Nymphaeaceae).



FIGURE 4. Aquatic macrophyte species photographed at the Pandeiros River Wildlife Sanctuary: Monocotyledons. A. *Helanthium bolivianum* (Alismataceae), B. *Sagittaria rhombifolia* (Alismataceae), C. *Echinodorus paniculatus* (Alismataceae), D. *Egeria najas* (Hydrocharitaceae), E. *Habenaria repens* (Orchidaceae), F. *Pontederia cordata* (Pontederiaceae), G. *Hydrothrix gardneri* (Pontederiaceae), H. *Eichhornia crassipes* (Pontederiaceae).

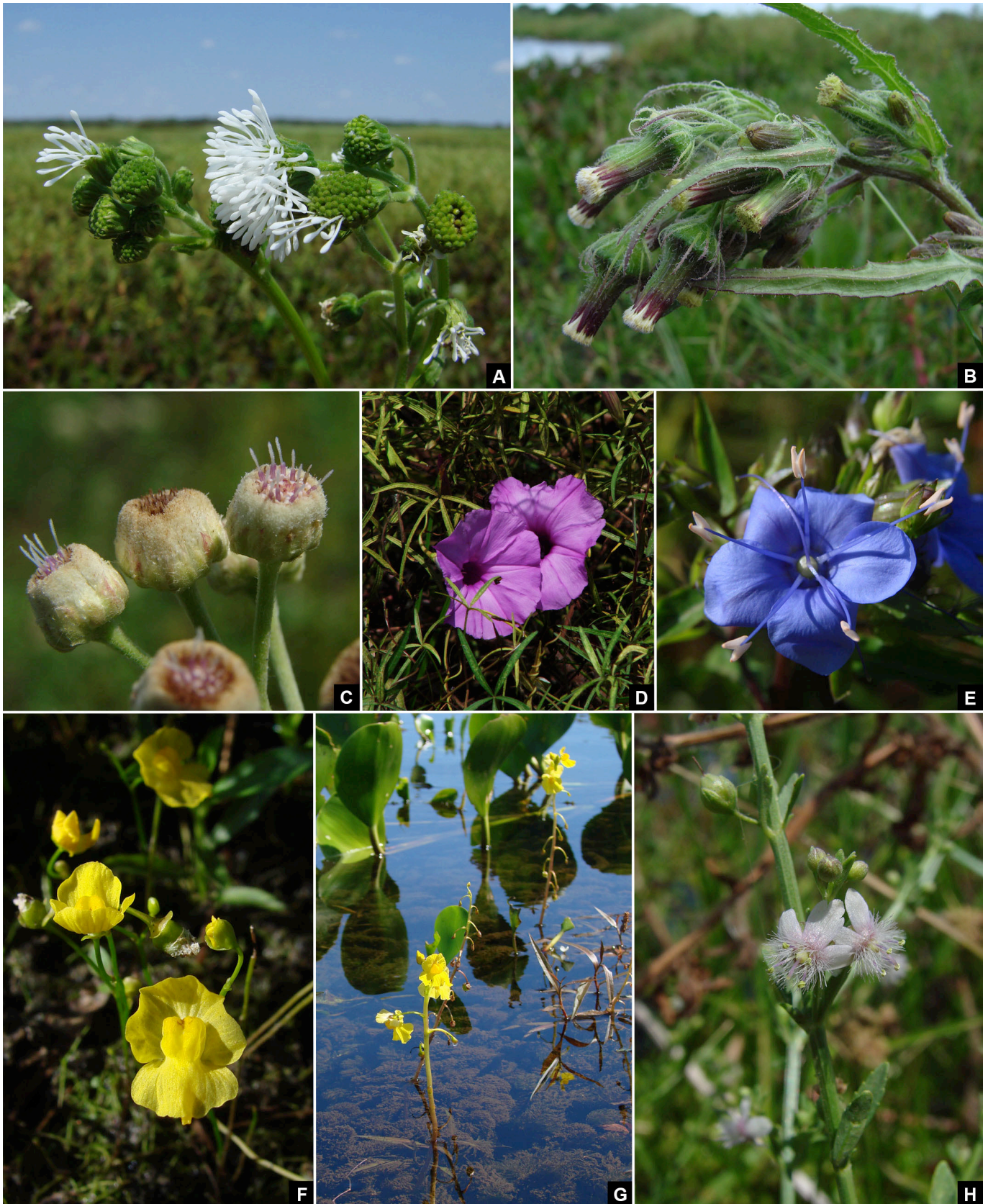


FIGURE 5. Aquatic macrophyte species photographed at the Pandeiros River Wildlife Sanctuary: Eudotyledons. A. *Gymnocoronis spilanthoides* (Asteraceae), B. *Erechites hieraciifolius* (Asteraceae), C. *Pluchea sagittalis* (Asteraceae), D. *Ipomoea* sp. (Convolvulaceae), E. *Hydrolea spinosa* (Hydroleaceae), F. *Utricularia gibba* (Lentibulariaceae), G. *Utricularia foliosa* (Lentibulariaceae), H. *Scoparia dulcis* (Plantaginaceae).



FIGURE 6. Aquatic macrophyte species photographed at the Pandeiros River Wildlife Sanctuary: Eudotyledons. A. *Ludwigia sedoides* (Onograceae), B. *Ludwigia leptocarpa* (Onograceae), C. *Ludwigia inclinata* (Onograceae), D. *Cuphea racemosa* (Lythraceae), E. *Bacopa monnierioides* (Plantaginaceae), F. *Nymphoides indica* (Menyanthaceae), G. *Cissus spinosa* (Vitaceae).

TABLE 2. Aquatic macrophyte species of the Pandeiros River Wildlife Sanctuary in Minas Gerais, Brazil (* charophytes; ** liverworts; *** ferns). Life form: A- amphibian, Em- emerging, FF- fixed floating, FL- free floating, Rf- rafted plant, SF- fixed submerged and SL- free submerged. Voucher: (collector numbers) L- J.A. Lombardi, P- M.O.D. Pivari, S- A. Salino. Aquatic environments: PAN- Pandeiros riverbed; FLP- floodplains; OXL- oxbow lakes; SWA- swamp.

TAXON	LIFE FORM	VOUCHER	PAN	FLP	OXL	SWP
Acanthaceae						
<i>Hygrophila cf. costata</i> Nees	Em	P 1030		x		
<i>Ruellia geminiflora</i> Kunth	A	L 4810			x	
Alismataceae						
<i>Echinodorus paniculatus</i> Micheli	A	P 558		x	x	
<i>Echinodorus subalatus</i> (Mart. ex Schult.f.) Griseb.	A	P 1015		x		
<i>Echinodorus grisebachii</i> Small	A	P 1027		x		
<i>Helanthium bolivianum</i> (Rusby) Lehtonen and Myllys	Em	P 1025		x		
<i>Sagittaria rhombifolia</i> Cham.	A	P 557			x	
Amaranthaceae						
<i>Pfaffia tuberosa</i> (Spreng.) Hicken	A	P 604		x		
Araceae						
<i>Pistia stratiotes</i> L.	FL	L 4801			x	
Araliaceae						
<i>Hydrocotyle bonariensis</i> Lam.	A	P 596		x		
Asteraceae						
<i>Baccharis genistelloides</i> (Lam.) Pers.	A	P 1039		x		
<i>Conocliniopsis prasiifolia</i> (DC.) R.M.King and H.Rob.	Rf	P 597			x	
<i>Eclipta prostrata</i> (L.) L.	A	P 575		x	x	
<i>Erechtites hieraciifolius</i> (L.) Raf. ex DC.	Rf	P 568			x	
<i>Gymnocoronis spilanthoides</i> (D.Don ex Hook. and Arn.) DC.	Rf	P 583			x	
<i>Pluchea sagittalis</i> Less.	Rf	P 593			x	
<i>Vernonanthura phosphorica</i> (Vell.) H.Rob.	Rf	P 609			x	
Cabombaceae						
<i>Cabomba furcata</i> Schult. and Schult.f.	SF	P 1019			x	
Ceratophyllaceae						
<i>Ceratophyllum demersum</i> L.	SL	P 578				x
Characeae *						
<i>Chara</i> sp. 1	SF	P 1024	x			
<i>Chara</i> sp. 2	SF	P 1021	x			
Commelinaceae						
<i>Commelina cf. schomburgkiana</i> Klotzsch	Rf	P 579			x	
<i>Commelina</i> sp.	A	P 594		x		
Convolvulaceae						
<i>Aniseia martinicensis</i> (Jacq.) Choisy	Rf	P 586			x	
<i>Ipomoea</i> sp.	Rf	P 553			x	
Cyperaceae						
<i>Cyperus giganteus</i> Vahl	Em	P 1053	x			
<i>Cyperus haspan</i> L.	A	P 562		x	x	
<i>Cyperus odoratus</i> L.	A	P 1034		x	x	
<i>Cyperus surinamensis</i> Rottb.	Rf	P 556			x	
<i>Cyperus</i> sp.	A	P 1048		x		
<i>Eleocharis geniculata</i> (L.) Roem. and Schult.	Em	P 1045		x	x	
<i>Eleocharis plicarhachis</i> (Griseb.) Svenson	Rf	P 610			x	
<i>Fuirena umbellata</i> Rottb.	A	P 1031		x		
<i>Kyllinga pumila</i> Michx.	A	P 1026		x		
<i>Oxycaryum cubense</i> (Poepp. and Kunth) Palla	Rf	P 567			x	
Fabaceae						
<i>Aeschynomene sensitiva</i> Sw.	Rf	P 572			x	
<i>Dioclea virgata</i> (Rich.) Amshoff	A	P 1057		x		
<i>Erythrina speciosa</i> Andrews	Em	P 1037	x			
<i>Senna splendida</i> (Vogel) H.S.Irwin and Barneby	Em	P 1042	x			
<i>Vigna cf. lasiocarpa</i> (Benth.) Verdc.	A	P 595		x		
<i>Vigna</i> sp.	A	P 617			x	
Hydrocharitaceae						
<i>Egeria najas</i> Planch.	SF	P 1018				x

TABLE 2. CONTINUED.

TAXON	LIFE FORM	VOUCHER	PAN	FLP	OXL	SWP
Hydroleaceae						
<i>Hydrolea spinosa</i> L.	A	P 559			x	
Lamiaceae						
<i>Hyptis pectinata</i> (L.) Poit.	Rf	P 592			x	
Indeterminate	A	P 1051		x		
Lentibulariaceae						
<i>Utricularia foliosa</i> L.	SL	P 573			x	
<i>Utricularia gibba</i> L.	Rf	P 566			x	
Lythraceae						
<i>Cuphea melvilla</i> Lindl.	Rf	P 1032			x	
<i>Cuphea racemosa</i> (L.f.) Spreng.	Rf	P 582			x	
Melastomataceae						
<i>Rhynchanthera</i> sp.	Rf	P 570			x	
Menyanthaceae						
<i>Nymphoides indica</i> (L.) Kuntze	A	L 4800		x		
Nymphaeaceae						
<i>Nymphaea lingulata</i> Wiersema	FF	L 4812			x	
<i>Nymphaea rudgeana</i> G.Mey.	FF	P 1017				x
Ochnaceae						
<i>Sauvagesia erecta</i> L.	A	P 1033		x		
Onagraceae						
<i>Ludwigia inclinata</i> (L.f.) M.Gómez	SF	P 1010				x
<i>Ludwigia leptocarpa</i> (Nutt.) H.Hara	A	P 554		x	x	
<i>Ludwigia octovalvis</i> (Jacq.) P.H.Raven	A	P 607		x		
<i>Ludwigia sedoides</i> (Humb. and Bonpl.) H.Hara	FF	Only photographed			x	
<i>Ludwigia</i> cf. <i>tomentosa</i> (Cambess.) H. Hara	Rf	P 587			x	
Orchidaceae						
<i>Habenaria repens</i> Nutt.	Rf	P 552			x	
Orobanchaceae						
<i>Melasma melampyroides</i> (Rich.) Pennell ex Britton and P.Wilson	Rf	P 600			x	
Plantaginaceae						
<i>Bacopa monnierioides</i> (Cham.) B.L.Rob.	Em	P 1029			x	
<i>Bacopa salzmännii</i> (Benth.) Edwall	A	L 4803		x		
<i>Bacopa serpylloides</i> (Cham. and Schltld.) Angely	A	P 608		x		
<i>Bacopa stricta</i> (Schrad.) Wettst. ex Edwall	A	P 1050		x		
<i>Bacopa</i> sp.	Rf	P 564			x	
<i>Scoparia dulcis</i> L.	Rf	P 581			x	
Poaceae						
<i>Arundinella hispida</i> (Willd.) Kuntze	A	P 1046		x		
<i>Axonopus fissifolius</i> (Raddi) Kuhlmann	A	P 1047		x		
<i>Hymenachne pernambucensis</i> (Spreng.) Zuloaga	A	P 1041		x		
<i>Imperata tenuis</i> Hack.	A	L 4808		x		
<i>Leersia hexandra</i> Sw.	Em	P 1013				x
<i>Panicum mertensii</i> Roth	A	P 1040		x		
<i>Paspalum repens</i> P.J.Bergius	FF	L 4799			x	
<i>Steinchisma laxa</i> (Sw.) Zuloaga	A	P 1044		x		
<i>Urochloa</i> sp.	Rf	P 611			x	
Polygonaceae						
<i>Polygonum acuminatum</i> Kunth	A	P 603				x
<i>Polygonum meisnerianum</i> Cham. and Schltld.	A	P 560			x	
<i>Polygonum persicaria</i> L.	Em	P 1012		x		
Pontederiaceae						
<i>Eichhornia azurea</i> (Sw.) Kunth	FF	P 576	x		x	x
<i>Eichhornia crassipes</i> (Mart.) Solms	FL	P 577				x
<i>Heteranthera seubertiana</i> Solms	Em	L 4813		x		
<i>Heteranthera zosterifolia</i> Mart.	Em	P 1022		x		
<i>Hydrothrix gardneri</i> Hook.f.	SF	L 4819		x		
<i>Pontederia cordata</i> L.	Rf	P 569			x	

TABLE 2. CONTINUED.

TAXON	LIFE FORM	VOUCHER	PAN	FLP	OXL	SWP
Potamogetonaceae						
<i>Potamogeton polygonus</i> Cham.	SF	P 1020				x
Pteridaceae ***						
<i>Ceratopteris pteridoides</i> (Hook.) Hieron.	Em	P 588			x	x
<i>Pityrogramma calomelanos</i> (L.) Link	Rf	P 591			x	
<i>Pityrogramma trifoliata</i> (L.) R.M.Tryon	A	P 1056		x		
Ricciaceae **						
<i>Ricciocarpus natans</i> (L.) Corda	FL	P 589			x	x
Rubiaceae						
<i>Borreria capitata</i> (Ruiz and Pav.) DC.	A	P 1049		x		
<i>Borreria scabiosoides</i> Cham. and Schtdl.	Rf	P 585			x	
<i>Borreria spinosa</i> (L.) Cham. and Schtdl.	A	P 555		x		
<i>Diodella</i> cf. <i>sarmentosa</i> (Sw.) Bacigalupo and Cabral ex Borhidi	Rf	P 563			x	
<i>Galianthe brasiliensis</i> (Spreng.) E.L.Cabral and Bacigalupo	A	P 606		x		
Salviniaceae ***						
<i>Azolla filiculoides</i> Lam.	FL	S 8013				x
<i>Salvinia auriculata</i> Aubl.	FL	P 590			x	x
<i>Salvinia oblongifolia</i> Mart.	FL	P 584			x	x
Thelypteridaceae ***						
<i>Thelypteris interrupta</i> (Willd.) Iwats.	A	P 1058		x		
Verbenaceae						
<i>Lantana</i> cf. <i>hypoleuca</i> Briq.	A	P 601		x		
Vitaceae						
<i>Cissus spinosa</i> Cambess.	A	P 605	x			

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