

FLORISTIC COMPOSITION AND LIFE FORMS OF AQUATIC MACROPHYTES IN THE PRIVATE NATURAL HERITAGE RESERVE (RPPN) FARM SÃO FRANCISCO, BACABAL, MARANHÃO, BRAZIL

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ABSTRACT The Private Natural Heritage Reserve (RPPN) Farm São Francisco is located in the municipality of Bacabal, Maranhão, northeastern Brazil. It lies within the Legal Amazon and is characterized by secondary vegetation dominated by the palm *Attalea speciosa*, known as Mata de Cocais. Although the vegetation of Maranhão has been relatively well studied, the diversity of aquatic plants remains poorly known, particularly within the Mata de Cocais ecosystem. Thus, the aquatic flora of the RPPN Farm São Francisco represents the first assessment of plant diversity in this environment. Monthly collections were carried out in the water bodies of the reserve, resulting in the record of 41 plant species distributed among 33 genera and 22 families. The most representative families were Verbenaceae (four genera/four species), Euphorbiaceae (three genera/four species), Araceae (three genera/three species), Fabaceae (three genera/three species), and Asteraceae (two genera/three species). Regarding life forms, amphibious species were the most representative (26 species), followed by emergent species (10 species). Most species occurred along the margins of water bodies. This study demonstrates the high richness of aquatic plants in a region of secondary vegetation subjected to intense pressure from agribusiness, highlighting its importance for the development of effective conservation strategies.

Keywords: biodiversity, conservation, aquatic plants, species richness, protected area.

COMPOSIÇÃO FLORÍSTICA E FORMAS DE VIDA DE MACRÓFITAS AQUÁTICAS NA FAZENDA DA RESERVA PRIVADA DE PATRIMÔNIO NATURAL (RPPN) SÃO FRANCISCO, BACABAL, MARANHÃO, BRASIL

RESUMO A Reserva Particular do Patrimônio Natural (RPPN) Fazenda São Francisco está localizada no município de Bacabal, Maranhão, nordeste do Brasil. Situada na Amazônia Legal, caracteriza-se por vegetação secundária dominada pela palmeira *Attalea speciosa*, conhecida como Mata de Cocais. Embora a vegetação do Maranhão tenha sido relativamente bem estudada, a diversidade de plantas aquáticas permanece pouco conhecida, particularmente no ecossistema da Mata de Cocais. Assim, a flora aquática da RPPN Fazenda São Francisco representa a primeira avaliação da diversidade vegetal nesse ambiente. Coletas mensais foram realizadas nos corpos d'água da reserva, resultando no registro de 41 espécies vegetais distribuídas em 33 gêneros e 22 famílias. As famílias mais representativas foram Verbenaceae (quatro gêneros/quatro espécies), Euphorbiaceae (três gêneros/quatro espécies), Araceae (três gêneros/três espécies), Fabaceae (três gêneros/três espécies) e Asteraceae (dois gêneros/três espécies). Quanto às formas de vida, as espécies anfíbias foram as mais representativas (26 espécies), seguidas pelas espécies emergentes (10 espécies). A maioria das espécies ocorreu nas margens dos corpos d'água. Este estudo demonstra a alta riqueza de plantas aquáticas em uma região de vegetação secundária submetida a intensa pressão do agronegócio, destacando sua importância para o desenvolvimento de estratégias de conservação eficazes. Palavras-chave: biodiversidade, conservação, plantas aquáticas, riqueza de espécies, área protegida.

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INTRODUCTION

The state of Maranhão encompasses three extremely rich phytogeographic domains: the Cerrado, the Amazon, and the Caatinga (Spinelli-Araújo, 2016). The Cerrado is a biome endemic to Brazil, characterized by high species richness and elevated levels of endemism, and is considered one of the world's biodiversity hotspots (Klink & Machado, 2005). In Brazil, approximately 25% of the Cerrado domain is located in Maranhão, occupying about 60% of the state's territory. However, a large portion of the Cerrado in Maranhão has already been destroyed, placing this domain under severe threat.

The Maranhão Amazon covers 81,208.40 km², corresponding to 24.46% of the state's territory, and includes 62 municipalities (Martins & Oliveira, 2011). Despite its extensive coverage, knowledge gaps regarding biological diversity remain large and unevenly distributed. To date, the Maranhão Amazon, which represents approximately 3% of the Brazilian Amazon (around 113,000 km²), has remained a substantial knowledge gap in terms of biodiversity.

The Caatinga, another biome endemic to Brazil, covers about 11% of the national territory, mainly in the northeastern region (IBGE, 2012). It is characterized by a semi-arid climate and xerophytic vegetation adapted to water scarcity, and it harbors high biodiversity, including endemic species. The term "Caatinga" originates from the Tupi language and means "white forest," referring to the appearance of the vegetation during the dry season (Rizzini, 1997). This biome faces serious degradation problems due to the unsustainable use of its natural resources.

Another important geographic concept is that of the Legal Amazon, which encompasses territories from nine Brazilian states: Acre, Amapá, Amazonas, Mato Grosso, Maranhão, Pará, Rondônia, Roraima, and Tocantins (Martins & Oliveira, 2011). The portion of the Legal Amazon within Maranhão corresponds to approximately 80% of the state, covering about 264,000 km², and is located west of the 44°W meridian, where 188 municipalities are situated (Martins & Oliveira, 2011).

According to the Brazilian Forest Code, the Legal Amazon is subject to stricter regulations regarding land use, as rural properties within this region are required to maintain 80% of their area as legal reserve in the Amazon biome and 35% in the Cerrado biome. Nevertheless, estimates from the National Institute for Space Research (INPE), based on data from the Amazon Deforestation Monitoring Program (PRODES), indicate that approximately 18% of the forests in the Legal Amazon have already been removed (Khan & Silva, 2023).

Maranhão is the state within the Legal Amazon with the lowest proportion of protected areas, and it exhibits high levels of deforestation and forest fragmentation. Despite favorable phytogeographic characteristics, Maranhão is also one of the Brazilian states whose flora is least known. Knowledge about the plant species that compose the state's flora remains very limited.

Bacabal is a municipality located in the interior of the state, within the central Maranhão mesoregion and the Mearim microregion (44°46'48"W and 04°13'30"S). It is situated in an area of secondary vegetation resulting from the expansion of agricultural frontiers, with a predominance of the palm *Attalea speciosa* Mart. ex Spreng. (babassu), forming extensive babassu forests that dominate the landscape (IBGE, 2012). Geographically, the municipality lies within an ecotonal zone between Ombrophilous Forest and Seasonal Forest, representing a transition area between the Amazon and Cerrado domains, which may exhibit characteristics of both or unique features (IBGE, 2019).

As in much of the Mearim microregion, large extensions of this environment have been entirely eliminated by agricultural and livestock activities. In Bacabal, only one conservation unit—the Private Natural Heritage Reserve (RPPN) Farm São Francisco—preserves a small

transition area between the Cerrado and Amazon domains, which is considered insufficient to maintain the diversity of this unique environment.

Aquatic macrophytes occur in a wide variety of aquatic environments, employing different adaptive mechanisms for survival and development, and are commonly found along the margins of lakes and watercourses. They are ecologically important due to their ability to establish a strong connection between aquatic and terrestrial systems.

Floristic surveys of aquatic macrophytes in the state of Maranhão are largely restricted to eastern Maranhão (Pestana et al., 2024; Paiva et al., 2025) and to the Maranhão Lowlands (Barbieri & Pinto, 1999; Barbieri & Carreiro, 2017; Costa Neto et al., 2002; Arouche et al., 2023; Penha et al., 2025; Alves et al., 2025), while other regions remain poorly studied.

In this context, a floristic survey of aquatic macrophytes was conducted in the RPPN Farm São Francisco with the aim of documenting and providing a checklist of the local flora. These data provide essential information on species richness, spatial distribution, and interactions with biotic and abiotic factors, supporting vegetation management, the conservation of remaining areas and their characteristic species, and the maintenance of genetic and biological diversity.

MATERIAL AND METHODS

Study Area

The Private Natural Heritage Reserve Farm São Francisco (RPPN São Francisco) is located at coordinates 4°08'2.20" S and 44°37'58.00" W, in the Middle Mearim microregion, central Maranhão State, within the municipality of Bacabal, and covers an area of 150 ha (Figure 1). The reserve was officially established on December 30, 1997, by Ordinance 173-N (Federal Official Gazette – DOU 252, 30/12/1997, section/page 1/31709).

The RPPN has predominantly flat relief, occasionally with gentle hills, and altitudes ranging approximately from 14 to 57 m. According to the Köppen climate classification, the climate is type As (tropical), warm, characterized by a dry season from September to December—when the highest temperatures are recorded—and a rainy season from January to June (Bandeira, 2013). The mean annual temperature is approximately 27.5 °C, and the rainfall regime is relatively low, with an average annual precipitation of 150.6 mm, ranging from 10.6 mm in the driest months to 263.8 mm in the wettest months (Bandeira, 2013). The rainy season extends from December to May, whereas the dry season occurs between June and November.

The RPPN is situated in a Cerrado–Amazon transition zone and is the only conservation unit in the state of Maranhão that preserves the Mata de Cocais phytophysognomy together with a Cerrado–Amazon transition area. Its vegetation comprises different phytophysognomies, including environments dominated by wetlands and Mata de Cocais.

The wetlands within the conservation unit were classified according to the concept proposed by Junk et al. (2013) and divided into two categories: permanently flooded areas and seasonally flooded areas. Permanently flooded areas include the central lagoon of the RPPN Farm São Francisco. Seasonally flooded areas comprise: (1) the lagoon's zone of influence, which is periodically inundated during flood events and, during the dry season, forms an open field dominated by predominantly herbaceous species, occasionally growing over decomposing stands of *Pontederia crassipes*; and (2) areas characterized by hydromorphic soils or marshes.

The RPPN contains a permanent water body (lagoon) that supplies water to the Piratininga stream (Figure 1). The lagoon exhibits marked seasonal variation in water volume, remaining full during the rainy season, when depths may reach approximately 2.5–3.0 m, and presenting reduced water levels during the dry season. During the dry period, the lagoon becomes fragmented into three distinct water bodies, with the largest measuring approximately

646 × 306 m. During the rainy season, these water bodies reconnect, forming a single lagoon with dimensions of approximately 1,296 × 696 m.

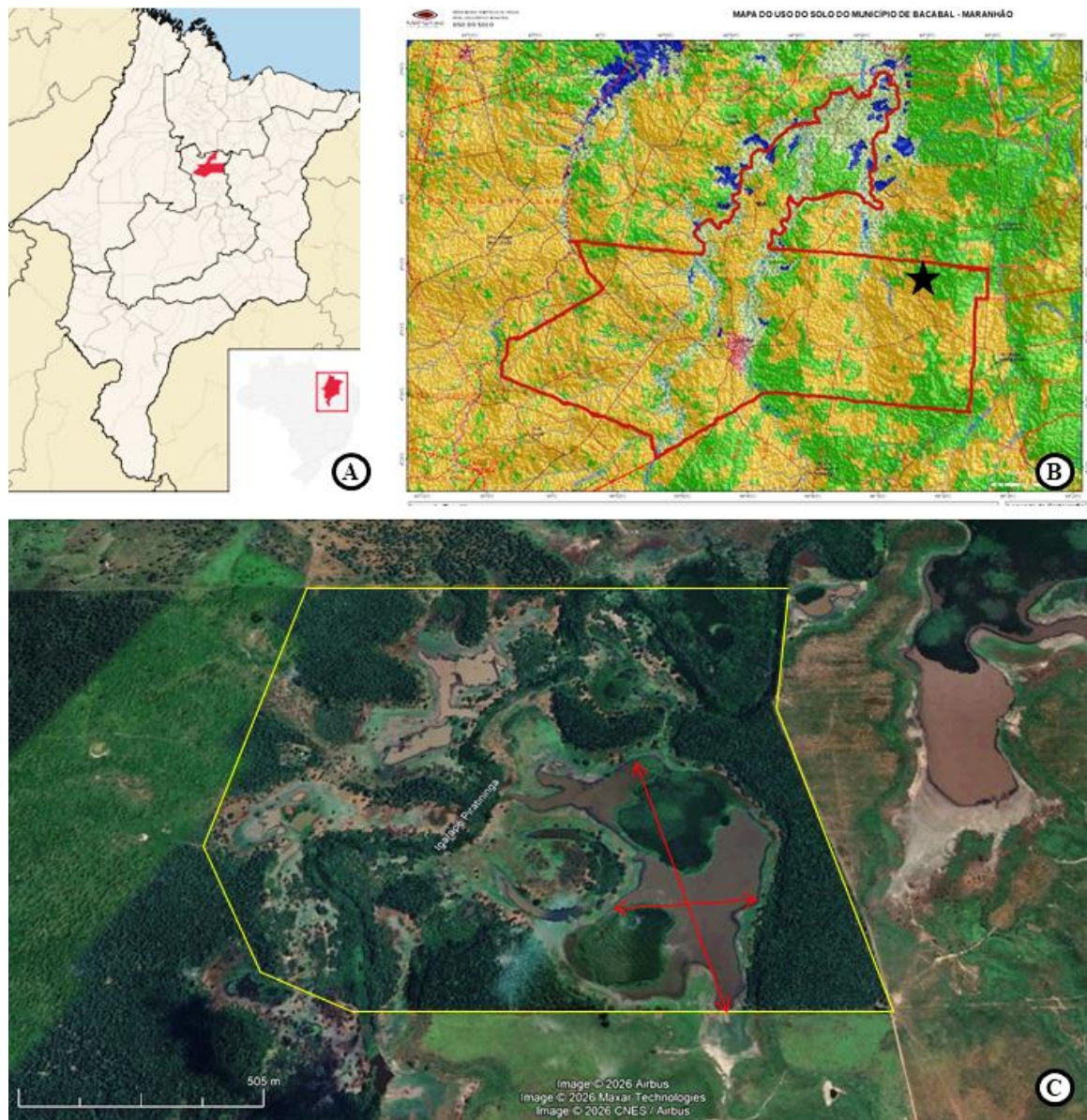


Figure 1: Location of the RPPN Farm São Francisco. (A) Map of the state of Maranhão highlighting the location of the municipality of Bacabal (red). (B) Map of the municipality of Bacabal showing the location of the RPPN Farm São Francisco (black star); degraded areas in orange; Mata de Cocais, aquatic or palustrine vegetation in green; aquatic environments in blue. (C) Area of the RPPN within the polygon (yellow outline), showing the dimensions of the lagoon during the dry season (red).

Floristic Composition

Fieldwork was conducted over a three-year period, from 2022 to 2025, with sampling campaigns lasting one to two days each, aiming to cover all months of the year. For the floristic composition study, all wetland areas within the RPPN Farm São Francisco were randomly surveyed.

Botanical material bearing flowers or fruits was collected and pressed following the procedures described by Mori et al. (1989) and subsequently incorporated into the Maranhão Continental Herbarium (BMA). During field collections, information on phytophysiognomy and geographic coordinates was recorded using a Global Positioning System (GPS), and specimens were additionally documented through photographs.

Plant identification was carried out based on specialized literature and by comparison with identified herbarium specimens deposited at the BMA (acronym according to Thiers 2026, continuously updated). The floristic list was organized alphabetically by family and species. Taxonomic delimitation followed APG IV (2016) for angiosperms and PPG I (2016) for ferns. Scientific names and author citations were updated according to *Flora e Funga do Brasil* (2026).

Conservation Status

The assessment of the conservation status of threatened species recorded in the RPPN Farm São Francisco was based on the methodology proposed by the International Union for Conservation of Nature (IUCN, 2001).

RESULTS

A total of 41 species of vascular plants were recorded in the aquatic environments of the RPPN Farm São Francisco, distributed among 33 genera and 22 families (Table 1).

Two species correspond to ferns (approximately 5% of the recorded species): *Ceratopteris thalictroides* (Pteridaceae) and *Salvinia auriculata* (Salviniaceae). The remaining 39 species (approximately 95%) are angiosperms (Figure 2).

The families with the highest species richness were Verbenaceae (four genera and four species) and Euphorbiaceae (three genera and four species), each representing 9.7% of the total species richness. These were followed by Araceae (three genera), Fabaceae (three genera), and Asteraceae (two genera), each with three species (7.3%). Seven families were represented by two species each (Alismataceae, Cyperaceae, Lamiaceae, Onagraceae, Pontederiaceae, Portulacaceae, and Rubiaceae), accounting for 39% of the total species richness. The remaining ten families were represented by a single species each, corresponding to 26% of the total richness (Figure 3). Families represented by one or two species together accounted for 65% of the total species richness.

The most representative genera were *Cyperus* (Cyperaceae), *Caperonia* (Euphorbiaceae), *Ludwigia* (Onagraceae), *Pontederia* (Pontederiaceae), *Portulaca* (Portulacaceae), and *Borreria* (Rubiaceae), each represented by two species. The remaining 26 genera were represented by a single species.

Regarding life forms (Figure 4), amphibious species were the most representative, with 28 species, followed by emergent species, with 10 species. Free-floating species were represented by four species, whereas rooted floating species were represented by three species. The epiphytic life form was represented by a single species.

Although widely distributed, *Caperonia palustris* and *Croton argenteus* are incorporated into a herbarium collection in Maranhão for the first time in this study.

Table 1. Floristic richness and life forms of macrophytes from the RPPN Farm São Francisco, Bacabal, Maranhão State, Brazil. *Species not previously recorded for the state of Maranhão in Flora e Funga do Brasil. NA = Native; EM = Emergent; EP = Epiphyte; FF = Fixed-floating; FL = Free-floating.

Families / Species	Habitat	Life form	Origin	Voucher
Pteridaceae				
<i>Ceratopteris thalictroides</i> (L.) Brong.	Aquatic	EM	Native	BMA 3737, BMA 3736
Salviniaceae				
<i>Salvinia auriculata</i> Aubl.	Aquatic	FL	Native	BMA 3803, BMA 3780, BMA 3804, BMA 3806, BMA 3799, BMA 3802, BMA 3801, BMA 3805
Alismataceae				
<i>Echinodorus paniculatus</i> Micheli	Palustrine	AN, EM	Native	BMA 3753, BMA 3754, BMA 3755
<i>Sagittaria guayanensis</i> Kunth.	Aquatic	FF	Native	BMA 3771, BMA 3789
Amaranthaceae				
<i>Pfaffia glomerata</i> (Spreng.) Pedersen	Palustrine	AN	Native	BMA 3784
Araceae				
<i>Lemna minor</i> (L.) Griff.	Aquatic	FL	Native	
<i>Montrichardia linifera</i> (Arruda) Schott	Aquatic	EM	Native	BMA 3774
<i>Pistia stratiotes</i> L.	Aquatic	FL	Native	BMA 3772, BMA 3746, BMA 3777, BMA 3773
Asteraceae				
<i>Egletes viscosa</i> (L.) Less	Palustrine	AN	Native	BMA 3766
<i>Erechtites hieracifolius</i> *(L.) Raf. Ex DC.	Aquatic	AN	Native	BMA 3786
<i>Sp1</i>	Floodplain	AN	-----	
Boraginaceae				
<i>Heliotropium indicum</i> L.	Floodplain	AN	Native	
Cyperaceae				
<i>Cyperus blepharoleptos</i> Steud.	Floodplain	AN	Native	BMA 3794, BMA 3795
<i>Cyperus esculentus</i> L.	Floodplain	AN/EM	Naturalized	BMA 3796

Euphorbiaceae					
<i>Astraea lobata</i> (L.) Klotzsch	Floodplain	AN	Native	BMA 3742	
<i>Caperonia palustris</i> (L.) A.St. Hil.	Aquatic	EM	Native	BMA 3783	
<i>Caperonia castaneifolia</i> (L.) A.St. Hil.	Aquatic	EM	Native	BMA 3785	
<i>Croton argenteus</i> L.	Floodplain	AN	Native	BMA 3748	
Fabaceae					
<i>Neptunia oleracea</i> Lour	Floodplain/palustrine.	AN	Native	BMA 3765, BMA 3764, BMA 3763	
<i>Phaseolus vulgaris</i> L.	Palustrine	EP	Cultivad	BMA 3762	
<i>Mimosa camporum</i> Benth.	Floodplain	AN	Native	BMA 3797, BMA 3787, BMA 3792	
Lamiaceae					
<i>Hyptis recurvata</i> Poit	Floodplain	AN	Native	BMA 3782	
<i>Marsypianthes chamaedrys</i> (Vahl) Kuntze	Floodplain	AN	Native		
Lentibulariaceae					
<i>Utricularia foliosa</i> L.	Aquatic	EM	Native	BMA 3733, BMA 3807, BMA 3735, BMA 3732, BMA 3734	
Nymphaeaceae					
<i>Nymphaea amazonum</i> Mart. e Zucc.	Aquatic	FF	Native	BMA 3781, BMA 3776, BMA 3780	
Ochnaceae					
<i>Piriqueta cistoides</i> (L.) Grisebach.	Floodplain	AN	Native	BMA 3738	
Onagraceae					
<i>Ludwigia helminthorrhiza</i> (Mart.) H.Hara	Aquatic	EM/FF	Native	BMA 3779, BMA 3778	
<i>Ludwigia leptocarpa</i> (Nutt.) H.Hara	Floodplain	AN	Native	BMA 3751, BMA 3750, BMA 3747, BMA 3749	
Poaceae					
<i>Hymenachne amplexicaulis</i> (Rudge) Nees	Floodplain	AN	Native	BMA 3728, BMA 3731, BMA 3729	
Polygonaceae					
<i>Polygonum acuminatum</i> Kunth	Floodplain	AN	Native	BMA 3744, BMA 3743	

Pontederiaceae					
	<i>Pontederia crassipes</i> (Mart.) Solms.	Aquatic	FL/AN	Native	BMA 3759, BMA 3761, BMA 3756, BMA 3760, BMA 3757, BMA 3758
	<i>Pontederia rotundifolia</i> L.f.	Aquatic	EM	Native	BMA 3727, BMA 3752
Portulacaceae					
	<i>Portulaca elatior</i> Mart. ex Rohrb.	Floodplain	AN	Native	BMA 3740, BMA 3726, BMA 3741
	<i>Portulaca mucronata</i> Lik	Floodplain	AN/EM	Native	BMA 3739
Rubiaceae					
	<i>Borreria scabiosoides</i> Cham. e Schldtl.	Floodplain	AN	Native	BMA 3790
	<i>Borreria verticillata</i> (L.) G. Mey.	Floodplain	AN	Native	BMA 3791
Sapindaceae					
	<i>Cardiospermum halicacabum</i> L.	Floodplain	AN	Native	BMA 3798
Verbenaceae					
	<i>Lantana fucata</i> Lindl.	Floodplain	AN	Native	BMA 3730
Wilson	<i>Lippia alba</i> (Mill.) N.E.Br. ex Britton e P.	Floodplain	AN	Native	BMA 3745
	<i>Phyla betulifolia</i> (kunth) Greene*	Floodplain	AN	Native	BMA 3788
	<i>Stachytarpheta angustifolia</i> (Mill.) Vahl	Floodplain	AN	Native	BMA 3775

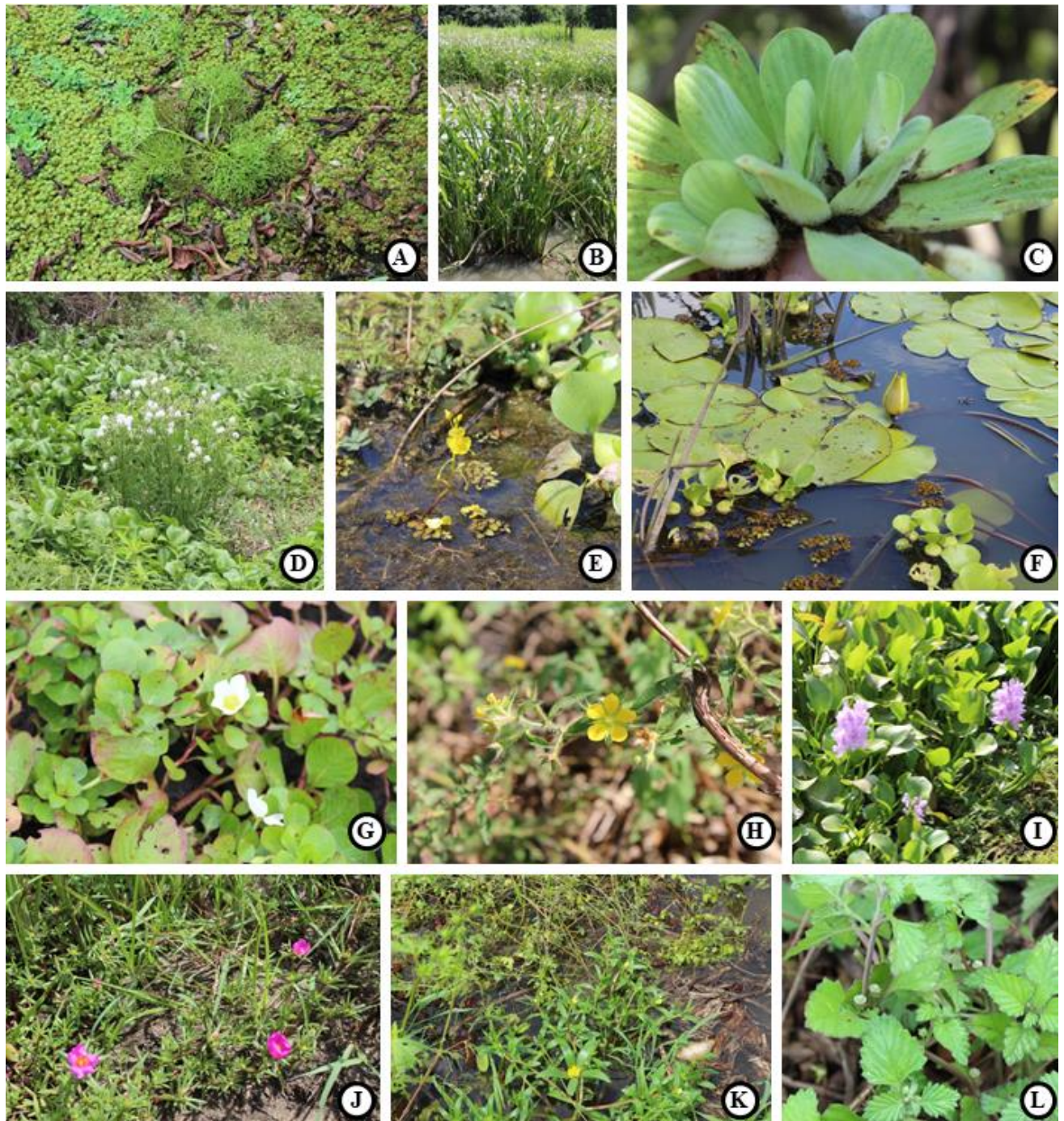


Figure 2. Macrophytes collected in the RPPN Farm São Francisco. **A.** *Ceratopteris thalictroides* (center) and *Salvinia auriculata*. **B.** *Echinodorus paniculatus*. **C.** *Pistia stratiotes*. **D.** *Erechites hieracifolius*. **E.** *Utricularia foliosa*. **F.** *Nymphaea amazonum*. **G.** *Ludwigia helminthorrhiza*. **H.** *Ludwigia leptocarpa*. **I.** *Pontederia crassipes*. **J.** *Portulaca elatior*. **K.** *Portulaca mucronata*. **L.** *Phyla betulifolia*. (Photos by Elidio Guarçoni).

DISCUSSION

The number of species recorded in the RPPN Farm São Francisco can be considered high in relation to the size of the investigated area, which covers 150 ha. Moreover, this is the first

study conducted in Mata de Cocais environments (Santos-Filho et al., 2013) in the Mearim River region.

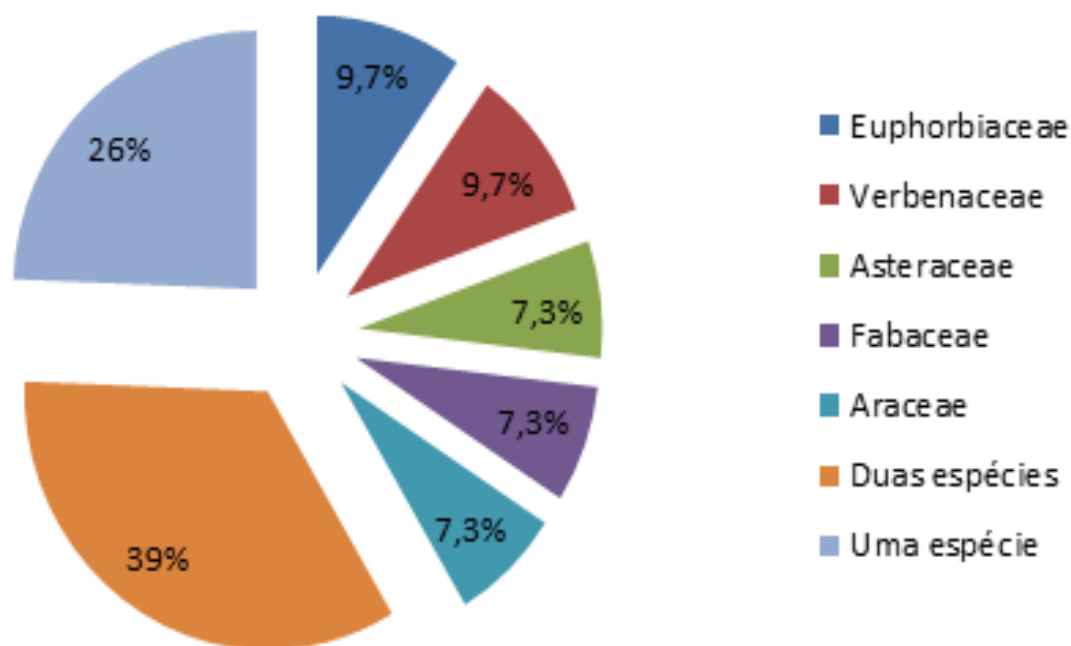


Figure 3. Representation of macrophyte botanical families in the RPPN Farm São Francisco.

In the state of Maranhão, the present study recorded a higher number of species than those reported by Barbieri & Pinto (1999), who documented 19 species in the municipality of São Bento; Barbieri & Carreiro (2017), who cataloged 12 species in the Pericumã River; Silva & Fontes (2018), who listed 16 species at sites in the municipality of Barreirinhas; and Arouche et al. (2024), who recorded 34 species in the Environmental Protection Area of the Baixada Maranhense, in the municipalities of Palmeirândia, Pinheiro, and São Bento. However, studies conducted over larger areas have reported higher species richness, such as Pestana et al. (2024), who recorded 69 species in the municipality of Barreirinhas; Arouche et al. (2023), who documented 106 species in the southwestern region of the Baixada Maranhense APA; Alves et al. (2025), with 52 species in the municipality of Guimarães; and Paiva et al. (2025), with 100 species in the Quilombo Saco das Almas, municipality of Brejos.

In similar studies conducted in the state of Maranhão, Cyperaceae, Plantaginaceae, Nymphaeaceae, Poaceae, Lentibulariaceae, and Fabaceae are the families that most contribute to species richness in aquatic flora surveys (Barbieri & Pinto, 1999; Barbieri & Carreiro, 2017; Costa Neto et al., 2002; Arouche et al., 2023; Pestana et al., 2024; Alves et al., 2025; Paiva et al., 2025). In the RPPN Farm São Francisco, the representativeness of families such as Verbenaceae, Euphorbiaceae, and Asteraceae may be associated with the type of aquatic environment, which is located in an open area with high solar radiation incidence. This condition likely increases water evaporation rates in the lagoon, favoring the development of amphibious species.

This representativeness may also be related to the surrounding vegetation, which lies in a transition zone between the Amazon and the Cerrado, forming a typical physiognomy of the Middle Mearim region known as Mata de Cocais (babassu forest), a secondary vegetation that replaced the original vegetation (Rizzini, 1997). In addition, the wetland area of the RPPN Farm São Francisco is surrounded by a closed forest formation dominated by the palm *Attalea*

speciosa and by *Brachiaria sp.*, two species associated with low floristic diversity. *Brachiaria*, in particular, is a genus of Poaceae known for its aggressive colonization of environments.

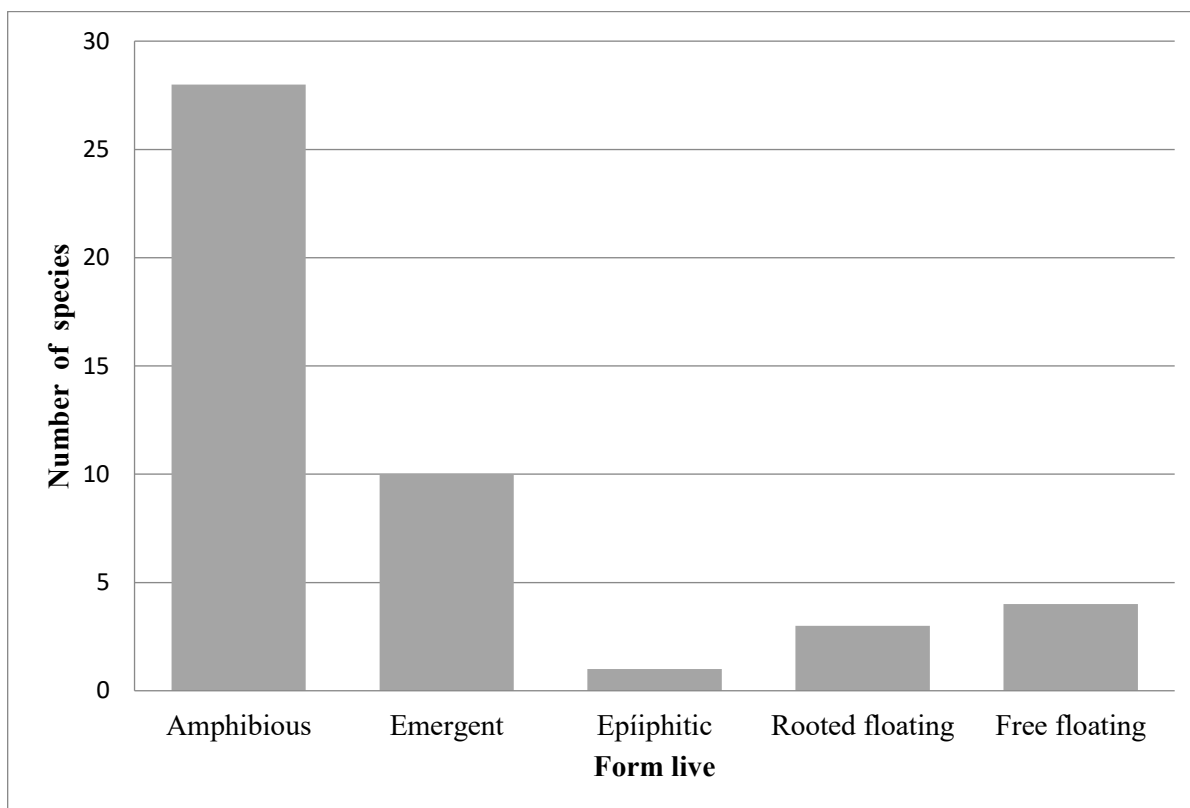


Figure 4. Representation of life forms recorded in the RPPN Farm São Francisco.

In Maranhão, several surveys have identified *Cyperus* and *Ludwigia* as major components of aquatic flora (Arouche et al., 2021; Pestana et al., 2024; Alves et al., 2025). The prominence of these genera may be associated with the environments in which they grow, typically characterized by moist substrates. In addition, the efficiency of asexual propagation by rhizomes and tubers in *Cyperus* may contribute to the representativeness of this cosmopolitan family in aquatic environments. For *Ludwigia*, the abundant production of seeds may be associated with its high representation in these habitats.

The predominance of amphibious and emergent species in the RPPN is related to the ability of these biological forms to survive in both flooded and dry conditions (Moreira et al., 2011). Thus, the present study corroborates findings from Maranhão (Barbieri & Pinto 1999; Barbieri & Carreiro, 2017; Costa Neto et al., 2002; Arouche et al., 2023; Pestana et al., 2024; Alves et al., 2025; Paiva et al., 2025) and from other regions of Brazil, which consistently report greater richness of amphibious and emergent species (Sousa et al., 2019).

The diversity of life forms observed can be explained by seasonal variation in water levels throughout the year. During the rainy season, increased water volume incorporates marginal plants into flooded areas. Amphibious species are typically associated with moist environments and remain in shallower areas near the margins (Barros, 2009). Habitat conditions, particularly water level fluctuations, may cause a single species to exhibit more than one biological form. Such environmental gradients create heterogeneous habitats that are generally positively associated with biodiversity (Pott and Pott 2000).

Accordingly, some life forms vary seasonally among species, such as *Echinodorus paniculatus* and *Portulaca mucronata*, which may occur as amphibious or emergent; *Ludwigia helminthorrhiza*, which may occur as emergent or rooted floating; and *Pontederia crassipes*, which may occur as rooted floating or amphibious. As water levels decrease, stands of *P.*

crassipes accumulate along the margins, often inhibiting the growth of other species until decomposition occurs, thereby creating conditions favorable for the establishment of amphibious species.

All species recorded in this study are common in aquatic environments in Maranhão and occur in nearly all phytogeographic domains (Flora e Funga do Brasil, 2026). In addition, all species exhibited high frequency of occurrence.

Among the species recorded, *Lemna minor*, *Neptunia oleracea*, *Pontederia crassipes*, *Pistia stratiotes*, and *Salvinia auriculata* are noteworthy. *Neptunia oleracea* and *Pontederia crassipes* form extensive macrophyte stands in the littoral zone during the dry season (Figure 5A). These stands provide important refuge for various fish and amphibian species that shelter among their roots (Figure 5B). During severe drought periods, they also produce large amounts of dry biomass that are incorporated into the lagoon during the rainy season. With the onset of flooding, *Lemna minor*, *Pistia stratiotes*, and *Salvinia auriculata* cover the water surface in littoral areas, limiting light penetration through the water column and serving as substrates for fish egg attachment during spawning, as well as for algae that serve as food for other organisms (Berg, 1986).

Similarly, *Montrichardia linifera* forms large stands in the central portion of the lagoon (Figure 5C), creating shaded environments where *Pontederia rotundifolia* (Figure 5D) may occur and providing suitable refuge for broad-snouted caimans (*Caiman latirostris*) during daylight hours.

Some species recorded in this survey have high ornamental and aquaculture value, with potential use in aquaria and artificial ponds, such as *Salvinia auriculata*, *Sagittaria guayanensis*, *Lemna minor*, *Pistia stratiotes*, *Neptunia oleracea*, *Nymphaea amazonum*, *Ludwigia helminthorrhiza*, and *Pontederia crassipes* (Kasselmann, 2003). The presence of these taxa in the lagoon of the RPPN Farm São Francisco highlights the importance of this wetland area for the region, due to its potential as an environmentally safer alternative to exotic ornamental plants and as a basis for sustainable and community-based cultivation, provided that harvesting and trade follow ecological management guidelines and comply with Brazilian environmental regulations.

Erechtites hieracifolius (Asteraceae) (US – O. de Carvalho 11; J.R. Swallen 3432; and J.R. Swallen 3443) and *Phyla betulifolia* (Verbenaceae) (NYGB – N.A. Rosa 2949; O. de Carvalho 1421; and SLUI – Alves, N.P.F. 32), although not listed for the state of Maranhão in Flora e Funga do Brasil (2026), have voucher specimens collected in the state available in the SpeciesLink network (CRIA, 2026). In the case of *E. hieracifolius*, the record from the RPPN Farm São Francisco represents a rediscovery of the species after 90 years without collections in the state, according to the SpeciesLink database (CRIA, 2026).

Phyla betulifolia is used in folk medicine to treat colds, bronchitis, cough, and also as a muscle relaxant. *Erechtites hieracifolius*, in turn, has several uses, such as wound healing and the treatment of digestive problems and circulatory disorders.



Figure 5. Ecological Aspects of the Lagoon in the RPPN Farm São Francisco.

CONCLUSION

Located within the phytogeographic domain of the Mata de Cocais, in the state of Maranhao, the lagoon situated in the RPPN Farm São Francisco constitutes a lentic ecosystem of high ecological relevance. It functions as a natural habitat for a wide range of aquatic plant species, fauna, and other associated organisms. Its hydrological dynamics, closely linked to the regional rainfall regime, directly influence the structure and composition of aquatic and palustrine vegetation, thereby representing an important refuge for biodiversity and contributing significantly to the ecological stability of the surrounding landscape.

Seasonal fluctuations in water level reflect the regional precipitation pattern. During the rainy season, the expansion of the water column promotes the establishment of submerged and free-floating species. In the dry season, water level reduction exposes shallow areas and marginal zones, enabling the colonization of emergent and amphibious taxa. This cyclical variation increases environmental heterogeneity and, consequently, biological diversity. Accordingly, the number of species inventoried in this study demonstrates the remarkable floristic richness and diversity of life forms occurring in the wetland environments of the RPPN Farm São Francisco. These findings substantially expand current knowledge of aquatic and palustrine flora in Maranhão, particularly in the Middle Mearim region.

The vegetation of the lagoon is generally organized into well-defined ecological zones distributed along a gradient from the margins toward the central portion. The marginal zone is characterized by the predominance of palustrine and emergent species adapted to waterlogged soils. The intermediate zone comprises rooted macrophytes with floating leaves, whereas the central zone is dominated by submerged species and, occasionally, free-floating forms. This spatial stratification creates multiple ecological niches and promotes diverse biotic interactions.

The lagoon also functions as a refuge and breeding site for various faunal groups, including aquatic insects, amphibians, fish, and birds. The high diversity of macrophytes contributes to the provision of shelter and substrate, nutrient cycling, sediment stabilization, and the maintenance of water quality.

In addition to its biological importance, the lagoon provides essential ecosystem services, including local hydrological regulation, carbon sequestration, natural filtration of sediments and nutrients, and maintenance of the regional microclimate.

The ecological integrity of the lagoon reinforces the importance of this Private Natural Heritage Reserve as a strategic conservation unit for the protection of wetland environments in the Middle Mearim region. Given the increasing anthropogenic pressure on aquatic ecosystems in Maranhão, the preservation of this lentic system is essential to ensure the continuity of ecological processes and the conservation of regional floristic diversity.

Considering the hydrographic potential of the region and the remaining gaps in floristic knowledge, further floristic surveys are strongly recommended in underexplored areas in order to improve documentation and support conservation strategies for the aquatic and palustrine flora of Maranhão.

AUTHOR CONTRIBUTIONS

EAEF coordinated all project activities; DSM conducted field collections and revised the manuscript; MVMS carried out collections and contributed to the botanical identification.

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