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Original Article

Floristic survey of aquatic macrophytes in eastern Maranhão, Brazil: richness, biological forms and three new records

Levantamento florístico de macrófitas aquáticas no leste do Maranhão, Brasil: riqueza, formas biológicas e três novos registros

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Abstract

The aim of this study was to carry out a floristic survey of aquatic macrophytes in the municipality of Chapadinha, eastern Maranhão, and classify their biological forms. The study was done between September 2021 and September 2022. A total of 31 families, 49 genera and 72 species of aquatic macrophytes were catalogued, of which 65 are angiosperms. Among them, *Bacopa stricta* (Plantaginaceae), *Staurogyne diantheroides* (Acanthaceae), and *Xanthosoma aristeguietae* (Araceae) are new records for the flora of Maranhão, with the last two new records for Northeast Brazil. The richest family was Cyperaceae, with 11 species, followed by Plantaginaceae (seven taxa), Fabaceae (five taxa) and Lentibulariaceae (five taxa). Six biological forms were recorded, amphibious (27 taxa) and emergent (26 taxa) being the most common. The aquatic environments of Chapadinha are home to a considerable number of species, families, and life forms of macrophytes. The results show that due to the lack of surveys, evidenced by the new records presented, the state aquatic flora is still underestimated. Further studies in poorly explored areas are suggested, especially in the eastern part of the state, to improve understanding of species richness.

Keywords: aquatic plants, aquatic vegetation, cerrado, wetlands.

Resumo

Este trabalho teve como objetivo realizar o levantamento florístico das macrófitas aquáticas presentes no município de Chapadinha, leste do Maranhão, e classificar as formas biológicas. O estudo foi conduzido entre setembro de 2021 e setembro de 2022. Foi catalogado um total de 31 famílias, 49 gêneros e 72 espécies de macrófitas aquáticas. A grande maioria das espécies é de angiospermas, totalizando 65 espécies. Dentre elas, *Bacopa stricta* (Plantaginaceae), *Staurogyne diantheroides* (Acanthaceae) e *Xanthosoma aristeguietae* (Araceae) são novos registros para a flora do Maranhão, sendo as duas últimas novos registros para o Nordeste do Brasil. A família com maior número de espécies foi Cyperaceae, com 11 espécies, seguida por Plantaginaceae (sete táxons), Fabaceae (cinco táxons) e Lentibulariaceae (cinco táxons). Registramos seis formas biológicas, sendo anfíbias (27 táxons) e emergentes (26 táxons) as mais comuns. Os ambientes aquáticos de Chapadinha abrigam um número considerável de espécies, famílias e formas de vida de macrófitas aquáticas. Os resultados demonstram que, devido ao baixo número de estudos com esse escopo, conforme evidenciado pelos novos registros apresentados, a flora aquática do estado ainda está subestimada. Sugere-se a realização de novos estudos em áreas pouco exploradas, especialmente na porção leste do estado, a fim de aprimorar a compreensão da riqueza de espécies dessa região.

Palavras-chave: plantas aquáticas, vegetação aquática, cerrado, áreas úmidas.

1. Introduction

Aquatic macrophytes are plants visible to the naked eye whose photosynthesizing parts are active throughout the year or only for a few months, totally or partially submerged in fresh or brackish water and may also be floating (Irgang and Gastal-Júnior, 1996). This definition encompasses phylogenetically distinct groups, including representatives of the angiosperms, bryophytes (mosses), ferns, lycophytes, and some freshwater macroalgae (Chambers et al., 2008). The flowering plants are the most representative group among aquatic macrophytes, corresponding to more than 80% of the species in this definition (Chambers et al., 2008; Murphy et al., 2019).

These plant communities play a relevant role in providing ecosystem services, serving as essential components in the structure and function of freshwater environments (Thomaz and Cunha, 2010; Thomaz and

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Esteves, 2011). Additionally, aquatic macrophytes provide oxygen and biomass to water bodies, participate in the cycling and storage of nutrients, reduce water velocity, serve as a food supply for primary consumers, provide shelter and nurseries for juvenile fish, aquatic macroinvertebrates, periphyton, and other aquatic organisms (Rocha et al., 2018; Schneider et al., 2018; Thomaz, 2022).

Due to the ecological importance of these plants and to understand their floristic composition, research on aquatic macrophytes in Brazil has been intensified after 1990 (Souza et al., 2017), especially Irgang and Gastal-Júnior (1996), Scremin-Dias et al. (1999), and Pott and Pott (2000). These classic works were the first comprehensive studies of this flora and are considered pertinent references to this day (Moura-Junior et al., 2013).

In the Northeast region of Brazil, surveys of aquatic macrophytes are concentrated in areas within the Caatinga domain, especially in reservoirs (e.g., Henry-Silva et al., 2010; Moura-Júnior et al., 2011; Lima et al., 2011). Nevertheless, as evidenced recently by Moura-Júnior and Cotarelli (2019), there is a need for more studies on aquatic macrophytes in the Northeast region, mainly in poorly sampled states, such as Maranhão.

The Maranhão state has 12 hydrographic basins, which provide favorable environments (e.g., rivers, streams and lagoons) for the growth and development of aquatic vegetation (NUGEO, 2016). However, there is still a lack of information about aquatic macrophytes in the literature, especially with a focus on floristic surveys. To validate this information, the first study in the state only took place in 1999 (Barbieri and Pinto, 1999). Since then, with a study gap of more than a decade, only the works of Barbieri and Carreiro (2017), Silva and Fontes (2018) and Arouche et al. (2021, 2023) were carried out, the last three floristic surveys.

Besides the limited research on aquatic macrophytes in Maranhão, it is notable that most of the existing studies (~60%) and collection records (see Arouche et al., 2021) have focused mainly on the Environmental Protection Area of Baixada Maranhense. For Chapadinha and elsewhere in Eastern Maranhão, knowledge about aquatic macrophyte richness and biological forms is incipient. Therefore, the information from floristic lists is relevant for understanding plant composition in specific areas and conserving natural resources (Uniyal and Singh, 2014).

Given these considerations, this study aims to provide a list of aquatic macrophytes occurring in the municipality of Chapadinha. The research questions that guided this study were: (1) What is the species richness of aquatic macrophytes in Chapadinha?, (2) What are their biological forms?

2. Material and Methods

2.1. Study area

The municipality of Chapadinha (-43.360278 , -3.741667, max. alt. a.s.l.: 110 m; Figure 1A) is located in the Eastern Mesoregion of Maranhão state, northeastern Brazil (IBGE, 2022). The climate, according to the Köppen classification, is tropical hot and humid (Aw) and presents two defined seasons: a rainy season from January to May, and a dry season from June to December (Alvares et al., 2013). The average annual temperature is approximately 27.6 °C and an average rainfall of 1613.2 mm annually (Passos et al., 2016).

Chapadinha is situated in the phytogeographic domain of the Cerrado, presenting varied physiognomies, including forest (Gallery Forest) and savanna formations (Veredas, characterized by the presence of *Mauritia flexuosa* L.f., and Palm groves, mainly formations of *Attalea speciosa* Mart. ex Spreng.) (Ribeiro and Walter, 2008). In addition, Chapadinha has several aquatic environments, such as flooded grassland, ponds (temporary and permanent), and streams (Pestana et al., 2022) (Figure 1B-E).

2.2. Data collection

Field collections were carried out between September 2021 and September 2022 in sampling sites within the municipality of Chapadinha. The environments were explored according to the walking method suggested by Filgueiras et al. (1994). The botanical samples were collected, photographed and herborized according to the usual techniques for aquatic plants (Haynes, 1984; Cook, 1996).

Taxonomic identification of the botanical samples was carried out through analysis of macroscopic structures under a stereomicroscope and consulting specialized literature (Cook, 1996; Irgang and Gastal-Júnior, 1996; Pott and Pott, 2000; Amaral et al., 2008; Lorenzi, 2008). High-definition images from the SpeciesLink (CRIA, 2023), Reflora (2023), and Jstor Global Plants (2023) databases were utilized. In addition, specific identification keys for families and genera were consulted. Duplicates/photographs were also sent to specialists for species confirmation. After identification, the exsiccates were deposited in the CCAA and BMA herbaria (acronyms according to Thiers (2023), continuously updated). In the species list, the angiosperms are by The Angiosperm Phylogeny Group (2016), while ferns and lycophytes follow the delimitation of the PPG I (2016). The species names and abbreviations of the taxa authors are per Flora e Funga do Brasil (2023).

2.3. Biological forms

For the biological form classification, the categories proposed by Pott and Pott (2000) were followed, as illustrated in Figure 2, which include:

1) Amphibious - Plants capable of living both in flooded areas and out of the water.
2) Emergent - Plants rooted in the bottom, partially submerged, and partially above the water.
3) Rooted floating - Plants rooted in the bottom, with floating stems or leaves.
4) Rooted submerged - Plants rooted in the bottom, completely submerged.
5) Free submerged - Plants not rooted in the bottom, with leaves submerged and only flowers emerged.
6) Free floating - Plants not rooted in the bottom, prone to be carried by currents, wind, or animals.
7) Epiphytes - Plants that establish themselves on other aquatic plants.

Additionally, the recommendations of Moura-Júnior and Cotarelli (2019) were adopted for increased accuracy in the classification of Amphibious species.

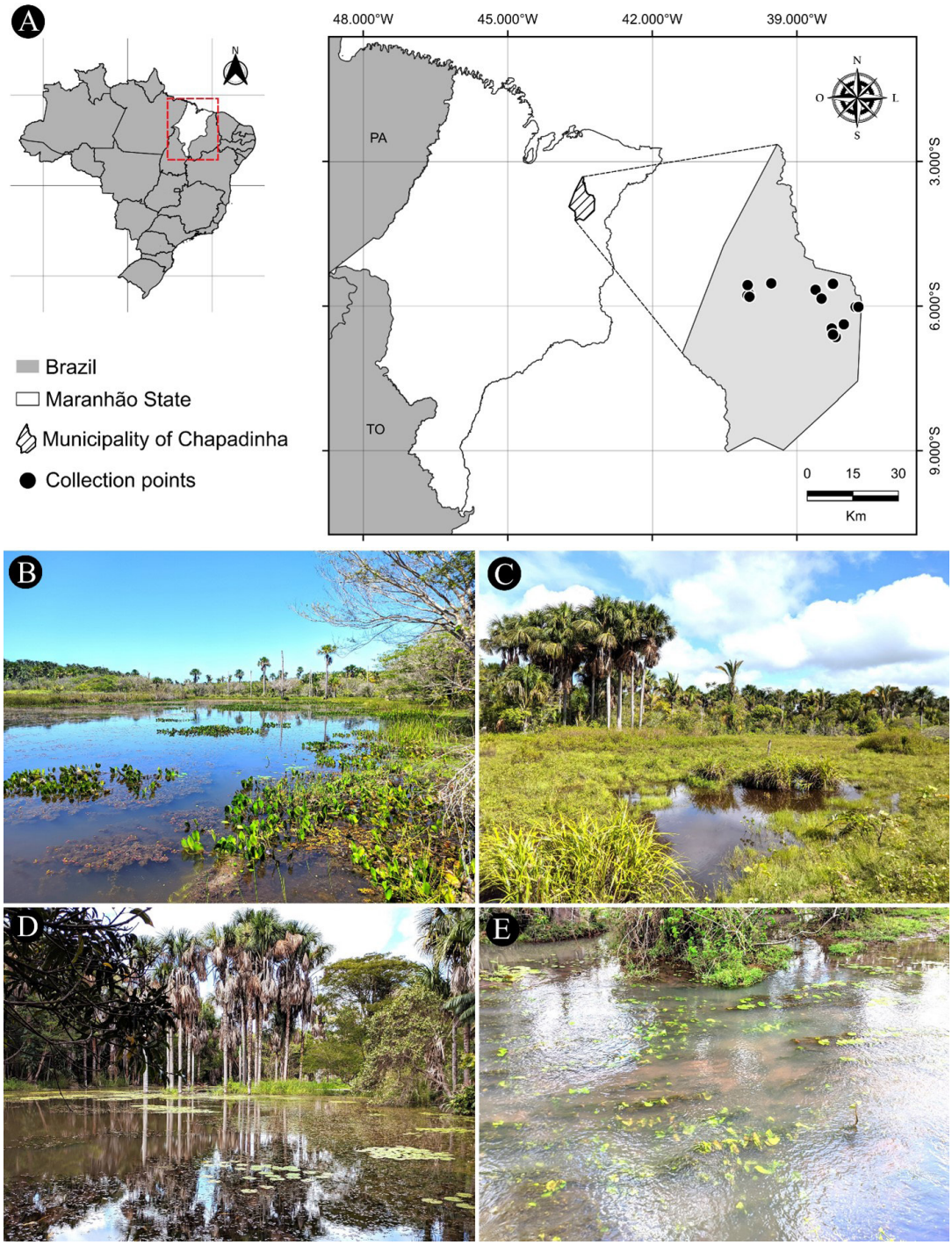

Figure 1. A: Location map of the municipality of Chapadinha (in gray) with the collection points (black circles). B: Permanent pond. C: Vereda. D: Artificial pond. E: Stream.

3. Results

A total of 72 species of aquatic macrophytes distributed in 31 families and 47 genera were recorded (Table 1). The Angiosperms were the most represented group in the survey, with 65 species, and only seven are Ferns and Lycophytes: *Ceratopteris thalictroides* (L.) Brongn. (Pteridaceae), *Cyclosorus interruptus* (Willd.) H. Ito (Thelypteridaceae), *Marsilea polycarpa* Hook. & Grev. (Marsileaceae), *Meniscium serratum* Cav. (Thelypteridaceae), *Palhinhaea cernua* (L.) Franco & Vasc. (Lycopodiaceae), *Pityrogramma calomelanos* (L.) Link (Pteridaceae), and

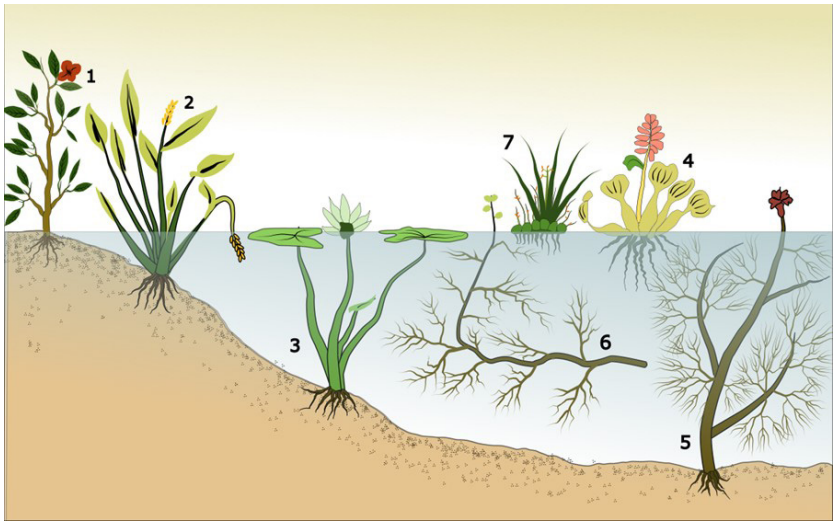

Figure 2. Biological forms of aquatic macrophytes modified from Pott and Pott (2000). 1: Amphibious. 2: Emergent. 3: Rooted floating. 4: Free floating. 5: Rooted submerged. 6: Free submerged. 7: Epiphyte.

Salvinia auriculata Aubl. (Salviniaceae). Three listed taxa are new records for Maranhão: *Bacopa stricta* (Schrad.) Wettst. ex Edwall (Plantaginaceae), *Staurogyne diantheroides* Lindau (Acanthaceae), and *Xanthosoma aristeguietae* (G.S. Bunting) Madison (Araceae), the last two species are new records for Northeastern Brazil. Examples of some of the collected species are illustrated in Figures 3 and 4.

The families with the highest species richness in the floristic survey were Cyperaceae (11 species), followed by Plantaginaceae (seven spp.), Fabaceae (five spp.), Lentibulariaceae (five spp.), Nymphaeaceae (four spp.), Poaceae (four spp.), Araceae (three spp.) and Onagraceae (three spp.). These seven families comprise 58% of the total species number in the study area. The families with only one or two species correspond to 22% and 20% of the richness, respectively.

The genera with the highest number of species were *Bacopa* (seven species), *Utricularia* (five spp.), *Eleocharis* (four spp.), *Nymphaea* (four spp.), *Cyperus* (three spp.) and *Ludwigia* (three spp.), all belonging to the most frequent families in the study area, mainly Cyperaceae and Plantaginaceae. However, more than half of the genera were represented by one or two species (74%), meaning a high generic diversity in the floristic survey.

Six biological forms of aquatic macrophytes were identified but did not find the epiphytic habit. Among them, 27 species were classified as amphibious and 26 as emergent. These two categories together accounted for 73% of the total species richness. Subsequently, the floating habit was represented by 12 species (17%), with ten species rooted in the substrate and two free in the water.

As for submerged group, seven species (9%) were found, four rooted submerged and three free submerged. The submerged habit was represented by three species of Lentibulariaceae (*Utricularia breviscapa* C.Wright ex Griseb., *U. gibba* L., and *U. hydrocarpa* Vahl), by two species of Cabombaceae (*Cabomba aquatica* Aubl., and *C. furcata* Schult. & Schult.f.), and Eriocaulaceae (*Tonina fluviatilis* Aubl., and *Paepalanthus* sp.), and by one of Hydrocharitaceae [*Apalanthe granatensis* (Humb. & Bonpl.) Planch.].

4. Discussion

The collection effort in this study is evident because the species richness of aquatic macrophytes recorded was higher than that of most previous studies in Maranhão state (see Table 2). However, fewer species than Arouche et al. (2023) were recorded, which may be related to the differences in data collection between studies. The species list resulting from this work was obtained exclusively through field collections in a single municipality. In contrast, Arouche et al. (2023) compiled their list from field collections in six municipalities, complementing it with previous records available in online databases (i.e., SpeciesLink, Reflora and GBIF) after filters were applied.

For Chapadinha and eastern Maranhão, information on aquatic macrophytes had only been reported by Costa (2014) in an ecological investigation of relationships between fish assembly associated with aquatic macrophytes in three locations within the Chapadinha microregion. Nevertheless, the author presents a list of aquatic macrophytes identified only at the genus level (Table 2) since the main focus was the associated fish species. Thus, the present study significantly contributes to understanding the floristic composition of aquatic macrophytes in this area.

In our species list, although it is common for works on aquatic macrophytes to list widely distributed species due to their high dispersal capacity (Santamaría, 2002), the novelty is to highlight that three species catalogued, i.e., *Bacopa egensis* (Poepp.) Pennell, *Staurogyne diantheroides* and *Xanthosoma aristeguietae* have a restricted distribution in Brazil according to the Flora e Funga do Brasil (2023) database.

Table 1. List of aquatic macrophytes from Chapadinha, eastern Maranhão, Brazil. Life forms: AM = Amphibious. EM = Emergent. RF = Rooted floating. FF = Free-floating. RS = Rooted submerged. FS = Free submerged. Vouchers: BMA = Maranhão Continental Herbarium. CCAA = Centro de Ciências Agrárias e Ambientais Herbarium.

Family (nº genera/species)/Scientific Name	Life form	Herbarium voucher
FERNS AND THE LICOPHYTE		
LYCOPODIACEAE (1/1)		
Palhinhaea cernua (L.) Franco & Vasc.	AM	CCAA 1283
MARSILEACEAE (1/1)		
Marsilea polycarpa Hook. & Grev.	RF	BMA 2834
PTERIDACEAE (2/2)		
Ceratopteris thalictroides (L.) Brongn.	EM	CCAA 3166
Pityrogramma calomelanos (L.) Link	AM	CCAA 3165
THELYPTERIDACEAE (2/2)		
Cyclosorus interruptus (Willd.) H. Ito	EM	CCAA 3164
Meniscium serratum Cav.	AM	CCAA 3169
SALVINIACEAE (1/1)		
Salvinia auriculata Aubl.	FF	CCAA 3145
FLOWERING PLANTS		
ACHANTHACEAE (1/1)		
Staurogyne diantheroides Lindau**	AM	BMA 2856
ALISMATACEAE (2/2)		
Limnocharis flava (L.) Buchenau	EM	CCAA 3147
Sagittaria guayanensis Kunth	RF	CCAA 3146
ARACEAE (3/3)		
Lemna aequinoctialis Welw.	FF	CCAA 3156
Montrichardia linifera (Arruda) Schott	EM	CCAA 3144
Xanthosoma aristeguietae (G.S.Bunting) Madison**	EM	CCAA 3172
BORAGINACEAE (1/1)		
Heliotropium indicum L.	AM	CCAA 3129
BURMANIACEAE (1/1)		
Burmannia capitata (Walter ex J.F.Gmel.) Mart.	AM	BMA 2877
CABOMBACEAE (1/2)		
Cabomba aquatica Aubl.	RS	CCAA 3141
C. furcata Schult. & Schult.f.	RS	CCAA 3160
COMELLINACEAE (2/2)		
Commelina diffusa Burm.f.	AM	CCAA 3143
Murdannia nudiflora (L.) Brenan	AM	BMA 2854
CONVOLVULACEAE (1/1)		
Ipomoea asarifolia (Desr.) Roem. & Schult.	AM	CCAA 3158
CYPERACEAE (4/11)		
Cyperus digitatus Roxb.	AM	CCAA 3135
C. esculentus L.	EM	BMA 2833
C. luzulae (L.) Retz.	AM	CCAA 3136
Eleocharis geniculata (L.) Roem. & Schult.	EM	CCAA 3173
E. interstincta (Vahl) Roem. & Schult.	EM	CCAA 3130
E. minima Kunth	EM	CCAA 3139
E. mutata (L.) Roem. & Schult.	EM	CCAA 3170
Fuirena umbellata Rottb.	EM	BMA 2844
Rhynchospora holoschoenoides (Rich.) Herter	EM	BMA 2852
R. nervosa (Vahl) Boeckeler	AM	CCAA 3153
Scleria gaertneri Raddi	AM	BMA 2831

Table 1. Continued...

Family (nº genera/species)/Scientific Name	Life form	Herbarium voucher
ERIOCAULACEAE (2/2)		
Paepalanthus sp.	AM	BMA 2851
Tonina fluviatilis Aubl.	EM/RS	BMA 2868
FABACEAE (3/5)		
Aeschynomene rudis Benth.	EM	BMA 2847
A. sensitiva Sw.	EM	BMA 2846
Mimosa pudica L.	AM	CCAA 3162
M. sensitiva L.	AM	CCAA 3126
Neptunia plena (L.) Benth.	EM	CCAA 3134
HELICONIACEAE (1/1)		
Heliconia psittacorum L.f.	AM	CCAA 3128
HYDROCHARITACEAE (1/1)		
Apalanthe granatensis (Humb. & Bonpl.) Planch.	RS	CCAA 3161
LENTIBULARIACEAE (1/5)		
Utricularia breviscapa C.Wright ex Griseb.	FS	CCAA 2850
U. gibba L.	FS/EM	CCAA 3124
U. hydrocarpa Vahl	FS	BMA 2827
U. simulans Pilg.	AM	BMA 2835
U. subulata L.	EM	BMA 2839
LINDERNIACEAE (1/1)		
Lindernia crustacea (L.) F.Muell.	AM	BMA 2829
MELASTOMATACEAE (1/1)		
Pterolepis glomerata (Rottb.) Miq.	AM	CCAA 3149
MENYANTHACEAE (1/1)		
Nymphoides humboldtiana (Kunth) Kuntze	RF	CCAA 3123
NYMPHAECEAE (1/4)		
Nymphaea amazonum Mart. & Zucc.	RF	CCAA 3174
N. lingulata Wiersema	RF	BMA 2879
N. rudgeana G.May.	RF	CCAA 3168
Nymphaea tenerinervia Casp.	RF	BMA 2828
OCHNACEAE (1/1)		
Sauvagesia erecta L.	AM	BMA 2848
ONAGRACEAE (1/3)		
Ludwigia leptocarpa (Nutt.) H.Hara	AM	CCAA 3137
L. octovalvis (Jacq.) P.H. Raven	EM	CCAA 3140
L. sedioides (Humb. & Bonpl.) H.Hara	RF	CCAA 3138
OXALIDACEAE (1/1)		
Oxalis cytisoides Mart. ex Zucc.	AM	CCAA 3155
PLANTAGINACEAE (1/7)		
Bacopa aubletiana Scatigna	EM	BMA 2836
B. angulata (Benth.) Edwall	EM	CCAA 3154
B. aquatica Aubl.	EM	CCAA 3131
B. egensis (Poepp.) Pennell	RF/EM	CCAA 2317
B. salzmannii (Benth.) Wettst. ex Edwall	EM	CCAA 3150
B. scoparioides (Cham. & Schltdl.) Scatigna	EM	BMA 2855
B. stricta (Schrad.) Wettst. ex Edwall*	AM	BMA 2826
POACEAE (4/4)		
Oryza latifolia Desv.	EM	BMA 2843
Panicum sp.	AM	BMA 2832
Paspalum millegrana Schrad. ex Schult.	EM	BMA 2842
Rugoloa pilosa (Sw.) Zuloaga	EM	BMA 2830

Table 1. Continued...

Family (nº genera/species)/Scientific Name	Life form	Herbarium voucher
PONTEDERIACEAE (1/2)		
Eichhornia diversifolia (Vahl) Urb.	RF	CCAA 3133
E. heterosperma Alexander	EM	CCAA 3125
RUBIACEAE (1/1)		
Borreria verticillata (L.) G.Mey.	AM	BMA 2841
XYRIDACEAE (1/1)		
Xyris jupicai Rich.	AM	CCAA 3148

Table 2. Studies on aquatic macrophytes performed in the state of Maranhão, their locations, and the number of catalogued taxa.

Author(s)	Study Site	Number of Species
Arouche et al. (2023)	Southwestern region of Baixada Maranhense, municipalities of Anajatuba, Ararai, Cajari, Vitória do Mearim and Viana	128
Present study (2023)	**Municipality of Chapadinha, eastern of the state**	**72**
Arouche et al. (2021)	Several municipalities, most of them belonging to Environmental Protection Area of Baixada Maranhense	40
Barbieri and Pinto (1999)	Municipality of São Bento, in the Environmental Protection Area of Baixada Maranhense Baixada Maranhense	19
Silva and Fontes (2018)	Municipality of Barreirinhas, in the eastern Coast	16
Costa (2014)	Anapurus, Mata Roma and Chapadinha, in the eastern of the state	14
Barbieri and Carreiro (2017)	Middle Pericumã River, in the Environmental Protection Area of Baixada Maranhense	12

Bacopa egensis is an aquatic herb recorded only in the states of Amazonas, Acre, Pará, Mato Grosso and Maranhão (Souza, 2023). The species first record in northeastern Brazil in Chapadinha also represents an important record for the Cerrado (see Pestana et al., 2023). *Xanthosoma aristeguietae* is a rhizomatous aquatic herb with records in Amazonas, Rondônia, Roraima, and Mato Grosso do Sul (Flora e Funga do Brasil, 2023), and now in Maranhão. *Staurogyne diantheroides* is an aquatic herb recognized by its numerous glandular trichomes distributed throughout the vegetative and reproductive structures. It has confirmed occurrences only in Tocantins, Mato Grosso do Sul (Flora e Funga do Brasil, 2023), and as reported here, in Maranhão state. Moreover, *S. diantheroides* has only 19 collection records for Brazil (CRIA, 2023), attributable to collection gaps or its inconspicuous look. Most records are in the Pantanal of Mato Grosso do Sul, a wetland facing habitat fragmentation and alterations in the seasonal flood pulse in the last years (Pott et al., 2011; Miranda et al., 2018). Therefore, further studies are recommended to understand the distribution of this species and evaluate its conservation in Brazil.

The new floristic records presented in this study for Maranhão demonstrate that significant gaps still exist in the distribution and species records within the state. Therefore, careful botanical exploration of various plant formations is necessary (Rodrigues et al., 2019; Sousa et al., 2022). Additionally, field research in wetlands throughout the state is crucial to gain a more comprehensive understanding of the floristic composition of these environments, which are still relatively unexplored at the state level.

The predominance in this survey of the families Cyperaceae, Plantaginaceae, Fabaceae, and Lentibulariaceae corroborates other studies conducted in the Northeast of Brazil (Lima et al., 2011; Aona et al., 2015; Sabino et al., 2015), as well as in other regions (Alves et al. 2011; Costa et al., 2016; Silva et al., 2021). These mentioned families comprise numerous taxa that inhabit a range of environments, from marshy soils (amphibious species) to truly aquatic environments (emergent, floating or submerged species), and also justify their abundance in this study, as in other studies (Pott and Pott, 2000; Amaral et al., 2008).

In addition, Lorenzi (2008) cites three main factors that may also contribute to the high representation of these families in aquatic environments: 1) the high number of species that these families have; 2) their cosmopolitan distribution, mainly in the Neotropics; and 3) the high competitive capacity for space, light and water that some taxa have, as well as high seed production, which can hinder or even prevent other species from establishing. For instance, Cyperaceae is a family with more than 5,000 species (Oliveira et al., 2011) and has often been identified as the most representative family in other studies on aquatic macrophytes in Brazil (Pivari et al., 2013; Medeiros et al., 2015; Souza et al., 2017; Fares et al., 2021). This predominance is linked to the efficient vegetative propagation of its representatives, which have a subterranean system composed of rhizomes, tubers

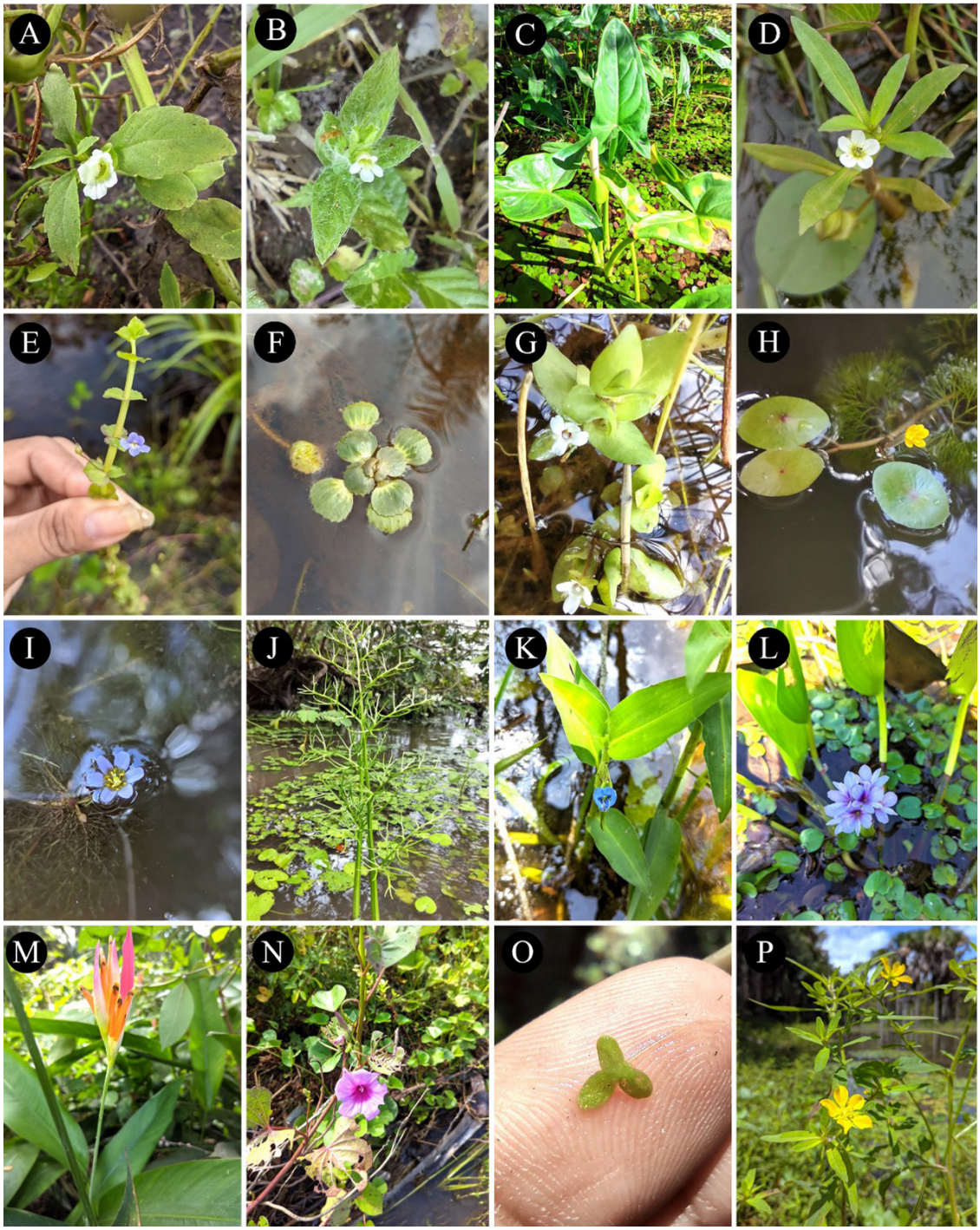

Figure 3. Aquatic macrophytes from Chapadinha, eastern Maranhão, Brazil (A-C are the new records). A: *Bacopa stricta*. B: *Staurogyne diantheroides*. C: *Xanthosoma aristeguietae*. D: *Bacopa aquatica*. E: *B. aubletiana*; F: *B. egensis*. G: *B. salzmannii*. H: *Cabomba aquatica*. I: *C. furcata*. J: *Ceratopteris thalictroides*. K: *Commelina diffusa*. L: *Eichhornia heterosperma*. M: *Heliconia psittacorum*. N: *Ipomoea asarifolia*. O: *Lemna aequinoctialis*. P: *Ludwigia leptocarpa*. Photos: A, E, and M: Ildilene Silva. All others: M.C.A. Pestana.

and stolons, enabling efficient vegetative propagation (Goetghebeur, 1998; Matias et al., 2003).

Regarding the most diverse genera, the high number of species of *Bacopa* sampled in this survey stands out, corresponding to 54% of the diversity recorded in the state of Maranhão and representing 35% of the total richness found in the Northeast region of Brazil (Souza, 2023). The predominance of this genus in the municipality of

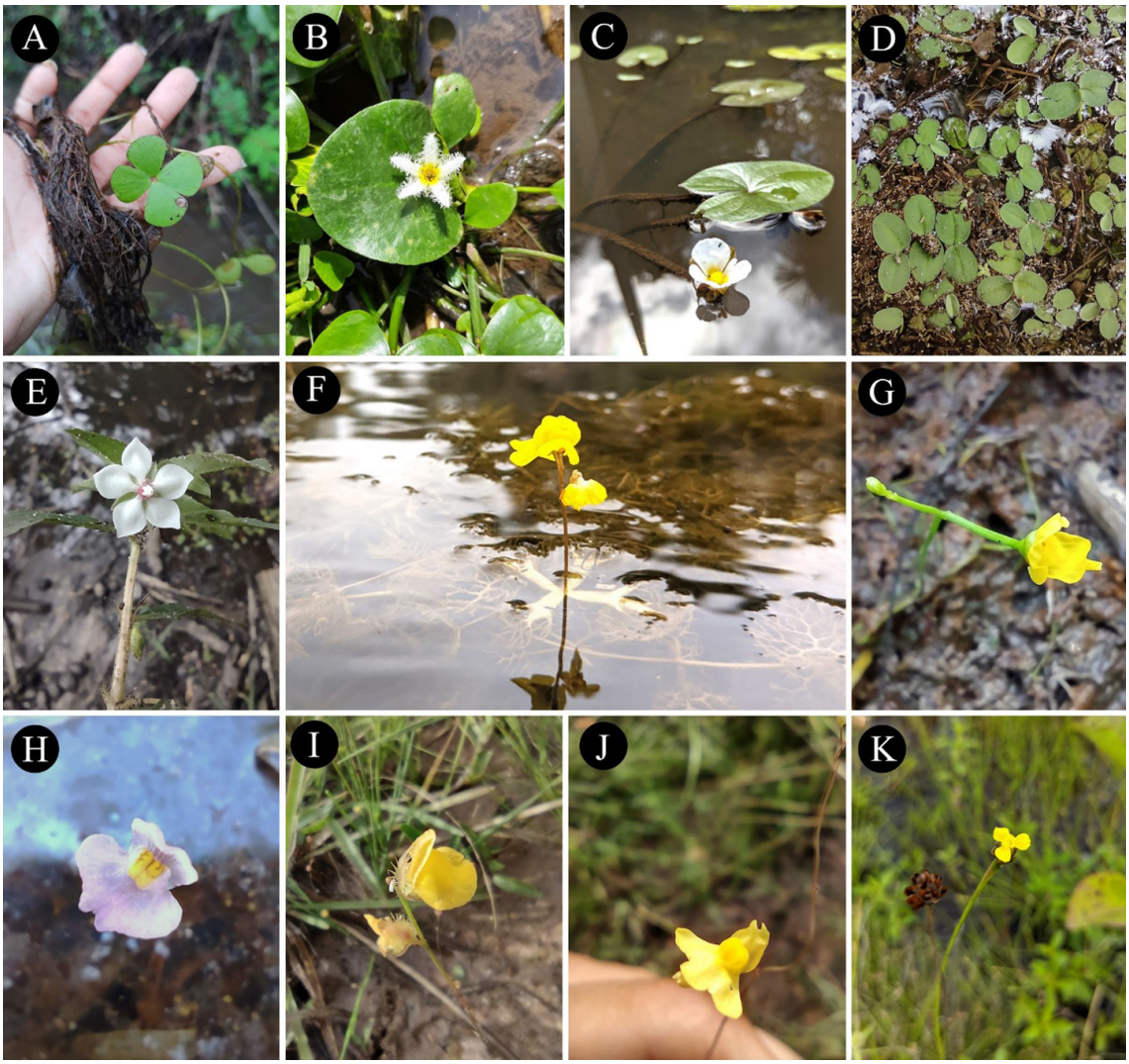

Figure 4. Aquatic macrophytes from Chapadinha, eastern Maranhão, Brazil. A: *Marsilea polycarpa*. B: *Nymphoides humboldtiana*. C: *Sagittaria guayanensis*; D: *Salvinia auriculata*. E: *Sauvagesia erecta*. F: *Utricularia breviscapa*. G: *U. gibba*. H: *U. hydrocarpa*. I: *U. simulans*. J: *U. subulata*. K: *Xyris jupicai*. Photos: M.C.A. Pestana.

Chapadinha may be related to the dispersal of propagules by water, reaching different collection points in the study area (Souza and Giulietti, 2009). Furthermore, the municipality of Chapadinha can be considered a relevant habitat for this genus in Maranhão, which could be explored in greater detail in future studies on the Plantaginaceae flora in the state.

Among the catalogued life forms, the predominance of amphibious and emergent species can be explained by the shallow water of the studied environments and the resistance of these biotypes to the dry period (Oliveira et al., 2011). In addition, growth by stolons is a common adaptation in species with an amphibious habit, which allows them to accompany variations in the water level during the seasonal flooding period (Goetghebeur, 1998). Another highlighted point concerns the alternating life forms in species in temporary aquatic habitats along the flooding cycle (Valadares et al., 2011).

This specificity was observed in three species: *Utricularia gibba*, *B. egensis*, and *T. fluviatilis*. The species *U. gibba* occurred free submerged during flood periods, and as the water level decreased, it changed to emergent habit. *Tonina fluviatilis* spends most of its life cycle rooted submerged but also as emergent. Only *B. egensis* was observed as emergent in the dry seasons and rooted floating in the flood, an unusual pattern of floating aquatic macrophytes. However, *B. egensis* is a versatile species in its biological form. Besides emergent and rooted floating as presented in this study, this species was reported as submerged and palustrine (amphibious) by Costa et al. (2016).

Among the free floating species, *Salvinia auriculata* and *Lemna aequinoctialis* Welw. are especially noteworthy, as they can become weeds with high nutrient availability (Lorenzi, 2008). When they reproduce excessively, *S. auriculata* and *L. aequinoctialis* quickly colonize extensive

water surfaces, limiting light into the water and interfering with the survival of submerged animals and plants through oxygen depletion (Pompêo, 2017). However, it is also worth mentioning that floating macrophytes are important plants widely used in the phytoremediation of water bodies (Freitas et al., 2018; Pang et al., 2023).

Although six of the seven biological forms proposed by Pott and Pott (2000) were found, the submerged species were the least sampled. The low number of submerged species in this study may be related to the low transparency and high turbidity of the water at the collection sites by organic matter from plant decomposition (Pestana et al., 2022). Thus, clear water with low turbidity is a condition that allows light to permeate the deeper layers of water bodies (Thomaz and Esteves, 2011; Schneider et al., 2018). Consequently, it increases photosynthetic rates of submerged plants and also influences their permanence in aquatic environments (Pereira et al., 2012).

The aquatic environments of Chapadinha are home to a considerable number of species, families, and life forms of aquatic macrophytes. Therefore, by carrying out this study, we have contributed new data to an area still little explored in floristic terms concerning aquatic macrophytes. Additionally, we present new records for the flora of Maranhão and Northeast Brazil. The results of new records and a few such reports in Maranhão indicate that the aquatic flora is still understudied. We therefore suggest further studies in poorly explored areas, especially in the eastern region, to better understand the species richness and floristic affinities of aquatic macrophytes in the state of Maranhão.

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