



## Ferns and lycophytes in Chapada das Mesas National Park and surroundings, Maranhão State, Brazil

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**Abstract:** In Brazil, the number of floristic inventories involving ferns and lycophytes in the Cerrado domain is considerable. However, most of the diversity is recorded for states in the Central-West Region. In addition to the Cerrado domain, Maranhão State contains part of Amazonia and a small portion of the Caatinga. However, for this state, ferns and lycophytes are poorly sampled in floristic studies and data related to the diversity of these species are insufficient. Due to the scarcity of data about these groups, conducting floristic inventories in the state is extremely important, mainly in protected areas that contain regional vegetation near primary vegetation. Thus, the objective of the present study was to conduct a floristic inventory of the fern and lycophyte species in Chapada das Mesas National Park. We identified 86 species: 69 species of ferns, distributed in 35 genera and 17 families; and 17 species of lycophytes, distributed in five genera and three families. Among the species identified, five are new records for the Northeast Region of Brazil, twenty-one are new records for Maranhão State and eleven are new records for the Cerrado; until now, these were only recorded for Amazonia and the Atlantic Forest. The most representative families were Pteridaceae with 14 species, Selaginellaceae with 12 species, Thelypteridaceae with 11 species, and Anemiaceae, Hymenophyllaceae and Dryopteridaceae with six species each. The rupicolous life form was predominant. The new occurrence records for the Cerrado, Northeast Region and Maranhão are evidence that floristic research of ferns and lycophytes is still insufficient in these areas, and a greater sampling effort is needed to increase what is known about the diversity of these plants.

**Keywords:** Cerrado; Riparian forest; Northeast; Vascular plants; Rupicolous.

## Samambaias e licófitas do Parque Nacional da Chapada das Mesas e arredores, Estado do Maranhão, Brasil

**Resumo:** No Brasil o número de inventários florísticos envolvendo samambaias e licófitas no domínio Cerrado são consideráveis. Entretanto, a maior parte dessa diversidade é registrada para os estados da região Centro-Oeste. Além do domínio Cerrado, o território do estado do Maranhão inclui parte da Amazônia e uma pequena porção da Caatinga. No entanto, para este estado, samambaias e licófitas são pouco amostradas nos estudos florísticos e os dados relacionados à diversidade dessas espécies são insuficientes. Devido à escassez de dados sobre esses grupos, a realização de inventários florísticos no estado é de extrema importância, principalmente em unidades de conservação que contêm vegetação regional similar à vegetação primária. Assim, o objetivo do presente estudo foi realizar um inventário florístico das espécies de samambaias e licófitas no Parque Nacional da Chapada das Mesas. Nós identificamos 86 espécies: 69 espécies de samambaias, distribuídas em 35 gêneros e 17 famílias; e 17 espécies de licófitas, distribuídas em cinco gêneros e três famílias. Dentre as espécies identificadas, cinco são novos registros para a região Nordeste do Brasil, vinte e uma são novos registros para o Estado do Maranhão e onze são novos registros para o Cerrado; até agora, esses foram registrados apenas para a Amazônia e a Mata Atlântica. As famílias mais representativas foram Pteridaceae com 14 espécies, Selaginellaceae com 12 espécies, Thelypteridaceae com 11 espécies e Anemiaceae, Hymenophyllaceae e Dryopteridaceae com seis espécies cada. A forma de vida rupícola foi predominante. Os novos registros de ocorrência para o Cerrado, Nordeste e Maranhão evidenciam que a pesquisa florística de samambaias e licófitas ainda é insuficiente nessas áreas, sendo necessário um maior esforço amostral para aumentar o conhecimento em relação a diversidade dessas plantas.

**Palavras-chave:** Cerrado; Mata ciliar; Nordeste; Plantas vasculares; Rupícolas.

## Introduction

Ferns and lycophytes are seedless vascular plants that reproduce from spores (Schuettpehl & Pryer 2008). They occur as various life forms, of which the most common are terrestrial, epiphytic, rupicolous and aquatic, and this has allowed them to widely colonize environments worldwide, excepts for the poles (Mehltreter 2008, Zuquim et al. 2008).

For the world, the PPG I (2016) classified ferns and lycophytes into two classes, 14 orders, 51 families, 337 genera, and 11,916 species. In Brazil, it is estimated that there are 1,403 species, including 315 species in the Cerrado phytogeographic domain, which represents 22.45% of the species in Brazil (Samambaias e Licófitas *in* Flora do Brasil 2020). Floristic inventories of these groups in the Cerrado have mostly been conducted in the Southeast and Central-West regions of Brazil (e.g., Athayde Filho & Felizardo 2010, Forsthofer & Athayde Filho 2012, Miguez et al. 2013).

The Cerrado occupies 21% of Brazil and is the second largest biome in the country; only Amazonia is larger. It is a world biodiversity hotspot (Myers et al. 2000, Silva & Bates 2002) and widely used for agricultural activities (Borlaug 2002). Although a large part of the Cerrado is extremely important to the conservation of biodiversity, only 5.5% of its original area consists of protected areas (PAs). Further, it is the world hotspot with the lowest percentage of areas that are completely protected (Brasil, Mittermeier et al. 2021).

In addition to the Cerrado domain, Maranhão contains other phytogeographic domains (i.e., a portion of Amazonia and a small part of the Caatinga) and extensive transition areas between them, resulting in high biodiversity in the state. However, the biodiversity in Maranhão, especially lycophytes and ferns, could be underestimated because not many areas have been sampled and studied (Table 1) (e.g., Bastos & Cutrim 1999, Azevedo & Silva 2001, Fernandes et al. 2007, 2010, Conceição & Ruggieri 2010, Conceição & Rodrigues 2010, Conceição et al. 2015, Santos-Silva 2016, Silva et al. 2017, Santos-Silva et al. 2018, Silva-Júnior et al. 2018, Santos-Silva et al. 2019a, b, c, Barbieri et al. 2020, Almeida et al. 2020, Silva-Junior et al. 2020). According to Samambaias e Licófitas *in* Flora do Brasil (2020), only 97 species of ferns and lycophytes have been recorded in Maranhão. However, based on a compilation of data published in floristic inventories about the state (mentioned above), there are 24 families and 130 species (Supplementary file 1). Among the studies cited above, most sampling was conducted in the Amazon domain (64 species) (e.g., Silva Junior et al. 2020), which includes an important federal protected area called the Gurupi Biological Reserve (Reserva Biológica do Gurupi) (Table 1). In Maranhão State, 12.5% of the Cerrado is within PAs, of which 5.7% is completely protected under the category National Park (Parque Nacional) and 6.8% is sustainably used and mainly environmental protection areas (Áreas de Proteção Ambiental) (Spinelli-Araújo et al. 2016). In the Cerrado in the state, 74 species of ferns and lycophytes have been recorded (Fernandes et al. 2007, 2010, Conceição & Ruggieri 2010, Conceição & Rodrigues 2010, Conceição et al. 2015, Silva et al. 2017, Santos-Silva et al. 2019b, c, Almeida et al. 2020, Samambaias e Licófitas *in* Flora do Brasil 2020) (Supplementary file 1). Despite the considerable number of studies conducted, the greatest diversity recorded was 21 species for the municipality of Caxias, which includes the Inhamum Environmental Protection Area (Área de Proteção Ambiental do Inhamum) (Fernandes et al. 2007, 2010). Among the studies published, only two were conducted in completely protected

PAs: an inventory of ferns and lycophytes in Mirador State Park (Parque Estadual do Mirador) (e.g., Conceição & Rodrigues 2010), which is the largest protected area in Maranhão State (437,000 ha); and an inventory of lycophytes conducted in Chapada das Mesas National Park (Parque Nacional da Chapada das Mesas) (e.g., Almeida et al. 2020).

Chapada das Mesas National Park (PNCM) is a protect area in Maranhão that is predominantly Cerrado, in an environment that transitions with the Caatinga and Amazon biomes (ICMBio 2021). All stratifications associated with the Cerrado biome occur in this area, including humid and dry forests, cerrado, cerrado ralo, marshes and veredas. This PA is part of the Araguaia Bananal ecological corridor, which is an important ecotone between the Cerrado and Amazon biomes (MMA 2007).

Despite being created over 15 years ago and possessing diverse phytophysiognomies of the Cerrado domain, including large areas of field and savanna formations, the management plan of the park lacks data about the floristic diversity (MMA 2012, ICMBio 2021). Further, studies about the plant diversity of the area are recent (e.g., Silva et al. 2018, Oliveira et al. 2018, Fernandes et al. 2021, Silva et al. 2021) and only one is about vascular plants (e.g., Almeida et al. 2020).

Thus, the objective of this work was to conduct a floristic survey in PNCM, an extremely important region for the conservation of biodiversity in the Cerrado that is in a transition area, with the goal of providing new information about the ferns and lycophytes of the Cerrado domain and Brazil. This data will contribute to future works about ecology, conservation and environmental education in the area, as well as the management plan for the park.

## Material and Methods

### 1. Study area

The Chapada das Mesas National Park, comprises approximately 160,000 ha of Cerrado divided into two polygons, one with around 120,000 ha and another with about 40,000 ha, which are distributed in the municipalities of Carolina, Riachão and Estreito in southeastern Maranhão State (Brasil 2006, ICMBio 2021).

The climate is predominantly seasonal tropical, type Aw (Köppen 1948), with a dry season for 3 to 5 months and a rainy season with average rainfall ranging from 1,250 to 1,500 mm, an average annual temperature between 20°C and 27°C and average relative air humidity of approximately 60% (Pereira et al. 2011).

Hydrologically, the area is very rich. The main watercourses are the Farinha River (norther portion) and Itapecuru River (southern portion), there are over 400 springs in the interior, and along the watercourses there are well-conserved riparian forests (ICMBio 2021).

The relief is characterized by the presence of sandstone and typical forms of paleokarst in sandstone (e.g., hilltop arches, small cavities, canyons, paleosinkholes, sinkholes and river resurgences), which is closely related to the evolution of the subterranean drainage and river incision (Martins et al. 2017). The soil is predominantly sandy where there are Cerrado *sensu stricto* and *campo sujo* physiognomies. However, there are also places with richer soils, mainly on the tops of mountains that have patches of semideciduous forest (ICMBio 2021).

In addition to the natural vegetation cover typical of the Cerrado biome that contains many phytophysiognomies, among which savanna

**Table 1.** Scientific studies of ferns and lycophytes conducted Maranhão State. Author(s), article title, species, genus and family numbers (Quant. spp./gen./fam.), new records, size of area and phytogeographic domain.

Author(s)	Article title	Quant. spp./ gen./ fam.	New records	Size of area	Phytogeographic domain
Bastos & Cutrim 1999	Pteridoflora da Reserva Florestal do Sacavém, São Luís-Maranhão	15 / 12 / 9	15	-	Amazonia
Azevedo & Silva 2001	Ocorrência de <i>Lycopodiella cernua</i> (L.) Pichi-Sermolli (Pteridophyta: Lycopodiopsida: Lycopodiaceae) nas bordas de manguezal, São Luís – Maranhão – Brasil	1 / 1 / 1	-	-	Amazonia
Fernandes et al. 2007	Diversidade Florística de Pteridófitas da Área de Preservação Ambiental do Inhamum, Caxias, Maranhão, Brasil	13 / 12 / 9	7	4,500 ha	Cerrado
Fernandes et al. 2010	Samambaias e licófitas do município de Caxias, Maranhão, Brasil	21 / 16 / 11	6	531,350 ha	Cerrado
Conceição & Rodrigues 2010	Pteridófitas do Parque Estadual do Mirador, Maranhão, Brasil	7 / 7 / 6	-	450,838 ha	Cerrado
Conceição & Ruggieri 2010	Pteridófitas do município de Tufilândia, estado do Maranhão, Brasil	9 / 9 / 7	-	134,6 km <sup>2</sup>	Transition areas Cerrado and Amazonia
Conceição et al. 2015	Pteridoflora e seus aspectos ecológicos no município de Timon, Maranhão, Brasil	9 / 7 / 6	-	-	Cerrado
Santos-Silva 2016	<i>Cyathea delgadii</i> Sternb. ( <i>Cyatheaceae</i> , Samambaia): Caracterização e ecologia populacional no domínio fitogeográfico do Cerrado	1 / 1 / 1	-	-	Cerrado
Silva et al. 2017	Licófitas e Samambaias no Cerrado do Leste do Maranhão, Brasil	19 / 15 / 11	1	1.439,1 km <sup>2</sup>	Cerrado
Santos-Silva et al. 2018a	Nova ocorrência de <i>Lycopodiaceae</i> ( <i>Lycophyta</i> ) para o estado do Maranhão: <i>Pseudolycopodiella carnosus</i> (Silveira) Holub	1 / 1 / 1	1	-	Cerrado
Santos-Silva et al. 2018b	Association of <i>Anuran</i> to <i>Cyathea delgadii</i> Sternb. ( <i>Cyatheaceae</i> ) in Cerrado from Brazil	1 / 1 / 1	-	-	Cerrado
Silva-Junior et al. 2018	First record of the exotic fern <i>Pteris tripartita</i> Sw. ( <i>Pteridaceae</i> ) for the Maranhão state, northeastern Brazil	1 / 1 / 1	1	-	Amazonia
Santos-Silva et al. 2019a	Formigas associadas à <i>Cyathea delgadii</i> Sternb. ( <i>Cyatheaceae</i> ) em um fragmento de Cerrado maranhense, Nordeste, Brasil	1 / 1 / 1	-	-	Cerrado
Santos-Silva et al. 2019b	New occurrences of <i>Schizaeaceae</i> for the Maranhão and Brazilian Cerrado	3 / 2 / 1	1	-	Cerrado
Santos-Silva et al. 2019c	Structure and spatial distribution pattern of <i>Cyathea delgadii</i> Sternb. ( <i>Cyatheaceae</i> ) in two Cerrado areas, in the Northeast of Brazil	1 / 1 / 1	-	1.438,1 km <sup>2</sup> , e 2.107,403 km <sup>2</sup>	
Almeida et al. 2020	Lycophytes of the Chapada das Mesas National Park, Cerrado, Maranhão, Brazil	6 / 3 / 3	1	160,000 ha	Cerrado
Silva Junior et al. 2020	Ferns and lycophytes of remnants in Amazônia Maranhense, Brazil	64 / 36 / 18	24	81.208,40 km <sup>2</sup>	Amazonia
Barbieri et al. 2020	Distribuição, Morfologia e Anatomia de Monilófitas (Samambaias) Aquáticas de pequenas lagoas na área Itaqui-Bacanga, ilha de São Luís – Ma	3 / 2 / 2	-	-	Amazonia

and forest aspects are notable, there are also Caatinga and Amazonian species, which help characterize the high diversity of the area (ICMBio 2021). These vegetation characteristics, including the presence of well-conserved riparian forests along watercourses, large patches of *cerradão* and other types of phytophysiognomies, are essential for maintaining the biodiversity in the region (Marques 2012).

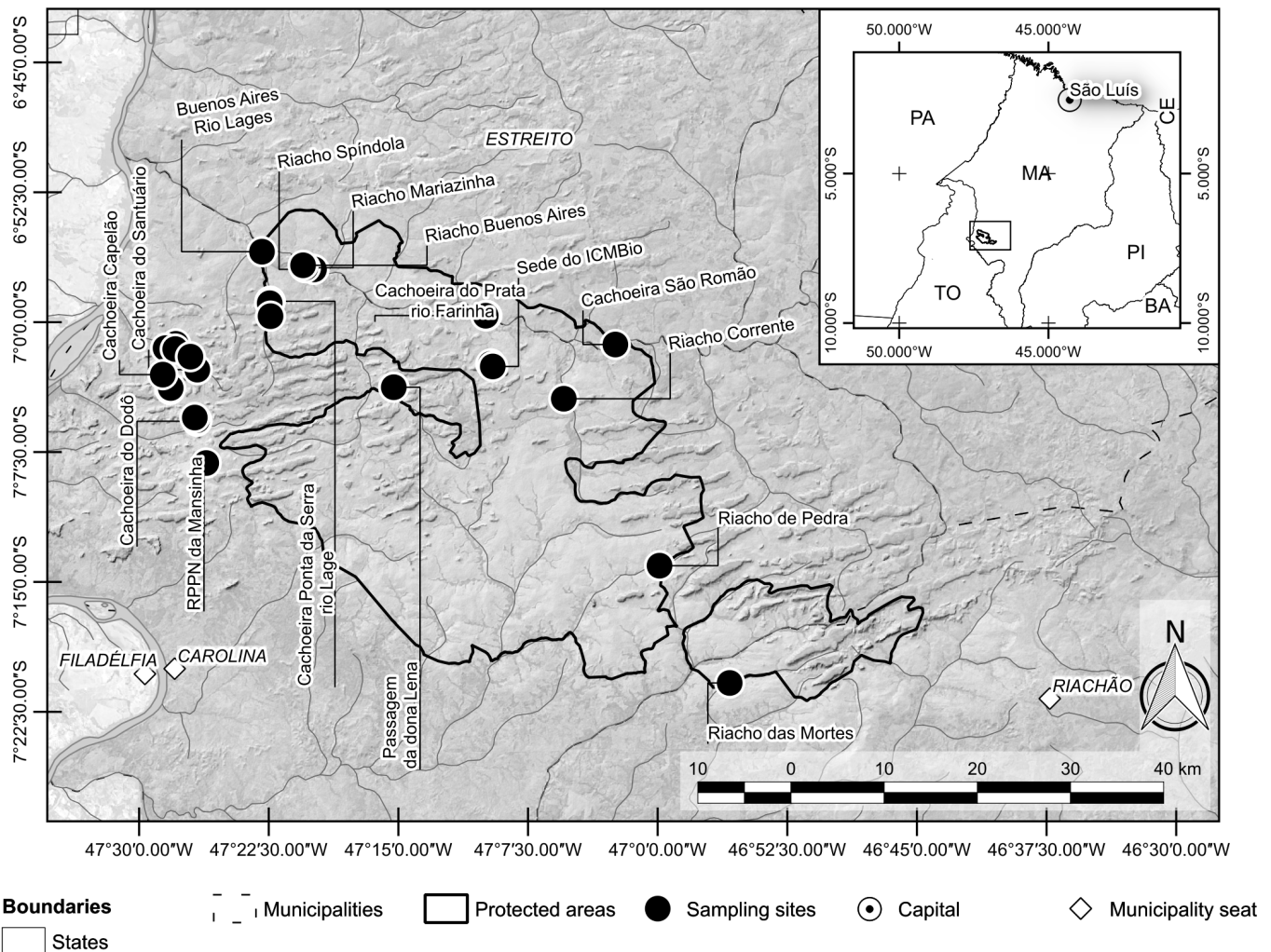
## 2. Data collection

The species were collected during four expeditions, in March and October 2017, June 2018 and February 2020, which were three days each and included the dry and rainy seasons. Collecting was based on the methods proposed by Filgueiras et al. (1994). Microenvironments in the study area were selected and explored randomly, with the goal of visiting the greatest number of places where taxa might occur. The sampling points were mapped (Figure 1).

Herbarium specimens were made based on standard techniques used for seedless vascular plants (Silva 1989). All the material was deposited in the CCAA herbarium (RBH 2019), at the Federal University of Maranhão, Campus Chapadinha. When available, duplicates were sent to the following institutions: MG, HBRA and BHCB (Thiers 2019).

The identification and distribution of the species and genera were based on specialized literature, such as PPG I (2016), IPNI (2019) the Flora do Brasil 2020 monographs, as well as revisions and regional floras (e.g., Tryon & Stolze 1994, Moran & Riba 1995, Mickel & Smith 2004). When needed, some species were sent to specialists to confirm the identification.

The terminology follows Lellinger (2002). Family and genus delimitations are based on PPG I (2016). Nomenclature and authors of the species follow the International Plant Names Index (IPNI 2019) and Tropicos (2019). The images of species were taken with a digital



**Figure 1.** Localization map of the study area, showing samples sites inside and outside the Chapada das Mesas National Park (Modified from: Silva et al. 2021).

camera in the field or from herbarium specimens (fertile parts). The photographic plates, preferentially of new records for Maranhão State, were made with Photoshop® CS6 v.13.0 (Adobe Systems 2012). Comments about the environment of occurrence are based on the area where the material was collected. Life forms were determined based

on Lellinger (2002), Zuquim et al. (2008) and Irgang et al. (1984). For floating aquatic plants that grow exclusively in aquatic environments (e.g., lakes, ponds), without connection to the soil, we follow Pedralli et al. (1985) *apud* Pott et al. (1989).

The **types of phytophysiognomies** (or habitat of occurrence) of the species were based on field observations and follow the classification of Flora do Brasil (2020). The following categories were considered:

- **Open riparian forest:** forest vegetation associated with watercourses that is wide with trees spaced apart; - **Closed riparian forest:** forest vegetation associated with watercourses that is narrower with trees closer together and a canopy; - **Cerrado *sensu stricto*:** presence of short, inclined, tortuous trees with thin trunks and irregular, twisted branches, generally with signs of past fires, and the presence of a lot of grass in the understory; - **Anthropogenic area (pasture):** environment where the original vegetation was destroyed in relation to the primary phytophysiognomy and transformed into pasture with babaçu palms; - **Vereda:** area of open marsh with grasses, buriti palms and a few shrubs, which is associated with nearby forest with watercourses.

The **microenvironments** preferred by the species were defined based on field observations, such as the following:

**Rocky banks:** located along the margins of watercourses inside forests, formed by rocks that are bare or only have a thin layer of humus, with a slight to vertical (90°) incline; - **Non-rocky banks:** located along the margins of watercourses inside forests, formed by various soil types (non-rocky), with a slight to vertical incline (90°); - **Waterfall areas:** locations near a waterfall and formed by vertical (90°) rock faces with constant water vapor; - **Rock walls:** blocks of continuous rock forming vertical (90°) rock extensions (taller than the banks), with bare rock or only a thin layer of humus, located along the margins of watercourses inside riparian forest or between Cerrado *sensu stricto* vegetation; - **Marshy areas with buriti palms:** locations with wet soil that are associated with watercourses inside forest where buriti palms predominate; - **Marshy areas with grasses:** locations with wet soil that are associated with watercourses in open areas where there are a few shrubs and grasses predominate; - **Pasture with babaçu palms;** - **Forest interior in flat area;** - **Open flooded area.**

## Results

### 1. Ferns and lycophytes diversity

We identified 86 species of ferns and lycophytes: 69 species of ferns, distributed in 35 genera and 17 families; and 17 species of lycophytes, distributed in five genera and three families (Table 2 and Supplementary file 2).

Among the species identified, five are new records for the Northeast Region of Brazil, twenty-one are new records for Maranhão State and eleven are new records for the Cerrado of Brazil that, until now, were only recorded for Amazonia and the Atlantic Forest (Table 2 and Supplementary file 2).

The most representative families were Pteridaceae with 14 species, Selaginellaceae with 12 species, Thelypteridaceae with 11 species, and Anemiaceae, Hymenophyllaceae and Dryopteridaceae with six species each (Table 2).

Seven species were identified to the genus level, and all other species were identified to the species level. *Elaphoglossum* sp. was identified to the genus level since only sterile material was collected. The other six species (*Selaginella* sp.1, *Selaginella* sp.2, *Selaginella* sp.3, *Blechnum* cf. *occidentale*, *Blechnum* sp., and *Adiantum* sp.) were identified to the

genus level due to the confusing taxonomy or probably hybrid (*pers. com.*, Vinicius Dittrich, Luis Armando Góes Neto and Jefferson Prado).

The rupicolous life form had the highest number of species, with 22 species (58% of the total number of species), followed by terrestrial with 15 species (22% of the total), epiphytic with three species, terrestrial climber with three species, fixed aquatic with two species, and floating aquatic with one species. Forty species had more than one life form: 32 terrestrial and rupicolous; seven epiphytic and rupicolous; and one terrestrial, epiphytic and rupicolous (Table 2).

### 2. New records: Northeast Region, Maranhão and the Cerrado domain

#### *Selaginella convoluta* (Arn.) Spring.

(Figure 2A)

Rupicolous on a rocky bank in a waterfall area. **Habitat:** open riparian forest.

**Geographic distribution:** AL, BA, CE, MA, PB, PE, PI, RN, SE, GO, MS, MT, ES, MG, RJ, SP, PR (Caatinga, Cerrado and Atlantic Forest). New record: Maranhão.

#### *Selaginella minima* Spring.

(Figure 2C)

Terrestrial on a non-rocky bank and rupicolous plant collected on a rocky bank in a waterfall area, near the margin of a trail. **Habitat:** closed riparian forest. **Geographic distribution:** AM, AP, PA, RO, MA, PI, GO, MT (Amazonia and Cerrado). New record: Maranhão.

#### *Selaginella sulcata* (Desv. ex Poir.) Spring ex Mart.

(Figure 2F)

Rupicolous on a rocky bank on the top of a hill, near a watercourse. **Habitat:** open riparian forest, closed riparian forest. **Geographic distribution:** AC, AM, PA, BA, CE, MA, PB, PE, MS, MT, ES, MG, RJ, SP, PR, RS, SC (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão and Cerrado.

#### *Lycopodiella longipes* (Grev. & Hook.) Holub.

(Figure 3A)

Terrestrial in an open marshy area with grasses. **Habitat:** vereda. **Geographic distribution:** AC, AM, RR, BA, MA, DF, GO, MG, RJ, SP, PR, RS, SC (Amazonia, Cerrado, Atlantic Forest and Pampa). New record: Maranhão and Cerrado.

#### *Palhinhaea camporum* (B. Øllg. & Windisch) Holub.

(Figure 3B)

Terrestrial in an open marshy area with grasses. **Habitat:** vereda. **Geographic distribution:** AC, AM, AP, PA, RO, RR, TO, BA, MA, PE, PI, DF, GO, MS, MT, MG, SP, PR, SC (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão.

#### *Anemia buniifolia* (Gardner) T.Moore.

(Figure 4A)

Rupicolous near the margin of a trail on a rocky bank in a waterfall area. **Habitat:** open riparian forest. **Geographic distribution:** AM, PA, TO, BA, MA, DF, GO, MT, MG (Amazonia and Cerrado). New record: Maranhão.

#### *Anemia elegans* (Gardner) C.Presl.

(Figure 4B)

Rupicolous on a rock wall and in rock cracks on the margin of a trail. **Habitat:** Cerrado *sensu stricto*. **Geographic distribution:** TO, BA, MA, DF, GO, MT, MG (Cerrado). New record: Maranhão.

#### *Anemia trichorhiza* Gardner.

**Table 2.** List of fern and lycophyte species in Chapada das Mesas National Park, Maranhão State, Brazil. New records for Maranhão, the Northeast Region and the Cerrado are in bold. Life form/growth, Habitat, Microenvironments.

<b>CLASS, FAMILY, species</b>	<b>Life forms/growth</b>	<b>Habitat</b>	<b>Microenvironments</b>
<b>LYCOPODIOPSIDA</b>			
<b>ISOETACEAE</b>			
<i>Isoetes panamensis</i> Maxon & C.V. Morton	Fixed aquatic	Open riparian forest	Waterfall areas
<b>SELAGINELLACEAE</b>			
<i>Selaginella conduplicata</i> Spring	Terrestrial/Rupicolous	Open riparian forest	Rocky banks/Waterfall areas
<i>Selaginella convoluta</i> (Arn.) Spring	Rupicolous	Open riparian forest	Rocky banks/Waterfall areas
<i>Seleginella erythropus</i> (Mart.) Spring	Terrestrial/Rupicolous	Closed riparian forest	Non-rocky banks/Waterfall areas
<i>Selaginella flagellata</i> Spring	Terrestrial	Closed riparian forest	Non-rocky banks
<i>Selaginella marginata</i> (Humb. & Bonpl. ex Willd.) Spring	Terrestrial/Rupicolous	Closed riparian forest	Non-rocky banks/Waterfall areas
<i>Selaginella minima</i> Spring	Terrestrial/Rupicolous	Closed riparian forest	Non-rocky banks/Waterfall areas
<i>Selaginella radiata</i> (Aubl.) Spring	Terrestrial/Rupicolous	Open riparian forest/Closed riparian forest	Non-rocky banks/Rock walls/Waterfall areas
<i>Selaginella simplex</i> Baker	Terrestrial/Rupicolous	Open riparian forest/Closed riparian forest	Non-rocky banks/Waterfall areas
<i>Selaginella sulcata</i> (Desv. ex Poir.) Spring ex Mart.	Rupicolous	Open riparian forest/Closed riparian forest	Rocky banks
<i>Selaginella</i> sp.1	Epiphytic	Closed riparian forest	Non-rocky banks/Waterfall areas
<i>Selaginella</i> sp.2	Epiphytic	Closed riparian forest	Non-rocky banks/Waterfall areas
<i>Selaginella</i> sp.3	Epiphytic/Rupicolous	Closed riparian forest	Non-rocky banks/Waterfall areas
<b>LYCOPODIACEAE</b>			
<i>Lycopodiella longipes</i> (Grev. & Hook.) Holub	Terrestrial	Vereda	Marshy areas with grasses
<i>Palhinhaea camporum</i> (B. Øllg. & Windisch) Holub	Terrestrial	Vereda	Marshy areas with grasses
<i>Palhinhaea cernua</i> (L.) Franco & Vasc.	Terrestrial	Vereda	Marshy areas with grasses
<i>Pseudolycopodiella meridionalis</i> (Underw. & Loyd) Holub	Terrestrial	Vereda	Marshy areas with grasses
<b>ANEMIACEAE</b>			
<i>Anemia buniifolia</i> (Gardner) T.Moore	Rupicolous	Open riparian forest	Rocky banks; Waterfall areas
<i>Anemia elegans</i> (Gardner) C.Presl	Rupicolous	Cerrado sensu stricto	Rock walls
<i>Anemia ferruginea</i> Humb. & Bonpl. ex Kunth	Terrestrial/Rupicolous	Closed riparian forest	Rocky banks/Non-rocky banks
<i>Anemia hirsuta</i> (L.) Sw.	Terrestrial/Rupicolous	Closed riparian forest	Rocky banks/Non-rocky banks
<i>Anemia oblongifolia</i> (Cav.) Sw.	Terrestrial/Rupicolous	Closed riparian forest/Open riparian forest/ Cerrado sensu stricto	Rocky banks/Non-rocky banks/Rock walls
<i>Anemia trichorhiza</i> Gardner	Rupicolous	Cerrado sensu stricto	Rock walls
<b>BLECHNACEAE</b>			
<i>Blechnum</i> cf. <i>occidentale</i>	Terrestrial/Rupicolous	Closed riparian forest	Rocky banks/Waterfall areas
<i>Blechnum</i> sp.	Rupicolous	Closed riparian forest/ Cerrado sensu stricto	Rock walls
<i>Salpichlaena hookeriana</i> (Kuntze) Alston	Terrestrial climber	Closed riparian forest	Rocky banks/Waterfall areas

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<i>Telmatoblechnum serrulatum</i> (Rich.) Perrie, D.J. Ohlsen & Brownsey	Terrestrial	Closed riparian forest	Marshy areas with buriti palms
<b>CYATHEACEAE</b>			
<i>Cyathea delgadii</i> Sternb.	Terrestrial/Rupicolous	Closed riparian forest	Rock walls/Waterfall areas
<i>Cyathea microdonta</i> (Desv.) Domin	Terrestrial	Closed riparian forest	Rock walls/Waterfall areas
<b>DENNSTAEDTIACEAE</b>			
<i>Pteridium esculentum</i> (G.Forst.) Cockayne subsp. <i>gryphus</i> Schwartzb. var. <i>harpianum</i> Schwartzb. & a.Yanez	Terrestrial/Rupicolous	Closed riparian forest	Rock walls/Waterfall areas
<b>DRYOPTERIDACEAE</b>			
<i>Bolbitis serratifolia</i> Schott	Rupicolous	Closed riparian forest	Rock walls/Waterfall areas
<i>Cyclodium meniscioides</i> (Willd.) C. Presl	Terrestrial/Rupicolous	Closed riparian forest	Marshy areas with buriti palms/Waterfall areas
<i>Dryopteris patula</i> (Sw.) Underw.	Rupicolous	Closed riparian forest	Rock walls
<i>Elaphoglossum scalpellum</i> (Mart.) T. Moore	Rupicolous	Closed riparian forest	Rock walls/Waterfall areas
<i>Elaphoglossum</i> sp.	Rupicolous	Closed riparian forest	Rock walls/Waterfall areas
<i>Polybotrya sorbifolia</i> Mett. ex Kuhn	Rupicolous	Closed riparian forest	Waterfall areas
<b>GLEICHENIACEAE</b>			
<i>Dicranopteris flexuosa</i> (Schröd.) Underw.	Terrestrial/Rupicolous	Closed riparian forest/ Cerrado sensu stricto/Vereda with grasses	Margin of riparian forest/ Waterfall areas
<b>HYMENOPHYLLACEAE</b>			
<i>Didymoglossum angustifrons</i> Fée	Epiphytic/Rupicolous	Closed riparian forest	Rocky banks/ Waterfall areas
<i>Didymoglossum pinnatinervium</i> (Jenman) Pic.Serm.	Rupicolous	Closed riparian forest	Rocky banks/Waterfall areas
<i>Trichomanes arbuscula</i> Desv.	Rupicolous	Closed riparian forest	Rocky banks
<i>Trichomanes cristatum</i> Kaulf.	Terrestrial/Rupicolous	Closed riparian forest	Rocky banks/Waterfall areas
<i>Trichomanes hostmannianum</i> (Klotzsch) Kunze	Rupicolous	Closed riparian forest	Rocky banks
<i>Trichomanes pinnatum</i> Hedw.	Terrestrial/Rupicolous	Open riparian forest/Closed riparian forest	Rocky banks/Waterfall areas
<b>LINDSAEACEAE</b>			
<i>Lindsaea divaricata</i> Klotzsch	Terrestrial/Rupicolous/ Epiphytic	Closed riparian forest	Marshy areas with buriti palms/Waterfall areas/ Rock walls
<i>Lindsaea guianensis</i> subsp. <i>lanceastrum</i> K.U.Kramer	Rupicolous	Closed riparian forest	Rocky banks
<i>Lindsaea lancea</i> (L.) Bedd.	Terrestrial/Rupicolous	Closed riparian forest	Rocky banks/Non-rocky banks
<i>Lindsaea pallida</i> Klotzsch	Terrestrial	Closed riparian forest	Non-rocky banks
<b>LYGODIACEAE</b>			
<i>Lygodium venustum</i> Sw.	Terrestrial climber	Open riparian forest	Rocky banks/Non-rocky banks
<i>Lygodium volubile</i> Sw.	Terrestrial climber	Open riparian forest	Rocky banks/Non-rocky banks
<b>METAXYACEAE</b>			
<i>Metaxya parkeri</i> (Hook. & Grev.) J. Sm.	Terrestrial/Rupicolous	Open riparian forest/Closed riparian forest	Marshy areas with buriti palms/Waterfall areas/ Rocky banks/Non-rocky banks
<b>NEPHROLEPIDACEAE</b>			
<i>Nephrolepis biserrata</i> (Sw.) Schott	Terrestrial/Rupicolous	Closed riparian forest	Rocky banks/Marshy areas with buriti palms
<i>Nephrolepis pectinata</i> (Willd.) Schott	Epiphytic	Anthropogenic area	Pasture with babaçu palms

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**POLYPODIACEAE**

<i>Microgramma persicariifolia</i> (Schrad.) C.Presl	Epiphytic/Rupicolous	Closed riparian forest	Shaded riparian forest/ Rock walls/Waterfall areas
<i>Phlebodium aureum</i> (L.) J. Sm.	Epiphytic/Rupicolous	Anthropogenic area/Open riparian forest	Pasture with babaçu palms; Rocky banks
<i>Pleopeltis burchellii</i> (Baker) Hickey & Sprunt ex A.R. Sm.	Epiphytic/Rupicolous	Closed riparian forest	Rock walls
<i>Serpocaulon triseriale</i> (Sw.) A.R.Sm.	Terrestrial/Rupicolous	Open riparian forest	Rocky banks/Non-rocky banks

**PTERIDACEAE**

<i>Adiantum deflectens</i> Mart.	Terrestrial/Rupicolous	Open riparian forest/Closed riparian forest	Rocky banks/Non-rocky banks/Waterfall areas
<i>Adiantum intermedium</i> Sw.	Terrestrial/Rupicolous	Closed riparian forest	Rocky banks/Non-rocky banks/Waterfall areas
<i>Adiantum latifolium</i> Lam.	Terrestrial/Rupicolous	Closed riparian forest	Rocky banks/Non-rocky banks
<i>Adiantum petiolatum</i> Desv.	Rupicolous	Closed riparian forest	Rocky banks
<i>Adiantum pulverulentum</i> L.	Rupicolous	Closed riparian forest	Rocky banks
<i>Adiantum serratodentatum</i> Willd.	Terrestrial	Open riparian forest	Non-rocky banks
<i>Adiantum sinuosum</i> Gardner	Rupicolous	Cerrado sensu stricto	Rock walls
<i>Adiantum terminatum</i> Kunze ex Miq.	Rupicolous	Closed riparian forest	Rocky banks/Waterfall areas
<i>Adiantum tetraphyllum</i> Willd.	Terrestrial	Open riparian forest	Forest interior in flat area
<i>Adiantum sp.</i>	Terrestrial	Open riparian forest	Forest interior in flat area
<i>Ceratopteris thalictroides</i> (L.) Brongn.	Fixed aquatic	Open riparian forest	Open flooded area
<i>Cheilanthes pohliana</i> Mett.	Rupicolous	Cerrado sensu stricto	Rock walls
<i>Pityrogramma calomelanos</i> (L.) Link	Terrestrial/Rupicolous	Closed riparian forest	Marshy areas with buriti palms/Rock walls/Non-rocky banks
<i>Vittaria lineata</i> (L.) Sm.	Epiphytic/Rupicolous	Open riparian forest/Closed riparian forest	Rock walls

**SALVINIACEAE**

<i>Azolla microphylla</i> Kaulf.	Floating aquatic	Open riparian forest	Open flooded area
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**SCHIZAEACEAE**

<i>Actinostachys pennula</i> (Sw.) Hook.	Terrestrial	Cerrado sensu stricto	Forest interior in flat area
<i>Schizaea elegans</i> (Vahl) Sw.	Terrestrial/Rupicolous	Closed riparian forest/Cerrado sensu stricto	Non-rocky banks/Forest interior in flat area
<i>Schizaea incurvata</i> Schkuhr	Terrestrial	Cerrado sensu stricto	Forest interior in flat area

**TECTARIACEAE**

<i>Tectaria incisa</i> Cav.	Rupicolous	Closed riparian forest	Rocky banks/Waterfall areas
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**THELYPTERIDACEAE**

<i>Christella conspersa</i> (Schrad.) Á.Löve & D.Löve	Terrestrial/Rupicolous	Closed riparian forest	Marshy areas with buriti palms/ Rock walls/Non-rocky banks
<i>Christella hispidula</i> (Decne.) Holttum	Terrestrial/Rupicolous	Closed riparian forest	Rock walls/Non-rocky banks
<i>Goniopteris biformata</i> (Rosenst) Salino & T.E. Almeida	Terrestrial/Rupicolous	Open riparian forest	Rock walls/Waterfall areas
<i>Macrothelypteris torresiana</i> (Gaudich.) Ching	Rupicolous	Closed riparian forest	Rock walls/Waterfall areas
<i>Meniscium angustifolium</i> Willd.	Terrestrial/Rupicolous	Closed riparian forest	Rock walls/Waterfall areas
<i>Meniscium arborescens</i> Humb. & Bonpl. ex Willd.	Terrestrial	Open riparian forest/Closed riparian forest	Marshy areas with buriti palms/ Rock walls/Non-rocky banks
<i>Meniscium chrysodioides</i> Fée.	Terrestrial	Open riparian forest/Closed riparian forest	Marshy areas with buriti palms/ Rock walls/Non-rocky banks/ Waterfall areas

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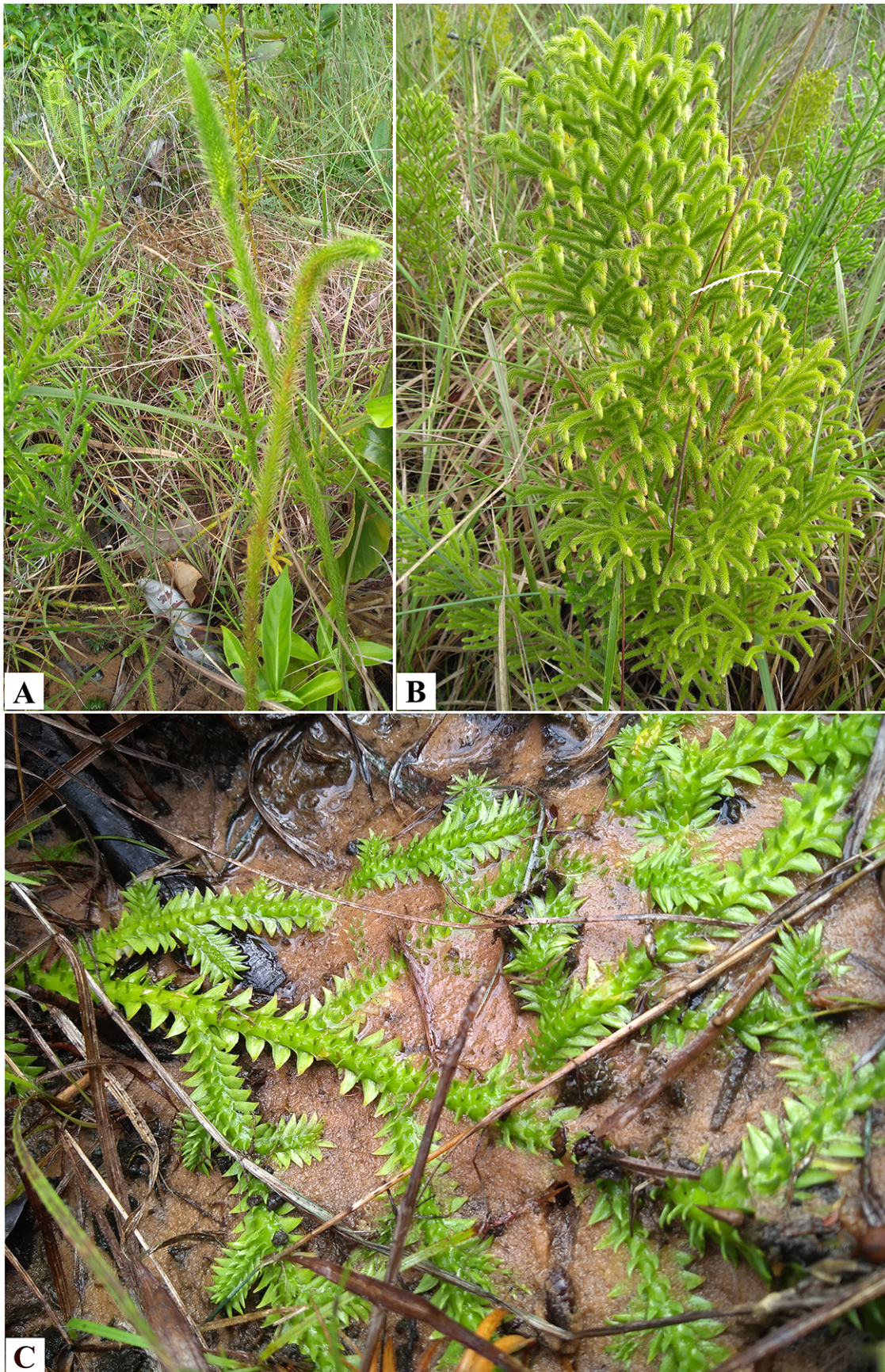


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<i>Meniscium delicatum</i> R.S. Fernandes & Salino	Rupicolous	Closed riparian forest	Rock walls/Waterfall areas
<i>Meniscium hostmannii</i> (Klotzsch) R.S. Fernandes & Salino	Terrestrial/Rupicolous	Closed riparian forest	Rock walls/Non-rocky banks
<i>Meniscium maxonianum</i> (A.R. Sm.) R.S. Fernandes & Salino	Terrestrial/Rupicolous	Closed riparian forest	Rock walls/Non-rocky banks
<i>Meniscium serratum</i> Cav.	Terrestrial/Rupicolous	Open riparian forest	Marshy areas with buriti palms/ Rock walls/Non-rocky banks

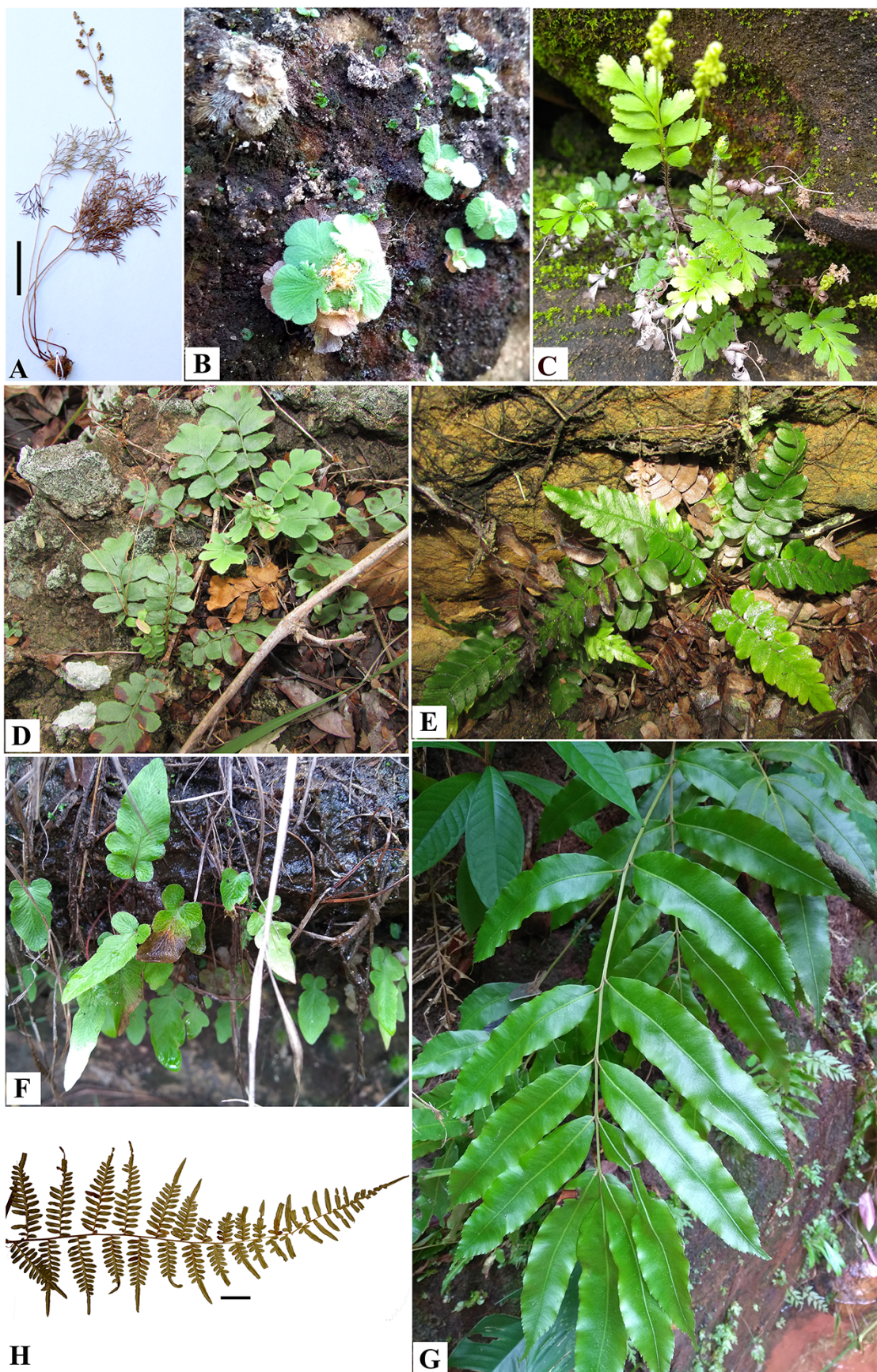


**Figure 2.** Habit. A. *Selaginella convoluta* (Arn.) Spring. B. *Selaginella marginata* (Humb. & Bonpl. ex Willd.) Spring. C. *Selaginella minima* Spring. D. *Selaginella simplex* Baker. Habit. E. *Selaginella erythropus* (Mart.) Spring. F. *Selaginella sulcata* (Desv. ex Poir.) Spring ex Mart. Scale bar: B; F = 2cm; C=1cm.



**Figure 3.** Habit. A. *Lycopodiella longipes* (Grev. & Hook.) Holub. B. *Palhinhaea camporum* (B. Øllg. & Windisch) Holub. C. *Pseudolycopodiella meridionalis* (Underw. & Loyd) Holub.

Ferns and lycophytes in Chapada das Mesas National Park



**Figure 4.** A. *Anemia buniifolia* (Gardner) T.Moore. Habit. B. *Anemia elegans* (Gardner) C.Presl. Habit. C. *Anemia hirsuta* (L.) Sw. Habit. D. *Anemia oblongifolia* (Cav.) Sw. Habit. E. *Blechnum* cf. *occidentale*. Habit. F. *Blechnum* sp. Habit. G. *Salpichlaena hookeriana* (Kuntze) Alston. Habit. H. *Pteridium esculentum* (G.Forst.) Cockayne subsp. *gryphus* Schwartsb. & A.Yanez. Sterile Pinnae. Scale bar: A; H = 2cm.

**Illustration.** Mickel (2016: 126, fig. 13A–C).

Rupicolous on a rock wall on the margin of a trail. **Habitat:** Cerrado *sensu stricto*. **Geographic distribution:** MA, DF, GO, MS, MT, MG, SP, PR (Cerrado and Pantanal). New record: Northeast Region.

*Salpichlaena hookeriana* (Kuntze) Alston  
(Figure 4G)

Terrestrial climber growing on a rocky bank near a waterfall area. **Habitat:** closed riparian forest. **Geographic distribution:** AC, AM, PA, MA, RO, MS, MT (Amazonia and Cerrado). New record: Northeast Region and Cerrado.

*Bolbitis serratifolia* Schott.  
(Figure 5A)

Rupicolous on a rock wall near a waterfall area. **Habitat:** closed riparian forest. **Geographic distribution:** AC, AM, PA, RO, CE, MA, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão and Cerrado.

*Cyclodium meniscioides* (Willd.) C. Presl  
(Figure 5B)

Terrestrial in a marshy area with buriti palms and rupicolous plant in a waterfall area. **Habitat:** closed riparian forest. **Geographic distribution:** AC, AM, AP, PA, RO, TO, BA, CE, MA, PB, PE, PI, RN, DF, GO, MS, MT, ES, MG, SP (Cerrado and Atlantic Forest). New record: Maranhão.

*Dryopteris patula* (Sw.) Underw.  
(Figure 5C)

Rupicolous on a rock wall on the margin of a watercourse. **Habitat:** closed riparian forest. **Geographic distribution:** AC, AM, AP, PA, RO, BA, MA, PI, GO, MT, ES, MG, RJ, SP, PR, RS, SC (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão.

*Elaphoglossum scalpellum* (Mart.) T. Moore.  
(Figure 5D)

Rupicolous on a rock wall and near a waterfall area. **Habitat:** closed riparian forest. **Geographic distribution:** AM, RO, TO, BA, MA, PI, DF, GO, MT, MG, SP (Cerrado). New record: Maranhão.

*Polybotrya sorbifolia* Mett. ex Kuhn.  
(Figure 5E)

Rupicolous on a rock wall. **Habitat:** closed riparian forest. **Geographic distribution:** PA, RO, AL, MA, PE, GO, MT, MG, SP (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão.

*Didymoglossum angustifrons* Fée  
(Figure 5F–G)

Epiphytic from the base of a trunk of a live tree and rupicolous plant on a rocky bank in a waterfall area. **Habitat:** closed riparian forest. **Geographic distribution:** AM, AP, PA, RO, BA, MA, CE, MT, MG, RJ, SP, PR (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão.

*Didymoglossum pinnatinervium* (Jenman) Pic.Serm.  
(Figure 5H)

Rupicolous on a rocky bank in a waterfall area. **Habitat:** closed riparian forest. **Geographic distribution:** MA (Cerrado). New record: Northeast Region and Cerrado.

*Trichomanes arbuscula* Desv.  
(Figure 5I)

Rupicolous on a rocky bank. **Habitat:** closed riparian forest. **Geographic distribution:** AC, AM, AP, PA, BA, MA, PE, MT, ES (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão and Cerrado.

*Lindsaea pallida* Klotzsch  
(Figure 6B)

Terrestrial on a sandy bank near the margin of a river. **Habitat:** closed riparian forest. **Geographic distribution:** AC, AM, AP, PA, BA, MA, PE, MT (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão.

*Metaxya parkeri* (Hook. & Grev.) J. Sm.  
(Figure 6D)

Terrestrial on a sandy bank with litter and rupicolous plant on rock walls near watercourses, such as creek banks and waterfalls. **Habitat:** closed riparian forest. **Geographic distribution:** AC, AM, AP, PA, BA, MA, PE, MT (Amazonia, Cerrado and Atlantic Forest). New record: Cerrado.

*Nephrolepis pectinata* (Willd.) Schott.

**Illustration.** Maciel (2016: 80, fig. 1h–k).

Epiphytic in the upper part of a babaçu palm in an area of pasture. **Habitat:** anthropogenic area. **Geographic distribution:** AC, AM, AP, PA, BA, MA, PE, MT (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão.

*Serpocaulon triseriale* (Sw.) A.R.Sm.  
(Figure 6C).

Terrestrial on a non-rocky bank near an area with buriti palms and rupicolous plant collected on a rocky bank. **Habitat:** open riparian forest. **Geographic distribution:** AC, AM, PA, TO, AL, BA, CE, MA, PE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC. (Amazonia, Caatinga, Cerrado, Atlantic Forest, Pampa and Pantanal). New record: Maranhão.

*Adiantum intermedium* Sw.  
(Figure 7A)

Rupicolous on a rocky bank and terrestrial plant collected on a non-rocky bank in a waterfall area. **Habitat:** closed riparian forest. **Geographic distribution:** MA, DF, GO, MS, MT, MG, RJ, SP, PR, SC (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão.

*Adiantum tetraphyllum* Humb. Bonpl. ex Willd..

**Illustration.** Prado et al. (2017: 45, fig. 46E, F).

Terrestrial in *capoeira* in terra firme forest near a watercourse. **Habitat:** closed riparian forest. **Geographic distribution:** AC, AM, AP, PA, RO, RR, TO, BA, CE, MA, PE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, SC (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão.

*Azolla microphylla* Kaulf.  
(Figure 7G)

Floating aquatic in open flooded area above a waterfall. **Habitat:** open riparian forest. **Geographic distribution:** AM, BA, CE, MA, PE, SE, MG, PR, SC. (Amazonia, Caatinga, Cerrado and Atlantic Forest). New record: Cerrado.

*Schizaea incurvata* Schkuhr.

Terrestrial on a non-rocky bank inside a forest in a flat area with litter. **Habitat:** Cerrado *sensu stricto*. **Geographic distribution:** AM, AP, PA, RO, MA (Amazonia and Cerrado). New record: Northeast Region and Cerrado.

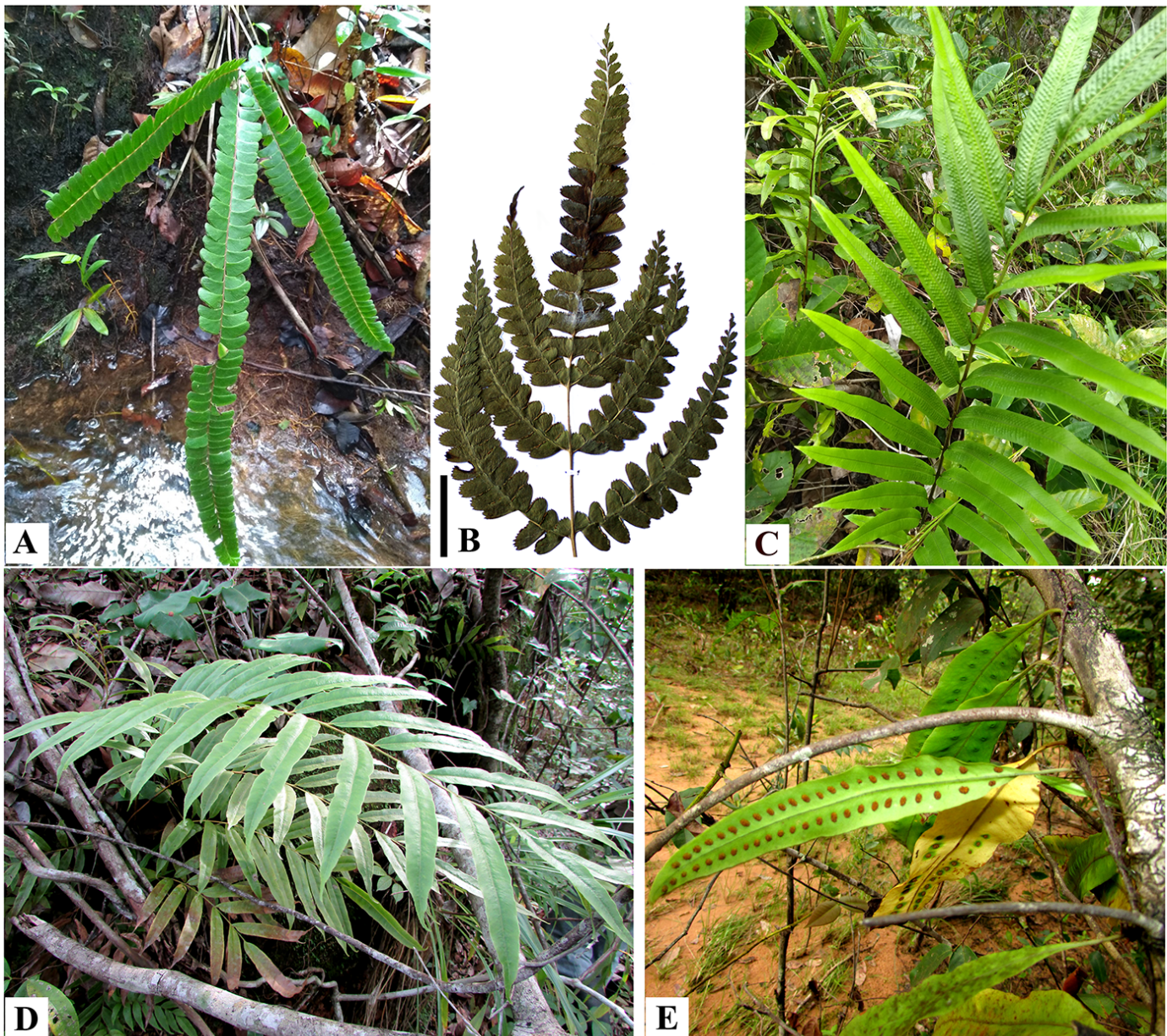
*Tectaria incisa* Cav.  
(Figure 8A)

Rupicolous on a rocky bank in a waterfall area. **Habitat:** closed riparian forest. **Geographic distribution:** AC, AM, AP, PA, RO, RR,

Ferns and lycophytes in Chapada das Mesas National Park



**Figure 5.** A. *Bolbitis serratifolia* Schott. Habit. B. *Cyclodium meniscioides* (Willd.) C. Presl. Habit. C. *Dryopteris patula* (Sw.) Underw. Habit. D. *Elaphoglossum scalpellum* (Mart.) T. Moore. Sterile fronds. E. *Polybotrya sorbifolia* Mett. ex Kuhn. F-G. *Didymoglossum angustifrons* Fée. F. Habit. G. Fertile frond. H. *Didymoglossum pinnatinervium* (Jenman) Pic.Serm. Fertile frond. I. *Trichomanes arbuscula* Desv. Habit. Scale bar: D = 2cm.



**Figure 6.** A. *Lindsaea guianensis* subsp. *lanceastrum* K.U.Kramer. Habit. B. *Lindsaea pallida* Klotzsch. Fertile frond. C. *Serpocaulon triseriale* (Sw.) A.R.Sm. Habit. D. *Metaxya parkeri* (Hook. & Grev.) J. Sm.. Habit. E. *Microgramma persicariifolia* (Schrad.) C.Presl. Habit. Scale bar: B = 2cm.

AL, BA, CE, MA, PE, MS, MT, ES, MG, RJ, SP, PR, RS, SC (Amazonia, Cerrado and Atlantic Forest). New record: Cerrado.

***Goniopteris biformata*** (Rosenst) Salino & T.E. Almeida (Figure 8D)

Terrestrial on the margin of a waterfall and rupicolous plant collected on a rock wall. **Habitat:** open riparian forest. **Geographic distribution:** AC, PA, GO, MS, MT, MG, SP (Amazonia, Cerrado and Atlantic Forest). New record: Cerrado.

***Macrothelypteris torresiana*** (Gaudich.) Ching.

**Illustration.** Smith (1992: 4, fig. 1a-d).

Rupicolous on a rock wall near a waterfall. **Habitat:** closed riparian forest. **Geographic distribution:** RO, AL, BA, CE, MA, PB, PE, RN, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC (Cerrado, Atlantic Forest and Pampa). New record: Maranhão.

***Meniscium chrysodioides*** Fée.

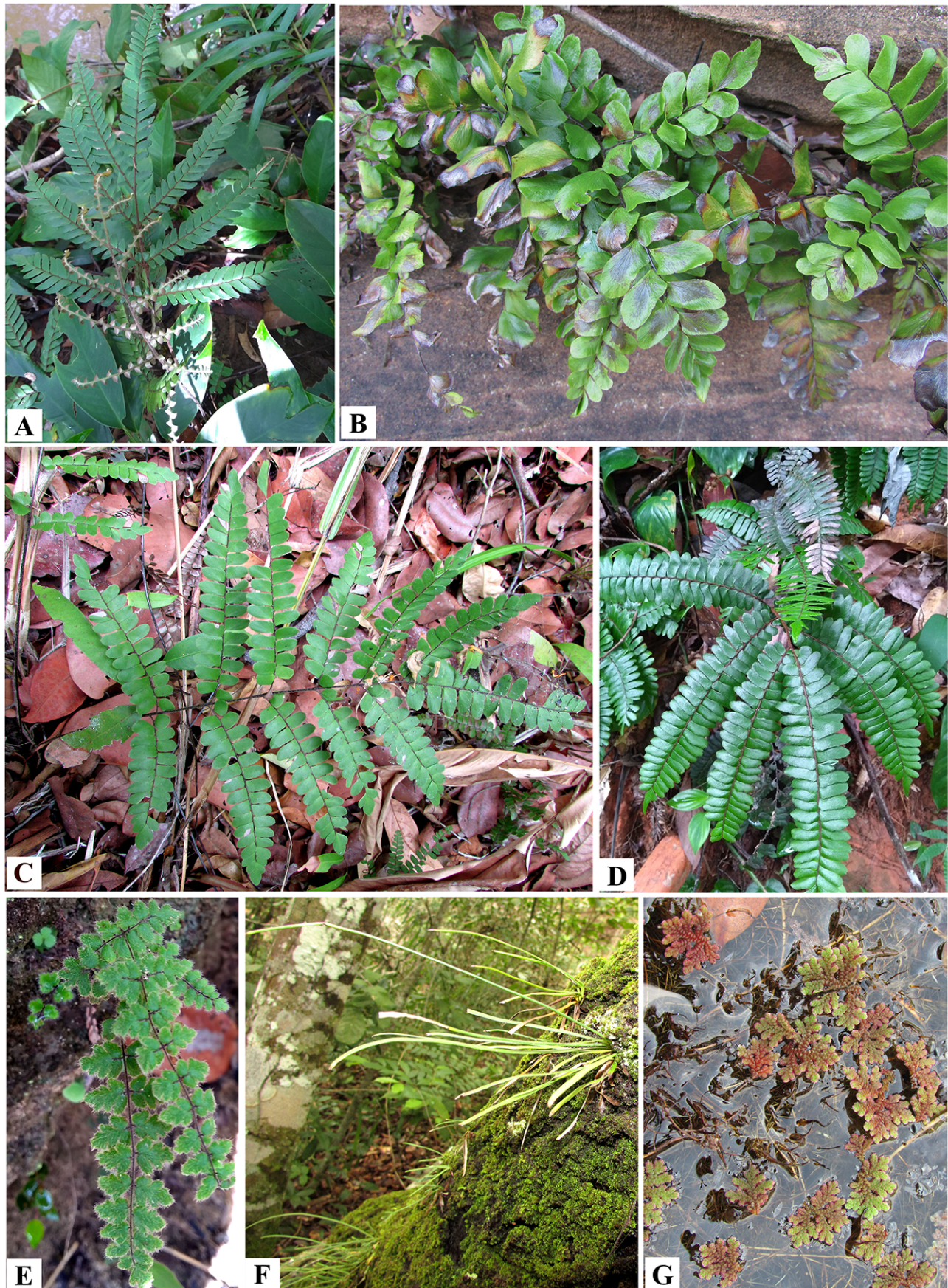
(Figure 8E)

Terrestrial on a non-rocky bank, in a marshy area with buriti palms, and rupicolous plant collected on a rock wall in a waterfall area. **Habitat:** open riparian forest; closed riparian forest. **Geographic distribution:** AC, PA, AL, MA, PE, GO, MS, MG, SP (Amazonia, Cerrado and Atlantic Forest). New record: Maranhão.

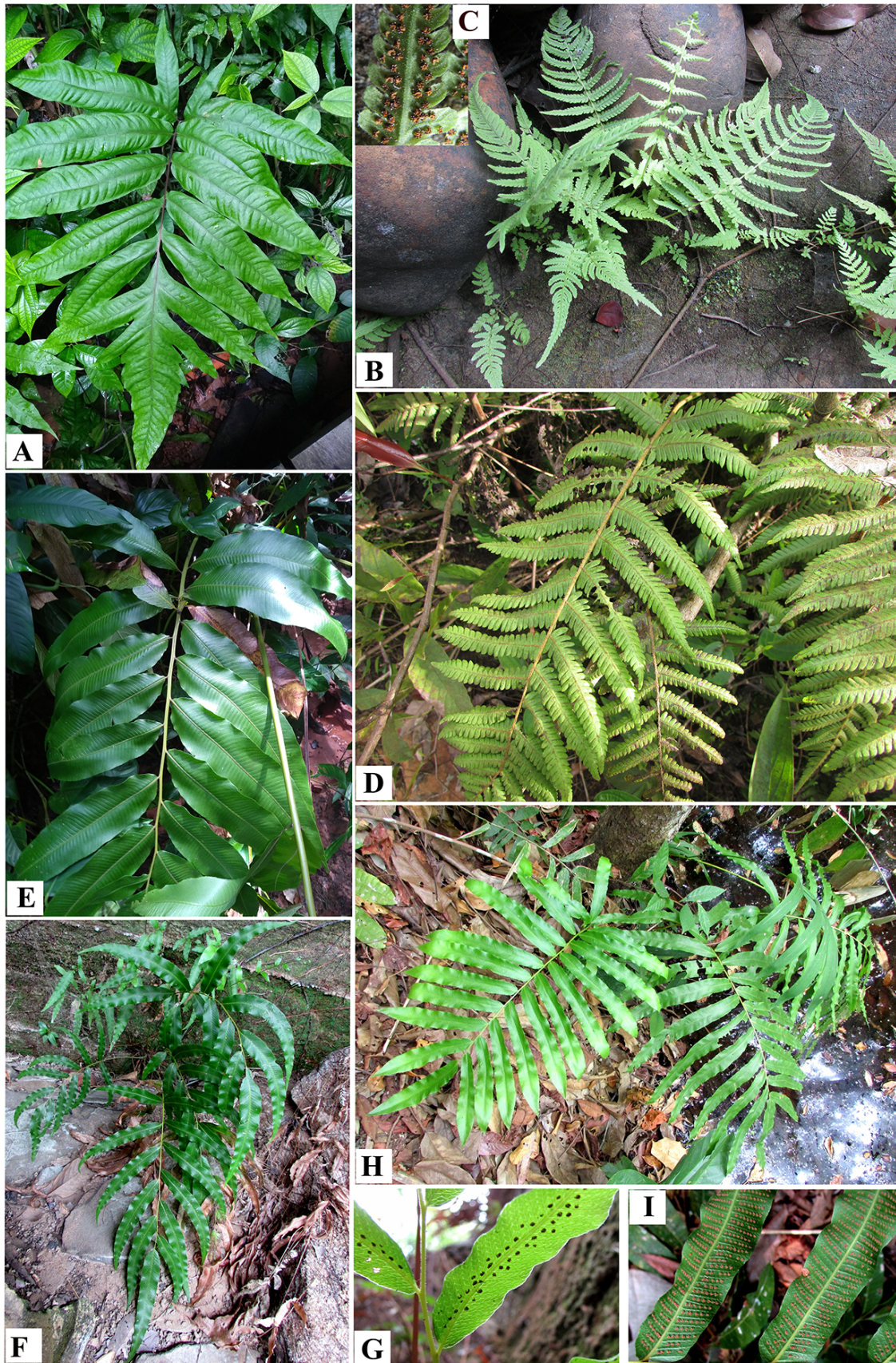
## Discussion

Based on the present study, PNCM is the area (protected or not) with the greatest diversity of ferns and lycophytes (86 species) in Maranhão State. Mirador State Park is another protected area of Cerrado in the state. Despite its large size (450,838 hectares), only seven species of lycophytes and ferns have been recorded in the area (Conceição & Rodrigues 2010). However, this low diversity could be related

## Ferns and lycophytes in Chapada das Mesas National Park



**Figure 7.** Habit. A. *Adiantum intermedium* Sw. B. *Adiantum latifolium* Lam. C. *Adiantum serratodentatum* Willd. D. *Adiantum terminatum* Kunze ex Miq. E. *Cheilanthes pohliana* Mett. F. *Vittaria lineata* (L.) Sm. G. *Azolla microphylla* Kaulf.



**Figure 8.** A. *Tectaria incisa* Cav. Habit. B-C. *Christella conspersa* (Schrad.) Á.Löve & D.Löve. B. | Habit. C. Detail of fertile pinnae showing a sori. D. *Goniopteris biformata* (Rosenst) Salino & T.E. Almeida. Habit. E. *Meniscium chrysodioides* Fée. Habit. F-G. *Meniscium delicatum* R.S. Fernandes & Salino. F. Habit. G. Detail of fertile pinnae showing a sori and anastomosing veins. H-I. *Meniscium hostmannii* (Klotzsch) R.S. Fernandes & Salino. H. Habit. I. Detail of fertile pinnae showing a sori.



to insufficient sampling, since it is a preserved area of Cerrado that probably has a diversity similar to PNCM. The Cerrado in Maranhão is strongly influenced by other domains (e.g., Amazonia and Caatinga) that, in general, favors a higher diversity of plant species (e.g., Ribeiro et al. 2020, Silva et al. 2021, Fernandes et al. 2021).

The species collected in the present study represent around 27.30% of the species recorded for the Brazilian Cerrado and increase the known diversity in this domain by 11 species that, until now, were only recorded for Amazonia and the Atlantic Forest (Flora do Brasil 2020). Additionally, this inventory resulted in 26 new records for Maranhão and five new records for the Northeast Region of Brazil. This shows the importance of this protected area for the conservation of the species of the groups studied. The number of new records in this study is probably a reflection of low sampling and local inventories (e.g., Fernandes et al. 2007, Conceição & Ruggieri 2010, Conceição & Rodrigues 2010, Fernandes et al. 2010, Conceição et al. 2015, Silva et al. 2017, Silva Júnior et al. 2018) that underestimated the diversity of lycophytes and ferns in the state.

The fern family with the most species is Pteridaceae (14 species). This can be explained by the wide distribution of the family in tropical regions and arid regions (Smith et al. 2006), and due to in Brazil the family is most diverse in Southeast (141 spp) and Northeast (104 spp) regions (Prado et al. 2020). Other studies in Cerrado (e.g., Fernandes et al. 2007, 2010, Silva et al. 2017) and Amazonia (e.g., Silva Junior et al. 2020) in Maranhão State also recorded more diversity for this family. In PNCM, 10 of the 14 Pteridaceae species recorded prefer a rocky substrate (Table 1). *Adiantum* L. (Pteridaceae) had the highest number of recorded species (10 species), of which two are new records for Maranhão (*Adiantum intermedium* Sw. and *A. tetraphyllum* Humb. & Bonpl. ex Willd.) and one (*A. petiolatum* Desv.) is a new record for the Brazilian Cerrado (Prado et al. 2020, Silva Junior et al. 2020).

The second most representative fern family is Thelypteridaceae with 11 species, of which three are reported for the first time for Maranhão State (*Goniopteris biformata* (Rosenst) Salino & T.E. Almeida, *Macrothelypteris torresiana* (Gaudich.) Ching, and *Meniscium chrysodioides* Fée); *Goniopteris biformata* is also a new record for the Northeast Region of Brazil (Fernandes & Salino 2020, Salino et al. 2020).

The diversity of lycophytes (17 species) in PNCM is high compared to other areas sampled in the state (e.g., Fernandes et al. 2007, 2010, Conceição & Rodrigues 2010). In Amazonia in Maranhão, for example, only two species of lycophytes have been recorded (Silva Junior et al. 2020), which is nine times less than that in PNCM. The lycophyte family with the most species is Selaginellaceae (12 species), of which three are reported for the first time for Maranhão State (*Selaginella convoluta* (Arn.) Spring, *Selaginella minima* Spring, and *Selaginella sulcata* (Desv. ex Poir.) Spring ex Mart.); the last one is also a new record for the Northeast Region of Brazil (Góes-Neto et al. 2020). Compared to Amazonia in Maranhão (Silva Junior et al. 2020), the high diversity of Selaginellaceae recorded in our study is due to the predominance of rupicolous habitats associated with waterfalls in PNCM (nine rupicolous species, Table 2).

The predominance of rupicolous species (22 species) in the present study was expected and is probably due to the wide availability of rock substrates in PNCM, such as rock walls of waterfalls and surroundings,

and extensive rocky fragments inside riparian forest. Since there is a lot of rock substrate, species that are normally epiphytic (e.g., *Didymoglossum angustifrons* Fée) or terrestrial (e.g., *Trichomanes hostmannianum*) (Costa & Pietrobon 2007) in the study area develop on rocks. The second most recorded habit was terrestrial (15 species). A high number of terrestrial species is common in most studies about ferns in Maranhão State, for example, Bastos & Cutrim (1999), Fernandes et al. (2007), Fernandes et al. (2010), Conceição & Ruggieri (2010), Conceição & Rodrigues (2010), Conceição et al. (2015), Silva et al. (2017), and Silva Junior et al. (2020).

In relation to environment type, most fern and lycophyte species generally occur in microhabitats in riparian forest, such as rocky banks, non-rocky banks, rock walls, waterfall areas and marshy areas (Table 2 and Supplementary file 1). Some species of Schizaeaceae (e.g., *Actinostachys pennula* (Sw.) Hook., *Schizaea incurvata* Schkuhr) and Anemiaceae (e.g., *Anemia elegans* (Gardner) C.Presl, *A. trichorhiza* Gardner) were collected in Cerrado *sensu stricto* (Table 1) in distinct microhabitats (inside forest in flat area and rock wall, respectively) (Table 2).

## Conclusion

The present work shows that the fern and lycophyte diversity in the Cerrado in Maranhão is underestimated. This is mainly due to low sampling in previous studies, or a low number of sampling points (locations), and because the collections in Maranhão herbaria do not properly represent these groups. Based on this study, we encourage others to conduct similar studies that collect a lot of material and deposit specimens in herbaria that are open to the public. Overall, this will contribute to a more accurate estimate of the diversity of ferns and lycophytes in the Cerrado in Maranhão.

## Supplementary Material

The following online material is available for this article:

Supplementary file 1 - List of ferns and lycophytes species recorded to the Maranhão State according to Scientific studies.

Supplementary file 2 - List of material examined.

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## Author Contributions

Rozijane Santos Fernandes: identified the plants, elaboration of the species list for Maranhão State, prepared the figure boards, writing and proofreading the text.

Laryssa Reis Silva: collected and photographed the plants, identified the plants, writing the text.

Sirlane Santos Oliveira: collected and photographed the plants, identified the plants, elaboration of the species list for Maranhão State, writing the text.

Felipe Polivanov Ottoni: collected and photographed the plants, writing and proofreading the text.

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## Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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