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DIVERSIDADE DE HEPÁTICAS TALOSAS NO CERRADO BRASILEIRO DO
PARQUE NACIONAL CHAPADA DAS MESAS, MARANHÃO, BRASIL

JOSÉ AUGUSTO DOS SANTOS SILVA

CHAPADINHA-MA

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DIVERSIDADE DE HEPÁTICAS TALOSAS NO CERRADO BRASILEIRO DO
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Linha de pesquisa: Biodiversidade e conservação.

Orientador: Felipe Polivanov Ottoni

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PARQUE NACIONAL CHAPADA DAS MESAS, MARANHÃO, BRASIL.**

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[...] *Às águas que formam os caminhos e me trouxeram até aqui* [...]

Io Dimitri

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RESUMO

O Parque Nacional Chapada das Mesas é um dos mais jovens Parques Nacionais do Brasil, criado pelo decreto presidencial do ano de 2005, este reúne formações rochosas diversas e em seu interior abriga um grande número de nascentes, riachos e cachoeiras. Além de brigar uma das áreas mais biodiversas do cerrado maranhense. No entanto, com o avanço da fronteira agrícola e pecuária na região toda essa diversidade pode estar ameaçada. Afim de compreendermos a diversidade de hepáticas talosas do Parque Nacional Chapada das Mesas, realizamos quatro expedições nos anos de 2017 a 2020 em áreas úmidas do parque. Nossos objetivos foram descrever as espécies de hepáticas talosas encontradas na área do parque e em seu entorno, como também os ambientes de ocorrências e substratos das espécies. Ao total foram coletadas mais de 350 amostras de briófitas e destas foram separadas e identificadas sete espécies de hepáticas talosas, sendo cinco novos registros para o estado maranhão, dois para a região nordeste e dois para o Cerrado brasileiro. As hepáticas da região mostraram certa preferência para substratos rochosos, seguidos por terrestres e troncos mortos, as mesmas foram sempre encontradas em áreas abertas com grande nível de umidade como por exemplo as cachoeiras. As espécies coletadas constituem 24% da diversidade de hepáticas talosas do Cerrado, 16% da diversidade do Nordeste e representam um aumento de 57% do número de espécies conhecidas para o Maranhão.

Palavras-chave: Marchantiophyta, Cerrado, conservação e taxonomia.

ABSTRACT

Chapada das Mesas National Park is one of the youngest National Parks in Brazil, created by the presidential decree of the year 2005, it gathers diverse rock formations and inside it houses a large number of springs, streams and waterfalls. In addition to fighting one of the most biodiverse areas of the Brazilian Savanna of Maranhão. However, with the advance of the agricultural and livestock frontier in the region, all this diversity may be threatened. In order to understand the diversity of liverworts in the Chapada das Mesas National Park, we carried out four expeditions in the years 2017 to 2020 in wet areas of the park. Our objectives were to describe the species of tall liverworts found in and around the park area, as well as the environments of occurrences and substrates of the species. In total, more than 350 samples of bryophytes were collected and seven species of thalloid liverworts were separated and identified, with five new records for the state of Maranhão, two for the Northeast region and two for the Brazilian Cerrado. The liverworts of the region showed a certain preference for rocky substrates, followed by terrestrial and dead trunks, they were always found in open areas with a high level of humidity, such as waterfalls. The species collected comprise 24% of the diversity of thalloid liverworts species in the Brazilian Savanna, 16% of the diversity of the Northeast, and represent an increase of 57% in the number of species known to Maranhão.

Keywords: Marchantiophyta, Cerrado, conservation and taxonomy.

CAPÍTULO I

INTRODUÇÃO GERAL

Briófitas é nome dado ao grupo monofilético de plantas avasculares, basal dentre Embryophytas (Harris et al. 2020). As hepáticas são plantas folhosas ou talosas, crescem preferencialmente em ambientes úmidos e sombreados, e absorvem água através do seu gametófito, não apresentando controle sobre a perda de água (poiquiloïdria) (Gradstein et al. 2001).

As hepáticas talosas são um grupo de plantas que apresentam um gametófito aplanado dorsiventralmente sem filídios e com uma estrutura interna variável. O talo pode ser dicotômico ou pinado (*Riccardia*), a grande maioria são caracterizadas por possuírem no talo uma epiderme com poros, uma camada fotossintética na parte dorsal e escamas presentes na parte ventral lateral (Bischler-Causse et al. 2005). São plantas normalmente terrícolas e tolerantes a seca, podendo colonizar ambientes áridos como a Caatinga e o Cerrado brasileiro (Gradstein & Costa 2003, Bischler-Causse et al. 2005).

Existem aproximadamente 7.500 espécies de hepáticas no mundo (Söderström et al. 2016) e destas, cerca de 850 espécies são talosas, sendo 500 espécies de talosas simples (Jungermannopsida subclasse Metzgeriidae) e 350 espécies de talosas complexas (Marchantiopsida) (Goffinet & Shaw 2009). No Brasil são registradas cerca de 1.610 espécies de briófitas, dentre essas 694 são espécies de hepáticas. O Cerrado brasileiro possui 162 espécies de hepáticas, das quais apenas as hepáticas talosas possuem espécies endêmicas para esse bioma (Gradstein & Costa 2003, Flora do Brasil 2020 em construção).

O Cerrado possui uma área de 2.116.000 km² ocupando 21% do território nacional. Este bioma pode ser classificado como a savana tropical mais diversa do planeta (Klink & Machado 2005), apresentando em toda sua extensão diferentes formas

vegetacionais. No Cerrado, a heterogeneidade espacial é um fator determinante para a ocorrência de uma grande diversidade de espécies. Os ambientes do Cerrado variam significativamente no sentido horizontal, favorecendo a ocorrência de áreas campestres, florestais e brejosas na mesma região (Medeiros 2011).

O Brasil conta atualmente com 438 unidades de conservação no Cerrado, incluindo 65 Parques Nacionais (PNs), sendo 15 localizados no bioma Cerrado (Rocha et al. 2010, MMA 2019). Existem poucos estudos relacionados a briófitas em PNs presentes no Cerrado (e.g Yano & Peralta 2011, Pinheiro et al. 2012, Sousa & Câmara 2015, Carmo & Peralta 2016 e Oliveira et al. 2018a), sendo os parques de Minas Gerais os que possuem maior números de inventários brioflorísticos para o bioma (Yano & Peralta 2011, Sousa & Câmara 2015 e Carmo & Peralta 2016). O estado do Maranhão possui cerca de 20 unidades de conservação, distribuídas em áreas de Proteção Integral (PI) e de Uso Sustentável (US) (Gerude 2013), destas apenas o Parque Nacional Chapada das Mesas e o Parque Estadual do Mirador possuem trabalhos publicados acerca da diversidade de briófitas do Cerrado (Santos & Conceição 2010, Oliveira et al. 2018 e Silva et al. 2018)

O estado do Maranhão está situado entre os biomas, Amazônia, Cerrado e Caatinga entretanto, são registradas 106 espécies de hepáticas, destas, somente seis espécies são de hepáticas talosas (Silva et al. 2018a, Flora do Brasil 2020, Silva et al. 2021b). No que se refere a estudos que citam espécies de hepáticas talosas para o estado do Maranhão pode se citar: Yano et al. (2009), que registraram três espécies: *Cronisia weddellii* (Mont.) Grolle e *Riccia vitalii* Jovet-Ast para a município de Montes Altos e *Riccia stenophylla* Spruce para município de Loreto; Varão et al. (2011) registraram uma espécie *Riccia stenophylla* Spruce para o município de Governador Edison Lobão e Oliveira et al. (2018b) em um inventário de hepáticas (Marchantiophyta) para o estado do Maranhão registraram quatro espécies de hepáticas talosas nos município de Caxias e

São João do Sóter, todas da família Ricciaceae. O único estudo taxonômico para as hepáticas talosas no estado do Maranhão é o de Silva et al. (2018a) entretanto, inclui apenas o gênero *Riccia*, nesse são registradas cinco espécies, além de contar com chaves taxonômicas, descrições e comentários ecológicos.

O estado do Maranhão conta atualmente com 15 trabalhos publicados, no entanto, a maioria deles são listas de espécies com raras citações de hepáticas talosas (Yano 2009, Varão et al. 2011, Oliveira et al. 2018b, Silva et al. 2018a) e outros focam nos musgos e nas hepáticas folhosas (Santos & Conceição 2010, Conceição et al. 2010, Peralta et al. 2011, Brito & Ilkiu Borges 2012, 2014, Macedo & Ilkiu-Borges 2014, Costa & Conceição 2015, Vieira et al. 2017, Oliveira et al. 2018a, Oliveira et al. 2018b, Silva et al. 2018a), deixando uma lacuna no que se refere a diversidade das hepáticas talosas.

DEGRADAÇÃO DE HABITAT NAS UNIDADES DE CONSERVAÇÃO

A degradação de habitat hoje representa a principal ameaça à biodiversidade (Wilcove et al. 1998, Brook et al. 2006).

As florestas tropicais são as mais biologicamente diversas e ecologicamente complexos de ecossistemas terrestres que estão desaparecendo a taxas alarmantes (Laurance 2007). Com a crescente demanda da sociedade por recursos naturais devido ao crescimento populacional humano a biodiversidade vive sério risco de desaparecimento (Brook et al. 2006).

Mesmo o Cerrado sendo o segundo maior bioma brasileiro e apresentar grande número de espécies endêmicas de plantas (4.252 espécies) (BFG 2015), 50% de sua área já foi desmatada e apenas 11% da área de cobertura do bioma se encontram no interior de áreas protegidas (Martinelli & Moraes 2013).

Queimadas, mineração, expansão da fronteira agrícola e avanço da pecuária são alguns dos fatores que constituem ameaças às espécies do Cerrado (Klimk & Machado 2005, Malhado 2010). Tais atividades resultam em perda ou degradação do hábitat que as espécies vivem. O que classifica o bioma como um *hotspot* para conservação (Myers 2000), pela sua riqueza, pelo número de espécies endêmicas que abriga e pela forte pressão antrópica a que está sujeito.

Essas modificações têm provocado a perda e extinção de espécies, inclusive daquelas ainda não conhecidas pela ciência, indo contra os objetivos estabelecidos pela Global Strategy for Plant Conservation GSPC. Esse panorama se torna ainda mais crítico pelo número insuficiente tanto de pesquisadores capacitados, quanto de estudos taxonômicos associados às áreas de grande biodiversidade (Wheeler 2008, BFG 2018).

Mesmo com um certo avanço do Brasil em relação às políticas ambientais, o país ainda carece de planos de manejo para suas unidades de conservação e estudos de ocorrência, de requisitos biológicos e/ou ecológicos das espécies ainda são escassos (Mittermeier et al. 2005). Neste cenário, encontra-se o estado do Maranhão, que das 20 UCs, apenas o Parque Estadual do Bacanga, a APA do Itapiracó e a Esec do Sítio Rangedor possuem plano de manejo, ambas estão localizadas em áreas da Amazônia maranhense. Até o momento nenhuma UCs em área do Cerrado maranhense possui um plano de manejo (Piedade 2013).

Muitas das informações que adquirimos sobre a taxonomia das espécies são obtidas como dados secundários de coletas e levantamentos de flora (Martinelli & Moraes 2013). Faltam, todavia, pesquisas taxonômicas e revisões para os principais grupos de plantas, como é o caso das hepáticas talosas, tanto para a região nordeste, quanto para o Cerrado e para o Brasil. Em se tratando de estudos taxonômicos para o grupo em área de Cerrado, existe apenas um estudo sobre o gênero *Riccia* (Silva et al. 2018).

Por se tratar de um grupo que ocorre em ambientes preferencialmente expostos e úmidos, como é o caso dos diferentes ambientes encontrados nas fitofisionomias do bioma Cerrado, provavelmente a diversidade nessas áreas estão subestimadas devido à baixa amostragem. Sendo assim, nota-se que o Cerrado maranhense carece de estudos mais abrangentes e continuados relacionados as hepáticas talosas, para assim termos uma estimativa mais precisa da biodiversidade desse grupo.

OBJETIVOS

Geral

Realizar um estudo taxonômico para espécies de hepáticas talosas do Parque Nacional Chapada das Mesas, Maranhão.

Objetivos Específicos

1. Realizar o inventário de hepáticas talosas no Parque Nacional Chapada das Mesas com informações sobre ambientes e tipos de substratos.
2. Fornecer subsídios para identificação e caracterização das espécies de hepáticas talosas por meio de chaves de identificação, descrições, ilustrações e comentários;

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CAPÍTULO II

DIVERSITY OF THALLOID LIVERWORTS IN BRAZILIAN SAVANNA OF PARQUE NACIONAL DA CHAPADA DAS MESAS, MARANHÃO, BRAZIL¹

DIVERSIDADE DE HEPÁTICAS TALOSAS NO CERRADO BRASILEIRO DO
PARQUE NACIONAL CHAPADA DAS MESAS, MARANHÃO, BRASIL.

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Diversity of thalloid liverworts in Brazilian Savanna of Parque Nacional da Chapada Das Mesas, Maranhão, Brazil

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Abstract

We investigate the diversity of thalloid liverworts in Parque Nacional da Chapada das Mesas (PNCM). Illustrations, descriptions, taxonomic characters, and notes on the geographic distributions of species, as well as an identification key, are provided. We collected specimens during the rainy seasons between 2017 and 2020. Six families, six genera, and seven species were recorded, of which five species are recorded for the first time from Maranhão state, two species are recorded for the first time from the Brazilian Northeast Region, and two are newly recorded from the Brazilian Cerrado. Our results increase in the number of thallose liverwort species in Maranhão by 57%. Our data add to what is known about PNCM, Maranhão, and Brazilian Cerrado liverworts, and reinforce the importance of PNCM for conservation.

Keywords

Cerrado, hotspot, Marchantiophyta, riparian forest, taxonomy

Introduction

Liverworts or hepatics are nonvascular terrestrial plants with dominant, leafy or thalloid gametophytes and growing in humid places worldwide. They represent the oldest lineage of embryophytes (Gradstein et al. 2001; Qiu et al. 2006). However, Puttick et al. (2018) found support for Setaphyta, a moss–liverwort clade which is the sister group to all other bryophytes. There are about 7,500 species of liverwort distributed in 398 genera and 92 families (Söderström et al. 2016), and including 850 species of thalloid liverworts (11%), 500 simple thalloids (6%) (Jungermanniopsida), and 350 complex thalloids (5%) (Marchantiopsida) (Goffinet and Shaw 2009). In Brazil, 105 species of thalloid liverworts are recorded (Flora do Brasil 2020). Notable work on this group has been especially conducted in the southern and southeastern Brazil and include Hell (1969), Vianna (1985), Costa and Yano (1987), Costa (2008), and Ayub et al. (2014). Vianna (1985) focused mostly on Rio Grande do Sul and left a vast legacy of information about the genus *Riccia* L., ranging from notes about morphological characteristics of different species (Vianna 1990, 1992a, 1992b, 1994a, 1994b) to floristic surveys (1970, 1976, 1981, 1985).

Thalloid liverworts possess a dorsiventrally flattened gametophyte, lacking leaves and having a variable internal structure, and a thallus that can be dichotomous (e.g. *Riccia*) or pinnate. They are usually terrestrial, and being drought-tolerant plants, they can colonize arid environments, such as the Caatinga and Brazilian Cerrado (Gradstein and Costa 2003; Bischler-Causse et al. 2005). Myers et al. (2000) designated biodiversity hotspots having a high degree of endemism and highly threatened biodiversity. Brazil includes two hotspots: the Atlantic Forest and the Brazilian Cerrado, which are the most threatened of the Brazilian biomes.

The Brazilian Cerrado has been annually suffering great losses due to diverse anthropic activities, such as agricultural expansion, deforestation, industrial activity, and unchecked urban growth, but the destruction of the Brazilian Cerrado has mainly occurred due to the expansion of soy cultivation. The high biodiversity of the Cerrado is still only partly known to science and under great risk of extinction. The climate of this biome is Tropical Seasonal, with a wet and dry season; the annual average temperature is about 25 °C, and the average annual precipitation is 1,200–1,800. Sporadic, spontaneous fires also occur in this biome (Myers et al. 2000; Silva and Bates 2002; Klink and Machado 2005; Malhado et al. 2010; Latrubesse et al. 2019; Colli et al. 2020).

In the Brazilian Cerrado, 156 species of hepatics have been recorded. About 30 species of thalloid liverworts are recorded for this biome, and they are distributed in 11 families and 12 genera (Flora do Brasil 2020), corresponding to 27% of all thalloid liverworts species occurring in Brazil. Thus, the Brazilian Cerrado the second most species-rich biome for thalloid liverworts, and second only to the Atlantic Forest, which harbors 89% of the species. Despite being a large region with unique vegetation and climate, the Brazilian Cerrado has only one endemic thalloid liverwort, *Riccia sanguineisporis* Jovet-Ast, which occurs only in Mato Grosso (Gradstein and Costa 2003; Bischler-Causse et al. 2005).

There are currently 65 national parks in Brazil, and 15 national parks (or slightly less than 25% of the total national parks in Brazil) are within the Cerrado biome (Rocha et al. 2010). There are some studies on the bryophytes in national parks within this unique

biome (e.g. Yano and Peralta et al. 2011; Pinheiro et al. 2012; Sousa and Câmara 2015; Carmo and Peralta 2016; Oliveira et al. 2018a), and the national parks in Minas Gerais are the best inventoried for this biome (Yano and Peralta et al. 2011; Sousa and Câmara 2015; Carmo and Peralta 2016).

Maranhão has two national parks: Parque Nacional dos Lençóis Maranhenses (dune and marine) and Parque Nacional da Chapada das Mesas (hereafter PNCM) (Brazilian Cerrado) (Rocha et al. 2010). Maranhão includes parts of the Amazonia, Caatinga, and Cerrado biomes, as well as transitional areas between them, giving the state great importance to the ecology, biodiversity and conservation of species in Brazil (Rebêlo et al. 2003; Ab'Sáber 2003; Fiaschi and Pirani 2009).

PNCM has a great tourist interest due to its scenic beauty, including numerous sandstone plateaus and waterfalls. It includes one of the most conserved plateau areas of Maranhão, with typical Savanna phytophysionomies and numerous watercourses (ICMBIO 2020). To date, only one inventory of bryophytes has been undertaken in this park, which focused on mosses (Oliveira et al. 2018a). Contrary to its ecological richness, only 26 species of liverworts have been recorded in the state, with just six of them being thalloid liverworts (Silva et al. 2018; Flora do Brasil 2020). This low number of species is probably due to the scarcity of taxonomic studies in Maranhão on this group. Yano (2009) recorded three species of thalloid liverworts: *Cronisia weddellii* (Mont.) Grolle and *Riccia vitalii* Jovet-Ast in the municipality of Montes Altos, and *Riccia stenophylla* Spruce in the municipality of Loreto. Varão et al. (2011) recorded only one species (*R. stenophylla*) in the municipality of Governador Edson Lobão, and Oliveira et al. (2018b) recorded five species in the municipality of Caxias. All these species belong to the family Ricciaceae. The only taxonomic study focusing on thalloid liverworts in Maranhão was by Silva et al. (2018), but it only included species of the genus *Riccia* (five species).

Therefore, the purpose of our study is to inventory the species of thalloid liverworts in PNCM. We provide an identification key to species, as well as descriptions and comments on the species found. Our study will support future ecological work, conservation, and management within PNCM, which is highly important for the protection of the Brazilian Cerrado, a world hotspot (Myers et al. 2000).

Methods

PNCM was created on 12 December 2005 by presidential decree to preserve the Savanna areas threatened by the expansion of the agricultural and steel industry in southern Maranhão (Fig. 1). The park's extent is about 160,000 ha and lies within the municipalities of Carolina, Estreito, and Riachão in the middle Tocantins river basin. The area is a transition zone between the Brazilian Cerrado and Amazonia biomes and is at 97–681 m above sea level (MMA 2007; Martins et al. 2017).

PNCM has many watercourses, over 400 springs, and two large waterfalls: São Romão and Prata (IBGE 2019; ICMBIO 2020). Its vegetation cover is typical of the Brazilian Cerrado, with formations of gallery forest, riparian forest, *cerradões* (a forest formation with xeromorphic elements, and characterized by the mixed composition of species common to Cerrado, Gallery Forest, and *mata seca*), *campo sujo* (a herbaceous-shrubby physiognomy with spaced shrubs and sub-shrubs), and *campo limpo* (a

herbaceous phytophysiology, with few shrubs and no trees) (Veloso et al. 1991). The region comprises plateaus, mountain ranges, and table mountains (mesas) (Veloso et al. 1991). The soils are formed by quartzarenic neosoils (SNUC 2020). The climate is tropical humid, with high temperatures throughout the year. The average annual temperature is about 26 °C, with low temperatures ranging from 25.2 °C in January to 27.8 °C in September, and a maximum temperature of about 36 °C in July and August (MMA 2007). There are two well-defined seasons: a dry summer and rainy winter (MMA 2007).

We collected specimens during four collecting expeditions in March and October 2017, June 2018, and February 2020 and included both rainy and dry seasons. Specimens were collected from waterfalls, along stream banks, and in gallery and riparian forests. We followed the methodology proposed by Yano (1989). Collecting efforts were carried out in several localities in PNCM, as well as in surrounding areas (Fig. 1). The specimens were dried and deposited in the CCAA herbarium. Duplicates of some species were sent to the RB herbarium.

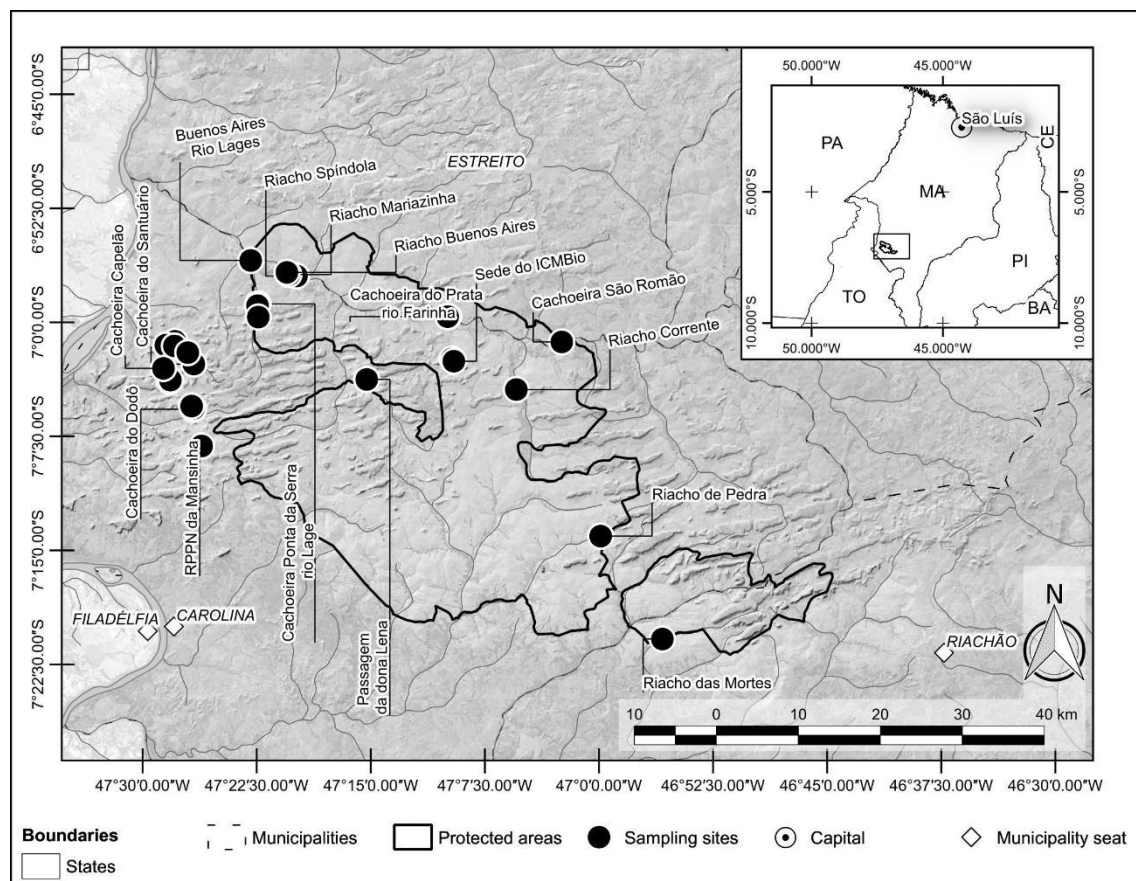


Figure 1. Map of the study area showing sampling sites inside and outside Parque Nacional da Chapada das Mesas, state of Maranhão, Brazil.

The classification follows Crandall-Stotler et al. (2009). Our list of species in PNCM is in alphabetical order by family, genus, and species. We identified the specimens using the following literature: Uribe and Aguirre (1995), Gradstein and Costa (2003), and Bischler-Causse et al. (2005). The geographic distribution of the species is based on Bischler-Causse et al. (2005), Gradstein et al. (2001), Gradstein and Costa (2003), Flora do Brasil (2020), GBIF.org (2020), speciesLink (2020), and Tropicos.org (2020).

Substrate type and the terms used in the species descriptions follow Gradstein et al. (2001).

Results

The species collected by us in PNCM represent 24% of the Brazilian Cerrado thalloid liverwort diversity. In our study area, we found seven species of thalloid liverworts, which are distributed in six genera and six families. These seven species represent 16% of the thalloid liverwort species in northeastern Brazil, a 57% increase in the number of thallose species known from Maranhão state (Silva et al. 2018; Flora do Brasil 2020). Most of the species found in our study are Neotropical in distribution, but *Cyathodium cavernarum* Kunze has a pantropical distribution (Gradstein and Costa 2003; Bischler-Causse et al. 2005; Söderström et al. 2020).

Key to the thalloid liverworts in PNCM

- 1 Thallus margin with sausage-shaped papillae. Sporophyte arising from leafy branches *Pteropsiella metzgeriiformis*
- 1' Thallus margin without papillae. Sporophyte not arising from leafy branches2
- 2 Thallus a ventral structurally complex, divided into a photosynthetic dorsal layer and non-photosynthetic layer. Archegonium protected by involucre or embedded in the thallus3
- 2' Thallus structurally simple, not divided into layers, except in the central midrib. Archegonium protected by scale-like structures*Symphogyna leptothelia*
- 3 Dorsal surface of the thallus with pores4
- 3' Dorsal surface of the thallus without pores5
- 4 Thallus more than 3 cells thick. Rhizoids with papillose walls. Ventral scales large (0.8 mm). Sporophyte on the dorsal surface of the thallus*Cronisia weddellii*
- 4' Thallus very thin, only 2 or 3 cells thick. Rhizoids with smooth walls. Ventral scales absent (or present at the apex of the thallus and very small). Sporophyte on the ventral surface of the thallus *Cyathodium cavernarum*
- 5 Thallus surface with whitish or blackish punctuations, margins crisped-undulate. Sporophyte arising from the thallus, and with linear capsule and thick seta *Monoclea gottschei*
- 5' Thallus surface without whitish or blackish punctuations, margins flat. Sporophyte embedded in the thallus, and with a rounded capsule and no seta6
- 6 Thallus >1 mm wide, with violet scales extend beyond the margin *Riccia vitalii*
- 6' Thallus <1 mm wide, without violet scales extend beyond the margin *Riccia stenophylla*

Corsiniaceae

***Cronisia* Berk.**

The genus is represented by two species in the Neotropics (Bischler-Causse 2005), and both are known to occur in Brazil and the Brazilian Northeast Region. The genus occurs in the Central-West, Northeast, North and Southeast regions in the Caatinga, Brazilian Cerrado, Atlantic Forest, and Pantanal biomes. Only *Cronisia weddellii* (Mont.) Grolle occurs in Maranhão state (Flora do Brasil 2020).

***Cronisia weddellii* (Mont.) Grolle**

Figure 2A–E

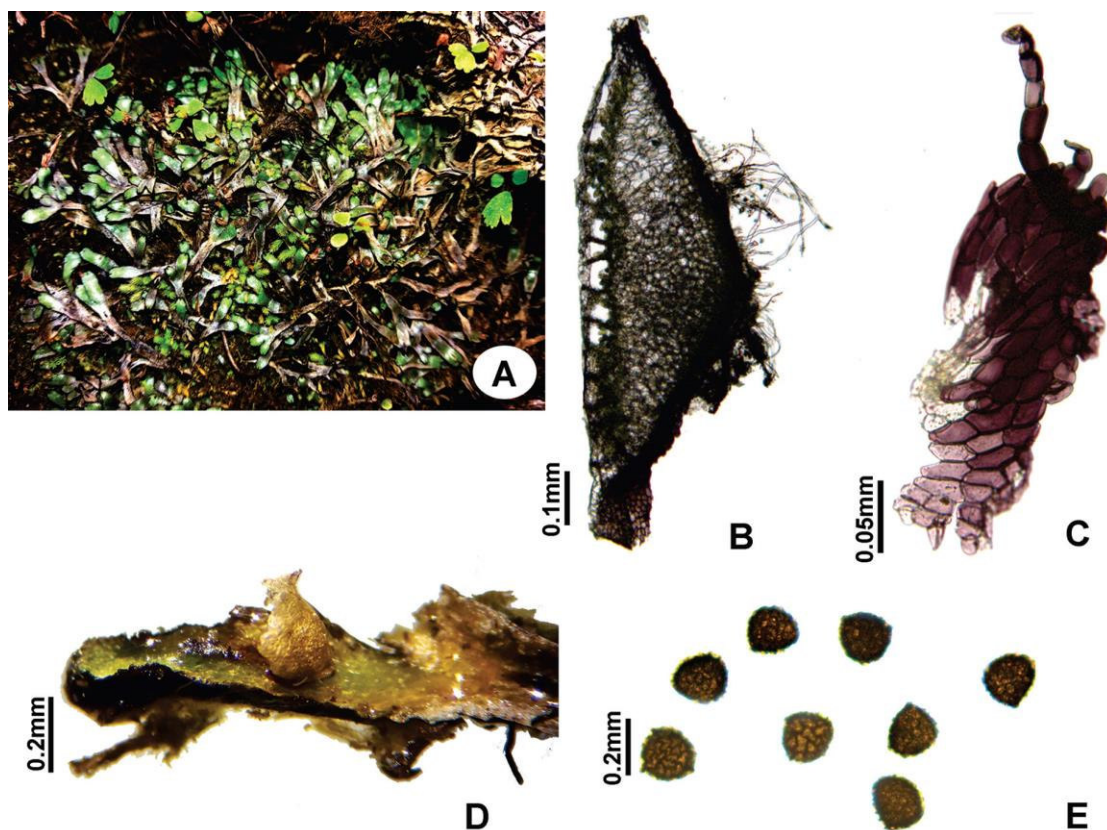


Figure 2. *Cronisia weddellii* (J.A.S.Silva 222 CCAA). A. Habit. B. Cross-section of thallus. C. Scale. D. Thallus with female involucre. E. Spores. Photos: J.A.S. Silva.

Material examined. BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, Rio Farinha; 06°56'43"S, 047°20'31"W; alt. 179 m; 11 Mar. 2017; J.A.S Silva 020 col.; CCAA 1502. • *ibid.*; J.A.S Silva 021 col.; CCAA 1553. • *ibid.*; Cachoeira do Prata; 06°59'41"S, 047° 09'53"W; alt. 197 m; 06 Jun. 2018; J.A.S Silva 218 col.; CCAA 1532. • *ibid.*; J.A.S Silva 222 col.; CCAA 1521. • *ibid.*; J.A.S Silva 223 col.; CCAA 1539. • *ibid.*; J.A.S Silva 227 col.; CCAA 1513. • *ibid.*; Cachoeira São Romão 07°04'25"S, 047°05'26"W; 7 Jun. 2018, J.A.S Silva 253 col.; CCAA 1517. • *ibid.*; Riacho Buenos Aires; 06°56'43"S, 047°20'31"W; alt. 179 m; 08 Jun. 2018; J.A.S Silva 300 col.; CCAA 1589. • *ibid.*; J.A.S Silva 302 col.; CCAA 1505.

Identification. Plants terrestrial and rupicolous. Thallus dichotomous, light green, whitish, or violet, $0.9\text{--}0.20 \times 0.8\text{--}1.1$ mm, without central midrib; main axis wider; dorsal surface chlorophyllose; epidermal pores with 5 or 6 ring cells; thallus in cross-section with one layer of air chambers with chlorophyllose filaments; ventral surface whitish; margin entire, green hyaline; ventral scales violet, large (0.8 mm long), with a filiform appendage, not extending beyond the margin. Sporophyte on the dorsal surface; involucre covering the sporophyte; capsule spherical; spores spherical, brown to dark brown; elaters short, no more than twice as wide.

Cronisia weddellii can be confused with species of *Riccia*. However, *C. weddellii* differs by having the cavities in the thallus containing antheridia, pores with ring cells, appendage scales filiform and sporophyte covered by the involucre (Bischler-Causse et al. 2005). Two species have been recorded from northeastern Brazil, *C. weddellii* and *C. fimbriata* (Nees) Whittem., of which the latter occurs mainly in the Caatinga (Yano and Porto 2006; Yano et al. 2009; Germano et al. 2016). *Cronisia weddellii* differs from *C. fimbriata* by having non-raised epidermal pores and scales that do not extend beyond the margins of the thallus.

Distribution and ecology. Neotropical (Bischler-Causse et al. 2005). In Brazil, it is known from Caatinga (Alagoas, Bahia, Ceará, Paraíba, Piauí and Pernambuco), Atlantic Forest (Espírito Santo), and Savanna biomes (Goiás, Maranhão, Mato Grosso, and Tocantins) (Gradstein and Costa 2003; Yano 2009; Flora do Brasil 2020). It is a typical species of the Brazilian Cerrado and Caatinga and tolerant to drought and high temperatures. We collected this species on soil and rocks on riverbanks where it was growing with mosses of the family Bartramiaceae. We observed that young plants differ from adults in the color of the thallus and shape of the scales. The thallus in young is light green, with scales almost or entirely hyaline and with only the apex violet; in adults the thallus is whitish to violet.

Cyathodiaceae

***Cyathodium* Kuntze**

The genus is represented by five species in the Neotropics (Bischler-Causse 2005). Only *Cyathodium cavernarum* has been recorded for Brazil, where it occurs in the Central-West, Northeast, and Southeast regions and in the following biomes: Brazilian Cerrado, Atlantic Forest and Pantanal (Flora do Brasil 2020). Our records of this species from PNCM are the first from Maranhão state.

***Cyathodium cavernarum* Kunze**

Figure 3A–E

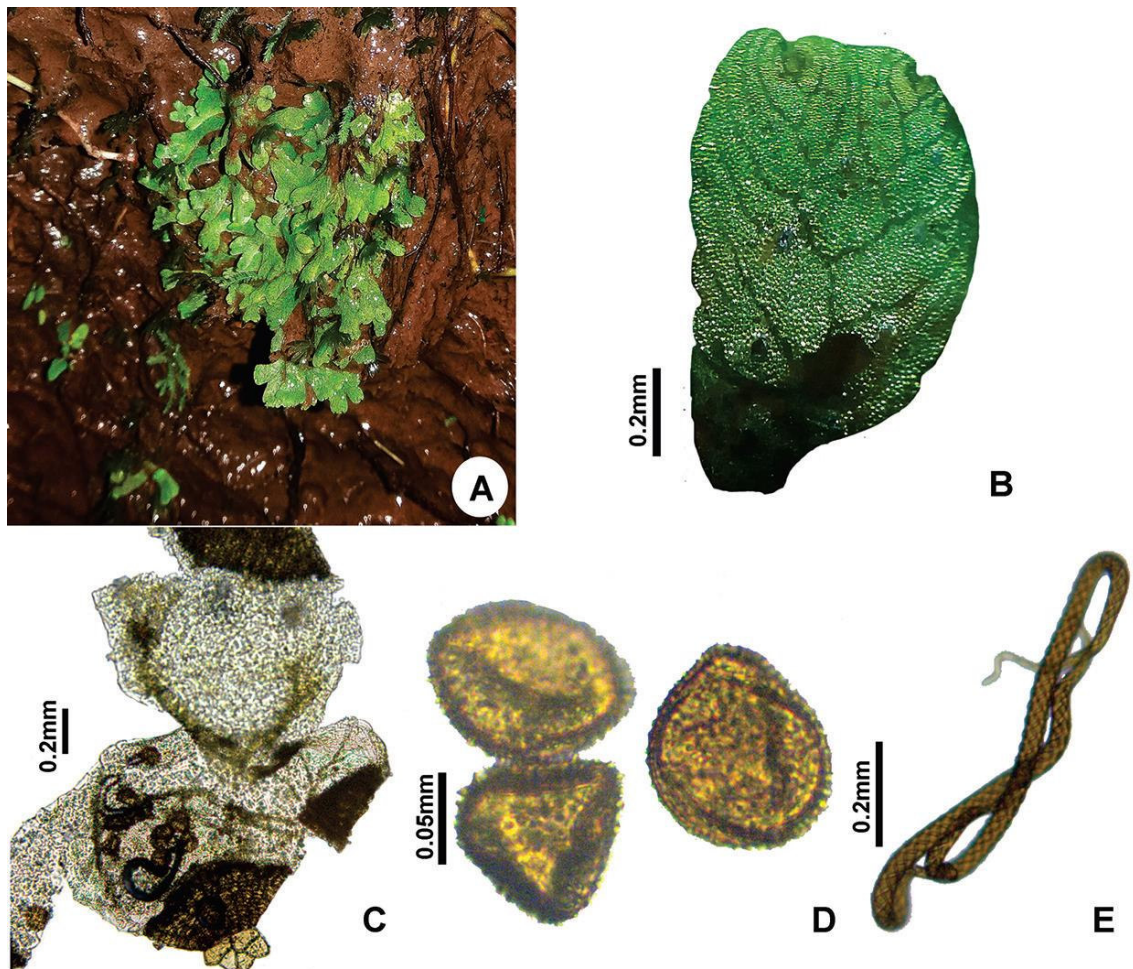


Figure 3. *Cyathodium cavernarum* (J.A.S.Silva 275 CCAA). **A.** Habit. **B.** Thallus. **C.** Capsule open with annulus cells at apex. **D.** Spores. **E:** Elaters. Photos: J.A.S.Silva.

Material examined. BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, Cachoeira São Romão; 07°04'25"S, 047°05'26"W; alt. 256 m; 07 Jun. 2018; J.A.S Silva 275 col.; CCAA 1587. • ibid., Complexo Pedra Caída, cachoeira do Santuário; 07°02'44"S, 047°27'01"W; alt. 128 m; 07 Feb. 2020; J.A.S Silva 551 col.; CCAA 2696.

Identification. Plants rupicolous. Thallus obcuneate, very thin, only 2 or 3 cells wide, with smooth rhizoids, bright green to yellowish, $4\text{--}6 \times 0.6\text{--}1.0$ mm, without central midrib; main axis broad and flat; dorsal surface of chlorophyllose thallus with epidermal pores with a ring of 6–8 cells; thallus in cross section with one layer of air chambers without chlorophyllose filaments; ventral surface with chlorophyllose cells; margin entire, greenish; ventral scales reduced or absent. Sporophyte on the ventral surface of the thallus (near the apex); involucre sac-shaped; capsule ovoid, dark brown, opening with an operculum; spores spherical and densely spinose, dark brown; elaters long.

Cyathodium cavernarum differs from other species of thallose liverworts in the study area by having a bright green thallus with few layers of cells, and a sporophyte capsule opening through a ring of cells. It differs from other species of *Cyathodium* by having the rhizoids with smooth walls, a sporophyte with an operculum, and spiny spores (Bischler-Causse et al. 2005).

Distribution and ecology. Worldwide (Bischler-Causse et al. 2005 and Söderström et al. 2020). Atlantic Forest (Minas Gerais), Caatinga (Bahia, Ceará, Paraíba, Pernambuco, and Piauí), Brazilian Cerrado (Goiás, Mato Grosso, Maranhão, and São Paulo), Pantanal (Mato Grosso do Sul) (Söderström et al. 2020; Flora do Brasil 2020; new data). We collected *C. cavernarum* on shaded rocks with a thin trickle of water running over the gametophyte. It was collected fertile only at the end of the rainy season.

Lepidoziaceae

***Pteropsiella* Spruce**

This genus is represented by two species in the Neotropics, *P. frondiformis* Spruce and *P. metzgeriiformis* Spruce ex Steph. (Söderström et al. 2016; Flora do Brasil 2020). These species are distributed mainly in the North and Southeast regions of the country, in the Amazonia and Atlantic Forest biomes (Flora do Brasil 2020). Our record of *P. metzgeriiformis* is the first from the Brazilian Cerrado, the Northeast Region, and Maranhão.

***Pteropsiella metzgeriiformis* Spruce ex Steph.**

Figure 4A–D

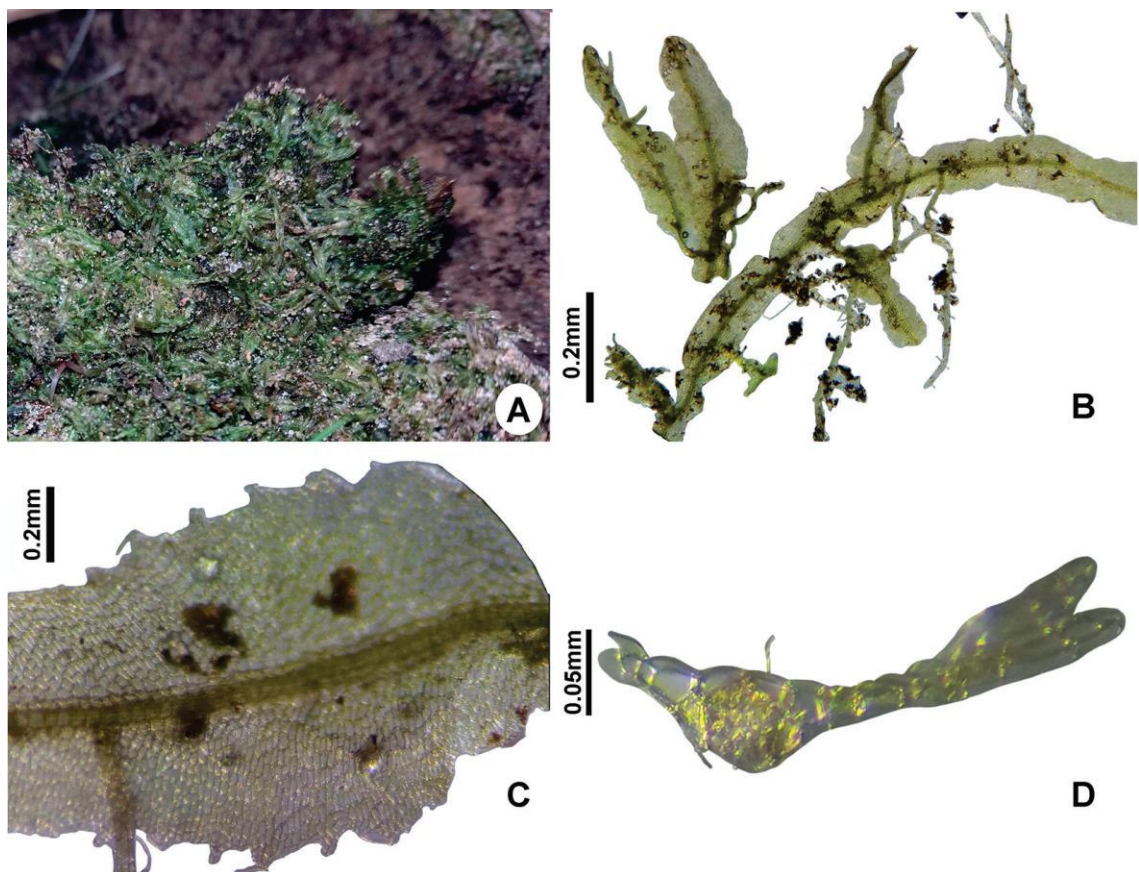


Figure 4. *Pteropsiella metzgeriiformis* (J.A.S.Silva 294 CCAA). **A.** Habit. **B.** Thalli, ventral view. **C.** Margin of thallus toothed with papillae. **D.** Cross section of thallus. Photos: J.A.S.Silva.

Material examined. BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, Riacho Corrente; 07°04'25"S, 047°05'26"W; alt. 277 m; 07 Jun. 2018; J.A.S Silva 294 col.; CCAA 1558.

Identification. Plants terrestrial. Thallus light green, 10–30 × 0.3–0.5 mm; branches inserted ventrally; midrib rounded in cross-section, with six cortical cells (two dorsal and four ventral, and less than 15 medullary cells); wings narrow and unistratose; dorsal surface of thallus without pores and air chambers; ventral surface with chlorophyllose cells; margin toothed, green, with one or two sausage-shaped papillae; scales absent. Sporophyte arising from leafy branches.

Pteropsiella is sometimes misidentified as species of Metzgeriaceae because they also have a unistratose, flat thallus, with a midrib. However, *Pteropsiella* has a toothed, green margin with one or two sausage-shaped papillae, and rhizoids present only on the midrib, while Metzgeriaceae has thallus margins with rhizoids and gametoeceia on the ventral side of the midrib. *Pteropsiella metzgeriiformis* differs from *P. frondiformis* by the light green thallus with fewer than 15 medullary cells, while *P. frondiformis* has a dark green thallus with more than 15 medullary cells.

Distribution and ecology. Brazil and Colombia (Lisboa 1976; Gradstein and Costa 2003; Pinzón et al. 2003; Carmo and Peralta 2016; Costa et al. 2017). Brazilian biomes and states: Amazonia (Amazonas and Roraima) and Atlantic Forest (Minas Gerais) (Carmo and Peralta 2016; Costa et al. 2017); and Brazilian Cerrado (Maranhão; new data). We collected this species near an open, sunny, sandy stream bank.

Monocleaceae

***Monoclea* Hook.**

This genus comprises two species, *Monoclea gottschei* Lindb. and *M. forsteri* Hook., of which the latter occurs in New Zealand (Gradstein and Costa 2003; Söderström et al. 2016). Until now, *M. gottschei* had been recorded in the North, Northeast, Southeast, and South regions of Brazil, in the Amazonia, Atlantic Forest, and Pampas biomes (Flora do Brasil 2020). Our new records are the first of the genus from the Brazilian Cerrado biome and Maranhão state.

***Monoclea gottschei* Lindb.**

Figure 5A–D

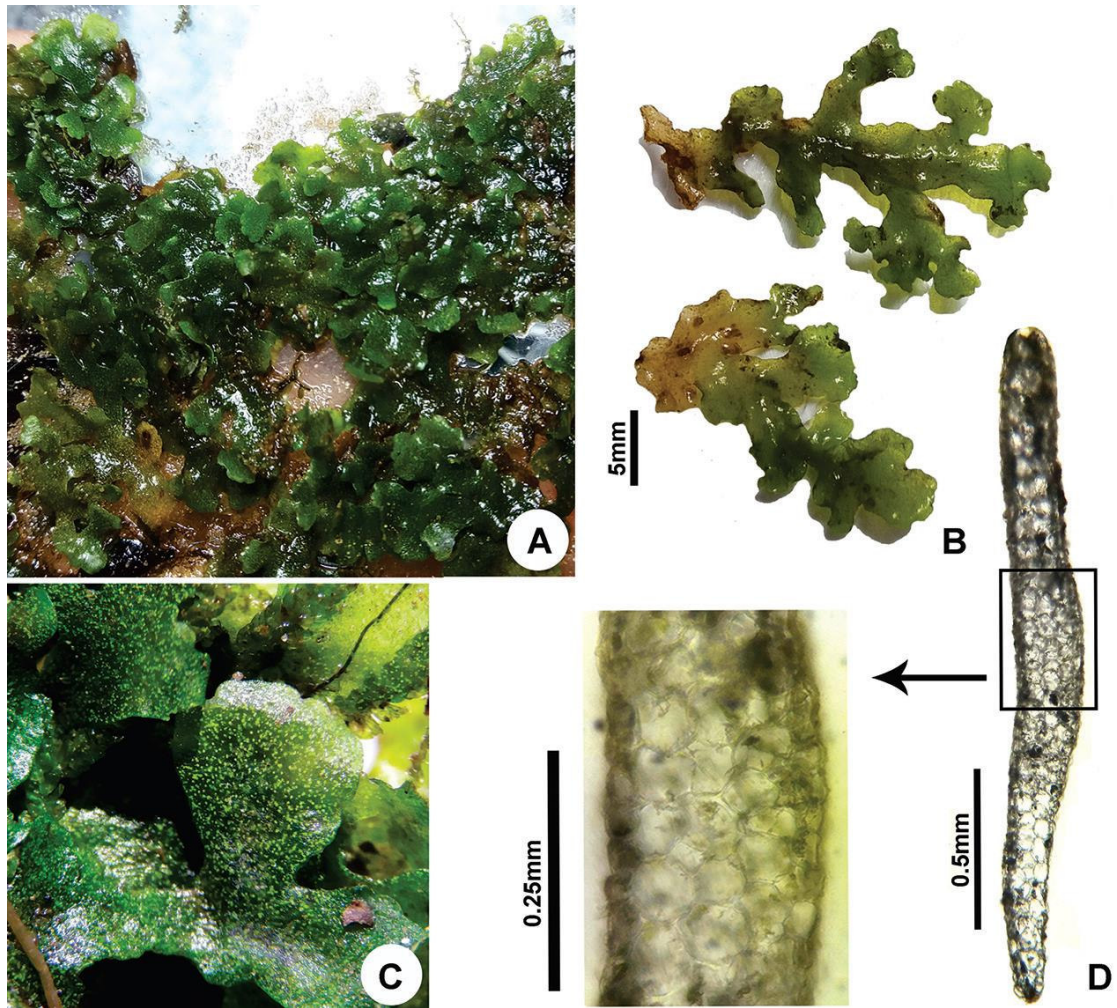


Figure 5. *Monoclea gottschei* (J.A.S.Silva 552 CCAA). **A.** Habit. **B.** Thalli. **C.** Thallus with whitish dots. **D.** Cross section of thallus. Photos: J.A.S.Silva.

Material examined. BRAZIL Maranhão • Carolina, Complexo Pedra Caída, cachoeira do Santuário; 07°02'44"S, 047°27'01"W; alt. 128 m; 07 Feb. 2020; J.A.S Silva 552 col.; CCAA 2578. • ibid., J.A.S Silva 557 col.; CCAA 2697.

Identification. Plants rupicolous. Thallus dark green, 20–30 × 5–10 mm wide, dichotomous, without central midrib, homogeneous; dorsal surface with chlorophyllose cells and without epidermal pores, densely spotted by whitish or darkish dots (observed in fresh material); air chambers absent; ventral surface with chlorophyllose cells; margins usually crispate-undulate. Sporophyte not seen.

Monoclea gottschei is a large plant, 2–3 cm long, with crispate-undulate margins. This species is sometimes misidentified as *Dumortiera hirsuta* (Sw.) Nees because it has a green, flattened thallus, without pores and air chambers, and often occurs in the same habitat. Otherwise, *M. gottschei* differs from *D. hirsuta* by having whitish dots on the thallus in fresh material and no ventral bundle of the rhizoid (Gradstein et al. 2001).

Distribution and ecology. Neotropical (Gradstein and Costa 2003; Gradstein 2017; Flora do Brasil 2020; GBIF.org 2020). Brazilian biomes and states: Amazonia (Amazonas), Atlantic Forest (Espírito Santo, Minas Gerais, Paraná, Pernambuco, Rio de Janeiro, and São Paulo), and Pampas (Rio Grande do Sul) (Gradstein and Costa 2003;

Flora do Brasil 2020); and Cerrado (Maranhão; new data). We collected this species on shaded rocks near a waterfall.

Pallaviniaceae

***Symphyogyna* Nees & Mont.**

The genus is represented by 11 species in the Neotropics (Uribe and Aguirre 1995; Gradstein and Costa 2003; Flora do Brasil 2020). Five species are known to occur in Brazil, in the Central-West, Northeast, North, and Southeast regions, in the Atlantic Forest, Caatinga, Cerrado, and Pantanal biomes (Flora do Brasil 2020). Of these five species, three occur in the Northeast Region. We report the first records of *Symphyogyna leptothelia* for the Northeast Region, making it the fourth species of the genus recorded for this region, and the first time that the genus is reported from Maranhão state.

***Symphyogyna leptothelia* Taylor**

Figure 6A–F

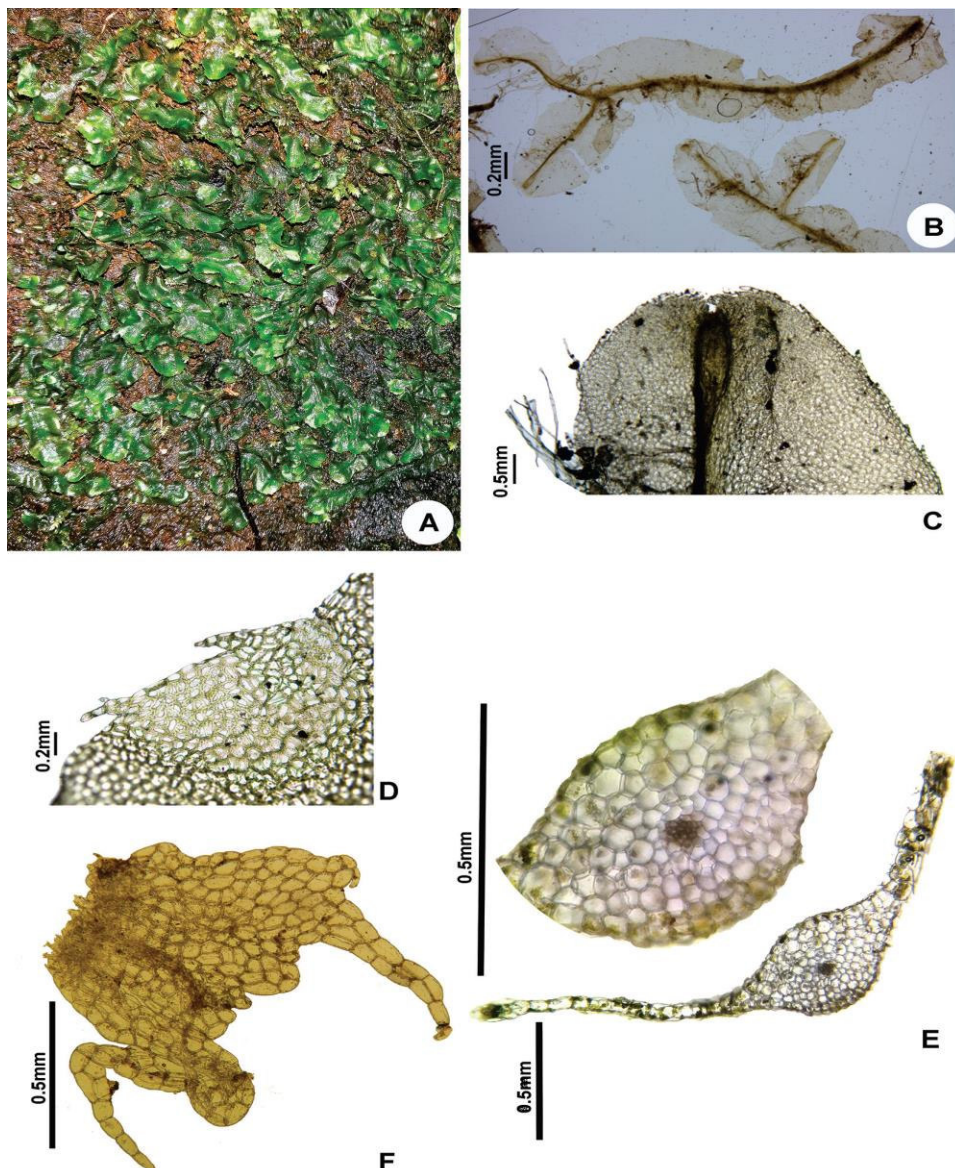


Figure 6. *Symphyogyna leptothelia* (J.A.S.Silva 292 CCAA). **A.** Habit. **B.** Thalli, ventral view. **C.** Apex of thallus. **D.** Detail of teeth of the margin. **E.** Cross section of thallus. **F.** Scale. Photos: J.A.S.Silva.

Material examined: BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, passagem da Dona Lena 07°03'45"S, 047°15'16"W; alt. 230 m; 07 Jun. 2018; J.A.S Silva 292 col.; CCAA 1528. • *ibid.*; 04 Feb. 2020; J.A.S Silva 491 col.; CCAA 2628.

Identification. Plants rupicolous. Thallus dichotomous, dark green, 21–26 × 2.2–5 cm, with central midrib; main axis convex to flat, 0.1 mm wide, with single prosenchyma band; wings large (0.2 mm); dorsal surface in cross-section without epidermal pores and air chambers; ventral surface with chlorophyllose cells; margin toothed; teeth with 5 or 6 cells; dorsal scales covering the archegonium. Sporophyte not seen.

Symphyogyna leptothelia grows prostrate on soil, and the thallus has wide undulate wings, a prominent central midrib with a single strand of prosenchyma tissue, and a toothed margin. *Symphyogyna aspera* Steph. is sometimes confused with *S. leptothelia* due to the prostrate habit, dark green thallus, and toothed margin. However, *S. leptothelia* has entire wings that are not divided into segments and a toothed thallus apex, while *S. aspera* has lobate wings, divided into segments, and a non-toothed thallus apex.

Distribution and ecology. Neotropical (Uribe and Aguirre 1995; Gradstein and Costa 2003; GBIF.org 2020; Tropicos.org 2020). Brazilian biomes and states: Atlantic Forest (Espírito Santo, São Paulo, and Paraná), Brazilian Cerrado (Goiás, Maranhão; new data), Mato Grosso do Sul, Minas Gerais) (Flora do Brasil 2020). We collected this species on shaded rocks near the sandbank of a stream in a riparian gallery forest.

Ricciaceae

***Riccia* L.**

This genus comprises 53 species in tropical America, of which 36 are recorded from Brazil (Bischler-Causse et al. 2005; Costa and Peralta 2015). It occurs in all regions of Brazil, and occurs in the Amazonia, Atlantic Forest, Caatinga, Pampas, Pantanal and Brazilian Cerrado biomes (Flora do Brasil 2020).

***Riccia stenophylla* Spruce**

Figure 7A–E

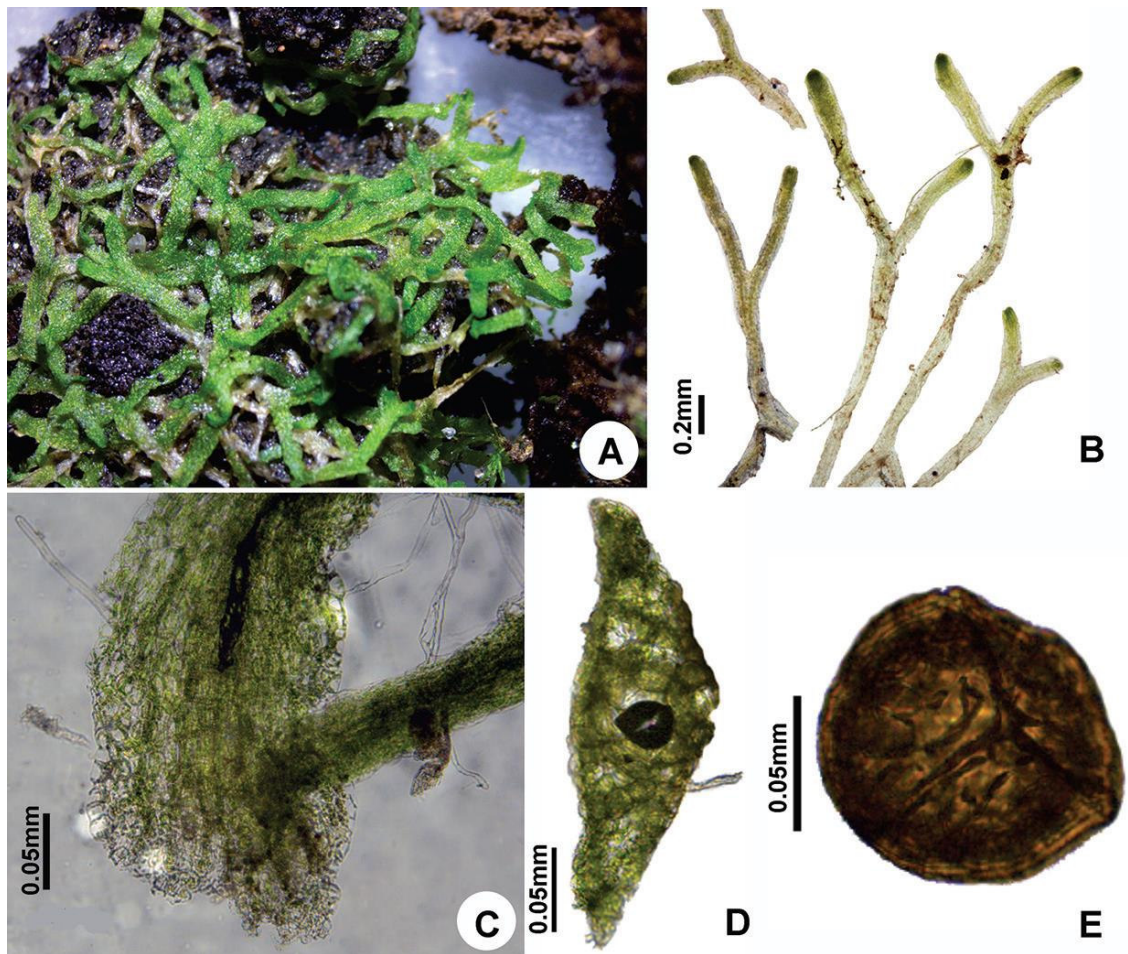


Figure 7. *Riccia stenophylla* (J.A.S.Silva 202 CCAA). **A.** Habit. **B.** Thalli. **C.** Apex of thallus. **D.** Cross section of thallus. **E.** Spore, distal face. Photos: J.A.S.Silva.

Material examined. BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, Cachoeira do Prata; 06°59'41"S, 047°09'53"W; alt. 197 m; 29 Oct. 2017; J.A.S. Silva 146 col.; CCAA 1533. • *ibid.*; J.A.S. Silva 202 col.; CCAA 1578. • *ibid.*; J.A.S. Silva 229 col.; CCAA 1551.

Identification. Plants terrestrial or semiaquatic. Thallus bright green, dichotomous, $2\text{--}8 \times 0.2\text{--}0.4$ mm, linear, without central midrib; dorsal surface with or without a slight median groove with photosynthetic cells, with pores bounded by four or five cells; air chambers in one or two layers; ventral surface greenish; margin entire, green to hyaline; ventral scales hyaline, 0.01 mm long. Sporophytes immersed in the thallus, forming a bulge ventrally, without involucre; capsule spherical, brown; spores tetrahedral, brown to yellow, without elaters.

Riccia stenophylla is a terrestrial or semiaquatic plant, with a long and slender thallus, smooth median area with or without a groove, and sporophyte forming a bulge ventrally. *Riccia stenophylla* is sometimes misidentified as *R. fluitans* L. since these species are both semiaquatic and have a thin stem and internal sporophyte forming a ventral bulge in the thallus. However, *R. fluitans* has a Holarctic distribution (Gradstein and Costa 2003; Stotler and Crandall-Stotler 2017), while *R. stenophylla* is a Neotropical species (Gradstein et al. 2016).

Distribution and ecology. Tropical and subtropical America (Argentina, Brazil, Colombia, Costa Rica, United States, Guatemala, Mexico, Nicaragua, Panama, Paraguay, Peru, and Uruguay) (Bischler-Causse et al. 2005; Gradstein et al. 2016; GBIF.org 2020). Brazilian biomes and states: Atlantic Forest (Espírito Santo, Paraná, Rio de Janeiro, Santa Catarina, and São Paulo), Caatinga (Bahia, Ceará, Paraíba, and Pernambuco), Cerrado (Goiás, Maranhão, and Mato Grosso), Pantanal (Mato Grosso do Sul), and Pampas (Rio Grande do Sul) (Flora do Brasil 2020). We found this species only at the end of the rainy season in ravines near rivers and streams in open habitats which were partially exposed to the sun.

***Riccia vitalii* Jovet-Ast.**

Figure 8A–E

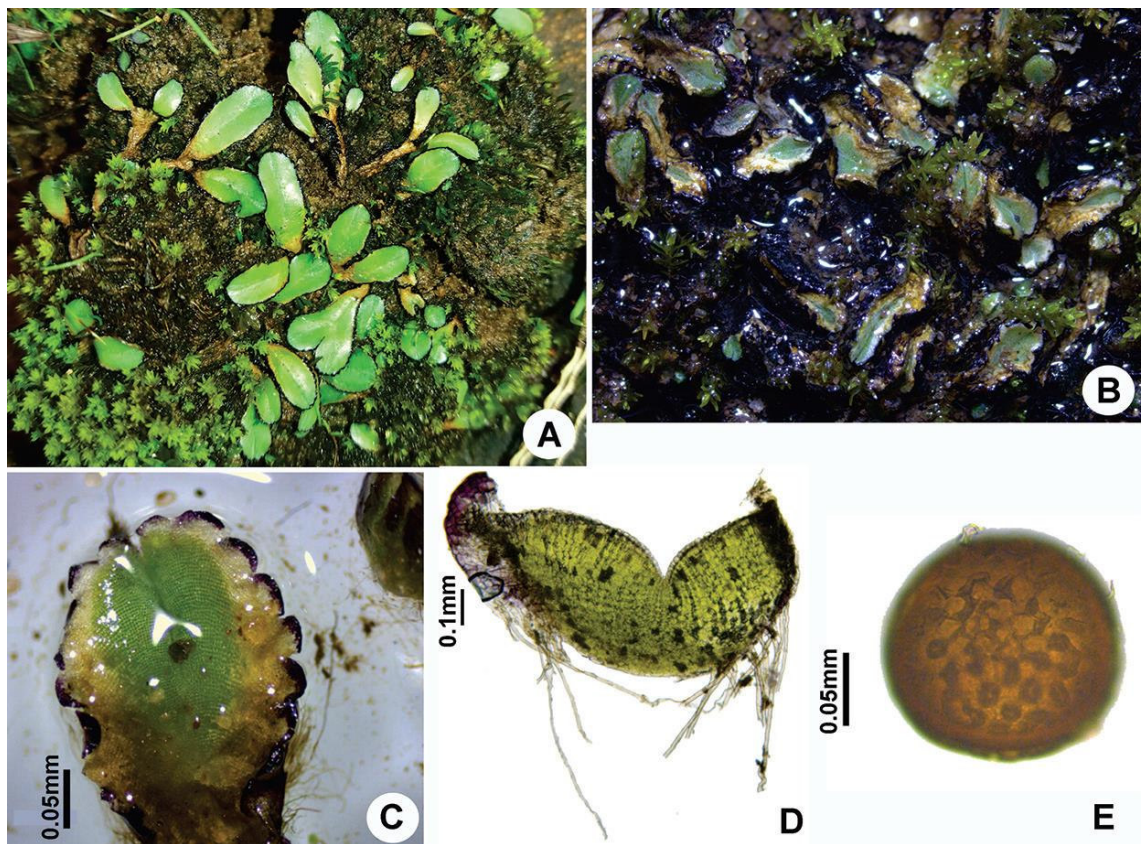


Figure 8. *Riccia vitalii* (J.A.S.Silva 073 CCAA). **A.** Habit (Wet). **B.** Herbarium specimen (habitat dry). **C.** Thallus in dorsal view with scales on the margin. **D.** Cross section of thallus. **E.** Spore, proximal face. Photos: J.A.S.Silva.

Material examined. BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, Cachoeira do Prata; 06°59'37"S, 047°09'57"W; alt. 197 m; 12. Mar. 2017; J.A.S. Silva 073, 075, 079 col.; CCAA 1564; 1494; 1507. • Estreito, Parque Nacional Chapada das Mesas, 06°59'39"S, 047°09'56"W; 12 Mar. 2017; J.A.S. Silva 085 col.; CCAA 1775.

Identification. Plants rupicolous. Thallus dichotomous, dark green, 5–8 × 2–4 mm, without central midrib; dorsal surface with one deep, median groove with photosynthetic cells; pores absent; ventral surface whitish to violet, without photosynthetic

cells; margin green to hyaline; ventral scales large, 0.05 mm long, violet, without filiform appendages, and extending beyond the margin. Sporophytes immersed in the thallus, without involucre; capsule spherical, brown; spores subspherical to subtetrahedral, reddish to dark brown, without elaters.

Riccia vitalii is terrestrial and differs from *R. stenophylla* in having the thallus with a deep median groove and large violet scales extending beyond the margin. In Brazil, *R. vitalii* when sterile can be misidentified as *Riccia weinionis* Steph. because both have a thallus with a deep median groove and dorsal cells with vertical bands of longitudinal thickenings which are seen in the thallus cross-section). However, *R. vitalii* can be easily distinguished from *R. weinionis* by the form and ornamentation of the spores. In *R. vitalii*, the spores are subspherical to subtetrahedral, with a granular proximal face and an evident trilete mark, whereas in *R. weinionis* the spores are tetrahedral with a proximal face with few areolas and without a trilete mark (Silva et al. 2018).

Distribution and ecology. Neotropical (Costa Rica, Paraguay, Colombia, and Brazil) (Bischler-Causse et al. 2005; Gradstein et al. 2016). In Brazil, it occurs in the Amazonia (Amazonas), Atlantic Forest (Espírito Santo), Caatinga (Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe), Pampas (Rio Grande do Sul), Pantanal (Mato Grosso do Sul), and Cerrado (Goiás, Maranhão, and Tocantins) biomes (Flora do Brasil 2020). We found it growing in open, sunny habitats near waterfalls.

Discussion

The thalloid liverworts collected in PNCM belong to four orders: Jungermanniales, Marchantiales, Metzgeriales, and Pallaviciniales. The majority (five) of the species are in Marchantiales. In the Neotropics, this is the most species-rich order, with 103 species in 12 families and 13 genera (Bischler-Causse et al. 2005; Villarreal et al. 2015; Söderström et al. 2016). Even though PNCM is located in the Brazilian Cerrado and has some transitional vegetation types, such as Cocais Forest, we found families more similar to the Caatinga biome than another study in the Cerrado biome by Gradstein and Costa (2003). In our study, the similarity with thalloid liverworts of the Caatinga biome is because we focused on gallery forest, but possibly also may have been influenced by the collection methods.

We present records of five species of thalloid liverworts newly reported from Maranhão state, and most notably *Pteropsiella metzgeriiformis* and *Monoclea gottschei*, which are also recorded for the first time from the Brazilian Cerrado. Until now, *P. metzgeriiformis* was only reported from Amazonia and the Atlantic Forest (Carmo and Peralta 2016; Lisbôa 1976). In Brazil, *M. gottschei* is distributed in the Amazonia, Atlantic Forest, Brazilian Cerrado, and Pampas biomes, occurring mainly in mountainous regions usually in habitats without drought stress and with high humidity throughout the year (Hell 1969; Costa and Yano 1987; Gradstein and Costa 2003; Flora do Brasil 2020).

Cyathodium and *Monoclea* were only collected in microhabitats near waterfalls where they were living on wet, shaded cliffs. The restricted occurrence of *Cyathodium* in extremely moist habitats, such as near waterfalls, might be because its thallus has few cell layers, and lacking a cell layer for water storage, it is impossible for this species to

colonize drier habitats unlike *Riccia* and *Cronisia* (Bischler-Causse et al. 2005). *Cronisia weddellii* was the most abundant species that we collected and occurred at the majority of our sites. This species is frequently collected in northeastern Brazil (Yano 2009; Germano et al. 2016; Oliveira et al. 2018b; Silva et al. 2018).

The most species-rich family of thalloid liverworts in the Neotropics is Ricciaceae (Bischler-Causse et al. 2005). We expected to find more species of this family because there are two centers of diversity for this family in Brazil (Caatinga and Pampa; Ayub 2014; Reis 2015) and Maranhão has two (Amazon basin and the Palm Forest) of the six main zones where *Riccia* occurs in the country (Jovet-Ast 1991). In our study, the Ricciaceae had the most species (two), while each of the other families were represented by only one species.

Riccia was collected in places exposed to the sun, and this preference for sunny, exposed habitats can explain the wide distribution of this genus in the tropics. *Riccia* has physiological characteristics, such as spores and stems adapted to desiccation, that allow it to survive drought. Additionally, rapid development of gametophytes and spores when water is available may offer another explanation (Bischler-Causse et al. 2005).

Most of the species found in our study have a rupicolous habit, which is possibly due to the large number of rocks near the streams and waterfalls. However, the soil characteristics must be considered, as the soil is porous and susceptible to erosion, which hinders the accumulation of water on the surface. This may force plants to grow on rocky substrates where they are less disturbed by erosion of their substrate (Martins et al. 2017). However, even where living and dead trunks are abundant, such as gallery forests in the Brazilian Cerrado and Atlantic Forest biomes, thalloid liverwort species tend to grow on rocks or soil (Hell 1969; Costa 1988; Yano and Pôrto 2006; Yano and Peralta et al. 2011; Carmo and Peralta 2016). Another possible explanation for plants growing on rocky surfaces is that they possess ventral cells specialized in water absorption. However, ecological studies are necessary to confirm this. While *Riccia stenophylla* and *P. metzgeriiformis* are unique because of their terrestrial habit, they were always found near river banks and, in the case of *R. stenophylla*, sometimes submerged in water.

We collected most of the thalloid liverwort species in PNCM in lowlands at elevations from 128 to 280 m. *Pteropsiella metzgeriiformes* was collected at an elevation of 277 m, similar to Pinzón (2003), who reported this species between 100 and 300 m. According to Gradstein (1995), the diversity of thalloid liverworts species is highest on plains (83 species) with an elevation range of 0–1200 m. One possible reason for this is that Marchantiales are drought-resistant plants which do not need permanent humidity and require open places with full-sun exposure (Bischler-Causse et al. 2005). According to Gradstein and Costa (2003), several species of liverworts are found in Brazil at elevations of 0–200 meters, which reflects the large latitudinal extension of the country's humid plains. Some thalloid liverwort species were found to be restricted to certain localities and habitats in PNCM; for example, *Cronisia weddellii*, *Riccia vitalii*, and *R. stenophylla* were only found near waterfalls and along the banks of the Rio Farinha, usually on rocks or in places partially exposed to the sun.

We found the diversity of thalloid liverwort species in PNCM to be 16% of the species known from northeastern Brazil. In comparison to other studies on thalloid liver-

worts in the Brazilian Cerrado, we did not find four families, Marchantiaceae, Dumortieraceae, Metzgeriaceae, and Pelliaceae, in PNCM. We believe that these families may occur in Maranhão and in PNCM, as there are still areas in the state and park that are still unexplored. More fieldwork is needed to better understand the diversity of thallose liverworts, as well as other bryophytes, in this state and national park. Our search for thalloid liverwort specimens on the SpeciesLink website (SpeciesLink 2020) yielded only nine records for all herbaria, revealing a scarcity of collections of these plants from Maranhão and demonstrating the need for more collections and increased study of thalloid liverworts.

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CAPÍTULO III

CONCLUSÃO GERAL

Este estudo compõem o primeiro trabalho taxonômico sobre hepáticas talosas em uma unidade de conservação do estado do Maranhão, reunindo dados sobre riqueza, diversidade e ecologia de hepáticas. O presente trabalho ressalta a importância do Parque Nacional Chapada das Mesas (PNCM) como área de conservação do Cerrado dentro do estado do Maranhão e de suas áreas de entorno, como áreas de grande diversidade biológica. O PNCM conta com 70% da diversidade de hepáticas talosas conhecidas para o estado e 24% da diversidade do Cerrado. Sendo assim, uma unidade de grande interesse florístico, o que ressalta a necessidade de proteção e conservação do parque, assim como de outras unidades de conservação. Uma vez que, os novos registros destacam a necessidade de aumentar as coleções no estado do Maranhão, incluindo todas as formações de vegetação.

Verificamos que a grande maioria das espécies registradas neste trabalho apresentam distribuição neotropical e no Brasil somente os gêneros *Cronisia* e *Cyathodium* apresentam distribuição restrita ao Cerrado e Caatinga. A ampliação do conhecimento sobre as espécies de hepáticas talosas no PNCM se mostrou significativa, pois anteriormente só se tinha registro de duas famílias e dois gêneros, para o estado do Maranhão. Agora o estado conta com seis famílias e seis gêneros. Com isso, destacamos a importância do esforço amostral e sistemático em áreas poucos ou nunca amostradas, uma vez que gêneros como *Riccia* apresentam sazonalidade portanto, quando as coletas são realizadas em vários períodos aumentam a possibilidade de registrar a verdadeira diversidade de uma região.

ANEXO.

Instruções para autores.

Checklist: the journal of biodiversity data

Authors' Guidelines

Main text

Manuscript Types, Templates, Spacing, Fonts, and Page Numbering

The two types of published articles are:

- **Annotated list of Species** of a given supraspecific taxon in a strict geographic area, with comments on the identifications and figures of most or all species. ALS must be based on original data. We no longer publish papers based solely on literature compilations.
- **Notes on the Geographic Distribution** reporting new records of one or more species while providing a complete overview on the known distribution of the treated taxa.

The use of templates is mandatory for all submitted manuscripts. The template for NGD is [here](#); for ALS, [here](#). By using the mandatory template, the general structure of your submission, as well as font, font size, line spacing, etc. will be correct.

Running head

Keep it short (up to 50 characters including spaces). Follow the format appropriate for the number of authors:

- Author | Short title
- Author and Author | Short title
- Author et al. | Short title

Title

The title should be in a sentence case (only scientific, English common names of taxa, and geographic or personal names should be with a first capital letter, e.g., *Elater ferrugineus* Linnaeus, 1758, Cuban Greater Funnel-eared Bat, Germany), and should include an accurate, clear, and concise description of the reported work, avoiding abbreviations. The higher taxa within the title should be separated with commas and not with a semicolon or colon, e.g.: (Coleoptera, Elateridae, Elaterini). Include authority (and year for animals) of publication of species- or genus-level taxa.

- Title in sentence case
- Colon between title and subtitle (if any)
- No footnotes

- No bold
- Higher taxa within the title should be separated with commas and not with a colon or semicolon

Authors and Affiliations

Provide the complete names of all authors as they should appear in the published work. Omit titles, degrees, and positions. Ensure that the authors' names and affiliations in the manuscript identically match the metadata in the system (you may need to edit them in the submission form at the time of submission). One of the authors should be designated as the corresponding author. It is the corresponding author's responsibility to ensure that the author list, and the individual contributions to the study are accurate and complete. If the article has been submitted on behalf of a consortium, all consortium members and their affiliations should be listed after the Acknowledgements section.

Affiliations

- Should not be the full mailing address but simply basic information (optional information is displayed in parenthesis in the following examples): (laboratory/department/institute), university/museum/institution, city, (state/province), country
- Unaffiliated authors can use: Independent researcher, city, (state/province), country.
- An email address and an ORCID iD can be included for authors that want to include them
- Follow this format:

1. (Department,) Institution, City, Country
2. (Department,) Institution, City, Country; email@a.bc
3. (Department,) Institution, City, Country; email@a.bc; <https://orcid.org/0000-0000-0000-0000>

Abstract

Up to 150 words for ALS; up to 90 words for NGD. Literature citations are not allowed. Avoid acronyms and abbreviations, but if using, explain these on first use. Generally, if the words to be abbreviated are used just once in the abstract, then it is best to spell out in full. Include authority (and year for animals) of publication of species- or genus-level taxa. Write in first person. The abstract must be a stand-alone entity which is a well written and concise summary of the article. Abstracts are only published in English.

Keywords

Up to seven (7) keywords, in alphabetical order and separated by commas, should be included in the text following the abstract. Keywords must not be repeated from the title, must be in alphabetical order, separated by commas, and lower case (except for proper nouns and the first keyword). Do not follow the keywords with a period.

Academic editor and citation

These will be completed by the editors after acceptance of the manuscript.

Language and style

Use American or British (international) English, but please be consistent. Using the formatting of the templates, keep the whole text left-aligned, and keep line numbering on the left margin of the page. Write with precision, clarity, and economy.

Use of active voice and first person, where appropriate, both in the abstract and main text.

While manuscripts are in English, the use of the local language is preferred for geographic and institutional names (e.g., Cordillera Occidental not Western Andes; Universidade de São Paulo not University of São Paulo).

Avoid the use of parenthetical comments.

Headings and subheadings

Main headings: The body text should be subdivided into main sections. Use the appropriate template (see above) and include these sections: **Introduction**, **Study Area** (only for ALS), **Methods**, **Results**, **Discussion**, **Acknowledgements**, **References**, **Appendix** (if there is an appendix). These headings need to be in bold font on a separate line and start with a first capital letter. Please do not number headings or subheadings.

- **Introduction** - The motivation or purpose of your research should appear in the Introduction, providing some of the historical basis for those questions. Be concise.
- **Study Area (only for ALS)** - Present the key features of the chosen study area in this section. Include information such as size (follow the International System of Units), type of habitat, ecosystem, ecoregion, ecological or eco-geographical classification of the selected study area. If your study site is a legally protected/conservation area, indicate the type of legal protection provided (e.g., Biosphere Reserve, Marine National Park, RAMSAR site, National Park, Wildlife Sanctuary, Critical Tiger Habitat, etc.). If appropriate, write briefly about the dominant flora and important faunal diversity of your study site

(exclude the organisms that you are reporting in this manuscript). Information on abiotic features such as terrain, current average rainfall, temperature, or precipitation can also be included here. DO NOT write about sampling design in this section; write about that in the **Methods**. Also, DO NOT include the reason or motivation behind choosing the study area; it should be a part of the Introduction. Cite appropriate references wherever the information provided here is not yours.

- **Methods** - A clear description of your experimental design and sampling procedures are especially important. Include protocols for specimen collection, permits for collection, and specialized methods for identification. If you list a product (e.g., animal food, analytical device), supply the name and location of the manufacturer. Give the model number for equipment used. Explicitly indicate where the voucher specimens were deposited; give full names and acronyms for collections, museums, or herbaria, but not catalog numbers or any of the details of records and vouchers. Include other taxon-specific abbreviations, such as sometimes used for specialized structures. Supply complete citations, including author or editor, title, year, publisher, and version number, for computer software mentioned in your article.
- **Results**—Results should be stated concisely and without interpretation. Do not present **Methods** or **Discussion** here.

For an NGD with one species, optionally add species name and other taxonomic information. For an NGD with more than one species, minimally include the name of the species here (other taxonomic information optional). For NGDs, this section should include a subsection called "**New records**" (or equivalent/similar: **Material examined** or perhaps **Observations**, for example for birds, where specimens are usually not collected). List each of your new records here. After the new records, optionally include any comments, e.g., observational notes that are more easily presented in sentence form. Include a subsection called "**Identification**"; this will show how you recognized the species. You may prepare a full description, but more important is that you compare your specimens to the species that you claim it to be and with similar or related taxa. You might also add results of molecular analysis here.

If your NGD includes two or more species, repeat **New records** and **Identification** sections for each.

For an ALS, results follow the same pattern as for NGD (but see Treatment of Taxa in these Guidelines).

Other subsections can optionally be added: e.g., **Distribution**, **Remarks**, **Taxonomic remarks**, **Habitat**, etc., for each species. Please give each section a subheading in bold font.

- **Discussion**—Focus on the rigorously supported aspects of your study. Carefully differentiate the results of your study from data obtained from other sources. Interpret your results, relate them to the results of previous research, and discuss the implications of your results or interpretations. In case of new records, previous research consists in all previously known records for that given species—cite, comment, and discuss them, highlighting why your new data is relevant. Clearly summarize the importance of your new record(s): e.g., distance and direction from nearest previous records, occurrence in a country, state, biome, etc.

Point out results that do not support speculations or the findings of previous research, or that are counterintuitive. You may choose to comment on new ideas suggested by your research, compare and contrast your research with findings from other systems or other disciplines, pose new questions that are suggested by the results of your study, and suggest ways of answering these new questions.

- **Acknowledgements**—Include people/organizations who provided help, guidance, or financial assistance. Consider acknowledging the subject editor and the reviewers, even when anonymous. Permits for fieldwork and collecting belong in **Methods**, but you can still acknowledge people here who aided you in obtaining permits.
- **References**—Must be complete, properly formatted, and fully checked that they are cited in the text (and vice versa).
- **Appendix**—Rarely, there is a need for an appendix. Material examined should be presented in **Results**. However, for example, the background data for producing a distributional map might be presented as an appendix. Manuscripts will have only one appendix, which may consist of multiple parts, e.g., Table A1, A2, etc., or Figure A1, A2, etc. Sometimes an Appendix simply may be text, not labelled as a table. The Appendix will form part of the published PDF and be included in the pagination (compare with **Supplemental Data**).
- **Supplemental Data**—Anything published as Supplemental Data will NOT be part of the published PDF but linked to the article's landing page. Supplemental Data are best used to publish non-text data, such as sound recordings, video, or very large datasets. For the latter, if the information would fit on a reasonable number of pages, publish it as part of the PDF publication, either within the main text or part of an appendix; this allows readers to access it most effectively. If you plan to include supplemental data, include a section head

called **Supplemental Data** and a brief description of what is included. This should follow **References** (or **Appendix**).

Subordinate headings

In **Results**, two subordinate sections **are required** for each species in an ALS or NGD:

- **New records** or equivalent/similar
- **Identification** (see Treatment of taxa in these guidelines for the minimum percentage of species that require this section in an ALS)
- Optional subordinate headings are also possible in **Methods** and in **Results** for each species in an ALS or NGD.

The **Introduction** and **Discussion** should not have subordinate headings.

Format subordinate headings left-justified, bold, and in a regular sentence case. All subordinate headings should end with a period and be on the same line as the subordinate text.

Scientific names

Scientific names should be written according to their specific nomenclatural code, the [International Code of Zoological Nomenclature](#) and its amendment, and the [International Code of Nomenclature for algae, fungi and plants](#).

- Use italics where required (but no italics for botanical family names).
- Include the naming authority for plant genera and species on first use. Include the naming authority and year for animal genera and species, enclosing both with parentheses when necessary, as required by the zoological code.
- The genus component of species names can be abbreviated after its first use in each main section (e.g., **Results** or **Discussion**). Exceptions can be made when abbreviating the genus results in loss of clarity. Never abbreviate the genus when it begins a sentence.
- Descriptions of new taxa are not published, nor any other nomenclatural act.
- Authors are encouraged to cite in **References** the publications of the original descriptions of the taxa treated in their manuscript. This is especially helpful for little-known or recently described taxa.

Synonym lists

If synonym lists are included, all cited works must be included in the **References** sections.

Capitalization

Initial capital letters should be used only in the beginning of a sentence, in proper names, English common names of species (the journal's style), Red List categories (e.g., Critically Endangered), and in headings of main sections, as well as to indicate tables, graphs and figure(s) within the text. German-language text, such as titles of books, require all nouns to be capitalized.

Italicization and underlining

Scientific names should be written according to their specific nomenclatural code, the International Code of Zoological Nomenclature and its amendment, and the International Code of Nomenclature for algae, fungi and plants.

Italics should not be used for emphasis, SD (standard deviation), SE (standard error), DF (degrees of freedom), NS (non significant), and not for abbreviations such as e.g., i.e., et al., etc., cf.

Underlining of any text is not acceptable for any purpose.

Quotations and quotation marks

Use quotation marks only for shorter direct quotations, words defined by the author, and words used in unusual contexts.

Shorter quotations should be embedded in the text and enclosed in double quotation marks ("..."). Long quotations should be as a separate line (paragraph), in regular font, without quotation marks, but with left and right margins indented. All quoted text should be attributed by a reference and page number(s): e.g., (Smith 2000: 345–346). Single quotation marks are to be used only for a quotation within another quotation.

Decimal marker

Denote decimal values by using a full stop or period (e.g., 0.07 mm, 4.3 km), not a comma. Check that all figures and tables use the correct kind of decimal marker.

Abbreviations and contractions

Abbreviations and contractions should both be followed by full stop or period (.) Examples:

- Abbreviations: a.s.l., cf., Ed. (editor), e.g., (for example), Fig., i.e. (that is), etc.
- Contractions: Figs., ca. (circa), Eds., Dr., and Mr.

Units

Use the International System of Units (SI) for all measurements.

If historical data includes non-SI measurements, include the approximate equivalent in brackets: e.g., 12 miles [19 km].

There should be a space between the value and unit (e.g., 12.5 km, not 12.5km).

All SI and similar units, for instance mm, cm, m, s, L, should be written without full stop.

Hyphens and dashes

Hyphens are used to link words such as personal names, some prefixes, and compound adjectives.

En-dashes (the width of an "N") are used to link spans. Use to link numerals, sizes, dates and page numbers (e.g., 1977–1981, Figs. 5–7, 237–258); and geographic or name associations (Murray–Darling River; a Federal–State agreement).

Em-dashes (the width of an "M") should be used rarely for introducing a subordinate clause in the text that is often used much as we use parentheses; in contrast to parentheses, an em-dash can be used alone. Check List typically uses the em-dash to separate names from references in synonym lists when the reference is a subsequent use of the name (i.e., not the original description).

There must be no space before or after either En- or em-dashes.

Footnotes

Footnotes are not permitted in the body text of the manuscript.

Geographic coordinates and altitude

Geographic coordinates are mandatory part of all new records (coordinates for historical records may be lacking but can be derived from modern sources and added, enclosed in square brackets, [...]).

Geographic coordinates may be derived from a GPS receiver, an online gazetteer, or mapping software (e.g., Google Earth). Geographic coordinates must be in one of these formats:

- Degrees, minutes, and seconds, e.g., 36°31'21"N, 114°09'50"W

- Degrees and decimal minutes, e.g., 36°31.46'N, 114°09.84'W
- Decimal degrees, e.g., 36.5243°S, 114.1641°W
- Decimal degrees, e.g., -36.5243, -114.1641 (minus indicate S and W hemispheres)

Do not mix $\pm$ with NS/EW: e.g., -123.01°W is wrong; this can only be -123.01 or 123.01°W

Accuracy is the tendency of measurements to agree with the true values. Many authors give the coordinates of their localities as recorded by their GPS. However, these readings are much too precise. As a general principle, do not give greater precision than the accuracy of the GPS. Too much precision (e.g., the many decimal places in 115.1329384°W) is misleading in that it implies a greater accuracy than the capacity of the GPS receiver. A GPS receiver might give the latitude in decimal seconds as 28°16'55.87"N. Because one second of latitude is about 30 m on the ground (but will vary depending on the distance from the equator), the second figure after the decimal in 55.87 represents 30 cm, yet a typical handheld GPS receiver is only accurate at best to ca. 3 m.

Round off geographic coordinates to an implied precision appropriate to the accuracy of the measurement (for standard GPS receivers, this is ca. 3 m error), or to the extent of the area sampled (the distance around a central point). We suggest rounding off:

- to the nearest second in degree-minute-second format (28°16'56"N), which implies roughly ± 25 –30 m at middle latitudes
- to two decimal places in decimal minute format (28°16.93'N), which implies roughly 15–20 m at middle latitudes
- to four decimal places in decimal degree format (28.2822°N), which implies roughly ± 10 –15 m at middle latitudes

Altitude. Many GPS users simply record the elevation given by their GPS receiver. However, GPS elevation is the elevation above a mathematical model of the Earth's surface and not the same as elevation above sea level. GPS elevations are also more prone to errors caused by improper calibration of the device and inherent problems of accuracy with the technology. Round off elevations to the nearest 10 m.

Treatment of Taxa

Identification

Only species-level identifications will be accepted; identifications to family- or genus-level will not be accepted. In the case of records based on genus-level identifications, these can be discussed as a personal observation but **cannot** be included as the main topic for an NGD nor as part of the results of an ALS. Papers submitted with family- or genus-level identifications might be subject to rejection prior the peer-review process.

Comments on identification

Mention of key characters, diagnoses, full descriptions, or comparisons with similar or related taxa is an important part of your manuscript to allow future validation by readers of your identifications and enhance the half-life of articles even in the face of taxonomic changes.

For NGD, all species must include comments on identification. For ALS, all treated taxa should ideally be commented, but:

- ≤ 100 species should minimally have $\geq 50\%$ of the species commented.
- > 100 species should minimally have $\geq 25\%$ of the species commented.

Give the key diagnostic characters used to separate your species from similar or related species, paying attention to those that with which it is most likely to be confused, and especially those in or suspected to be in the study area. Compare your specimens to published descriptions and illustrations, or type or other verified material in collections, if possible. Comments on the observed variation in your material or how the specimens differ from the species original description/definition are especially useful.

Figures of Treated Taxa

Figures must be provided to allow the unambiguous identification of the treated species and generally should show the important characters used in identifying the species. Figures may be photographs or illustrations of living individuals and/or preserved or dead specimens. These are intended to allow verification of your identification of the species by editors, reviewers, and readers and together with comments on identification contribute to enhance the half-life of your article in the face of taxonomic changes.

For NGD, all species must be appropriately figured. For ALS, all treated taxa should ideally be figured, but:

- ≤ 100 species should minimally have $\geq 50\%$ of the species illustrated.
- > 100 species should minimally have $\geq 25\%$ of the species illustrated.

Voucher Specimens

To be published, manuscripts must be in accordance with Check List's voucher policy, as below. The information here applies to all taxa, except when otherwise noted.

- Voucher specimens must be listed in **Results**.
- Voucher specimens must have been legally collected.
- Collecting permit numbers and the issuing agency, where applicable, should be included in **Methods**, and a statement that specimens were euthanized using approved/accepted/standard methods for the taxonomic group is recommended for inclusion in **Methods**.
- Voucher specimens must be deposited in scientific collections open to the public. Vouchers must be deposited before submission to Check List, and for most taxa, the institutional catalog number of the vouchers must be included in the manuscript.
- For plants, the collector's numbers and herbarium numbers must be cited.
- For insects deposited in museums that do not use catalog numbers, an author's number will be accepted if a label containing this unique and individual information is attached to each specimen.
- It is recommended to state if tissue samples for DNA analysis were taken from the vouchers.

When specimens cannot be collected for vouchers

For species threatened by extinction or legally protected, or when collecting of specimens is prohibited in the study area, special circumstances apply.

However, for certain taxa (e.g., most invertebrates or those vertebrates that are difficult to identify), the absence of voucher specimens may not allow for the proper vetting of your manuscript and it may not be acceptable for publication, and the decision to consider your manuscript will be up to a Subject Editor specializing in the taxonomic group. When voucher specimens are not available:

- Provide evidence other than voucher specimens, including photographs or voice records, if it allows an unambiguous identification of the taxon.
- For ALS on birds or mammals, observational records will only be accepted if standard procedures for the taxon are followed, and if the species are easily discernible.

Sequence data

Manuscripts containing novel amino acid sequences (e.g., primer sequences) will only be accepted if they carry an International Nucleotide Sequence Databases (INSD) accession number from the European Biology Laboratory

(EMBL), GenBank Data Libraries (GenBank) or DNA Data Bank of Japan (DDBJ). We strongly recommend that authors include institutional catalog numbers for specimens preserved in collections, and information identifying sequences that are derived from type specimens (see below) when they deposit data in genetic databanks. A summary table with the INSD accession [catalog] numbers should be included in the **Methods** section of the paper. If specimens were not vouchered (tissued specimens should be vouchered whenever possible!), collection locality data and possibly photographs of tissued specimens must be provided.

Citations and References

Before submitting the manuscript and at each revision, please check that every citation in the text has a corresponding entry in **References** and vice-versa.

Format of citations in the text

One author: Smith (1990) or (Smith 1990); e.g., "According to Smith (1990), ..." or "The species was not collected above 220 m (Smith 1990)".

Two authors: Brock and Gunderson (2001) or (Brock and Gunderson 2001)

Three or more authors: Smith et al. (1998) or (Smith et al. 1998)

When **citing more than one source**, order citations by the year of publication, starting with the earliest one; e.g., (Smith et al. 1998, 2000, 2016a, 2016b; Brock and Gunderson 2001a, 2001b; Felt 2006). **Two or more fully identical citations:** this can happen when you have more than one reference with exactly the same authors and years for one or two authors, or the same first author and year for author teams of three or more. Distinguish citations by adding letters after the years to citations and in **References**: (Reyes-Velasco et al. 2018a, 2018b). Repeat the year (2018a, 2018b; not 2018a, b).

Citations with page numbers or figures included: Smith (2000: 231), Smith (2000: figs. 4–9), Smith (2000: fig. 12)

For authorities and year for taxonomic names in zoology include a comma (,) between author and year; for multiple authors, use an "&" not "and"; use parentheses as needed (this is governed by the ICZN):

Brianmyia stuckenbergi Woodley, 2012
Micrurus camilae Renjifo & Lundberg, 2003
Tantilla alticola (Boulenger, 1903)

References

Please format the references properly. Your manuscript will be returned if references are incomplete or not well formatted. All book and journal titles should be spelled out completely and should NOT be italicized. Ensure that punctuation (or lack of punctuation) between parts is correct.

- Author names: surname first; all given names abbreviated, no full stops, commas or spaces, i.e.:
 - Albuquerque PRA (or de Albuquerque PRA)
 - Linnaeus C
 - Middendorff AT von
 - Smith CA Jr
 - van Tol J
- Authors separated by comma
- Year in brackets; no comma or full stop after it
- No italics (except for scientific names below family rank)

Capitalization is kept minimal in the titles of articles, books, chapters, reports. In English, capitalize the first word and proper nouns only; in German, capitalize all nouns; in other languages, capitalize where required, using minimal capitalization. Journal titles should have important words with initial capitals; treat non-English journal titles as if they were English.

Include DOIs (digital object identifiers) when available for either the full-text or title and abstract of an article, book chapter, or other reference; this is **required**. We do not accept standard URLs instead of DOIs; if journals do not offer DOIs, then no link is to be added. Please form DOIs using the full URL link: <https://doi.org> + prefix (10.xxxxxx) + suffix ; for example in the DOI <https://doi.org/10.15560/14.4.579>, 10.15560 is the prefix (identifies the publisher) and 14.4.579 is the suffix (identifies the article). Include the <https://doi.org/> in all DOIs. Use the <https://doi.org>, not the deprecated <http://dx.doi.org>, <http://doi>: or any other form. Use/correct the DOI to these guidelines even when the publisher shows something different. Also ensure that each hyperlinked DOI works (do not insert spaces or break hyperlinks).

Other, non-DOI hyperlinks to references are included only for some kinds of references that are only online, such as online databases, software download sites, online published reports, and similar. When inserting a reference to a webpage, please include the <http://> or <https://> portion of the web address. In every case, there must be the date accessed.

Follow the examples below:

Journal article, no DOI

Polaszek A, Alonso-Zarazaga M, Bouchet P, Brothers DJ, Evenhuis NL, Krell FT, Lyal CHC, Minelli A, Pyle RL, Robinson N, Thompson FC, van Tol J (2005) ZooBank: the open-access register for zoological taxonomy: technical discussion paper. *Bulletin of Zoological Nomenclature* 62: 210–220.

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Diversity of thalloid liverworts in Brazilian Savanna of Parque Nacional da Chapada das Mesas, Maranhão, Brazil

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Abstract

We investigate the diversity of thalloid liverworts in Parque Nacional da Chapada das Mesas (PNCM). Illustrations, descriptions, taxonomic characters, and notes on the geographic distributions of species, as well as an identification key, are provided. We collected specimens during the rainy seasons between 2017 and 2020. Six families, six genera, and seven species were recorded, of which five species are recorded for the first time from Maranhão state, two species are recorded for the first time from the Brazilian Northeast Region, and two are newly recorded from the Brazilian Cerrado. Our results increase in the number of thallose liverwort species in Maranhão by 57%. Our data add to what is known about PNCM, Maranhão, and Brazilian Cerrado liverworts, and reinforce the importance of PNCM for conservation.

Keywords

Cerrado, hotspot, Marchantiophyta, riparian forest, taxonomy

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Introduction

Liverworts or hepatics are nonvascular terrestrial plants with dominant, leafy or thalloid gametophytes and growing in humid places worldwide. They represent the oldest lineage of embryophytes (Gradstein et al. 2001; Qiu et al. 2006). However, Puttick et al. (2018) found support for Setaphyta, a moss–liverwort clade which is the sister group to all other bryophytes. There are about 7,500 species of liverwort distributed in 398 genera and 92 families (Söderström et al. 2016), and including 850 species

of thalloid liverworts (11%), 500 simple thalloids (6%) (Jungermanniopsida), and 350 complex thalloids (5%) (Marchantiopsida) (Goffinet and Shaw 2009). In Brazil, 105 species of thalloid liverworts are recorded (Flora do Brasil 2020). Notable work on this group has been especially conducted in the southern and southeastern Brazil and include Hell (1969), Vianna (1985), Costa and Yano (1987), Costa (2008), and Ayub et al. (2014). Vianna (1985) focused mostly on Rio Grande do Sul and left a

vast legacy of information about the genus *Riccia* L., ranging from notes about morphological characteristics of different species (Vianna 1990, 1992a, 1992b, 1994a, 1994b) to floristic surveys (1970, 1976, 1981, 1985).

Thalloid liverworts possess a dorsiventrally flattened gametophyte, lacking leaves and having a variable internal structure, and a thallus that can be dichotomous (e.g. *Riccia*) or pinnate. They are usually terrestrial, and being drought-tolerant plants, they can colonize arid environments, such as the Caatinga and Brazilian Cerrado (Gradstein and Costa 2003; Bischler-Causse et al. 2005). Myers et al. (2000) designated biodiversity hotspots having a high degree of endemism and highly threatened biodiversity. Brazil includes two hotspots: the Atlantic Forest and the Brazilian Cerrado, which are the most threatened of the Brazilian biomes.

The Brazilian Cerrado has been annually suffering great losses due to diverse anthropic activities, such as agricultural expansion, deforestation, industrial activity, and unchecked urban growth, but the destruction of the Brazilian Cerrado has mainly occurred due to the expansion of soy cultivation. The high biodiversity of the Cerrado is still only partly known to science and under great risk of extinction. The climate of this biome is Tropical Seasonal, with a wet and dry season; the annual average temperature is about 25 °C, and the average annual precipitation is 1,200–1,800. Sporadic, spontaneous fires also occur in this biome (Myers et al. 2000; Silva and Bates 2002; Klink and Machado 2005; Malhado et al. 2010; Latrubesse et al. 2019; Colli et al. 2020).

In the Brazilian Cerrado, 156 species of hepatics have been recorded. About 30 species of thalloid liverworts are recorded for this biome, and they are distributed in 11 families and 12 genera (Flora do Brasil 2020), corresponding to 27% of all thalloid liverworts species occurring in Brazil. Thus, the Brazilian Cerrado the second most species-rich biome for thalloid liverworts, and second only to the Atlantic Forest, which harbors 89% of the species. Despite being a large region with unique vegetation and climate, the Brazilian Cerrado has only one endemic thalloid liverwort, *Riccia sanguineisporis* Jovet-Ast, which occurs only in Mato Grosso (Gradstein and Costa 2003; Bischler-Causse et al. 2005).

There are currently 65 national parks in Brazil, and 15 national parks (or slightly less than 25% of the total national parks in Brazil) are within the Cerrado biome (Rocha et al. 2010). There are some studies on the bryophytes in national parks within this unique biome (e.g. Yano and Peralta et al. 2011; Pinheiro et al. 2012; Sousa and Câmara 2015; Carmo and Peralta 2016; Oliveira et al. 2018a), and the national parks in Minas Gerais are the best inventoried for this biome (Yano and Peralta et al. 2011; Sousa and Câmara 2015; Carmo and Peralta 2016).

Maranhão has two national parks: Parque Nacional dos Lençóis Maranhenses (dune and marine) and Parque Nacional da Chapada das Mesas (hereafter PNCM) (Brazilian Cerrado) (Rocha et al. 2010). Maranhão includes parts of the Amazonia, Caatinga, and Cerrado

biomes, as well as transitional areas between them, giving the state great importance to the ecology, biodiversity and conservation of species in Brazil (Rebêlo et al. 2003; Ab'Sáber 2003; Fiaschi and Pirani 2009).

PNCM has a great tourist interest due to its scenic beauty, including numerous sandstone plateaus and waterfalls. It includes one of the most conserved plateau areas of Maranhão, with typical Savanna phytophysionomies and numerous watercourses (ICMBIO 2020). To date, only one inventory of bryophytes has been undertaken in this park, which focused on mosses (Oliveira et al. 2018a). Contrary to its ecological richness, only 26 species of liverworts have been recorded in the state, with just six of them being thalloid liverworts (Silva et al. 2018; Flora do Brasil 2020). This low number of species is probably due to the scarcity of taxonomic studies in Maranhão on this group. Yano (2009) recorded three species of thalloid liverworts: *Cronisia weddellii* (Mont.) Grolle and *Riccia vitalii* Jovet-Ast in the municipality of Montes Altos, and *Riccia stenophylla* Spruce in the municipality of Loreto. Varão et al. (2011) recorded only one species (*R. stenophylla*) in the municipality of Governador Edson Lobão, and Oliveira et al. (2018b) recorded five species in the municipality of Caxias. All these species belong to the family Ricciaceae. The only taxonomic study focusing on thalloid liverworts in Maranhão was by Silva et al. (2018), but it only included species of the genus *Riccia* (five species).

Therefore, the purpose of our study is to inventory the species of thalloid liverworts in PNCM. We provide an identification key to species, as well as descriptions and comments on the species found. Our study will support future ecological work, conservation, and management within PNCM, which is highly important for the protection of the Brazilian Cerrado, a world hotspot (Myers et al. 2000).

Methods

PNCM was created on 12 December 2005 by presidential decree to preserve the Savanna areas threatened by the expansion of the agricultural and steel industry in southern Maranhão (Fig. 1). The park's extent is about 160,000 ha and lies within the municipalities of Carolina, Estreito, and Riachão in the middle Tocantins river basin. The area is a transition zone between the Brazilian Cerrado and Amazonia biomes and is at 97–681 m above sea level (MMA 2007; Martins et al. 2017).

PNCM has many watercourses, over 400 springs, and two large waterfalls: São Romão and Prata (IBGE 2019; ICMBIO 2020). Its vegetation cover is typical of the Brazilian Cerrado, with formations of gallery forest, riparian forest, cerradões (a forest formation with xeromorphic elements, and characterized by the mixed composition of species common to Cerrado, Gallery Forest, and mata seca), campo sujo (a herbaceous-shrubby physiognomy with spaced shrubs and sub-shrubs), and campo limpo (a herbaceous phytophysiology, with

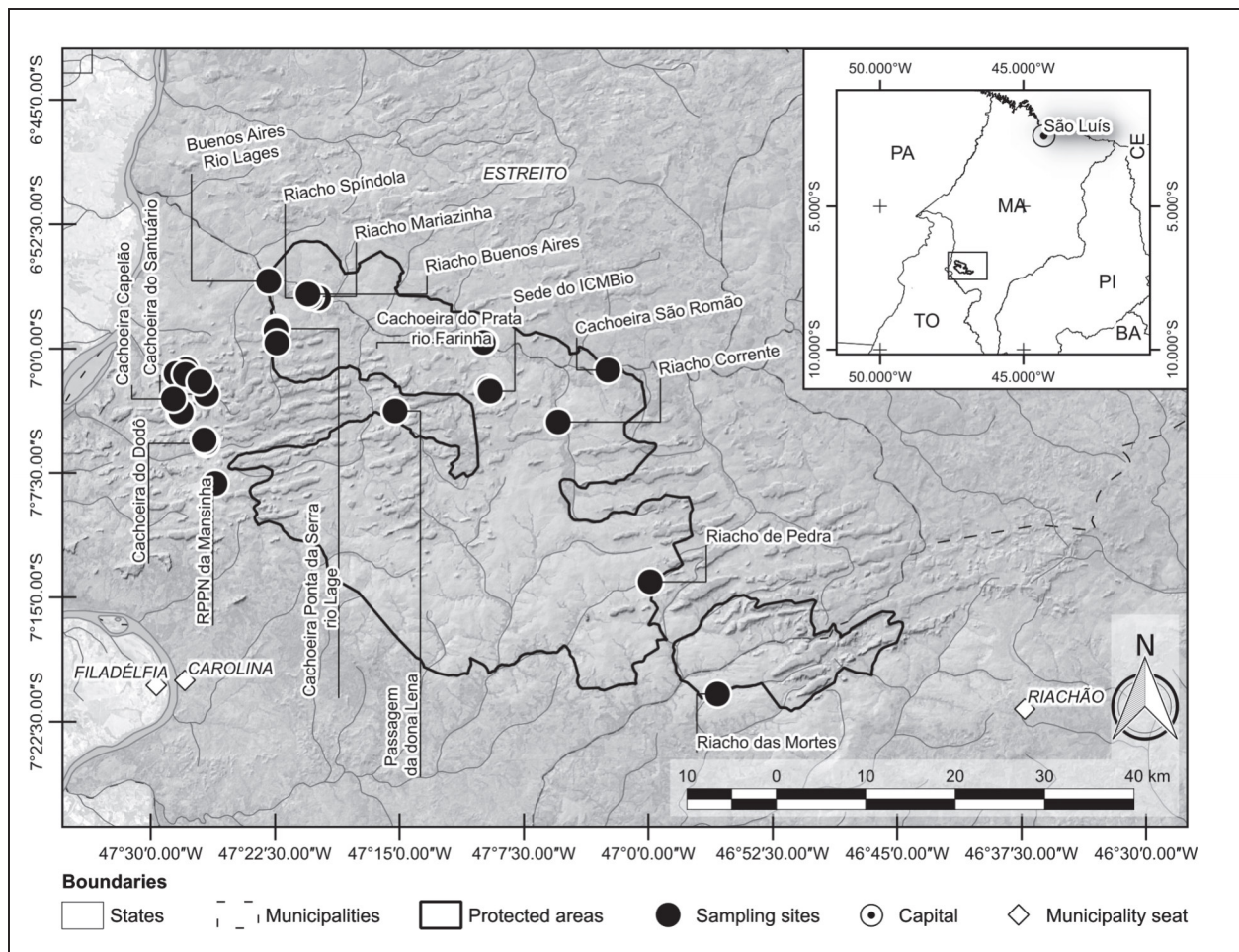


Figure 1. Map of the study area showing sampling sites inside and outside Parque Nacional da Chapada das Mesas, state of Maranhão, Brazil.

few shrubs and no trees) (Veloso et al. 1991). The region comprises plateaus, mountain ranges, and table mountains (mesas) (Veloso et al. 1991). The soils are formed by quartzarenic neosoils (SNUC 2020). The climate is tropical humid, with high temperatures throughout the year. The average annual temperature is about 26 °C, with low temperatures ranging from 25.2 °C in January to 27.8 °C in September, and a maximum temperature of about 36 °C in July and August (MMA 2007). There are two well-defined seasons: a dry summer and rainy winter (MMA 2007).

We collected specimens during four collecting expeditions in March and October 2017, June 2018, and February 2020 and included both rainy and dry seasons. Specimens were collected from waterfalls, along stream banks, and in gallery and riparian forests. We followed the methodology proposed by Yano (1989). Collecting efforts were carried out in several localities in PNCM, as well as in surrounding areas (Fig. 1). The specimens were dried and deposited in the CCAA herbarium. Duplicates of some species were sent to the RB herbarium.

The classification follows Crandall-Stotler et al. (2009). Our list of species in PNCM is in alphabetical order by family, genus, and species. We identified

the specimens using the following literature: Uribe and Aguirre (1995), Gradstein and Costa (2003), and Bischler-Causse et al. (2005). The geographic distribution of the species is based on Bischler-Causse et al. (2005), Gradstein et al. (2001), Gradstein and Costa (2003), Flora do Brasil (2020), GBIF.org (2020), species-Link (2020), and Tropicos.org (2020). Substrate type and the terms used in the species descriptions follow Gradstein et al. (2001).

Results

The species collected by us in PNCM represent 24% of the Brazilian Cerrado thalloid liverwort diversity. In our study area, we found seven species of thalloid liverworts, which are distributed in six genera and six families. These seven species represent 16% of the thalloid liverwort species in northeastern Brazil, a 57% increase in the number of thallose species known from Maranhão state (Silva et al. 2018; Flora do Brasil 2020). Most of the species found in our study are Neotropical in distribution, but *Cyathodium cavernarum* Kunze has a pantropical distribution (Gradstein and Costa 2003; Bischler-Causse et al. 2005; Söderström et al. 2020).

Key to the thalloid liverworts in PNCM

- 1 Thallus margin with sausage-shaped papillae. Sporophyte arising from leafy branches *Pteropsiella metzgeriiformis*
- 1' Thallus margin without papillae. Sporophyte not arising from leafy branches..... 2
- 2 Thallus a ventral structurally complex, divided into a photosynthetic dorsal layer and non-photosynthetic layer. Archegonium protected by involucre or embedded in the thallus. 3
- 2' Thallus structurally simple, not divided into layers, except in the central midrib. Archegonium protected by scale-like structures..... *Symphogyna leptothelia*
- 3 Dorsal surface of the thallus with pores..... 4
- 3' Dorsal surface of the thallus without pores 5
- 4 Thallus more than 3 cells thick. Rhizoids with papillose walls. Ventral scales large (0.8 mm). Sporophyte on the dorsal surface of the thallus *Cronisia weddellii*
- 4' Thallus very thin, only 2 or 3 cells thick. Rhizoids with smooth walls. Ventral scales absent (or present at the apex of the thallus and very small). Sporophyte on the ventral surface of the thallus *Cyathodium cavernarum*
- 5 Thallus surface with whitish or blackish punctuations, margins crisped-undulate. Sporophyte arising from the thallus, and with linear capsule and thick seta *Monoclea gottschei*
- 5' Thallus surface without whitish or blackish punctuations, margins flat. Sporophyte embedded in the thallus, and with a rounded capsule and no seta ... 6
- 6 Thallus >1 mm wide, with violet scales extend beyond the margin *Riccia vitalii*
- 6' Thallus <1 mm wide, without violet scales extend beyond the margin *Riccia stenophylla*

Corsiniaceae

Cronisia Berk.

The genus is represented by two species in the Neotropics (Bischler-Causse 2005), and both are known to occur in Brazil and the Brazilian Northeast Region. The genus occurs in the Central-West, Northeast, North and Southeast regions in the Caatinga, Brazilian Cerrado, Atlantic Forest, and Pantanal biomes. Only *Cronisia weddellii* (Mont.) Grolle occurs in Maranhão state (Flora do Brasil 2020).

Cronisia weddellii (Mont.) Grolle

Figure 2A–E

Material examined. BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, Rio Farinha; 06° 56'43"S, 047°20'31"W; alt. 179 m; 11 Mar. 2017; J.A.S Silva 020 col.; CCAA 1502. • *ibid.*; J.A.S Silva 021 col.; CCAA 1553. • *ibid.*; Cachoeira do Prata; 06°59'41"S, 047° 09'53"W; alt. 197 m; 06 Jun. 2018; J.A.S Silva 218 col.;

CCAA 1532. • *ibid.*; J.A.S Silva 222 col.; CCAA 1521. • *ibid.*; J.A.S Silva 223 col.; CCAA 1539. • *ibid.*; J.A.S Silva 227 col.; CCAA 1513. • *ibid.*; Cachoeira São Romão 07°04'25"S, 047°05'26"W; 7 Jun. 2018, J.A.S Silva 253 col.; CCAA 1517. • *ibid.*; Riacho Buenos Aires; 06°56'43"S, 047°20'31"W; alt. 179 m; 08 Jun. 2018; J.A.S Silva 300 col.; CCAA 1589. • *ibid.*; J.A.S Silva 302 col.; CCAA 1505.

Identification. Plants terrestrial and rupicolous. Thallus dichotomous, light green, whitish, or violet, 0.9–0.20 × 0.8–1.1 mm, without central midrib; main axis wider; dorsal surface chlorophyllose; epidermal pores with 5 or 6 ring cells; thallus in cross-section with one layer of air chambers with chlorophyllose filaments; ventral surface whitish; margin entire, green hyaline; ventral scales violet, large (0.8 mm long), with a filiform appendage, not extending beyond the margin. Sporophyte on the dorsal surface; involucre covering the sporophyte; capsule spherical; spores spherical, brown to dark brown; elaters short, no more than twice as wide.

Cronisia weddellii can be confused with species of *Riccia*. However, *C. weddellii* differs by having the cavities in the thallus containing antheridia, pores with ring cells, appendage scales filiform and sporophyte covered by the involucre (Bischler-Causse et al. 2005). Two species have been recorded from northeastern Brazil, *C. weddellii* and *C. fimbriata* (Nees) Whittm., of which the latter occurs mainly in the Caatinga (Yano and Porto 2006; Yano et al. 2009; Germano et al. 2016). *Cronisia weddellii* differs from *C. fimbriata* by having non-raised epidermal pores and scales that do not extend beyond the margins of the thallus.

Distribution and ecology. Neotropical (Bischler-Causse et al. 2005). In Brazil, it is known from Caatinga (Alagoas, Bahia, Ceará, Paraíba, Piauí and Pernambuco), Atlantic Forest (Espírito Santo), and Savanna biomes (Goiás, Maranhão, Mato Grosso, and Tocantins) (Gradstein and Costa 2003; Yano 2009; Flora do Brasil 2020). It is a typical species of the Brazilian Cerrado and Caatinga and tolerant to drought and high temperatures. We collected this species on soil and rocks on riverbanks where it was growing with mosses of the family Bartramiaceae. We observed that young plants differ from adults in the color of the thallus and shape of the scales. The thallus in young is light green, with scales almost or entirely hyaline and with only the apex violet; in adults the thallus is whitish to violet.

Cyathodiaceae

Cyathodium Kuntze

The genus is represented by five species in the Neotropics (Bischler-Causse 2005). Only *Cyathodium cavernarum* has been recorded for Brazil, where it occurs in the Central-West, Northeast, and Southeast regions and in the following biomes: Brazilian Cerrado, Atlantic Forest and Pantanal (Flora do Brasil 2020). Our records of this species from PNCM are the first from Maranhão state.

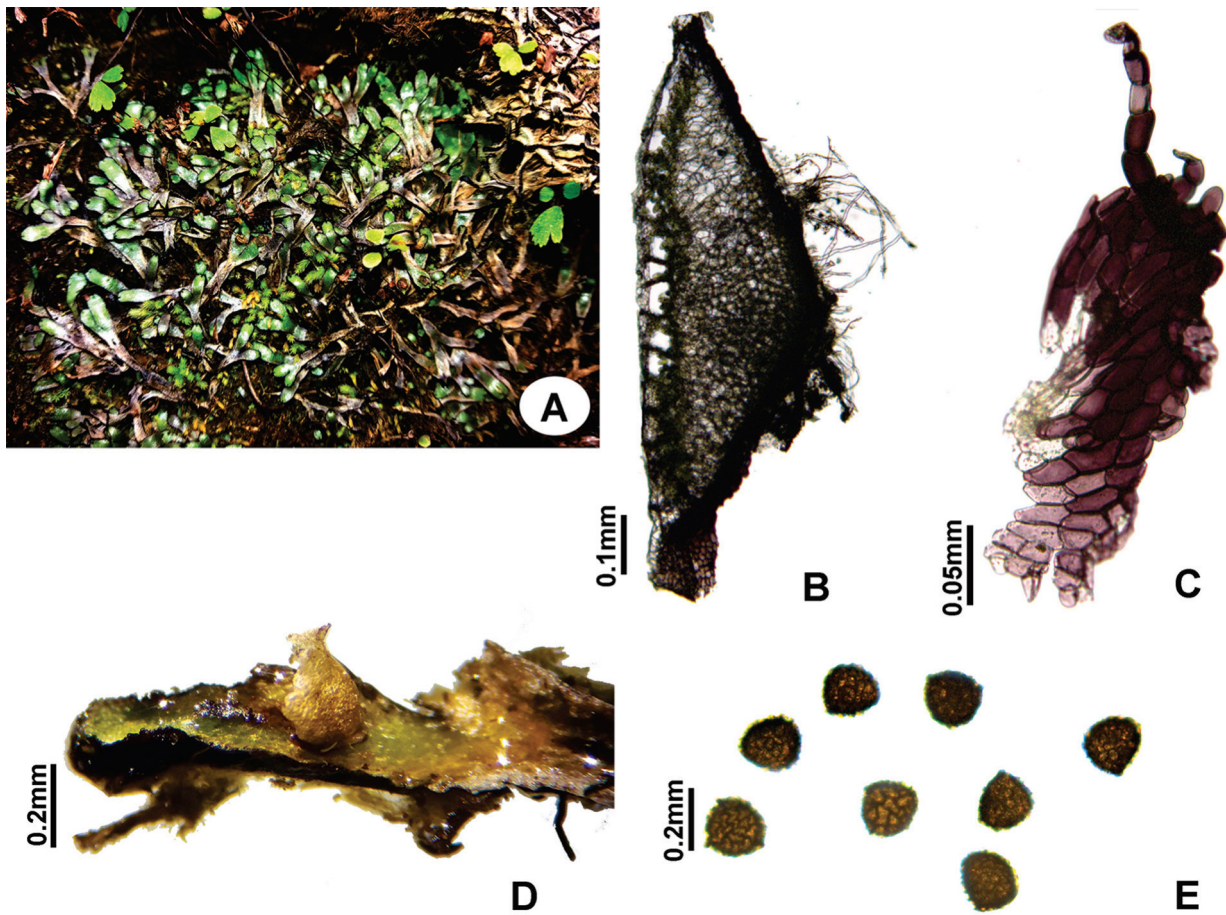


Figure 2. *Cronisia weddellii* (J.A.S.Silva 222 CCAA). **A.** Habit. **B.** Cross-section of thallus. **C.** Scale. **D.** Thallus with female involucre. **E.** Spores. Photos: J.A.S. Silva.

Cyathodium cavernarum Kunze

Figure 3A–E

Material examined. BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, Cachoeira São Romão; 07°04'25"S, 047°05'26"W; alt. 256 m; 07 Jun. 2018; J.A.S Silva 275 col.; CCAA 1587. • *ibid.*, Complexo Pedra Caída, cachoeira do Santuário; 07°02'44"S, 047°27'01"W; alt. 128 m; 07 Feb. 2020; J.A.S Silva 551 col.; CCAA 2696.

Identification. Plants rupicolous. Thallus obcuneate, very thin, only 2 or 3 cells wide, with smooth rhizoids, bright green to yellowish, 4–6 × 0.6–1.0 mm, without central midrib; main axis broad and flat; dorsal surface of chlorophyllose thallus with epidermal pores with a ring of 6–8 cells; thallus in cross section with one layer of air chambers without chlorophyllose filaments; ventral surface with chlorophyllose cells; margin entire, greenish; ventral scales reduced or absent. Sporophyte on the ventral surface of the thallus (near the apex); involucre sac-shaped; capsule ovoid, dark brown, opening with an operculum; spores spherical and densely spinose, dark brown; elaters long.

Cyathodium cavernarum differs from other species of thallose liverworts in the study area by having a bright green thallus with few layers of cells, and a sporophyte capsule opening through a ring of cells. It differs

from other species of *Cyathodium* by having the rhizoids with smooth walls, a sporophyte with an operculum, and spiny spores (Bischler-Causse et al. 2005).

Distribution and ecology. Worldwide (Bischler-Causse et al. 2005 and Söderström et al. 2020). Atlantic Forest (Minas Gerais), Caatinga (Bahia, Ceará, Paraíba, Pernambuco, and Piauí), Brazilian Cerrado (Goiás, Mato Grosso, Maranhão, and São Paulo), Pantanal (Mato Grosso do Sul) (Söderström et al. 2020; Flora do Brasil 2020; new data). We collected *C. cavernarum* on shaded rocks with a thin trickle of water running over the gametophyte. It was collected fertile only at the end of the rainy season.

Lepidoziaceae

Pteropsiella Spruce

This genus is represented by two species in the Neotropics, *P. frondiformis* Spruce and *P. metzgeriiformis* Spruce ex Steph. (Söderström et al. 2016; Flora do Brasil 2020). These species are distributed mainly in the North and Southeast regions of the country, in the Amazonia and Atlantic Forest biomes (Flora do Brasil 2020). Our record of *P. metzgeriiformis* is the first from the Brazilian Cerrado, the Northeast Region, and Maranhão.

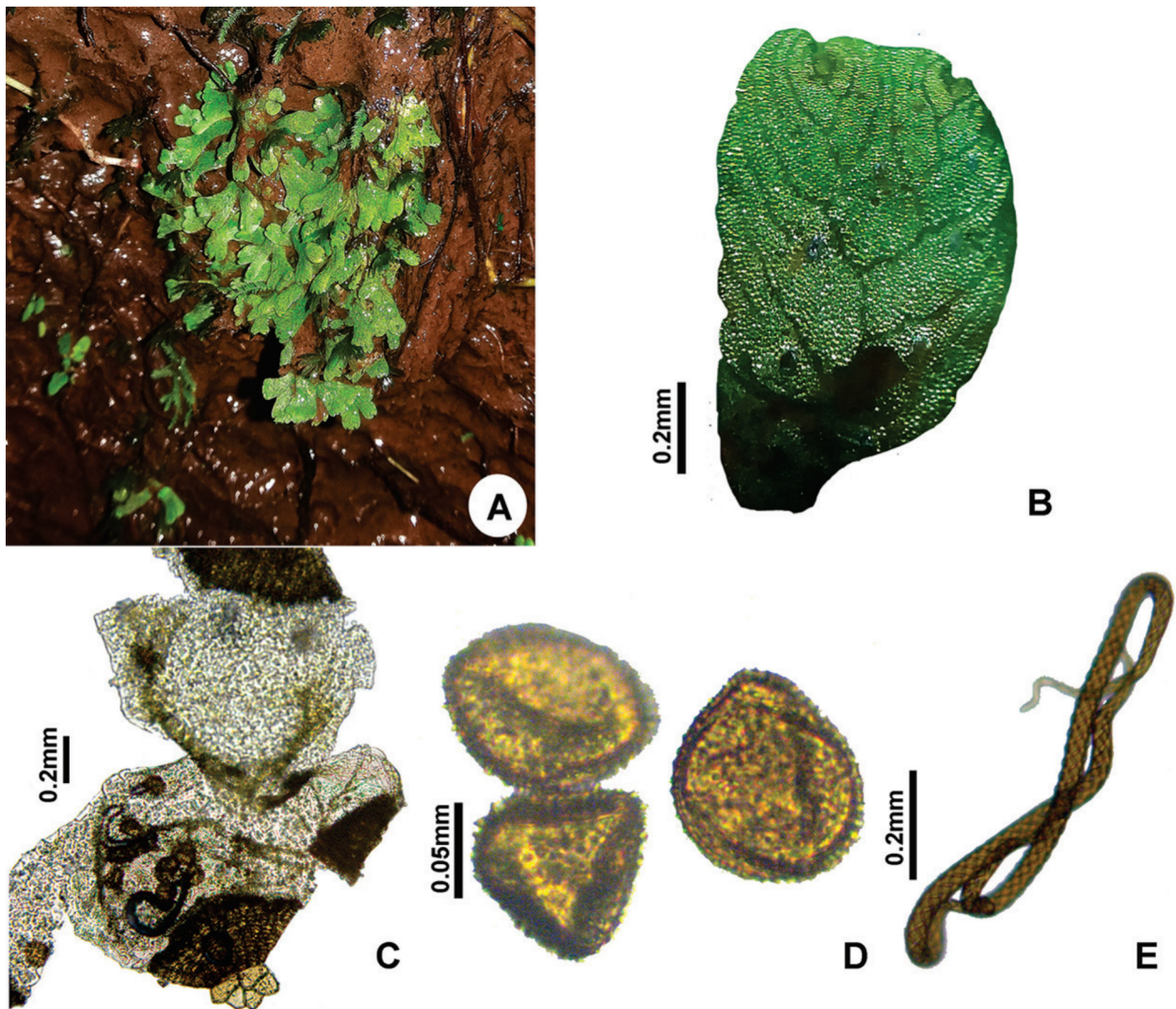


Figure 3. *Cyathodium cavernarum* (J.A.S.Silva 275 CCAA). **A.** Habit. **B.** Thallus. **C.** Capsule open with annulus cells at apex. **D.** Spores. **E.** Elaters. Photos: J.A.S.Silva.

***Pteropsiella metzgeriiformis* Spruce ex Steph.**

Figure 4A–D

Material examined. BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, Riacho Corrente; 07° 04'25"S, 047°05'26"W; alt. 277 m; 07 Jun. 2018; J.A.S. Silva 294 col.; CCAA 1558.

Identification. Plants terrestrial. Thallus light green, 10–30 × 0.3–0.5 mm; branches inserted ventrally; midrib rounded in cross-section, with six cortical cells (two dorsal and four ventral, and less than 15 medullary cells); wings narrow and unistratose; dorsal surface of thallus without pores and air chambers; ventral surface with chlorophyllose cells; margin toothed, green, with one or two sausage-shaped papillae; scales absent. Sporophyte arising from leafy branches.

Pteropsiella is sometimes misidentified as species of Metzgeriaceae because they also have a unistratose, flat thallus, with a midrib. However, *Pteropsiella* has a toothed, green margin with one or two sausage-shaped papillae, and rhizoids present only on the midrib, while Metzgeriaceae has thallus margins with rhizoids and gametoeccia on the ventral side of the midrib. *Pteropsiella*

metzgeriiformis differs from *P. frondiformis* by the light green thallus with fewer than 15 medullary cells, while *P. frondiformis* has a dark green thallus with more than 15 medullary cells.

Distribution and ecology. Brazil and Colombia (Lisboa 1976; Gradstein and Costa 2003; Pinzón et al. 2003; Carmo and Peralta 2016; Costa et al. 2017). Brazilian biomes and states: Amazonia (Amazonas and Roraima) and Atlantic Forest (Minas Gerais) (Carmo and Peralta 2016; Costa et al. 2017); and Brazilian Cerrado (Maranhão; new data). We collected this species near an open, sunny, sandy stream bank.

Monocleaceae

***Monoclea* Hook.**

This genus comprises two species, *Monoclea gottschei* Lindb. and *M. forsteri* Hook., of which the latter occurs in New Zealand (Gradstein and Costa 2003; Söderström et al. 2016). Until now, *M. gottschei* had been recorded in the North, Northeast, Southeast, and South regions of Brazil, in the Amazonia, Atlantic Forest, and Pampas

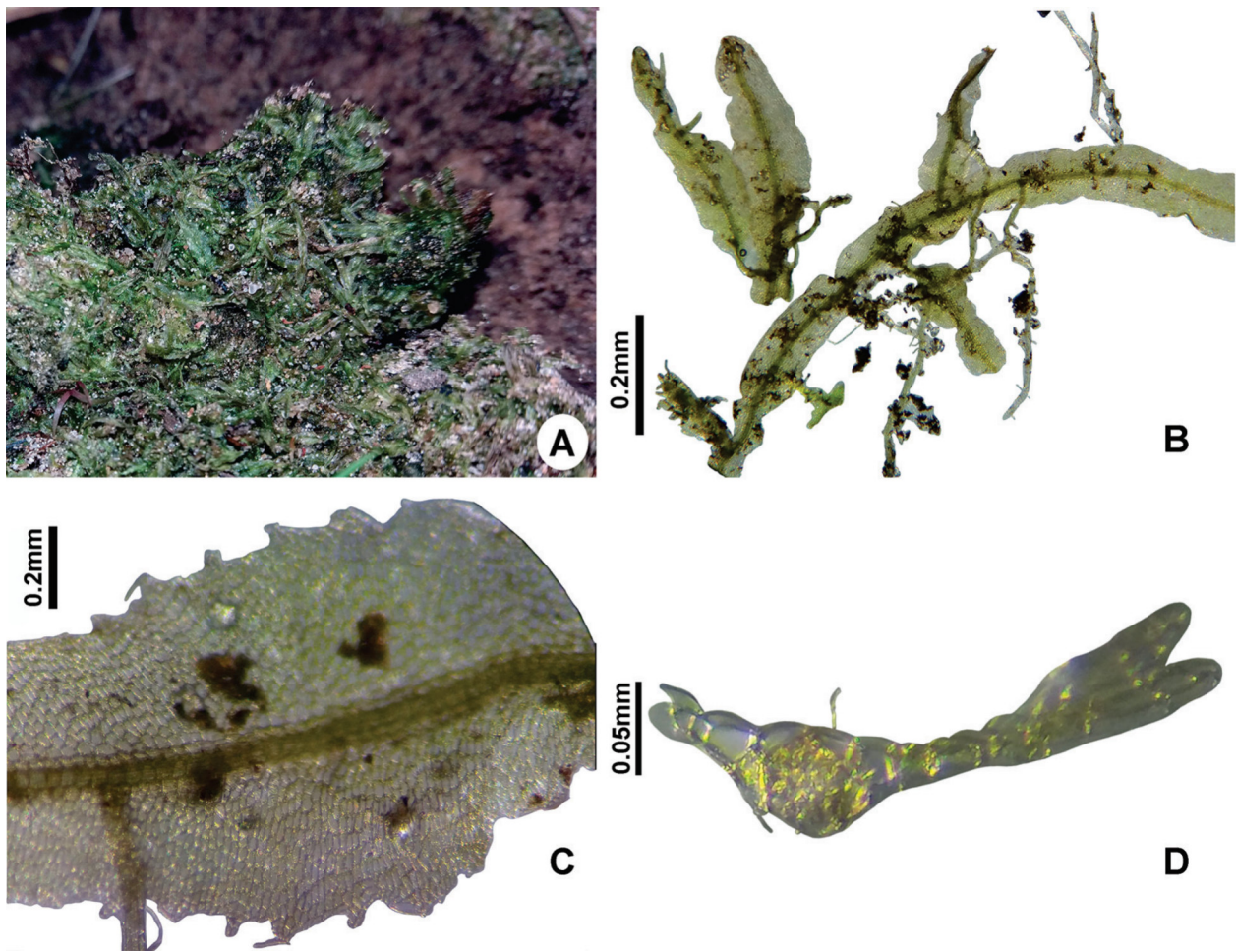


Figure 4. *Pteropsiella metzgeriiformis* (J.A.S.Silva 294 CCAA). **A.** Habit. **B.** Thalli, ventral view. **C.** Margin of thallus toothed with papillae. **D.** Cross section of thallus. Photos: J.A.S.Silva.

biomes (Flora do Brasil 2020). Our new records are the first of the genus from the Brazilian Cerrado biome and Maranhão state.

***Monoclea gottschei* Lindb.**

Figure 5A–D

Material examined. BRAZIL Maranhão • Carolina, Complexo Pedra Caída, cachoeira do Santuário; 07°02' 44"S, 047°27'01"W; alt. 128 m; 07 Feb. 2020; J.A.S Silva 552 col.; CCAA 2578. • *ibid.*, J.A.S Silva 557 col.; CCAA 2697.

Identification. Plants rupicolous. Thallus dark green, 20–30 × 5–10 mm wide, dichotomous, without central midrib, homogeneous; dorsal surface with chlorophyllose cells and without epidermal pores, densely spotted by whitish or darkish dots (observed in fresh material); air chambers absent; ventral surface with chlorophyllose cells; margins usually crispate-undulate. Sporophyte not seen.

Monoclea gottschei is a large plant, 2–3 cm long, with crispate-undulate margins. This species is sometimes misidentified as *Dumortiera hirsuta* (Sw.) Nees because it has a green, flattened thallus, without pores and air chambers, and often occurs in the same habitat. Otherwise, *M. gottschei* differs from *D. hirsuta* by having whitish dots on the thallus in fresh material and no

ventral bundle of the rhizoid (Gradstein et al. 2001).

Distribution and ecology. Neotropical (Gradstein and Costa 2003; Gradstein 2017; Flora do Brasil 2020; GBIF.org 2020). Brazilian biomes and states: Amazonia (Amazonas), Atlantic Forest (Espírito Santo, Minas Gerais, Paraná, Pernambuco, Rio de Janeiro, and São Paulo), and Pampas (Rio Grande do Sul) (Gradstein and Costa 2003; Flora do Brasil 2020); and Cerrado (Maranhão; new data). We collected this species on shaded rocks near a waterfall.

Pallaviniaceae

***Symphyogyna* Nees & Mont.**

The genus is represented by 11 species in the Neotropics (Uribe and Aguirre 1995; Gradstein and Costa 2003; Flora do Brasil 2020). Five species are known to occur in Brazil, in the Central-West, Northeast, North, and Southeast regions, in the Atlantic Forest, Caatinga, Cerrado, and Pantanal biomes (Flora do Brasil 2020). Of these five species, three occur in the Northeast Region. We report the first records of *Symphyogyna leptothelia* for the Northeast Region, making it the fourth species of the genus recorded for this region, and the first time that the genus is reported from Maranhão state.

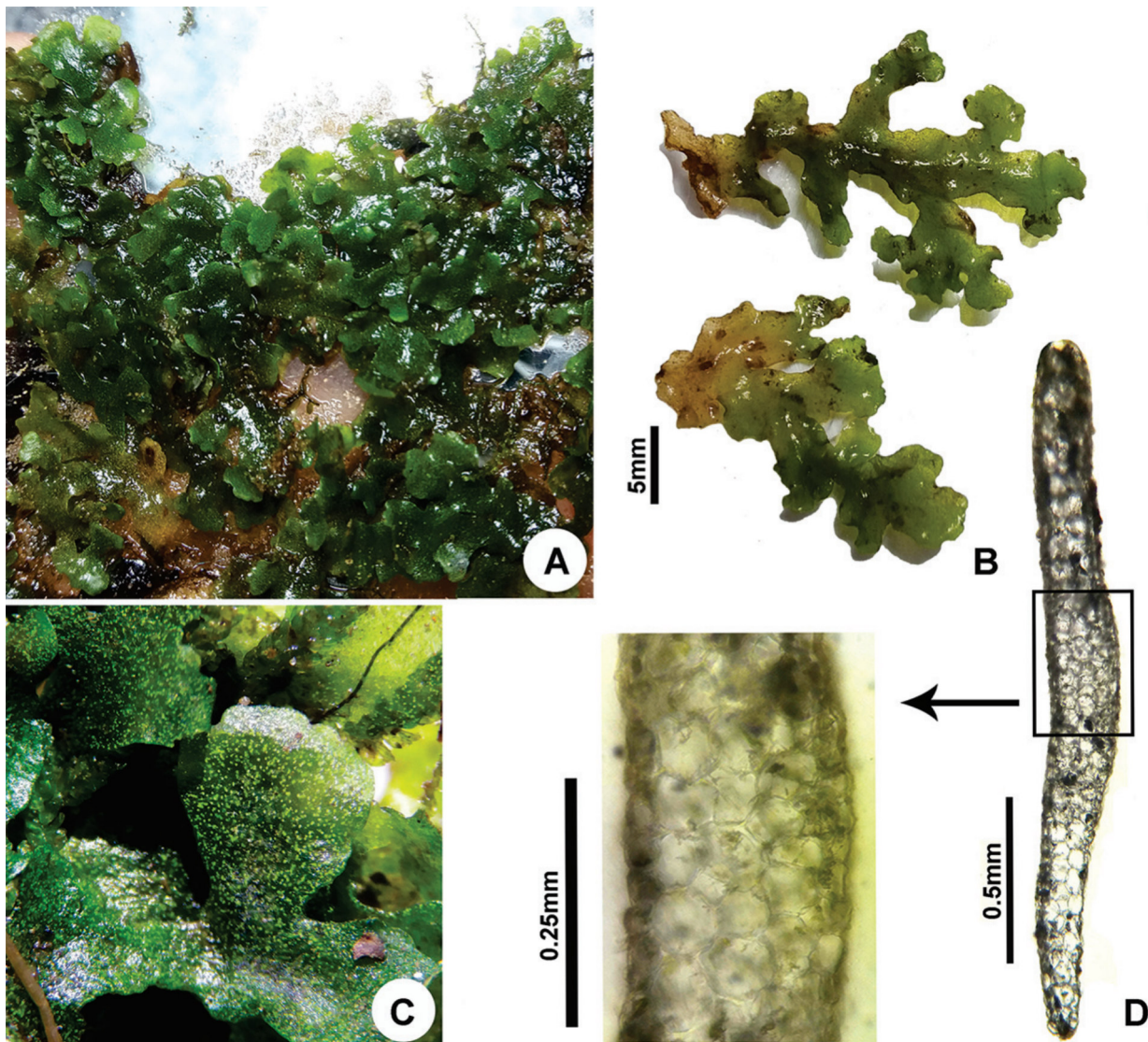


Figure 5. *Monoclea gottschei* (J.A.S.Silva 552 CCAA). **A.** Habit. **B.** Thalli. **C.** Thallus with whitish dots. **D.** Cross section of thallus. Photos: J.A.S.Silva.

***Symphyogyna leptothelia* Taylor**

Figure 6A–F

Material examined: BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, passagem da Dona Lena 07°03'45"S, 047°15'16"W; alt. 230 m; 07 Jun. 2018; J.A.S Silva 292 col.; CCAA 1528. • ibid.; 04 Feb. 2020; J.A.S Silva 491 col.; CCAA 2628.

Identification. Plants rupicolous. Thallus dichotomous, dark green, 21–26 × 2.2–5 cm, with central midrib; main axis convex to flat, 0.1 mm wide, with single prosenchyma band; wings large (0.2 mm); dorsal surface in cross-section without epidermal pores and air chambers; ventral surface with chlorophyllose cells; margin toothed; teeth with 5 or 6 cells; dorsal scales covering the archegonium. Sporophyte not seen.

Symphyogyna leptothelia grows prostrate on soil, and the thallus has wide undulate wings, a prominent central midrib with a single strand of prosenchyma tissue, and a toothed margin. *Symphyogyna aspera* Steph. is sometimes confused with *S. leptothelia* due to the prostrate

habit, dark green thallus, and toothed margin. However, *S. leptothelia* has entire wings that are not divided into segments and a toothed thallus apex, while *S. aspera* has lobate wings, divided into segments, and a non-toothed thallus apex.

Distribution and ecology. Neotropical (Uribe and Aguirre 1995; Gradstein and Costa 2003; GBIF.org 2020; Tropicos.org 2020). Brazilian biomes and states: Atlantic Forest (Espírito Santo, São Paulo, and Paraná), Brazilian Cerrado (Goiás, Maranhão; new data), Mato Grosso do Sul, Minas Gerais (Flora do Brasil 2020). We collected this species on shaded rocks near the sandbank of a stream in a riparian gallery forest.

Ricciaceae

***Riccia* L.**

This genus comprises 53 species in tropical America, of which 36 are recorded from Brazil (Bischler-Causse et al. 2005; Costa and Peralta 2015). It occurs in all regions of Brazil, and occurs in the Amazonia, Atlantic Forest,

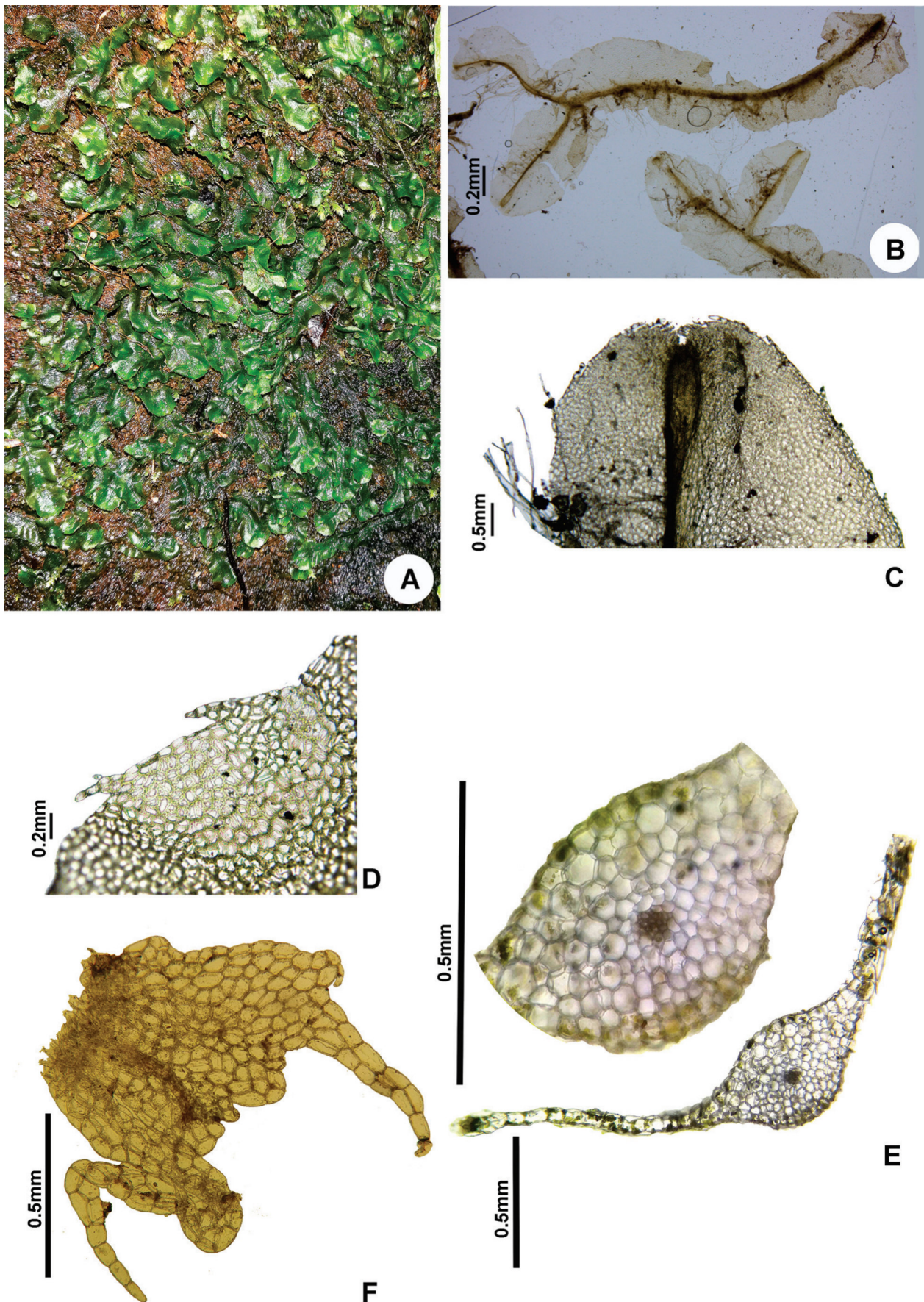


Figure 6. *Symphyogyna leptothelia* (J.A.S.Silva 292 CCAA). **A.** Habit. **B.** Thalli, ventral view. **C.** Apex of thallus. **D.** Detail of teeth of the margin. **E.** Cross section of thallus. **F.** Scale. Photos: J.A.S.Silva.

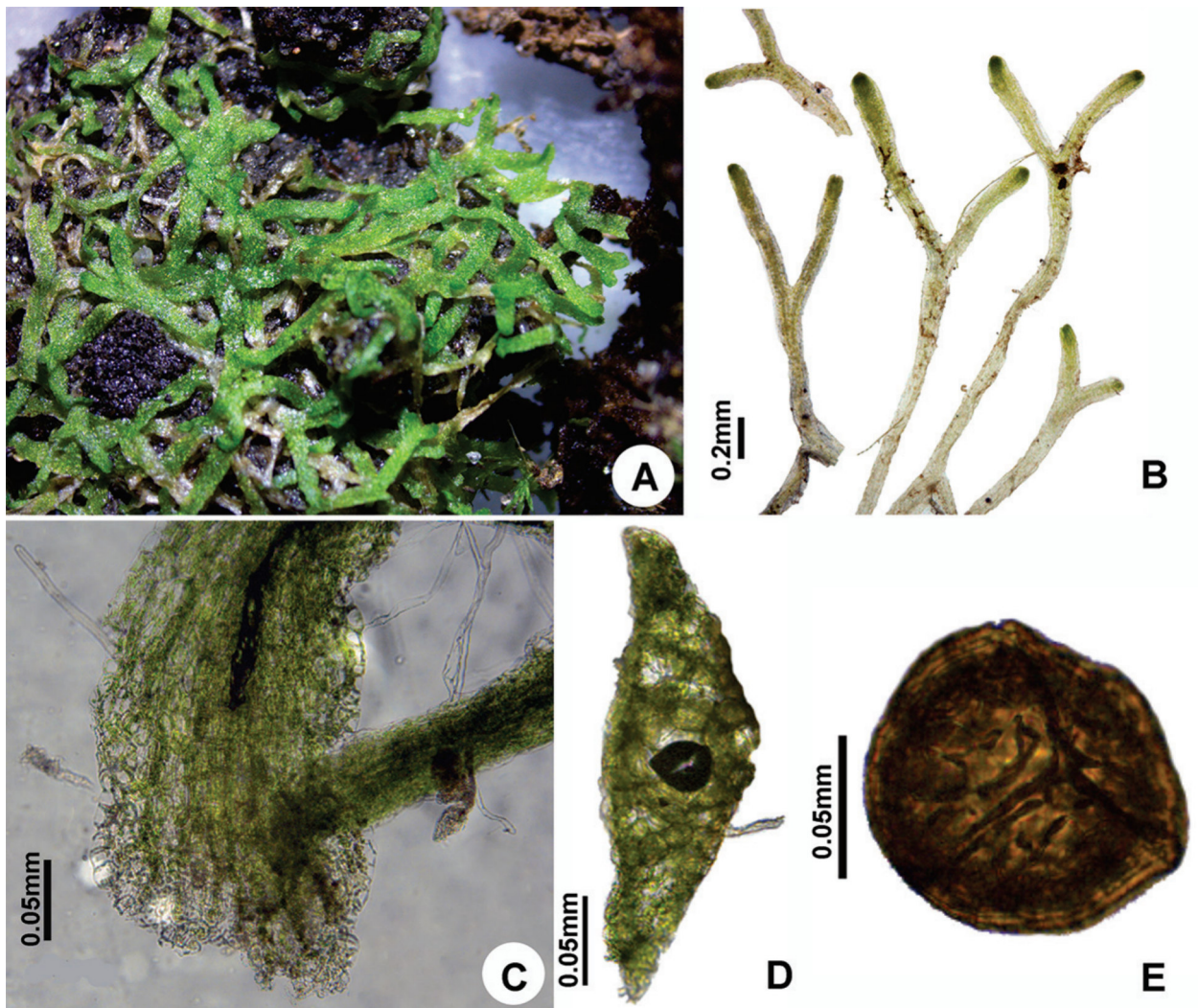


Figure 7. *Riccia stenophylla* (J.A.S.Silva 202 CCAA). **A.** Habit. **B.** Thalli. **C.** Apex of thallus. **D.** Cross section of thallus. **E.** Spore, distal face. Photos: J.A.S.Silva.

Caatinga, Pampas, Pantanal and Brazilian Cerrado biomes (Flora do Brasil 2020).

Riccia stenophylla Spruce

Figure 7A–E

Material examined. BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, Cachoeira do Prata; 06°59'41"S, 047°09'53"W; alt. 197 m; 29 Oct. 2017; J.A.S. Silva 146 col.; CCAA 1533. • *ibid.*; J.A.S. Silva 202 col.; CCAA 1578. • *ibid.*; J.A.S. Silva 229 col.; CCAA 1551.

Identification. Plants terrestrial or semiaquatic. Thallus bright green, dichotomous, $2\text{--}8 \times 0.2\text{--}0.4$ mm, linear, without central midrib; dorsal surface with or without a slight median groove with photosynthetic cells, with pores bounded by four or five cells; air chambers in one or two layers; ventral surface greenish; margin entire, green to hyaline; ventral scales hyaline, 0.01 mm long. Sporophytes immersed in the thallus, forming a bulge ventrally, without involucre; capsule spherical, brown; spores tetrahedral, brown to yellow, without elaters.

Riccia stenophylla is a terrestrial or semiaquatic plant, with a long and slender thallus, smooth median

area with or without a groove, and sporophyte forming a bulge ventrally. *Riccia stenophylla* is sometimes misidentified as *R. fluitans* L. since these species are both semiaquatic and have a thin stem and internal sporophyte forming a ventral bulge in the thallus. However, *R. fluitans* has a Holarctic distribution (Gradstein and Costa 2003; Stotler and Crandall-Stotler 2017), while *R. stenophylla* is a Neotropical species (Gradstein et al. 2016).

Distribution and ecology. Tropical and subtropical America (Argentina, Brazil, Colombia, Costa Rica, United States, Guatemala, Mexico, Nicaragua, Panama, Paraguay, Peru, and Uruguay) (Bischler-Causse et al. 2005; Gradstein et al. 2016; GBIF.org 2020). Brazilian biomes and states: Atlantic Forest (Espírito Santo, Paraná, Rio de Janeiro, Santa Catarina, and São Paulo), Caatinga (Bahia, Ceará, Paraíba, and Pernambuco), Cerrado (Goiás, Maranhão, and Mato Grosso), Pantanal (Mato Grosso do Sul), and Pampas (Rio Grande do Sul) (Flora do Brasil 2020). We found this species only at the end of the rainy season in ravines near rivers and streams in open habitats which were partially exposed to the sun.

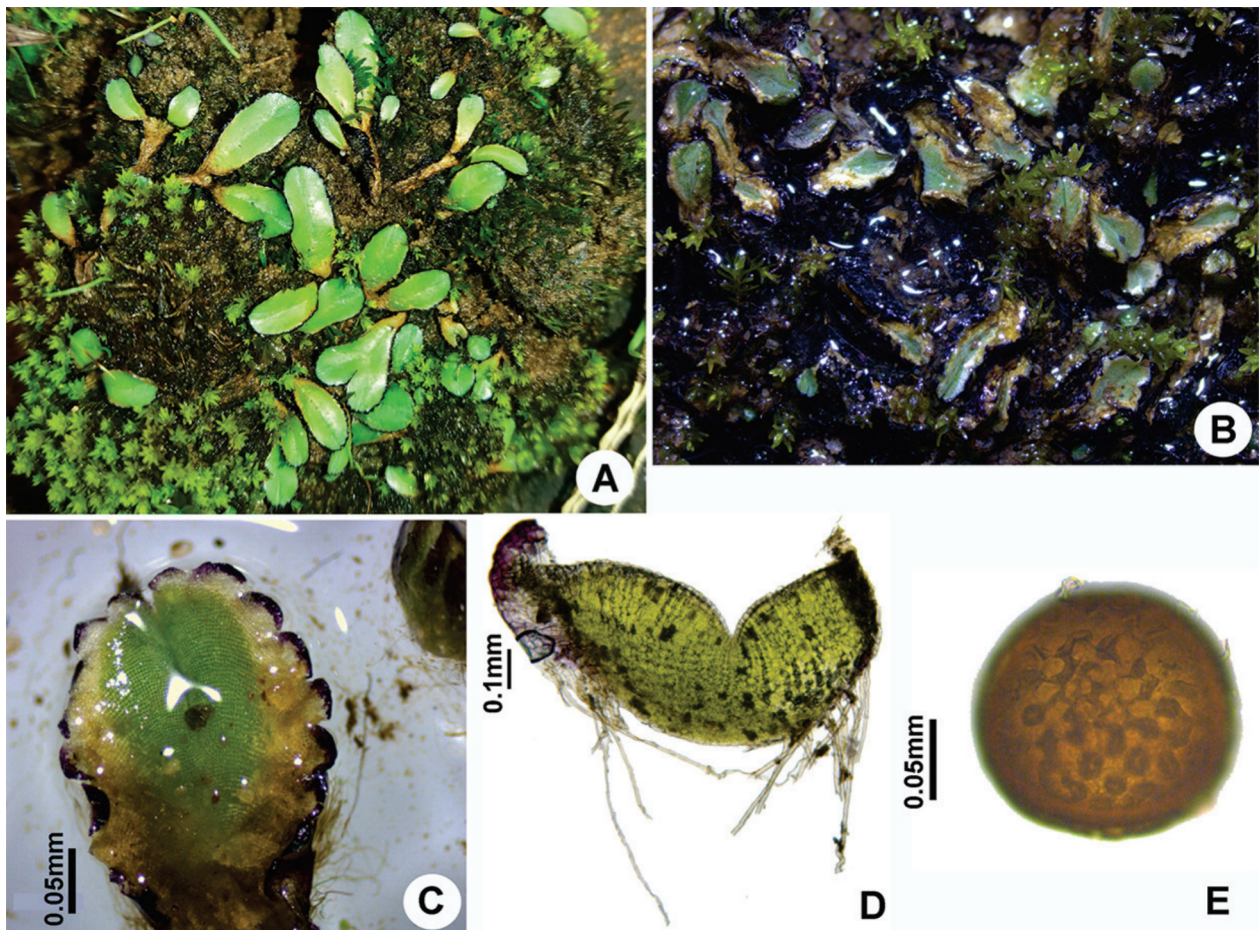


Figure 8. *Riccia vitalii* (J.A.S.Silva 073 CCAA). **A.** Habit (Wet). **B.** Herbarium specimen (habitat dry). **C.** Thallus in dorsal view with scales on the margin. **D.** Cross section of thallus. **E.** Spore, proximal face. Photos: J.A.S.Silva.

Riccia vitalii Jovet-Ast.

Figure 8A–E

Material examined. BRAZIL – Maranhão • Carolina, Parque Nacional Chapada das Mesas, Cachoeira do Prata; 06°59'37"S, 047°09'57"W; alt. 197 m; 12. Mar. 2017; J.A.S. Silva 073, 075, 079 col.; CCAA 1564; 1494; 1507. • Estreito, Parque Nacional Chapada das Mesas, 06°59'39"S, 047°09'56"W; 12 Mar. 2017; J.A.S. Silva 085 col.; CCAA 1775.

Identification. Plants rupicolous. Thallus dichotomous, dark green, 5–8 × 2–4 mm, without central midrib; dorsal surface with one deep, median groove with photosynthetic cells; pores absent; ventral surface whitish to violet, without photosynthetic cells; margin green to hyaline; ventral scales large, 0.05 mm long, violet, without filiform appendages, and extending beyond the margin. Sporophytes immersed in the thallus, without involucre; capsule spherical, brown; spores subspherical to subtetrahedral, reddish to dark brown, without elaters.

Riccia vitalii is terrestrial and differs from *R. stenophylla* in having the thallus with a deep median groove and large violet scales extending beyond the margin. In Brazil, *R. vitalii* when sterile can be misidentified as *Riccia weinionis* Steph. because both have a thallus with a deep median groove and dorsal cells with vertical bands of longitudinal thickenings which are seen in the thallus

cross-section). However, *R. vitalii* can be easily distinguished from *R. weinionis* by the form and ornamentation of the spores. In *R. vitalii*, the spores are subspherical to subtetrahedral, with a granular proximal face and an evident trilete mark, whereas in *R. weinionis* the spores are tetrahedral with a proximal face with few areolas and without a trilete mark (Silva et al. 2018).

Distribution and ecology. Neotropical (Costa Rica, Paraguay, Colombia, and Brazil) (Bischler-Causse et al. 2005; Gradstein et al. 2016). In Brazil, it occurs in the Amazonia (Amazonas), Atlantic Forest (Espírito Santo), Caatinga (Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe), Pampas (Rio Grande do Sul), Pantanal (Mato Grosso do Sul), and Cerrado (Goiás, Maranhão, and Tocantins) biomes (Flora do Brasil 2020). We found it growing in open, sunny habitats near waterfalls.

Discussion

The thalloid liverworts collected in PNCM belong to four orders: Jungermanniales, Marchantiales, Metzgeriales, and Pallaviciniales. The majority (five) of the species are in Marchantiales. In the Neotropics, this is the most species-rich order, with 103 species in 12 families and 13 genera (Bischler-Causse et al. 2005; Villarreal et al. 2015; Söderström et al. 2016).

Even though PNCM is located in the Brazilian Cerrado and has some transitional vegetation types, such as Cacaia Forest, we found families more similar to the Caatinga biome than another study in the Cerrado biome by Gradstein and Costa (2003). In our study, the similarity with thalloid liverworts of the Caatinga biome is because we focused on gallery forest, but possibly also may have been influenced by the collection methods.

We present records of five species of thalloid liverworts newly reported from Maranhão state, and most notably *Pteropsiella metzgeriiformis* and *Monoclea gottschei*, which are also recorded for the first time from the Brazilian Cerrado. Until now, *P. metzgeriiformis* was only reported from Amazonia and the Atlantic Forest (Carmo and Peralta 2016; Lisboa 1976). In Brazil, *M. gottschei* is distributed in the Amazonia, Atlantic Forest, Brazilian Cerrado, and Pampas biomes, occurring mainly in mountainous regions usually in habitats without drought stress and with high humidity throughout the year (Hell 1969; Costa and Yano 1987; Gradstein and Costa 2003; Flora do Brasil 2020).

Cyathodium and *Monoclea* were only collected in microhabitats near waterfalls where they were living on wet, shaded cliffs. The restricted occurrence of *Cyathodium* in extremely moist habitats, such as near waterfalls, might be because its thallus has few cell layers, and lacking a cell layer for water storage, it is impossible for this species to colonize drier habitats unlike *Riccia* and *Cronisia* (Bischler-Causse et al. 2005). *Cronisia weddellii* was the most abundant species that we collected and occurred at the majority of our sites. This species is frequently collected in northeastern Brazil (Yano 2009; Germano et al. 2016; Oliveira et al. 2018b; Silva et al. 2018).

The most species-rich family of thalloid liverworts in the Neotropics is Ricciaceae (Bischler-Causse et al. 2005). We expected to find more species of this family because there are two centers of diversity for this family in Brazil (Caatinga and Pampa; Ayub 2014; Reis 2015) and Maranhão has two (Amazon basin and the Palm Forest) of the six main zones where *Riccia* occurs in the country (Jovet-Ast 1991). In our study, the Ricciaceae had the most species (two), while each of the other families were represented by only one species.

Riccia was collected in places exposed to the sun, and this preference for sunny, exposed habitats can explain the wide distribution of this genus in the tropics. *Riccia* has physiological characteristics, such as spores and stems adapted to desiccation, that allow it to survive drought. Additionally, rapid development of gametophytes and spores when water is available may offer another explanation (Bischler-Causse et al. 2005).

Most of the species found in our study have a rupicolous habit, which is possibly due to the large number of rocks near the streams and waterfalls. However, the soil characteristics must be considered, as the soil is porous and susceptible to erosion, which hinders the accumulation of water on the surface. This may force plants to

grow on rocky substrates where they are less disturbed by erosion of their substrate (Martins et al. 2017). However, even where living and dead trunks are abundant, such as gallery forests in the Brazilian Cerrado and Atlantic Forest biomes, thalloid liverwort species tend to grow on rocks or soil (Hell 1969; Costa 1988; Yano and Pôrto 2006; Yano and Peralta et al. 2011; Carmo and Peralta 2016). Another possible explanation for plants growing on rocky surfaces is that they possess ventral cells specialized in water absorption. However, ecological studies are necessary to confirm this. While *Riccia stenophylla* and *P. metzgeriiformis* are unique because of their terrestrial habit, they were always found near river banks and, in the case of *R. stenophylla*, sometimes submerged in water.

We collected most of the thalloid liverwort species in PNCM in lowlands at elevations from 128 to 280 m. *Pteropsiella metzgeriiformis* was collected at an elevation of 277 m, similar to Pinzón (2003), who reported this species between 100 and 300 m. According to Gradstein (1995), the diversity of thalloid liverworts species is highest on plains (83 species) with an elevation range of 0–1200 m. One possible reason for this is that Marchantiales are drought-resistant plants which do not need permanent humidity and require open places with full-sun exposure (Bischler-Causse et al. 2005). According to Gradstein and Costa (2003), several species of liverworts are found in Brazil at elevations of 0–200 meters, which reflects the large latitudinal extension of the country's humid plains. Some thalloid liverwort species were found to be restricted to certain localities and habitats in PNCM; for example, *Cronisia weddellii*, *Riccia vitalii*, and *R. stenophylla* were only found near waterfalls and along the banks of the Rio Farinha, usually on rocks or in places partially exposed to the sun.

We found the diversity of thalloid liverwort species in PNCM to be 16% of the species known from northeastern Brazil. In comparison to other studies on thalloid liverworts in the Brazilian Cerrado, we did not find four families, Marchantiaceae, Dumortieraceae, Metzgeriaceae, and Pelliaceae, in PNCM. We believe that these families may occur in Maranhão and in PNCM, as there are still areas in the state and park that are still unexplored. More fieldwork is needed to better understand the diversity of thallose liverworts, as well as other bryophytes, in this state and national park. Our search for thalloid liverwort specimens on the SpeciesLink website (SpeciesLink 2020) yielded only nine records for all herbaria, revealing a scarcity of collections of these plants from Maranhão and demonstrating the need for more collections and increased study of thalloid liverworts.

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Authors' Contributions

JASS and FPO collected the plants; JASS photographed the plants; JASS, RSF and DPC identified the plants; FPO and RSF edited the images and financed the collecting expeditions; JASS revised herbarium collections; JASS, FPO, DPC, and RSF wrote and revised the manuscript.

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