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Bryophytes in Caatinga–Cerrado Ecotones: A Floristic Survey in Piauí, Brazil

Briófitas em Ecótonos de Caatinga–Cerrado: Um Inventário Florístico no Estado do Piauí, Brasil

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Keywords

bryoflora, geographic distribution, moss, transitional zone, species diversity

Palavras-chave

brioflora, distribuição geográfica, musgos, zonas de transição, diversidade de espécies

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Abstract

This study investigated the richness and distribution of bryophyte species in ecotonal areas of the state of Piauí, Brazil, based on collections carried out between 2022 and 2023 and specimens deposited in the Cryptogamic Herbarium of the State University of Piauí. Sampling was conducted in nine municipalities within transitional zones between the Caatinga and Cerrado biomes and in the Sete Cidades National Park, using exploratory walks and sampling on different substrates. A total of 22 Bryophyta (moss) species from 16 genera and 12 families were identified. Three species represent new records for the Caatinga biome, one for the Northeast region of Brazil, and three for the state of Piauí. Several taxa showed broad geographic distributions and high local frequency in the sampled areas. These results provide updated data on the geographic distribution of bryophyte species in Brazil and information on the bryoflora of Piauí and the Northeast region.

Resumo

Este estudo investigou a riqueza e a distribuição de espécies de briófitas em áreas ecotonais do estado do Piauí, Brasil, com base em coletas realizadas entre 2022 e 2023 e em espécimes depositados no Herbário de Criptógamas da Universidade Estadual do Piauí. A amostragem foi conduzida em nove municípios situados em ecótones entre os biomas Caatinga e Cerrado e no Parque Nacional de Sete Cidades, por meio de caminhadas exploratórias e coleta em diferentes substratos. Foram identificadas 22 espécies de Bryophyta (musgos), distribuídas em 16 gêneros e 12 famílias. Três espécies representam novos registros para a Caatinga, uma para a Região Nordeste do Brasil e três para o estado do Piauí. Vários táxons apresentaram ampla distribuição geográfica e elevada frequência local nas áreas amostradas. Esses resultados fornecem dados atualizados sobre a distribuição geográfica de espécies de briófitas no Brasil e informações sobre a brioflora do Piauí e da Região Nordeste.

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Introduction

Bryophytes represent an ancient lineage of non-vascular land plants and are considered among the earliest plant groups to colonize terrestrial environments. They are classified into three distinct phyla: Bryophyta (mosses), Marchantiophyta (liverworts), and Anthocerotophyta (hornworts) (Goffinet & Shaw, 2009). Together, they constitute the second largest group of terrestrial plants and were pioneers in the evolutionary transition from aquatic to terrestrial habitats (Vanderpoorten & Goffinet, 2009). Bryophytes contribute significantly to carbon and nutrient cycling and act as primary colonizers, facilitating the establishment of other plant species and providing microhabitats for small organisms (Glime, 2017).

Globally, approximately 17,900 bryophyte species are currently recognized (Gradstein et al., 2001). In Brazil, bryophytes are represented by 1,614 species, including 18 hornworts, 700 liverworts, and 896 mosses; the Northeast region, bryophytes are represented by approximately 736 species (Flora e Funga do Brasil, 2020). In recent years, the Northeast region of Brazil has shown a steady increase in bryological studies (Batista et al., 2018; Farias et al., 2017; Germano et al., 2016; Oliveira et al., 2018). However, the state of Piauí remains poorly explored, and its bryoflora still requires further investigation. In this context, Castro et al. (2002) provided an initial contribution by reporting bryophyte records from Sete Cidades National Park. The catalogs compiled by Yano (1989, 1995, 2005, 2006) also contributed important records on the bryophyte flora of Piauí.

The Caatinga and Cerrado phytophysiognomies are recognized as areas of high biodiversity, encompassing a wide range of vegetation formations and numerous rare and endemic taxa (Tabarelli & Silva 2002). In the state of Piauí, these environments exhibit pronounced spatial and environmental heterogeneity, including vegetation types ranging from the driest formations to more humid ones, such as babaçu palm forests and semideciduous seasonal forests (Emperaire, 1985; Rizzini, 1963).

Recent studies have expanded the number of bryophyte species known for the state of Piauí. Nascimento et al. (2019) conducted a bryofloristic survey in Serra da Capivara National Park, recording 62 species, of which 34 were new records for the state. Sousa and Oliveira (2019) identified 39 bryophyte species in Caatinga–Cerrado transition areas, including 22 new records for Piauí, 17 new occurrences for the Caatinga, and two for the Cerrado biome. Similarly, Nascimento et al. (2020) investigated bryophyte diversity in Sete Cidades National Park and recorded 90 species, including 53 new records for Piauí and four for the Northeast region of Brazil.

This study investigated the richness and distribution of bryophyte species through a floristic survey conducted in ecotonal areas of the state of Piauí, Brazil, contributing to the scientific understanding of local biodiversity.

Material and Methods

Study Area

Piauí is the third largest state in the Northeast region of Brazil, after Bahia and Maranhão, with a territorial area of 251,577 km² (Instituto Brasileiro de Geografia e Estatística [IBGE], 2012). The study was conducted in the Central-North Mesoregion of Piauí (Figure 1), an area drained by the Parnaíba and Longá rivers and located in a transitional zone between the humid domains of Maranhão and the semiarid hinterlands of the Sertão region (IBGE, 1990).

The climate is classified as tropical, with well-defined seasonal patterns characterized by a rainy period from December to April and a dry period from May to November. Temperatures range from 19–36 °C, and relative humidity varies between 40% and 80% (Medeiros, 2004). The predominant vegetation consists of semideciduous forest and transitional formations that include Cerrado and Caatinga vegetation types (IBGE, 2002).

Sample Collection and Analysis

Bryological material was collected bimonthly during both the dry and rainy seasons between October 2022 and April 2023. Samples were gathered in waterfall areas characterized by humid enclaves. Collection, herborization, and specimen preservation followed the procedures established by Gradstein et al. (2001). Random walks were conducted along pre-existing trails and off-trail areas, and samples were collected from all available substrates. The sampling approach was similar to the "walk-through" method described by Filgueiras et al. (1994).

Material was collected from all available substrate types and classified as corticolous (living tree trunks), epixylic (decomposing wood), epiphyllous (leaf surfaces), rupicolous (rock surfaces), and terricolous (soil) (Robbins, 1952). After collection, samples were air-dried and subsequently analyzed at the Biodiversity Laboratory of the State University of Piauí (UESPI). Macro- and microscopic analyses considered diagnostic morphological characters of the gametophyte and sporophyte, using a stereomicroscope and a compound light microscope. Forceps, needles, Petri dishes, slides, coverslips, and razor blades for sectioning were used during sample handling. The Bryophyta (mosses) species were classified according to the classification system of Goffinet & Shaw (2009). The geographic distribution of species was verified using the online platform Flora e Funga do Brasil (2020).

Examined Material

BRAZIL, Piauí: Altos, Alto Longá, Boa Hora, Cabeceiras do Piauí, Campo Maior, Jatobá do Piauí, Piripiri, Pedro II, and Sete Cidades National Park, *Santos & Oliveira et al:* Campo Maior, Buraco do Pinga SSM 6 (HUESPI 3054), 26/06/2022; Campo Maior, Buraco do Pinga SSM 9 (HUESPI 3057), 26/06/2022; Cabeceiras do Piauí, Balneário Barreiro, SSM 46 (HUESPI 3075), 04/02/2023; Cabeceiras do Piauí, Balneário Barreiro, SSM 50 (HUESPI 3079), 04/02/2023; Campo Maior, Cachoeira dos Macacos, SSM 13 (HUESPI 3061), 26/06/2022; Campo Maior, Cachoeira do Funil, SSM 7 (HUESPI 3055), 26/06/2022; Campo Maior, Cachoeira dos Macacos, SSM 12 (HUESPI 3060), 26/06/2022; Altos, Mucambo, OJWP UN (HUESPI 3102), 04/03/2015; Campo Maior, Cachoeira do Funil, SSM 7 (HUESPI 3055), 26/06/2022; Piripiri, Cachoeira do Bota Fora, GMSG UN (HUESPI 3100), 12/10/2017; Cabeceiras do Piauí, Balneário Barreiro, SSM 41 (HUESPI 3070), 04/02/2023; Cabeceiras do Piauí, Balneário Barreiro, SSM 53 (HUESPI 3024), 04/02/2023; Pedro II, Cachoeira do Urubu Rei, GMSG 267 (HUESPI 3103), 22/02/2018; Campo Maior, Buraco do Pinga, SSM 19 (HUESPI 3067), 26/06/2022, Campo Maior, Buraco do Funil, SSM 15 (HUESPI 3063), 26/06/2022, Campo Maior, Buraco do Pinga, SSM 18 (HUESPI 3066), 26/06/2022, Campo Maior, Buraco do Pinga, SSM 8 (HUESPI 3056), 26/06/2022, Boa Hora, Quebra Bunda - Faveira, SSM 61 (HUESPI 3084), 18/03/2023, Campo Maior, Buraco do Funil, SSM 14 (HUESPI 3062), 26/06/2022, Jatobá do Piauí, Cachoeira da Bica, SSM 79 (HUESPI 3090), 26/02/2023, Campo Maior, Buraco do Funil, SSM 16 (HUESPI 3064), 26/02/2022, Altos Piauí, Mucambo, OJWP UN (HUESPI 3095), 04/03/2015, Jatobá do Piauí, Cachoeira da Bica, SSM 77 (HUESPI 3088), 26/02/2023.

Results

A total of 22 bryophyte species were recorded (Table 1), distributed among 16 genera and 12 families. The recorded species included three new records for the Caatinga biome, comprising one new species (*Fissidens yanoae* Pursell) for the Northeast region of Brazil, and three (*Fissidens ramicola* Broth.; *Weisiopsis bahiensis* (Müll.Hal.) Broth.; *Sematophyllum adnatum* (Michx.) Brid.) for the state of Piauí. The most representative families were Fissidentaceae (6 species) and Sematophyllaceae (3 species), with the highest species richness.

The diagnostic morphological features of selected bryophyte species recorded in the study highlighted characters used for species identification (Figure 2).

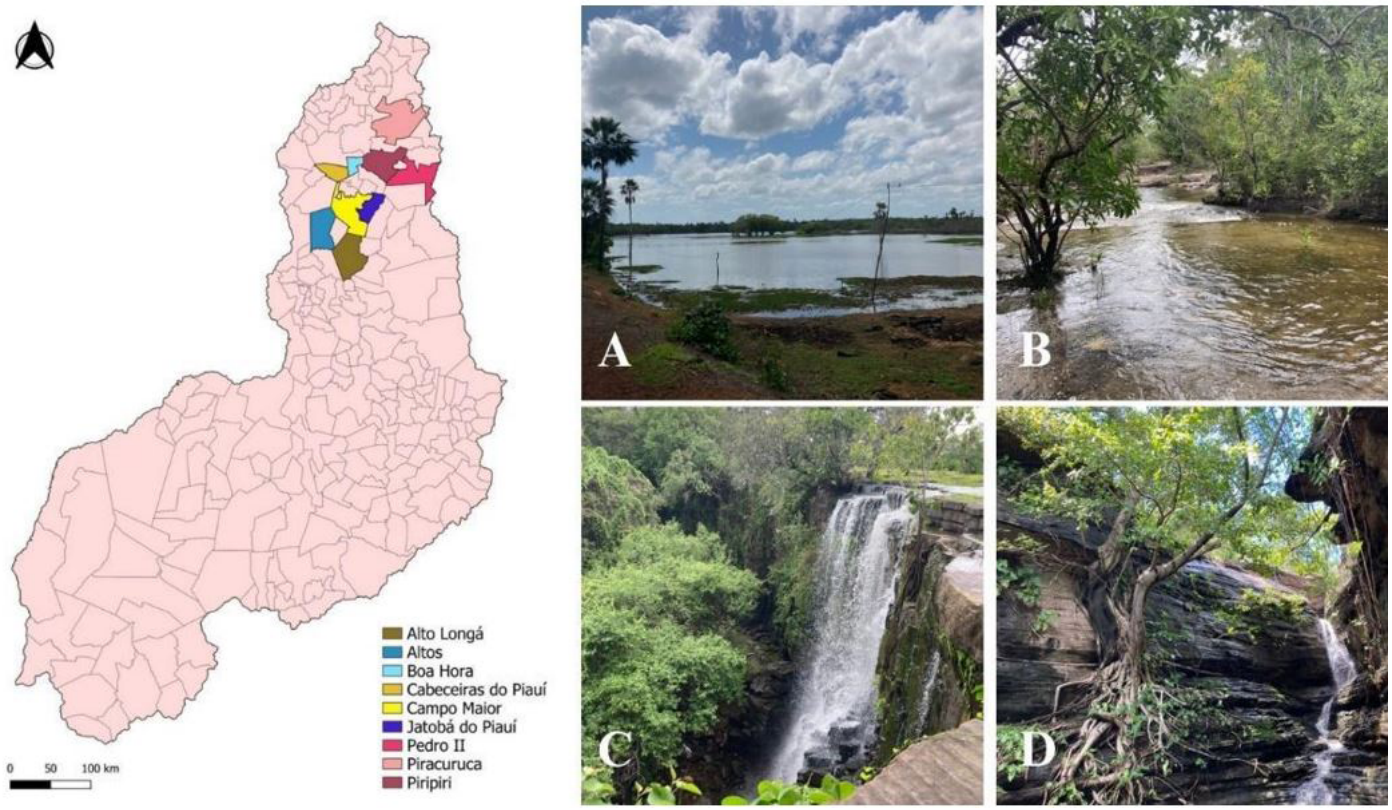
Discussion

The highest species richness of families Fissidentaceae (6 species) and Sematophyllaceae (3 species) is consistent with other inventories

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Figure 1

Map Showing the Collection Sites and Examples of Sampling Sites



Note. (A) Balneário Barreiro, Cabeceiras do Piauí; (B) Boa Hora; (C) Cachoeira da Bica, Jatobá do Piauí; (D) Serra de Santo Antônio, Campo Maior, Piauí, Brazil. Photographs by Stefani Machado dos Santos, 2024.

Table 1

List of Bryophyte Species Recorded in the Survey Conducted Between 2022 and 2023 and Specimens Deposited in the Cryptogamic Herbarium of the State University of Piauí (HUESPI), Heróis do Jenipapo Campus, Piauí, Brazil

Taxon (Family/Genus/Species)	Substrate	Phytogeographic Domains (Biomes)	Distribution in Brazil (States)	HUESPI Voucher
Bartramiaceae				
Philonotis cernua (Wilson) Griffin & W.R.Buck	Rupicolous	Caatinga, Cerrado, Atlantic Forest	PI, CE, MA, PB, PE, SE, DF, GO, MT, ES, MG, RJ, SP, PR, RS, SC	SSM 6 (HUESPI 3054)
Philonotis longiseta (Michx.) E.Britton	Rupicolous	Caatinga, Atlantic Forest	PI, BA, CE	SSM 9 (HUESPI 3057)
Calymperaceae				
Octoblepharum albidum Hedw.	Epixylic/ Terricolous	Amazon, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal	AL, BA, CE, MA, PB, PE, PI, RN, SE, AC, AP, AM, PA, RO, RR, TO	SSM 46 (HUESPI 3075)
Calymperes tenerum Müll. Hal.	Corticolous	Caatinga, Amazon, Atlantic Forest	PI, TO, MG, RJ, SP	SSM 50 (HUESPI 3079)
Dicranaceae				
Campylopus fragilis (Brid.) Bruch. & Schimp.	Rupicolous	Caatinga, Atlantic Forest	PI, MG, RJ	SSM 13 (HUESPI 3061)
Campylopus heterostachys (Hampe) A.Jaeger	Rupicolous	Amazon, Caatinga, Cerrado, Atlantic Forest	PI, BA, CE, MA, PE, RR, GO, MT, ES, MG, RJ, SP, PR, RS	SSM 7 (HUESPI 3055)
Fissidentaceae				
Fissidens goyazensis Broth.	Rupicolous	Amazon, Caatinga, Cerrado, Atlantic Forest	BA, CE, PB, PE, PI, AM, DF, GO, MG, RJ, SP	SSM 12 (HUESPI 3060)

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Table 1 (Continued)

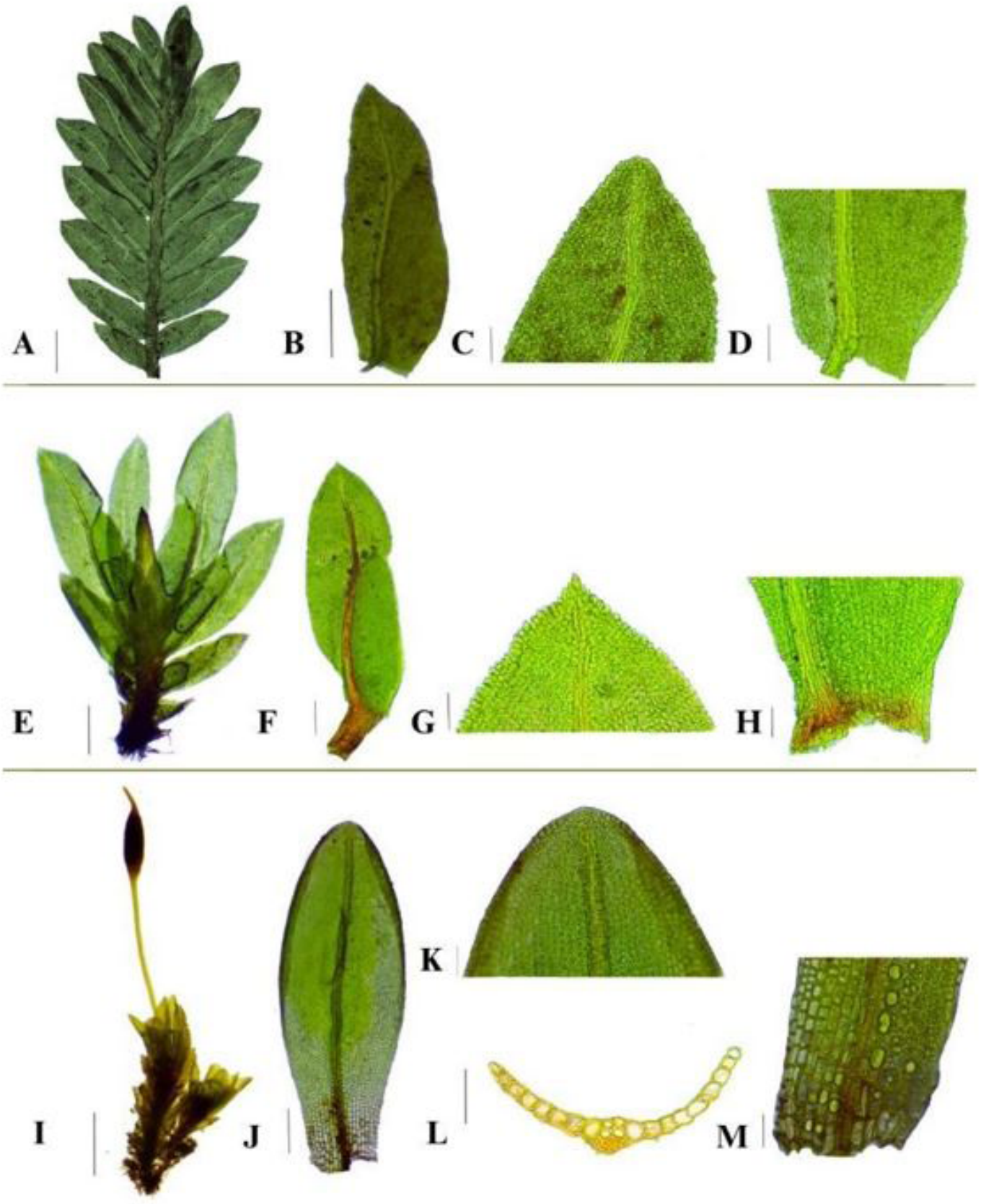
Taxon (Family/Genus/Species)	Substrate	Phytogeographic Domains (Biomes)	Distribution in Brazil (States)	HUESPI Voucher
Fissidens zollingeri Mont.	Terricolous	Amazon, Caatinga, Cerrado, Atlantic Forest, Pantanal	PI, AL, BA, CE, MA, PB, PE, SE, AC, AM, PA, RO, RR, TO, DF, GO, MT, MS, ES, MG, RJ, SP, PR, RS, SC	OJWP UN (HUESPI 3102)
Fissidens steerei Grout.	Rupicolous	Caatinga, Cerrado, Atlantic Forest	PI, GO, SP	SSM 7 (HUESPI 3055)
**Fissidens ramicola* Broth.	Rupicolous	Caatinga, Amazon, Cerrado, Atlantic Forest	PI, BA, AM, GO, SP	GMSG UN (HUESPI 3100)
Fissidens submarginatus Bruch.	Rupicolous/ Terricolous/ Corticolous	Amazon, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal	BA, CE, MA, PB, PE, PI, RN, AC, AM, PA, RO, DF, GO, MT, ES, MG, RJ, SP, RS, SC	SSM 41 (HUESPI 3070)
***Fissidens yanoae* Pursell	Epixylic	Caatinga, Atlantic Forest	PI, SP, RS	SSM 53 (HUESPI 3024)
Pilotrichaceae				
Callicostella pallida (Hornsch.) Ångström.	Rupicolous	Amazon, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal	PI, AL, BA, CE, PE, RN, SE, AC, AM, AP, PA, RO, RR, TO, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC	GMSG 267 (HUESPI 3103)
Pottiaceae				
**Weisiopsis bahiensis* (Müll.Hal.) Broth.	Rupicolous	Caatinga, Cerrado	BA, PI	SSM 19 (HUESPI 3067)
Hyophila involuta (Hook.) A.Jaeger	Rupicolous	Amazon, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal	AL, BA, CE, MA, PB, PE, PI, AM, PA, RO, RR, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS	SSM 16 (HUESPI 3064)
Sematophyllaceae				
Trichosteleum subdemissum (Besch.) A.Jaeger	Corticolous/ Rupicolous	Caatinga, Amazon, Cerrado, Atlantic Forest	BA, MA, PI, AM, PA, RO, RR, DF, GO, MT, MG, RJ, SP	SSM 18 (HUESPI 3066)
**Sematophyllum adnatum* (Michx.) Brid.	Epixylic/ Rupicolous	Caatinga	PI	SSM 8 (HUESPI 3056)
Microcalpe subsimplex (Hedw.) Spruce	Terricolous	Caatinga, Amazon, Cerrado, Atlantic Forest	AL, BA, CE, MA, PE, PI	SSM 61 (HUESPI 3084)
Hypnaceae				
Isopterygium tenerifolium Mitt.	Rupicolous	Caatinga, Amazon, Cerrado, Atlantic Forest	PI, BA, CE, AM, PA, RO, DF, GO, MT, MG, RJ, SP, PR, RS, SC	SSM 14 (HUESPI 3062)
Helicophyllaceae				
Helicophyllum torquatum (Hook.) Brid.	Corticolous	Amazon, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal	AL, BA, CE, PB, PE, PI, AM, PA, TO, GO, MS, MT, ES, MG, RJ, SP, PR, SC	SSM 79 (HUESPI 3090)
Splachnobryaceae				
Splachnobryum obtusum (Brid.) Müll. Hal.	Rupicolous	Caatinga, Amazon, Cerrado, Atlantic Forest, Pantanal	PI, AL, CE, AC, AM, AP, GO, MS, SP, RS	SSM 15 (HUESPI 3063)
Stereophyllaceae				
Entodontopsis leucostega (Brid.) W.R.Buck & Ireland	Corticolous/ Epixylic	Amazon, Caatinga, Cerrado, Atlantic Forest, Pantanal	BA, CE, MA, PB, PE, PI, AC, AM, PA, RO, RR, TO, DF, GO, MT, MS, MG, RJ, SP	OJWP UN (HUESPI 3095)
Eulacophyllum cultelliforme (Sull.) W.R.Buck & Ireland	Rupicolous	Caatinga, Amazon, Cerrado, Atlantic Forest, Pantanal	BA, PB, PE, PI, AM, TO, MT, MS, ES, MG, RJ, SP, PR	SSM 77 (HUESPI 3088)

Note. New records for the Caatinga biome: (*) new records for the state of Piauí; (**) new record for the Northeast region of Brazil; UN = unnumbered. All marked species represent new records for the Caatinga biome, except *Fissidens ramicola*. State abbreviations: Acre (AC); Alagoas (AL); Amapá (AP); Amazonas (AM); Bahia (BA); Ceará (CE); Distrito Federal (DF); Espírito Santo (ES); Goiás (GO); Maranhão (MA); Mato Grosso (MT); Mato Grosso do Sul (MS); Minas Gerais (MG); Pará (PA); Paraíba (PB); Paraná (PR); Pernambuco (PE); Piauí (PI); Rio de Janeiro (RJ); Rio Grande do Norte (RN); Rio Grande do Sul (RS); Rondônia (RO); Roraima (RR); Santa Catarina (SC); São Paulo (SP); Sergipe (SE); Tocantins (TO).

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Figure 2

Diagnostic Morphological Features of the Main Species Recorded in Ecotonal Areas in Piauí, Brazil



Note. Fissidens yanoae Pursell: gametophyte (A), leaf (B), leaf apex (C), leaf base (D). *Fissidens ramicola* Broth.: gametophyte (E), leaf (F), leaf apex (G), leaf base (H). *Weisiopsis bahiensis* (Müll. Hal.) Broth.: gametophyte with sporophyte (I), leaf (J), leaf apex (K), transverse section of the leaf (L), basal leaf cells (M).

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conducted in tropical environments, where these families frequently show high frequency due to their broad ecological plasticity and ability to colonize diverse substrates (Gradstein et al., 2001).

The predominance of the family Fissidentaceae, represented exclusively by the genus *Fissidens*, is noteworthy (Gradstein et al., 2001), as this genus is characterized by marked morphological diversity and the ability to colonize a wide range of microhabitats, from humid and shaded environments to open areas subject to seasonal variation in water availability (Glime, 2017). The first record of *Fissidens yanoae* Pursell for the Northeast region of Brazil substantially extends its known geographic distribution and indicates the relevance of ecotonal areas as zones of floristic enrichment and as locations where poorly documented taxa may occur. This species shows considerable ecological plasticity, occurring in primary forests, anthropogenic environments, dry areas, seasonally flooded sites, and on a wide range of substrates, including corticolous, epixylic, terricolous, rupicolous, epiphyllous, and artificial substrates (Glime, 2017). This ecological versatility explains its occurrence in the present survey and emphasizes the importance of ecotones as environments that support both broadly distributed species and taxa with restricted distributions (Gradstein et al., 2001).

The predominance of mosses among bryophyte species corroborates previous studies conducted in semiarid regions, where the greater structural and physiological complexity of mosses confers increased tolerance to water stress (Frahm, 2003). Adaptive traits such as desiccation tolerance, rapid resumption of metabolic activity after rehydration, and establishment in protected microhabitats contribute to the persistence of these species under low-humidity conditions typical of transitional ecosystems between the Caatinga and Cerrado (Pôrto et al., 1994). Widely distributed species such as *Octoblepharum albidum* Hedw. and *Hyophila involuta* (Hook.) A.Jaeger exemplify this pattern, as their opportunistic life-history strategies facilitate colonization of different substrates and persistence in environments subject to marked microclimatic variation (Glime, 2017).

Rupicolous substrates showed the highest species richness, indicating that rocky surfaces constitute favorable habitats for bryophytes in semiarid ecosystems. This pattern may be associated with the ability of rocks to retain water in fissures and irregular surfaces, as well as their function as microrefugia with greater microclimatic stability. Accordingly, the predominance of rupicolous species emphasizes the importance of microhabitats in maintaining bryophyte diversity in landscapes characterized by strong seasonality in water availability and high solar radiation (Frahm, 2003).

The new records for the Caatinga biome, the state of Piauí, and the Northeast region of Brazil indicate the need to intensify floristic inventories in the region. The bryoflora of the semiarid zone remains insufficiently documented, and the present results indicate that ecotonal areas, due to their transitional nature and the overlap of distinct floristic elements, are important for detecting additional taxa and understanding bryophyte distribution patterns in Brazil. Moreover, updating species occurrence records contributes to national and international databases and supports future studies in conservation, biogeography, and climate change research. This study expands current knowledge of bryophyte diversity and distribution in Piauí and underscores the relevance of ecotones for floristic and ecological research. The results demonstrate the need for conservation policies that recognize these environments as areas of significant biodiversity.

Conclusion

The new records reported here highlight the relevance of ecotonal areas for documenting bryophyte diversity in the state of Piauí and the Northeast region of Brazil. This study adds distributional data for species occurring in Caatinga–Cerrado transition zones, contributing to a more complete characterization of the regional bryoflora.

Acknowledgments

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Author Contributions

Conceptualization: SMS, HCO. Data curation: SMS, HCO. Formal analysis: SMS, HCO. Funding acquisition: SMS, HCO. Investigation: SMS, HCO. Methodology: SMS, HCO. Project administration: SMS, HCO. Resources: SMS, HCO. Software: SMS, HCO. Supervision: SMS, HCO. Validation: SMS, HCO. Visualization: SMS, HCO. Writing – original draft: SMS, HCO. Writing – review & editing: SMS, HCO.

Conflict of Interest

The authors declare no conflicts of interest to report.

Data Availability Statement

The complete datasets analyzed during the current study are available from the corresponding author on reasonable request.

Ethical Compliance

Not applicable.

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