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Original Papers

Lycophytes of the Parque Nacional das Nascentes do Rio Parnaíba, Brazilian Cerrado

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Abstract

The floristic-taxonomic treatment of lycophytes from the Parque Nacional das Nascentes do Rio Parnaiba (PNNRP), a protected area in the northern portion of the Brazilian *Cerrado*, within the boundaries of the states of Maranhão, Tocantins, Piauí and Bahia, is presented. The Park is considered the largest full protection area of the *Cerrado* and is located in a region that is rapidly losing its native coverage due to the expansion of agribusiness. Despite this, the area has no studies focusing on plant diversity. This treatment includes keys for the identification of genera and species, descriptions, comments on diagnostic and ecological characteristics, geographical distribution of the species and illustrations. Eight species were recorded in the study area, distributed in four genera: *Lycopodiella*, *Palhinhaea*, *Pseudolycopodiella* and *Selaginella*. *Lycopodiella longipes*, *Pseudolycopodiella carnosa* and *Pseudolycopodiella paradoxa* are new records for the state of Piauí.
Key words: floristics, Lycopodiaceae, *Selaginella*, taxonomy.

Resumo

É apresentado o tratamento florístico-taxonômico das licófitas do Parque Nacional Nascentes do Rio Parnaíba (PNNRP), uma Unidade de Conservação (UC) situada na porção norte do Cerrado brasileiro, nos limites dos estados do Maranhão, Tocantins, Piauí e Bahia. O Parque é considerado a maior área de proteção integral do Cerrado e está localizado em uma região que está perdendo rapidamente sua cobertura nativa devido à expansão do agronegócio na área. Apesar disso, a área não possui estudos focando na diversidade vegetal. Este tratamento inclui chaves para a identificação de gêneros e espécies, ilustrações, descrições, comentários sobre características diagnósticas e ecológicas, bem como a distribuição geográfica das espécies. Na área de estudo, foram registradas oito espécies distribuídas em quatro gêneros, *Lycopodiella*, *Palhinhaea*, *Pseudolycopodiella* e *Selaginella*. *Lycopodiella longipes*, *Pseudolycopodiella carnosa* e *Pseudolycopodiella paradoxa* representam novos registros para o estado do Piauí.
Palavras-chave: florística, Lycopodiaceae, *Selaginella*, taxonomia.

Introduction

Class Lycopodiopsida refers to the group informally known as lycophytes, that were in the past classified together with ferns, forming an artificial group known as *pteridophytes*, due to their similar lifecycle and spore reproduction (Haufler *et al.* 2016; Schuettpelz & Pryer 2008). Following molecular studies that determined that lycophytes are a monophyletic group characterized by lycophylls and adaxial sporangia with transverse dehiscence, it was established that these were among the most basal groups among extant vascular plants (Cantino *et al.* 2007; Pryer *et al.* 2004). Counting approximately 1.338 species worldwide, this group comprises three families: Lycopodiaceae, Isoetaceae and Selaginellaceae (PPG I 2016).

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Spanning over an area of approximately 2,036,448 km^2, the *Cerrado* biome covers around 24% of the area of Brazil, occurring mostly in the central plateau, reaching the sea coast at its Northern limit in Maranhão, and the state of Paraná at its southern limit, presenting a vast array of vegetation types (IBGE 2004; Sano *et al.* 2007). Approximately 3% of this biome falls within fully protected areas (Françoso *et al*. 2015; MMA 2023), and the Parque Nacional das Nascentes do Rio Parnaíba (PNNRP) is the largest among these areas. The PNNRP is part of the Mosaico do Jalapão, a conservation region that concentrates several conservation units that, so far have been little impacted by human activities (ICMBIO 2021). This region is known as the Ecological Corridor / Chapada das Mangabeiras, constituting an important migratory route for species, aiming to preserve gene flow between populations (IBAMA 2007; ICMBIO 2013).

Examples of floristic and taxonomic studies of lycophytes in the *Cerrado* biome are the works by Hirai (2007), Arantes *et al.* (2010) and Almeida *et al.* (2020), however the majority of research on this group is concentrated in the Amazon and Atlantic Rainforest biomes (Freitas & Windisch 2005; Prado & Freitas 2005; Prado & Hirai 2008; Assis & Labiak 2009; Pietrobom *et al.* 2009; Ramos & Sylvestre 2010; Góes-Neto *et al.* 2015, 2016; Salino & Arruda 2016; Pereira *et al.* 2017). In the last few years new Lycophyte species have been described for Brazil, some of them with restricted distribution or recorded solely in the Cerrado (Valdespino *et al.* 2015, 2018; Øllgaard & Windisch 2016; Pereira & Prado 2022).

The present work aims to provide a taxonomic treatment of the lycophytes found at the PNNRP a yet little-explored area of Cerrado, providing identification keys for genera and species, descriptions, taxonomic, ecological and distribution comments.

Material and Methods

Found in the Chapada das Mangabeiras, the watershed of three large river basins, comprising Rio Parnaíba, Rio Tocantins and Rio São Francisco, the Parque Nacional das Nascentes do Rio Parnaíba (PNNRP) covers an area of 749,813.55 hectares in the Cerrado biome, distributed in the states of Maranhão - MA (48,06%), Piauí - PI (34,4%), Tocantins - TO (17,4%) and Bahia - BA (0,14%) (Fig. 1). Nine municipalities share areas within the PNNRP: Alto Parnaíba (MA), Gilbués (PI), São Gonçalo do Gurguéia (PI), Barreiras do Piauí (PI), Corrente (PI), Mateiros (TO), São Félix do Tocantins (TO), Lizarda (TO) and Formosa do Rio Preto (BA) (IBMA 2007; ICMBIO 2021). A diversity of vegetation types are found in the area, from savannas to grasslands (*campo limpo*, *campo sujo*, *cerrado ralo*, *cerrado rupestre*, and *veredas*) to forest areas (*cerradão*, *mata seca*, *mata de galeria*, and *mata ciliar*) (IBAMA 2007; Ribeiro & Walter 2008). The climate is tropical semi-humid with two marked seasons, a dry period between May and October and a wet period between December and April. The mean yearly temperature is 26 °C, while the annual average rainfall is 1,200 mm (IBAMA 2007; MMA 2019).

Four expeditions were carried out in April and December 2022 and March and July 2023, aiming at sampling all vegetation types, and resulting specimens were prepared according to the specific methodology used for ferns and lycophytes (Pietrobom *et al.* 2023). The specimens were deposited in the herbaria of the Universidade de Brasília (UB) and of the Universidade Federal do Maranhão (CCAA) (acronyms according to Thiers, continuously updated). Plant identifications were carried out using specialized bibliography (Alston 1981; Ollgaard 1992; Mickel *et al.* 2004; Assis & Labiak 2009; Arana & Øllgaard 2012; Góes-Neto *et al.* 2015; Góes-Neto 2016; Øllgaard & Windisch 2016; Smith & Kessler 2018; Smith *et al.* 2018; Øllgaard *et al.* 2018; Arana *et al.* 2019; Almeida *et al.* 2020; Windisch *et al.* 2023).

The identification keys and descriptions were based on the material collected at PNNRP, bibliography and authoritatively named additional material when necessary, following the morphologic concepts of Lellinger (2002). The taxonomic treatment is arranged in alphabetical order, family circumscription is based on PPG I (2016). We are aware of the alternative classification for Selaginellaceae by Zhou & Zhang (2023), however in the study area only *Selaginella* was found. The overall geographic distribution of the taxa is based on the existing literature, including generic revisions and relevant floristic treatments. State and biome distribution is based on the Flora and Funga of Brazil 2023 (continuously updated), with additional information for some species, when necessary, from Fernandes *et al.* (2022).

Results and Discussion

During the fieldwork, 12 collecting points were sampled, six in the state of Maranhão, five in

Piauí and one in Tocantins. Access to the portion of the PNNRP in Bahia was not possible as there are no roads reaching this part of the park. From the 35 specimens collected, we recorded six species of Lycopodiaceae and two species of Selaginellaceae for the PNNRP. Among the Lycopodiaceae found in the area, three are new records for the state of Piauí (*Lycopodiella longipes* (Grev. & Hook.) Holub, *Pseudolycopodiella carnosa* (Silveira) Holub and *Pseudolycopodiella paradoxa* (Mart.) Holub). A complete taxonomic treatment for these two families is provided below.

Key for Lycophyte families in the PNNRP

1. Homosporous plants; sporangia forming cylindric strobili; lycophylls eligulate, spirally arranged..... ..... 1. Lycopodiaceae
1'. Heterosporous plants; sporangia forming flattened or 4-sided strobili; lycophylls ligulate, arranged in rows..... 2. Selaginellaceae

1. Lycopodiaceae.

Cosmopolitan family comprising 16 genera with approximately 388 species (PPG I 2016). Six species of Lycopodiaceae were recorded in the study area.

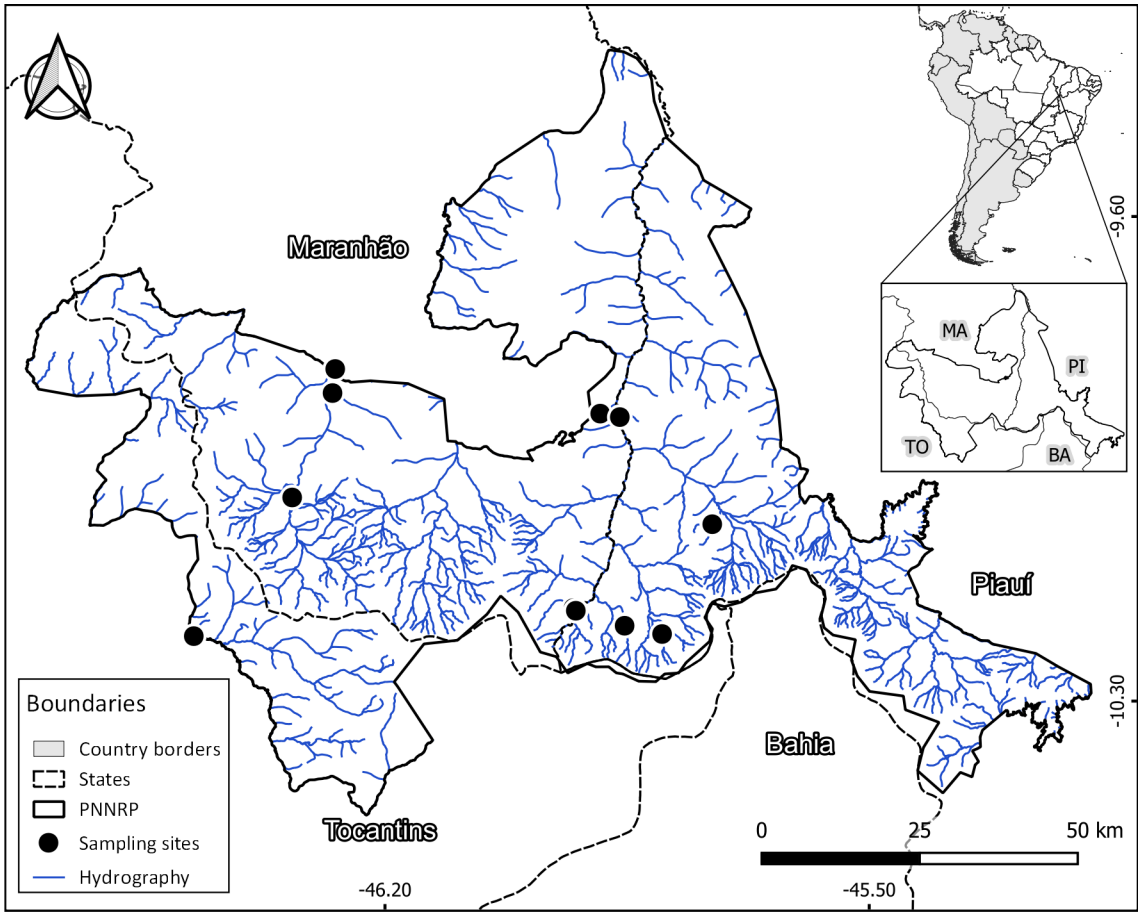

Figure 1 – Location of the study area, Nascentes do Rio Parnaíba National Park (PNNRP) in the Brazilian *Cerrado*.

Key for the genera of Lycopodiaceae in the PNNRP

1. Strobili pendant, apically disposed in lateral branches that arise from the main arborescent shoot..... .....1.2. *Palhinhaea*
1'. Strobili erect, apically disposed on erect simple branches that arise from creeping shoots 2
   2. Creeping shoots with anisophyllous lycophylls; erect branch lycophylls needle-like, margin entire; sporophylls with denticulate-fimbriate margins.....1.3. *Pseudolycopodiella*
   2'. Creeping shoots with isophyllous lycophylls; erect branch lycophylls lanceolate, margin basally denticulated; sporophylls with denticulate margins..... 1.1. *Lycopodiella*

1.1. *Lycopodiella* Holub.

Lycopodiella comprises approximately 15 species (PPG I 2016), four of these occurring in Brazil. The genus has been recorded in the Amazon, *Cerrado*, Atlantic Rainforest and *Pampa*, with a single species restricted to the Atlantic Rainforest and Brazilian *Pampa*, *Lycopodiella duseniana* (B.Øllg. & P.G.Windisch) B.Øllg. (Øllgaard & Windisch 2016; Windisch *et al.* 2023).

1.1.1. *Lycopodiella longipes* (Hook. & Grev.) Holub, Folia Geobot. Phytotax. 26(1): 93 (1991). Fig. 2a-b

Creeping shoot rooting in short intervals 7–10.3 mm wide, with simple or bifurcate lateral branches; lycophylls isophylous 6–7 × 1–1.4 mm, linear-lanceolate, apex acuminate, base denticulate, entire towards the apex. Erect shoot (14.7–)22–49.5(–62) cm, simple, with linear-lanceolate, ascending, irregularly verticillate lycophylls, apex long-acuminate, base denticulate, entire towards the apex, 5–7 × 0.6–1 mm. Strobili 20.2–60 × 7–10.3 mm, sessile, erect, apical; sporophylls 5.9–6.5 × 0.9–1.4 mm, linear-lanceolate, base subpeltate, margin with proeminente, recurved teeth at base, entire towards the apex, apex long-acuminate; sporangia axillary, globose, yellow.

Examined material: MARANHÃO: Alto Parnaíba, PNNRP, Povoado Curupá, 09°53'05''S, 45°53'20''W, 380 m, 19.IV.2022, *P.H.C. Aguiar et al. 1* (CCAA, UB); *P.H.C. Aguiar et al. 7* (CCAA, UB); *P.H.C. Aguiar et al. 11* (CCAA, UB). PIAUÍ: Barreiras do Piauí, PNNRP, 09°59'09''S, 45°36'02''W, 445 m, 20.IV.2022, *P.H.C. Aguiar et al. 14* (CCAA, UB); Cachoeira do Pintado, 10°11'28''S, 45°51'13''W, 430 m, 21.IV.2022, *P.H.C. Aguiar et al. 44* (CCAA); Brejo do Madeiro, 10°02'40''S, 45°43'37''W, 423 m, 16.XII.2022, *P.H. Castro-Aguiar et al. 241* (CCAA, UB). TOCANTINS: São Félix do Tocantins, PNNRP, Cachoeira do Prata, 10°12'22''S, 46°28'35''W, 485 m, 17.III.2023, *P.H. Castro-Aguiar et al. 275* (CCAA, UB).

Lycopodiella longipes occurs in South America, in Colombia, Venezuela, Guyana, Suriname, Brazil, Paraguay, Uruguay and Argentina (Øllgaard & Windisch 2016; Arana *et al*. 2019). In Brazil, it has been recorded in the Amazon, *Cerrado*, Atlantic Forest and *Pampa* biomes (Fernandes *et al*. 2022; Windisch *et al*. 2023). It was found growing in open, wet environments, such as campos alagados associated with *buriti* grooves (*veredas*) and cerrado ripário, especially in wet ground, exposed to the sunlight.

This species differs from other species found in the area because of its creeping, not arching stem with isophyllous lycophylls, rooting in short intervals, and its erect simple shoots that are rarely branched, covered with densely aggregated lycophylls and strobiles with sporophylls with basally denticulated margins It may be confused with *Lycopodiella geometra* B.Øllg. & P.G.Windisch, found in Central Brazil and reaching Paraguay and Argentina. *Lycopodiella longipes* is more widely distributed in Brazil, in the Northern part of the *Cerrado* and reaching the Amazonian states of Acre, Amazonas and Roraima (Øllgaard & Windisch 2016; Windisch *et al.* 2023). The main difference between them is that *L. longipes* stem is always creeping while *Lycopodiella geometra* shoots are sarmentose and strongly arched at the intervals between rooting (Arana & Øllgaard 2012).

1.2. *Palhinhaea* Franco & Vasc.

Palhinhaea is a Pantropical genus comprising around 25 species (PPG I 2016), with 16–20 species restricted to the Neotropical region (Øllgaard & Windisch 2016; Øllgaard *et al.* 2018). Six species are recorded in Brazil, occurring in all biomes (Salino & Almeida 2008; Windisch *et al.* 2023).

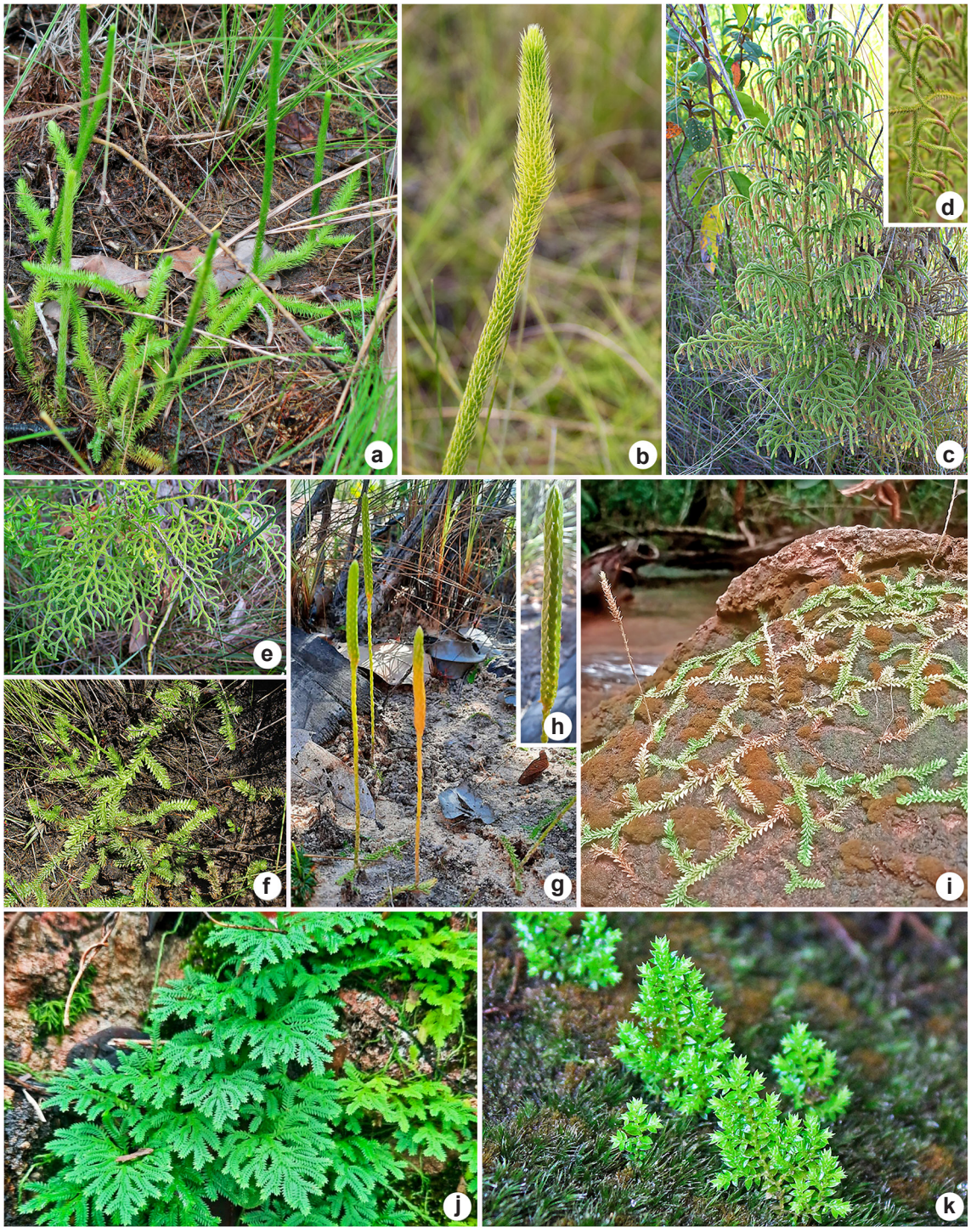

Figure 2 – a-b. *Lycopodiella longipes* – a. habit; b. Strobilus. c-d. *Palhinhaea camporum* – c. habit; d. strobiles. e. *P. cernua* – habit. f. *Pseudolycopodiella carnosa* – habit. g-h. *P. meridionalis* – g. habit; h. Strobilus. i. *P. paradoxa* – habit. j. *Selaginella radiata* – habit. k. *Selaginella simplex* – habit. (a. *P.H.C. Aguiar et al. 11*; b. *P.H. Castro-Aguiar et al. 275*; c-d. *P.H.C. Aguiar et al. 15*; e. *P.H.C. Aguiar et al. 4*; f. *P.H.C. Aguiar et al. 01a*; g-h. *P.H. Castro-Aguiar et al. 331*; i. *P.H. Castro-Aguiar et al. 158*; j. *P.H. Castro-Aguiar et al. 281*; k. *P.H. Castro-Aguiar et al. 255*).

Key for the species of *Palhinhaea* in the PNNRP

1. Lateral branches stiff and ascending, with densely aggregated lycophylls; strobiles strongly recurved at the apex of the branches .....1.2.1. *Palhinhaea camporum*
1'. Lateral branches patent to slightly ascending, lycophylls sparse; strobiles slightly recurved at the apex of the branches .....1.2.2. *Palhinhaea cernua*

1.2.1. *Palhinhaea camporum* (B.Øllg. & P.G.Windisch) Holub, Folia Geobot. Phytotax. 26(1): 93 (1991). Fig. 2c-d

Creeping shoot arched, rooting when in contact with the soil. Erect shoots 23.5–122.5 cm long, rigid, much branched and dendroid, formed dorsally, with several systems of lateral, rigid, densely aggregated, ascending branches; lateral branches lycophylls 4.4–5 mm long, acicular, subulate, densely aggregated and ascending, base adnate and decurrent, apex long-acuminate, distally arched, with hyaline trichomes. Strobili 4–18 × 2.5–3.5 mm, numerous, strongly recurved at the apex of lateral branches, pendulous, sessile; sporophylls 1.9–2.3 × 0.7–1.1 mm, deltoid, yellow, base subpeltate, margin erose and laciniate, apex cuspidate to caudate; sporangia globose, anisovalvate, yellow.

Examined material: MARANHÃO: Alto Parnaíba, PNNRP, Povoado Curupá, 09°53'05''S, 45°53'20''W, 380 m, 19.IV.2022, *P.H.C. Aguiar et al. 2* (CCAA, UB); *P.H.C. Aguiar et al. 3* (CCAA, UB). PIAUÍ: Barreiras do Piauí, PNNRP, 09°59'09''S, 45°36'02''W, 445 m, 20.IV.2022, *P.H.C. Aguiar 15* (CCAA); *P.H.C. Aguiar 16* (CCAA); Cachoeira do Pintado, 10°11'26''S, 45°51'08''W, 436 m, 13.XII.2022, *P.H. Castro-Aguiar et al. 75* (CCAA); *P.H. Castro-Aguiar et al. 76* (CCAA); Cachoeira Várzea Grande, 10°12'11''S, 45°47'58''W, 474 m, 14.XII.2022, *P.H. Castro-Aguiar et al. 113* (CCAA, UB); Brejo do Madeiro, 10°02'40''S, 45°43'37''W, 423 m, 16.XII.2022, *P.H. Castro-Aguiar et al. 242* (CCAA, UB); Acampamento Várzea Grande, 10°00'21''S, 46°20'3''W, 437 m, 17.III.2023, *P.H. Castro-Aguiar et al. 276* (CCAA). TOCANTINS: São Félix do Tocantins, PNNRP, Cachoeira do Prata, 10°12'22''S, 46°28'35''W, 485 m, 16.III.2023, *P.H. Castro-Aguiar et al. 253* (CCAA, UB); *P.H. Castro-Aguiar et al. 254* (CCAA, UB).

Palhinhaea camporum is a South American species that spread from Colombia in the north to Argentina and Bolivia in the south (Boudrie *et al.* 2023). In Brazil, it occurs in the Amazon, *Cerrado* and Atlantic Rainforest biomes (Windisch *et al*. 2023) and is very common throughout the study area, growing in damp or flooded ground, in open places near *buriti* grooves (*veredas*), and also in river and stream margins near waterfalls.

Palhinhaea camporum resembles *P. cernua* in most characters, however, the first one has a dendroid habit, with lateral branches stiff and ascendent, densely covered by lycophylls, while the latter is mostly subscandent, with lateral branches patent and sparsely clad by lycophylls.

1.2.2. *Palhinhaea cernua* (L.) Franco & Vasc., Bol. Soc. Brot. sér. 2, 41: 25 (1967). Fig. 2e

Creeping shoot arched, rooting when reaching the soil. Erect shoot 125–156 cm long, generally subscandent, branched, formed dorsally, sustaining several lateral, patent to slightly ascending branching systems; lateral branch lycophylls 2.4–4 mm long, acicular, subulate, patent and sparse, base adnate and decurrent, apex long-acuminate, with short, hyaline trichomes at the base. Strobili 3–14.5 × 1.7–2 mm, sessile, pendulous and numerous, slightly recurved at the apex of lateral branches; sporophylls 1.6–2 × 0.6–1 mm, lanceolate, yellow, base subpeltate, margin erose and laciniate, apex cuspidate to caudate; sporangia globose, anisovalvate, yellow.

Examined material: MARANHÃO: Alto Parnaíba, PNNRP, Povoado Curupá, 09°53'05''S, 45°53'20''W, 380 m, 19.IV.2022, *P.H.C. Aguiar et al. 4* (CCAA, UB); Cachoeira do Riozinho, 09°49'13''S, 46°16'19''W, 380 m, 18.VII.2023, *P.H. Castro-Aguiar et al. 301* (CCAA, UB).

Palhinhaea cernua is a Pantropical species, representing the widest distribution of the genus (Øllgaard & Windisch 2016; Arana *et al*. 2017). In Brazil, it occurs in all biomes, (Salino & Almeida 2008; Windisch *et al*. 2023). In the study area it was found in wet and humid soil along the *buriti* grooves (*veredas*), both in sunny and shady places.

Palhinhaea cernua is morphologically similar to *Palhinhaea camporum* and their differences are stated above. These species were recorded growing sympatrically.

1.3. *Pseudolycopodiella* Holub.

Pseudolycopodiella comprises around 10 species in tropical and temperate America, Africa, Asia, Australia, and New Caledonia (PPG I 2016; Øllgaard *et al*. 2018), with seven species found

in Brazil and occurring in all major biomes. *Pseudolycopodiella squamata* B.Øllg. & P.G.Wind. is the only species of the genus endemic to Brazil (Øllgaard & Windisch 2016; Windisch *et al.* 2023).

Key for the species of *Pseudolycopodiella* in the PNNRP

1. Strobili 4.7–5.3 cm long; creeping shoot (7–)8–11.5 mm wide including lycophylls, with upper side wide and flattened .....1.3.1. *Pseudolycopodiella carnosa*
1'. Strobili 1.8–4 cm long; creeping shoot 4.5–8(–9) mm wide including lycophylls, upper side not wide or flattened 2
    2. Creeping shoot 6–8(–9) mm wide with lycophylls, lateral lycophylls lanceolate to rarely triangular-ovates; erect shoots (8.7–)9.6–15.3 cm long..... 1.3.2. *Pseudolycopodiella meridionalis*
    2'. Creeping shoot 4.5–6(–6.5) mm wide with lycophylls, lateral lycophylls triangular-ovates; erect shoots 7.3–8.3 cm long ..... 1.3.3. *Pseudolycopodiella paradoxa*

1.3.1. *Pseudolycopodiella carnosa* (Silveira) Holub, Folia Geobot. Phytotax. 20: 79 (1985). Fig. 2f

Creeping shoots (7–)8–11.5 mm wide with lycophylls, indeterminate, dorsiventrally flattened, with anisophylous lycophylls: the lateral ones 4.5–5 × 2.5–3.5 mm, triangular-ovate, decurrent, margin entire; dorsal lycophylls 2.5–2.7 × 1.2–1.5 mm, in e longitudinal rows, sparse, not covering the shoot, ovate-deltoid, apex acuminate. Erect shoots 25.7–31 cm long, terete; lycophylls spirally arranged, 3.5–5.3 × 0.4–0.6 mm, acicular-lanceolate, margin entire, apex long-acuminate. Strobili 4.7–5.3 × 0.4–0.5 cm, sessile, in the apex of erect shoots, rarely bifurcate; sporophylls 6–7 × 2–2.2 mm, base ovate, margin fimbriate, apex long-acuminate; sporangia reniform, isovalvate.

Examined material: MARANHÃO: Alto Parnaíba, PNNRP, Povoado Curupá, 09°53'05''S, 45°53'20''W, 380 m, 19.IV.2022, *P.H.C. Aguiar et al. 01a* (CCAA). PIAUÍ: Barreiras do Piauí, PNNRP, 09°59'09''S, 45°36'02''W, 445 m, 20.IV.2022, *P.H.C. Aguiar et al. 15a* (CCAA); Brejo do Madeiro, 10°02'40''S, 45°43'37''W, 423 m, 16.XII.2022, *P.H. Castro-Aguiar et al. 240* (CCAA, UB).

Pseudolycopodiella carnosa occurs in South America and has been recorded in Bolivia, Paraguay and Brazil, where it occurs in the *Cerrado* and Atlantic Rainforest biomes (Øllgaard & Windisch 2016). In the study area, this species was collected at the edge of the *buriti* grooves (*veredas*), growing amidst the herbs and shrubs, and exposed to the sunlight.

Characterized by its wide, flattened creeping shoots with spaced dorsal lycophylls. The creeping shoots in the study area were firmly adhered to the soil, and often broke when we tried to collect them.

The species that most resemble *Pseudolycopodiella carnosa* are *P. squamata* B. Øllgaard & P.G.Windisch and *P. tatei* (A.C.Smith) Holub; both present fleshy, dorsiventrally flattened creeping shoots that are strongly rooted to the substrate. It is possible to recognize them because *P. squamata* has contiguous dorsal lycophylls that completely cover the stem, while in *P. carnosa* the dorsal lycophylls are sparse, therefore the pale-green colour of the stem is clearly visible (Øllgaard & Windisch 2016). *Pseudolycopodiella tatei* has a creeping shoot with isophyllous, uniform lycophylls and the shoot surface clearly visible between the bases of the lycophylls.

Pseudolycopodiella carnosa can be distinguished from *P. paradoxa*, also found in the study area, by the width (8–11.5 mm wide) of its creeping shoots and the size of the strobiliferous, erect branches (25.7–31 cm long), meanwhile, the creeping shoots of *P. paradoxa* are 4.5–6 mm wide and the erect branches vary between 7.3–8.3 cm long.

1.3.2. *Pseudolycopodiella meridionalis* (Underw. & F.E.Lloyd) Holub, Folia Geobot. Phytotax. 18: 442 (1983). Fig. 2g-h

Creeping shoots 6–8(–9) mm wide with lycophylls, indeterminate, with anisophyllous lycophylls: lateral ones 2.5–4.5(–5) × 2–2.6 mm, lanceolate to rarely triangular ovate, decurrent, margin entire; dorsal lycophylls 1.9–2.5 × 0.9–1.2 mm in up to three longitudinal rows, lanceolate, sparse or imbricate, apex acuminate. Erect shoots (8.7–)9.6–15.3 cm long, terete; lycophylls spirally arranged, 2.8–3.8 × 0.7–1 mm, acicular-lanceolate, margin entire, apex acuminate. Strobili 2.3–4 × 0.6–0.9 cm, sessile, in the apex of erect shoots,

not bifurcate; sporophylls 4–4.8 × 2–2.5 mm, ovate at base, margin fimbriate-denticulate, apex acuminate; sporangia reniform, isovalvate.
Examined material: PIAUÍ: Barreiras do Piauí, PNNRP, Cachoeira do Pintado, 10°11'28''S, 45°51'13''W, 21.IV.2022, *P.H.C. Aguiar et al. 44a* (CCAA); 10°11'26''S, 45°51'08''W, 13.XII.2022, *P.H. Castro-Aguiar et al. 69* (CCAA); margem do Rio Parnaíba, próximo ao limite com o Maranhão, 09°53'23''S, 45°51'38''W, 20.VII.2023, *P.H. Castro-Aguiar et al. 331* (CCAA, UB).

Pseudolycopodiella meridionalis is widely distributed throughout Central America, the Caribbean and South America, reaching Uruguay and Argentina in the south (Øllgaard & Testo 2021). In Brazil, it was reported for the Amazon, Atlantic Rainforest, *Pantanal*, *Pampa* and *Cerrado* biomes (Assis & Labiak 2009; Fernandes *et al*. 2022; Windisch *et al*. 2023). In the study area, this species was found in cliffs near waterfalls and river margins, in sandy soil.

Pseudolycopodiella meridionalis differs from other species in the genus by its narrow creeping shoots [6–8(–9) mm wide], lateral lycophylls lanceolate to rarely triangular-ovate, and erect shoots (8.7–)9.6–15.3 cm long.

Specimens *P.H.C. Aguiar et al. 44a* and *69* resemble morphologically *P. paradoxa* due to the size of the erect shoot (8.7–11.4 cm long) and strobiles (2–2.3 cm long). However, they were included under *P. meridionalis* due to the width of the creeping shoots (between 6 and 9 mm wide) and the shape of the lateral lycophylls that are lanceolate or rarely triangular-ovate.

1.3.3. *Pseudolycopodiella paradoxa* (Mart.) Holub, Folia Geobot. Phytotax. 18: 442. 1983. Fig. 2i

Creeping shoots indeterminate with lycophylls, terete, 4.5–6(–6.5) mm wide, with lycophylls anisophyllous: the lateral ones 2.5–3.2 × 1.4–2.1 mm, triangular-ovate, decurrent, margin entire; dorsal lycophylls 1.5–1.8 × 0.9–1.1 mm in (1–)2 longitudinal rows, ovate-acuminate, imbricate and covering the stem, apex acuminate. Erect shoots 7.3–8.3 cm long, terete; lycophylls spirally arranged, 2.9–3.6 × 0.8–1 mm, acicular-lanceolate, margin entire, apex acuminate. Strobili 1.8–2.4 × 0.3–0.5 cm, sessile, in the apex of erect shoots, not bifurcate; sporophylls 4.2–5.1 × 2–2.6 mm, base ovate, margin fimbriate-denticulate, apex acuminate; sporangia reniform, isovalvate.
Examined material: PIAUÍ: Barreiras do Piauí, PNNRP, Cachoeira Várzea Grande, 10°12'11''S, 45°47'58''W, 474 m, 14.XII.2022, *P.H. Castro-Aguiar et al. 158* (CCAA, UB).

Pseudolycopodiella paradoxa occurs in Venezuela, Colombia and Paraguay, occurring mainly in the *Cerrado* biome in Brazil (Øllgaard & Windisch 2016). In the study area, this species was collected near waterfalls, on wet or humid rocks exposed to the sunlight.

The differences between this species and *P. carnosa* are explained above. According to Øllgaard & Windisch 2016, *P. paradoxa* resembles *P. meridionalis*, however, the first one differs in the much smaller overall size and the proportion of the lateral and dorsal lycophylls. In our study area, *P. paradoxa* can be distinguished from *P. meridionalis* by the width of the creeping shoots (4.5–6 mm wide) and the erect shoots, 7.3–8.3 cm long, while *P. meridionalis* has wider creeping shoots, exceeding 6 mm wide, and erect shoots varying between 9.6 and 15.3 cm long.

2. Selaginellaceae.

Selaginellaceae is a cosmopolitan family comprising a single genus, *Selaginella*, with approximately 700 to 800 species (Zhou & Zhang 2015; PPG I 2016). Two species of *Selaginella* P.Beauv. were recorded in the study area.

2.1. *Selaginella* P.Beauv.

Selaginella reaches higher diversity in tropical and subtropical regions (Jermy 1990; Zhou & Zhang 2015). Ninety-one species are recorded in Brazil, with the Amazon biome as its center of diversity, with 51 species (Góes-Neto *et al*. 2023).

Key for the species of *Selaginella* in the PNNRP

1. Shoots stoloniferous; lateral lycophylls with acroscopic margin long-ciliate the base; dorsal lycophylls ovate to ovate-elliptic, apex long-aristate; axillary lycophylls lanceolate with margin basally long-ciliate ..... 2.1.1. *Selaginella radiata*
1'. Shoots not stoloniferous; lateral lycophylls with margin denticulate; dorsal lycophylls ovate-elliptic, apex long-acuminate; axillary lycophylls ovate-elliptic with denticulate margin ..... 2.1.2. *Selaginella simplex*

2.1.1. *Selaginella radiata* (Aubl.) Baker, J. Bot. 22(Za): 374 (1884). Fig. 2j

Plants terrestrial or rupicolous, 2.4–5.3 cm long. Shoots decumbent, light green, glabrous, stoloniferous, non-articulate. Rhizophores restricted to shoot base. Lateral lycophylls 2–2.5 mm long, ovate-lanceolate, base rounded, usually asymmetrical, acroscopic margin long-ciliate the base, denticulate towards the apex, hyaline, basioscopic margin entire or 1–2-ciliate, denticulate towards the apex, apex acute, upper surface usually rugged. Dorsal lycophylls 1.4–1.6 mm long, ovate to ovate-elliptic, base rounded, long-ciliate at base, short-ciliate to denticulate towards the apex, hyaline, apex long-aristate. Axillary lycophylls 1.8–2 mm long, lanceolate, base rounded, without auricles, margin long-ciliate at the base, denticulate towards the apex, hyaline, apex acute. Strobili 2–6 mm long, erect at the apex of branches; megaspores whitish; microspores orange.

Examined material: MARANHÃO: Alto Parnaíba, PNNRP, Ladeira da Galiléia, 10°3'21''S, 46°22'51''W, 578 m, 17.III.2023, *P.H. Castro-Aguiar et al. 281* (CCAA, UB); 18.III.2023, *P.H. Castro-Aguiar et al. 291* (CCAA, UB).

Additional material examined: BRAZIL. MARANHÃO: Estreito, Parque Nacional da Chapada das Mesas, Cachoeira do Prata, Rio Farinha, 06°59'36,7''S, 47°09'53,1"W, 210 m, 12.III.2017, *L.R. Silva & M.R. Pietrobom 47* (CCAA). Carolina, Parque Nacional da Chapada das Mesas, Cachoeira São Romão, 07°01'17,2"S, 47°02'27,8"W, 258 m, 13.III.2017, *L.R. Silva & M.R. Pietrobom 55* (CCAA); *L.R. Silva & M.R. Pietrobom 59* (CCAA).

Selaginella radiata occurs in Northern South America, being recorded for Colombia, Ecuador, Guianas, Venezuela and Brazil (Góes-Neto *et al.* 2016), where it occurs in the Amazon and *Cerrado* biomes (Fernandes *et al*. 2022; Góes-Neto *et al*. 2023). In the study area, this species was found in hills in the savanna (cerrado rupestre), growing on rocks in shady or sunny sites.

All specimens of *S. radiata* we were able to collect were young and sterile, varying between 2.4 and 5.3 cm long, while fertile specimens are larger, reaching 20 to 35 cm (Góes-Neto *et al.* 2016; Almeida *et al.* 2020). The stoloniferous, non-articulate shoot with basal rhizophores distinguishes *S. radiata* from other species. In living specimens, the intense green colour of the upper side of the branches contrasts with the paler, silvery colour of the lower side (Góes-Neto *et al.* 2016).

2.1.2. *Selaginella simplex* Baker, J. Bot. 23: 293 (1885). Fig. 2k

Plants terrestrial or rupicolous, 0.8–3.5 cm long. Shoots suberect, light green to stramineous, glabrous, not stoloniferous, non-articulate. Rhizophores restricted to the lower half of the shoot. Lateral lycophylls 1.6–2 mm long, ovate, base rounded, denticulate acroscopic margin, slightly overlapping the stem, denticulate basioscopic margin, slightly greenish, apex acute. Dorsal lycophylls 1.1–1.4 mm long, ovate-elliptic, base rounded, margin denticulate, slightly greenish, apex long-acuminate. Axillary lycophylls 1.7–2 mm long, ovate-elliptic, base rounded to slightly subcordate, without auricules, margin denticulate, slightly prominent, slightly greenish, apex acute. Strobili 2.5–8 mm long, at the apex of the branches, dorsoventrally flattened; megaspores yellow; microspores orange.

Examined material: MARANHÃO: Alto Parnaíba, PNNRP, 10°10'10''S, 45°55'27''W, 21.IV.2022, *P.H.C. Aguiar et al. 23* (CCAA); Cachoeira do Sussuapara, 10°09'57''S, 45°55'39''W, 21.IV.2022, *P.H.C. Aguiar et al. 50* (CCAA, UB); 15.XII.2020, *P.H. Castro-Aguiar et al. 236* (CCAA). TOCANTINS: São Félix do Tocantins, PNNRP, Cachoeira do Prata, 10°12'22''S, 46°28'35''W, 485 m, 16.III.2023, *P.H. Castro-Aguiar et al. 255* (CCAA, UB).

Selaginella simplex is a Neotropical species found from Costa Rica south to Bolivia (Valdespino *et al*. 2022) occurring in the *Caatinga* and *Cerrado* biomes in Brazil (Góes-Neto *et al*. 2023) and, in the Amazon, growing in savannas (Della *et al*. 2019). In the study area, it was collected growing on rocks inside the gallery forest and waterfall margins, in deep of partial shade.

Easily recognized by its small stature, *S. simplex* reached a maximum of 3.5 cm long in the study area. Its suberect, non-articulate shoots, ovate-elliptic dorsal lycophylls with rounded base and denticulate margins, lateral lycophylls slightly overlapping beneath the shoot and yellow megaspores are also characteristic of this species. The closest Brazilian species is *S. minima* Spring, also found in the states of Maranhão and Piauí (Fernandes *et al.* 2022; Góes-Neto *et al.* 2023), however, this species has not been found so far in the PNNRP. *Selaginella minima* is distinguished by the ovate and basally asymmetric dorsal lycophylls with long-ciliate margins, as well as white megaspores (Smith & Kessler 2018).

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Data availability statement

In accordance with Open Science communication practices, the authors inform that all data are available within the manuscript.

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