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Ferns and Lycophytes as new challenges

Original Paper

Ferns and Lycophytes from the Estação Ecológica Serra Geral do Tocantins: a contribution to the flora of the Jalapão, Brazil

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Abstract

This study contributes to the flora of ferns and lycophytes, also referred to as pteridophytes, from the Estação Ecológica Serra Geral do Tocantins (EESGT), which is part of the Jalapão region in Tocantins. Although Jalapão is one of the largest protected areas in the *Cerrado* vegetation of Northern Brazil, its biodiversity has, thus far, been poorly reported in the literature. Therefore, fieldwork was recently carried out at EESGT in different habitats. Our collections and data from digital repositories included 31 ferns and four lycophyte species belonging to 20 genera of 15 families. Despite occupying only a small fraction of the landscape, forests concentrate most pteridophyte diversity, reinforcing their importance for the conservation of this group within the *Cerrado*. Eleven species are new records for Tocantins, one is new for Bahia, and one was recently described (*Anemia areniticola*). In addition to a list of all taxa, we provide illustrations and an identification key to encourage further studies on this often-neglected component of *Cerrado* flora.

Key words: *Cerrado rupestre*, forest, protected areas, pteridophytes, savanna.

Resumo

Este estudo é uma contribuição à flora de samambaias e licófitas, também conhecidas como pteridófitas, da Estação Ecológica Serra Geral do Tocantins (EESGT), que faz parte da região do Jalapão no Tocantins. O Jalapão é uma das maiores áreas protegidas da vegetação do Cerrado do Norte do Brasil, mas com poucas informações sobre sua biodiversidade até o momento. Os trabalhos de campo foram realizados na EESGT, em diferentes habitats. Nossas coletas e dados de repositórios digitais resultaram em 31 samambaias e quatro espécies de licófitas, pertencentes a 20 gêneros de 15 famílias. Apesar de ocuparem uma pequena fração da paisagem, as florestas concentram a maior parte da diversidade de pteridófitas, reforçando sua importância para a conservação do grupo no Cerrado. Onze espécies são novos registros para o Tocantins, uma para a Bahia, e uma espécie foi recentemente descrita (*Anemia arenticola*). Além de uma lista com todos os táxons, também fornecemos ilustrações e uma chave de identificação para incentivar novos estudos sobre esse componente frequentemente negligenciado da flora do Cerrado.

Palavras-chave: Cerrado rupestre, floresta, unidades de conservação, pteridófitas, savana.

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Introduction

Ferns and lycophytes, popularly known as pteridophytes, are cosmopolitan plant groups that encompass diverse life forms with adaptive mechanisms allowing them to inhabit various ecosystems. The greatest diversity of species occurs in the tropics (Jermy 1990; Sharpe & Mehltreter 2010; Tryon & Tryon 1982; Zuquim *et al.* 2008). Brazil has 1,411 species of ferns and lycophytes, of which 524 are endemics (BFG 2022). Although most species of pteridophytes are found in the Amazon and Atlantic forests, the *Cerrado* of Central Brazil is also an important region for these plant groups, including about 320 species, in other words, 22.6% of the national flora (BFG 2022). The lower species richness in the *Cerrado*, which is dominated by open habitats under a seasonally dry climate, reflects the ecological preference of most pteridophyte groups for moist and forested areas. Nevertheless, many species can be found in wet environments associated with water bodies, such as gallery forests and swamps (Colli *et al.* 2004; Fernandes *et al.* 2022; Kreutz *et al.* 2016; Miguez *et al.* 2013; Nunes & Labiak 2021). On the other hand, some dry-adapted lineages have successfully colonized open habitats of the *Cerrado*, such as species of *Anemia* (Hietz 2010; Mickel 2016), a genus especially diverse in Central Brazil (Mickel 2016). These open habitats harbor the largest number of *Cerrado* endemics (Prado *et al.* 2015), as well as most new species of pteridophytes recently described for the biome (Hirai *et al.* 2018; Labiak *et al.* 2018; Mickel 2016; Oliveira & Schwartsburd 2021; Pereira & Prado 2022).

Documenting the diversity of pteridophytes in the *Cerrado* has been challenging given the low number of floristic surveys, so most biome regions still need to be sampled. One of these regions is the Jalapão, in the northeastern portion of the *Cerrado*, which encompasses the most significant remnants of *Cerrado*'s native vegetation, including an extensive mosaic of natural reserves (Alencar *et al.* 2020). Despite some recent progress in documenting the flora of Jalapão (Antar & Sano 2019; Proença *et al.* 2002; Santana & Simon 2022; Silva *et al.* 2017), most inventories have been exclusively focused on angiosperms while neglecting the diversity of ferns and lycophytes.

Therefore, we aim to fill this gap by conducting a floristic survey of the Estação Ecológica Serra Geral do Tocantins, one of the largest protected areas in the *Cerrado*. We present an expert-vetted checklist and provide information about habitat, photographic plates, and a key for ferns and lycophytes.

Material and Methods

Study area

The Estação Ecológica Serra Geral do Tocantins (EESGT) comprises an area of 716,306 hectares (centroid 10°51'25"S, 46°41'33"W; Fig. 1). It is included within the boundaries of four municipalities in eastern Tocantins (Almas, Mateiros, Ponte Alta do Tocantins, and Rio da Conceição) and one in western Bahia (Formosa do Rio Preto), and it is part of a mosaic of protected areas in the Jalapão region. According to Köppen's classification, the climate corresponds to type Aw (Alvares *et al.* 2013) with dry winters, an average annual temperature of 24–26 °C, and average annual precipitation of 1,300 mm (data from Mateiros Weather Station; <https://www.snirh.gov.br/hidroweb/serieshistoricas>). Sequences of sedimentary plateaus and terraces are the dominant landforms in the landscape, where altitudes range from 400 m in the west to 730 m in the east (Villela & Nogueira 2011).

Vegetation in EESGT is dominated by open formations of grasslands and savannas, which cover around 98% of the reserve, whereas forests represent only 2% of the area (Franke *et al.* 2018). According to the classification of Ribeiro & Walter (2008), vegetation types in the EESGT include savanna and grassland physiognomies (*Campo limpo*, *Campo sujo*, *Cerrado ralo*, *Cerrado rupestre*, and *Vereda*), as well as riverine forests (*Mata ciliar* and *Mata de galeria*), Figs. 2 and 3.

Fieldwork and botanical identification

Five expeditions were carried out between 2018 and 2022 during dry and rainy seasons, totaling 26 field days. Surveys encompassed all habitats in the EESGT (Figs. 2-3) and all life forms of vascular plants. The density of collections of all groups of vascular plants (1192 collections) sampled in the EESGT provides a measure of sampling effort (Fig. 1). After the usual herborization process (Fidalgo & Bononi 1984), specimens were deposited in the CEN herbarium, and duplicates were sent to herbaria CESJ and UPCB (acronyms according to Thiers, continuously updated). A herbarium voucher was selected to represent each species in the checklist. Identification was made using taxonomic revisions and keys provided in the Flora

e Funga do Brasil 2022 (continuously updated), and by comparisons with specimens already deposited in CEN and CESJ collections. Digital images of specimens, as determined by specialists and/or nomenclatural types available in virtual herbaria of the repositories SpeciesLink (CRIA 2022), Global Biodiversity Information Facility (GBIF 2022), and Reflora (2022), were also consulted. When necessary, images or duplicates were sent for identification by specialists. The nomenclature of scientific names followed IPNI (2022), and the morphological terms used in the identification key followed Beentje (2010) and Lellinger (2002). The order in which the species are presented in the photographic plates follows the sequence they appear in the dichotomous key.

Additional data search

To complement the list obtained from our field expeditions, an additional search for taxa was carried out in GBIF (<https://www.gbif.org/>) and SpeciesLink (<https://specieslink.net/search/>). Searches of botanical records were conducted in September 2022, as follows: First, municipalities in Tocantins (Almas, Mateiros, Ponte Alta do Tocantins, and Rio da Conceição) and Bahia (Formosa do Rio Preto) were included in accordance with data in the repository SpeciesLink. Second, SpeciesLink and GBIF repository records located within the EESGT area plus a 5 km buffer were retained. Third, all retrieved records were checked individually for the precision of geographic coordinates and/or mistakes to ensure

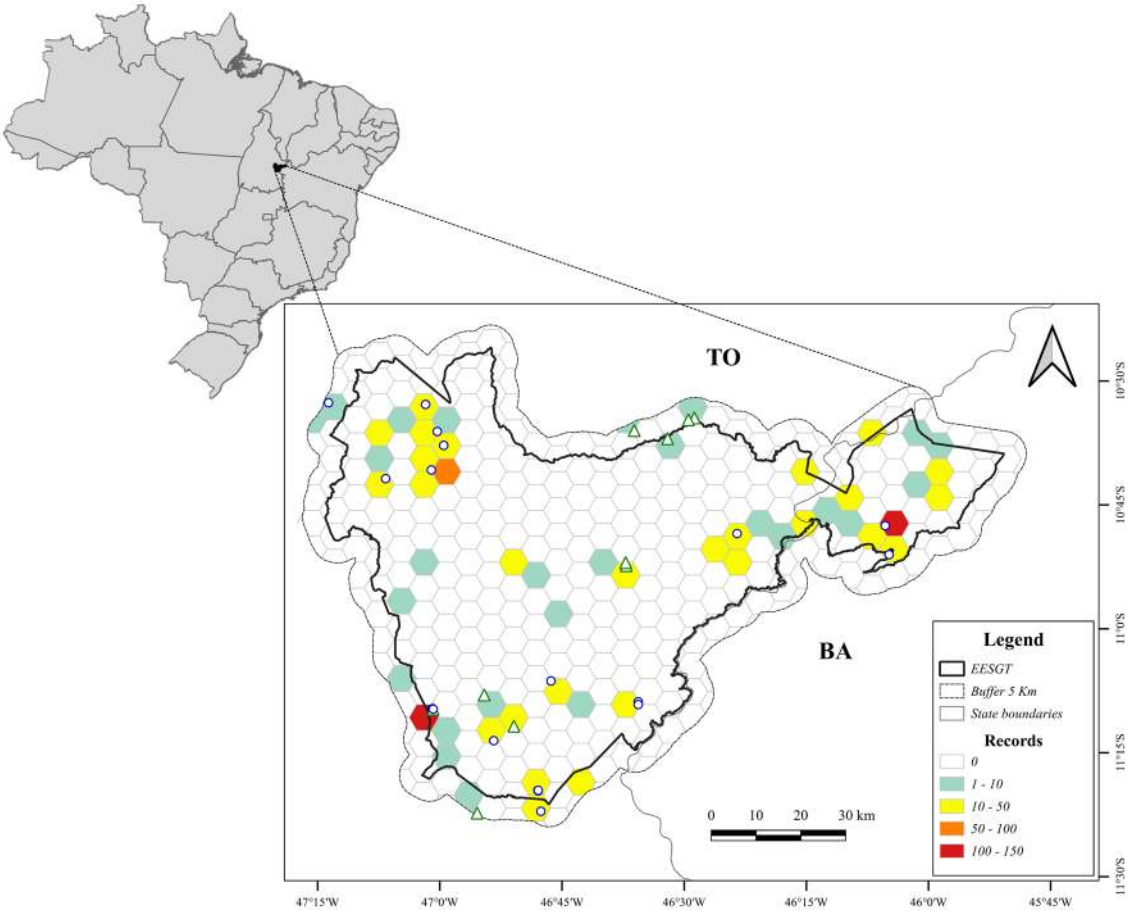

Figure 1 – Location of the Estação Ecológica Serra Geral do Tocantins (EESGT) and density of collections of vascular plants. Each hexagonal grid cell has an area of 28.9 km^2, and colors represent the count of botanical records per grid cell (1192 total, 1116 angiosperms, and 76 ferns and lycophytes). Ferns and lycophytes: records from field expeditions (54 records; circles); records from digital repositories (22 records; triangles). Brazilian states: BA (Bahia), TO (Tocantins). Map produced with QGIS, version 3.10 (QGIS Development Team 2019).

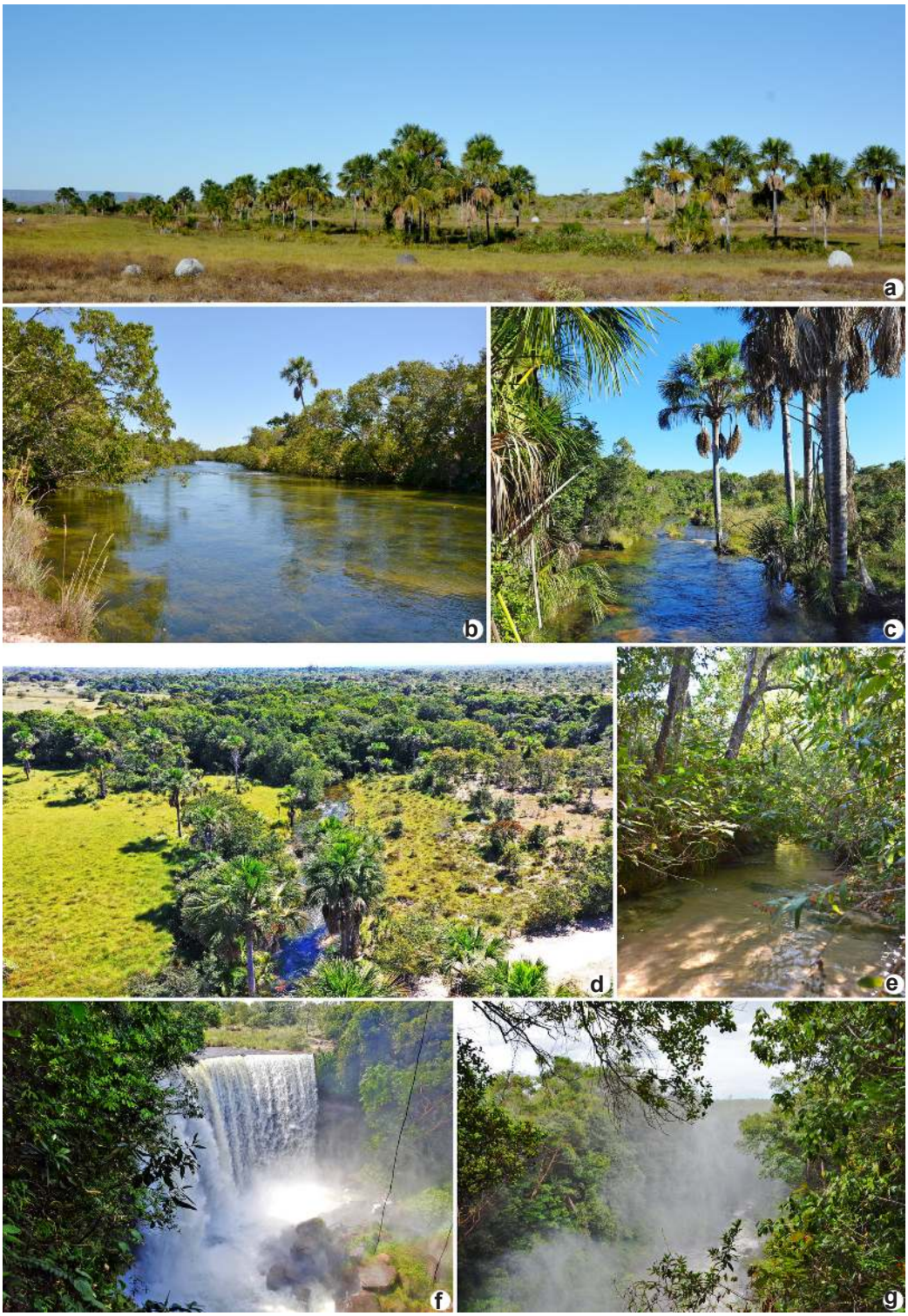

Figure 2 – a-g. Vegetation types found in the Estação Ecológica Serra Geral do Tocantins (EESGT) – a. *Vereda*; b. *Mata Ciliar* at "Rio Novo"; c. *Vereda*; d. vegetation mosaic with *Vereda* in the foreground and *Mata de galeria* in the background; e. *Mata de galeria* at "Rio Verdinho"; f. "Cachoeira da Fumaça"; g. detail of *Mata ciliar* downstream of "Cachoeira da Fumaça" and its conspicuous water vapor during the rainy season. (Photographs: a-c, e-g. M. Figueira & B. Schindler; d. S.E. Noronha).

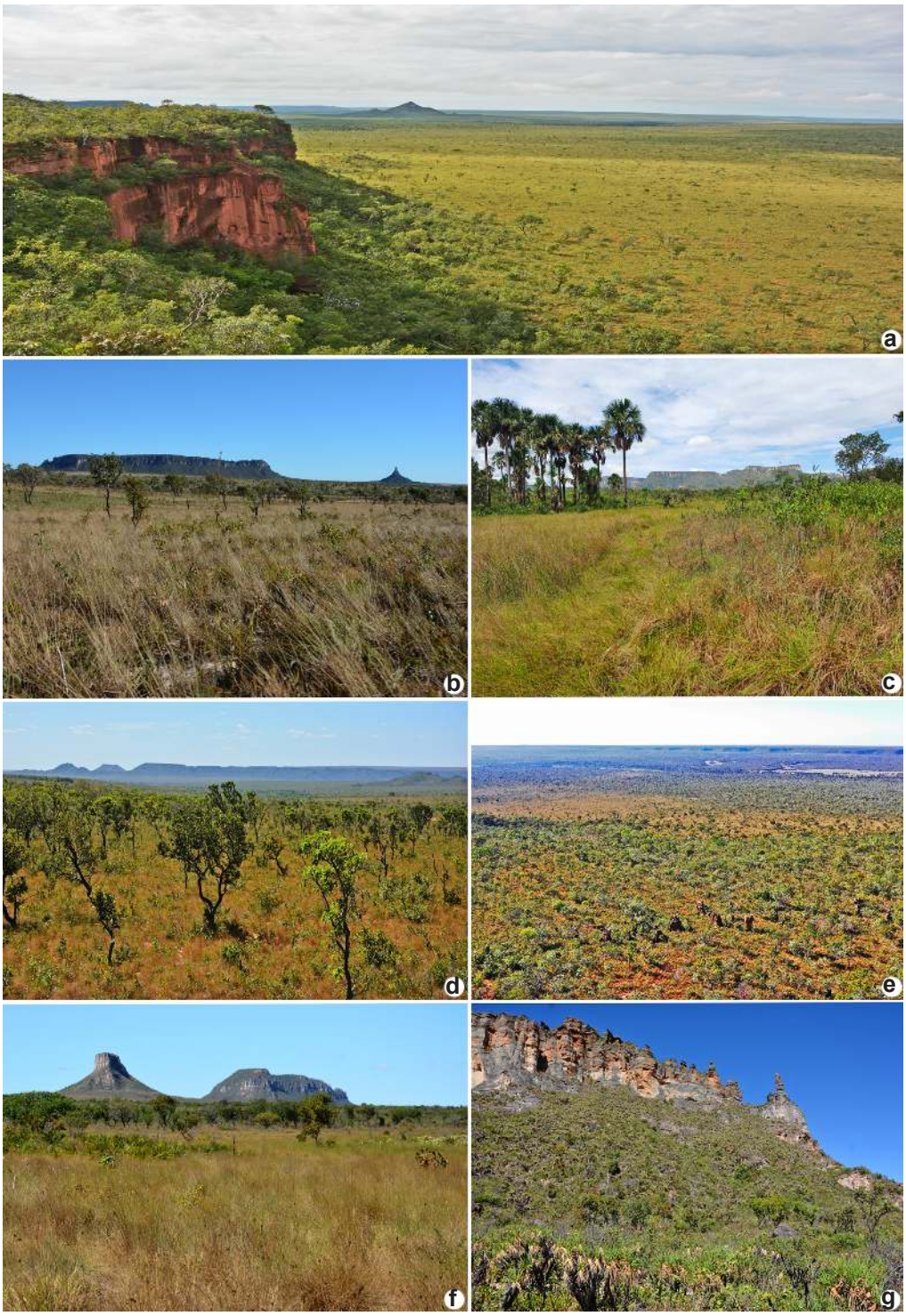

Figure 3 – a-g. Vegetation types found in the Estação Ecológica Serra Geral do Tocantins (EESGT) – a. predominant physiognomy with a significant extension of the vegetation mosaic of *Campo sujo* and *Cerrado ralo*; b. *Campo sujo* in the foreground; c. transition between *Campo sujo* (right) and *Campo limpo úmido* (left) near "Lagoa da Serra"; d. *Cerrado ralo*; e. *Cerrado ralo* with large rocky blocks, Formosa do Rio Preto, Bahia; f. *Campo limpo* in the foreground; *Cerrado ralo* and testimonial hills in the background; g. *Cerrado rupestre* at "Morro do Fumo". (Photographs: a-d, f-g. M. Figueira & B. Schindler; e. S.E. Noronha).

they corresponded to genuine collections made in the study area. Finally, locality notes containing the terms "Jalapão", "Estação Ecológica Serra Geral do Tocantins", "estação ecológica", "ESEC", "fumaça", "Rio Balsa", "vila dos Prazeres", and "Rio Peixinho", among others, were considered, even if geographic coordinates were absent or mistaken. Records obtained from online databases were checked case-by-case for taxonomic identity. When confirmation was not possible, specimens were disregarded.

Detection of new occurrence records

We also checked for new occurrence records for Bahia and Tocantins. A taxon could be considered a new record if it was not previously mentioned for Bahia and Tocantins in Flora e Funga do Brasil 2022 (continuously updated). In addition, a bibliographic search was conducted for relevant floristic surveys, taxonomic reviews, and regional floras, as well as searches in GBIF and SpeciesLink databases, to make sure that collections comprise genuine new occurrence records.

Results and Discussion

Field expeditions at EESGT resulted in 54 collections of 29 species of ferns and four lycophytes. Secondary data from online repositories included 22 records and two species not recorded in our field surveys (Fig. 1). A total of 35 species belonging to 15 families and 20 genera are compiled for the EESGT (see Tab. 1 for all species and authors), including one taxon identified at the genus level (*Blechnum* sp.). Species are illustrated in photographic plates (Figs. 4-12), and can be determined with the help of the dichotomous key presented below.

Table 1 – Checklists of Ferns and Lycophytes recorded at the Estação Ecológica Serra Geral do Tocantins. New occurrence records: TO = Tocantins; BA = Bahia. (*) = second record for Tocantins. Substrate: Rup = rupicolous; Ter = Terrestrial. Physiognomies *sensu* Ribeiro & Walter (2008) CUm = *Campo úmido*; CRu = *Cerrado rupestre*; MC = *Mata ciliar*; MG = *Mata de galeria*; Ve = *Vereda*.

Family / Species	New record	Substrate	Habitat	Physiognomy	Voucher
Anemiaceae					
Anemia andersonii Mickel & Labiak*		Rup	Savanna	CRu	*B.Schindler et al. 396* (CEN)
Anemia areniticola J.B.S.Pereira, M.G.Nunes & Labiak	TO	Rup	Savanna	CRu	*B.Schindler et al. 29* (CEN)
Anemia humilis (Cav.) Sw.		Rup	Savanna	CRu	*B.Schindler et al. 205* (CEN)
Anemia presliana Prantl		Rup	Savanna	CRu	*B.Schindler et al. 28* (CEN)
Anemia trichorhiza Gardner*	BA	Rup	Savanna	CRu	*B.Schindler et al. 207* (CEN)
Blechnaceae					
Blechnum sp.		Rup	Forest	MC	*B.Schindler et al. 45* (CEN)
Telmatoblechnum serrulatum (Rich.) Perrie, D.J.Ohlsen & Brownsey		Ter	Grassland, Savanna	CUm, Ve	*M.F.Simon 3532* (CEN)
Cyatheaceae					
Cyathea delgadii Sternb.	TO	Ter	Forest	MC, MG	*B.Schindler et al. 365* (CEN)
Cyathea myriotricha (Baker) R.C.Moran & J.Prado		Rup	Forest	MC	*B.Schindler et al. 44* (CEN)
Cyathea pungens (Willd.) Domin*		Ter	Forest	MC	*B.Schindler et al. 366* (CEN)
Dryopteridaceae					
Cyclodium meniscioides (Willd.) C.Presl		Rup, Ter	Forest	MC	*B.Schindler et al. 364* (CEN)
Gleicheniaceae					
Dicranopteris flexuosa (Schrad.) Underw.		Ter	Forest	Edge of MC, MG	*B.Schindler et al. 373* (CEN)

Family / Species	New record	Substrate	Habitat	Physiognomy	Voucher
Hymenophyllaceae					
Trichomanes cristatum Kaulf.		Ter	Forest	MC	*J.Cordeiro et al. 4218* (CESJ)
Trichomanes pilosum Raddi	TO	Ter	Forest	MC, MG	*B.Schindler et al. 363* (CEN)
Trichomanes pinnatum Hedw.		Rup/Ter	Forest	MG	*B.Schindler et al. 35* (CEN)
Lindsaeaceae					
Lindsaea divaricata Klotzsch	TO	Ter	Forest	MG	*B.Schindler et al. 34* (CEN)
Lindsaea lancea (L.) Bedd.		Ter	Forest	MC, MG	*B.Schindler et al. 362* (CEN)
*Lindsaea quadrangulari*s Raddi	TO	Ter	Forest	MC	*B.Schindler et al. 370* (CEN)
Lindsaea stricta (Sw.) Dryand.		Ter	Forest	MG	*M.Figueira et al. 1064* (CEN)
Lycopodiaceae					
Lycopodiella longipes (Grev. & Hooker) Holub		Ter	Grassland, Savanna	CUm, Ve	*B.Schindler et al. 188* (CEN)
Palhinhaea camporum (B.Øllg. & P.G.Windisch) Holub		Ter	Grassland, Forest, Savanna	MG	*M.Figueira et al. 1060* (CEN)
Marattiaceae					
Danaea leprieurii Kunze	TO	Rup	Forest	MC	*B.Schindler et al. 367* (CEN)
Metaxyaceae					
Metaxya parkeri (Hook. & Grev.) J.Sm.	TO	Rup, Ter	Forest	MC	*B.Schindler et al. 43* (CEN)
Nephrolepidaceae					
Nephrolepis biserrata (Sw.) Schott	TO	Ter	Forest	MG	*B.Schindler et al. 33* (CEN)
Pteridaceae					
Adiantum deflectens Mart.		Rup, Ter	Forest	MC	*J.Cordeiro et al. 2628* (MBM)
Adiantum serratodentatum Willd.		Ter	Forest	MG	*B.Schindler et al. 32* (CEN)
Adiantum sinuosum Gardn.		Rup, Ter	Savanna	CRu	*B.Schindler et al. 30, 393* (CEN)
Cheilanthes pohliana Mett.		Rup	Savanna	CRu	*B.Schindler et al. 376* (CEN)
Mineirella eriophora (Fée) Ponce & Scataglini		Rup	Savanna	CRu	*B.Schindler et al. 206* (CEN)
Pityrogramma calomelanos (L.) Link		Ter	Grassland, Savanna	Cum	*B.Schindler et al. 27* (CEN)
Schizaeaceae					
Schizaea elegans (Vahl) Sw.		Ter	Forest	MC	*B.Schindler et al. 368* (CEN)
Selaginellaceae					
Selaginella flexuosa Spring	TO	Rup	Forest	MC	*B.Schindler et al. 42* (CEN)
Selaginella radiata (Aubl.) Spring	TO	Rup	Forest, Savanna	CRu, MC	*B.Schindler et al. 40* (CEN)
Thelypteridaceae					
Meniscium arborescens Humb. & Bonpl. *ex* Willd.		Ter	Forest	MG	*B.Schindler et al. 36* (CEN)
Meniscium maxonianum (A.R.Sm.) R.S.Fernandes & Salino	TO	Ter	Forest	MC, MG	*B.Schindler et al. 374* (CEN)

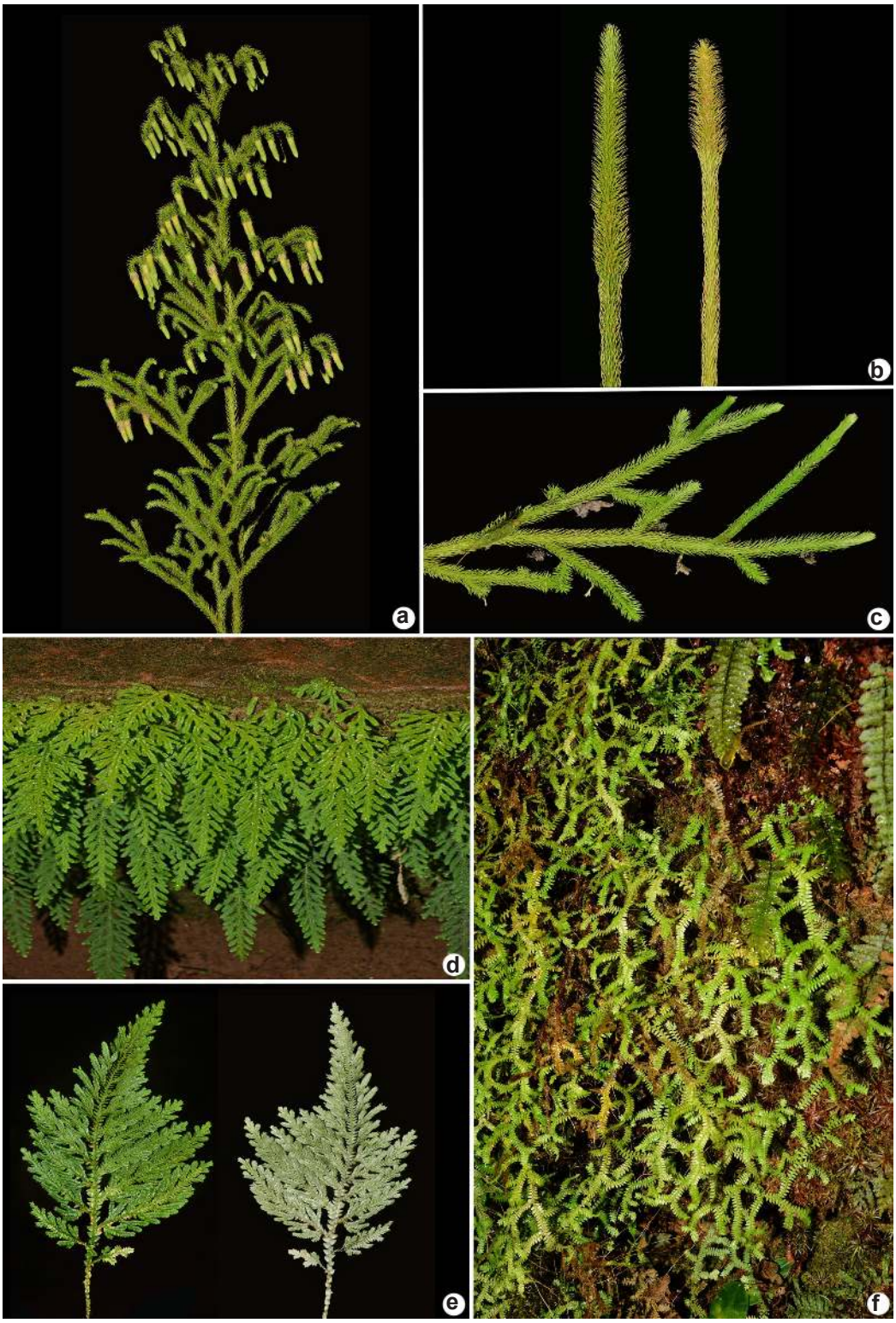

Figure 4 – a-f. Lycophytes of Estação Ecológica Serra Geral do Tocantins (EESGT) – a. *Palhinhaea camporum* – erect stem and detail of pendent strobili; b-c. *Lycopodiella longipes* – b. erect strobili; c. prostrate stem; d-e. *Selaginella radiata* – d. habit; e. detail of the discolored laminar surface; f. *S. flexuosa* – habit with prostrate stem. (Photographs: M. Figueira & B. Schindler).

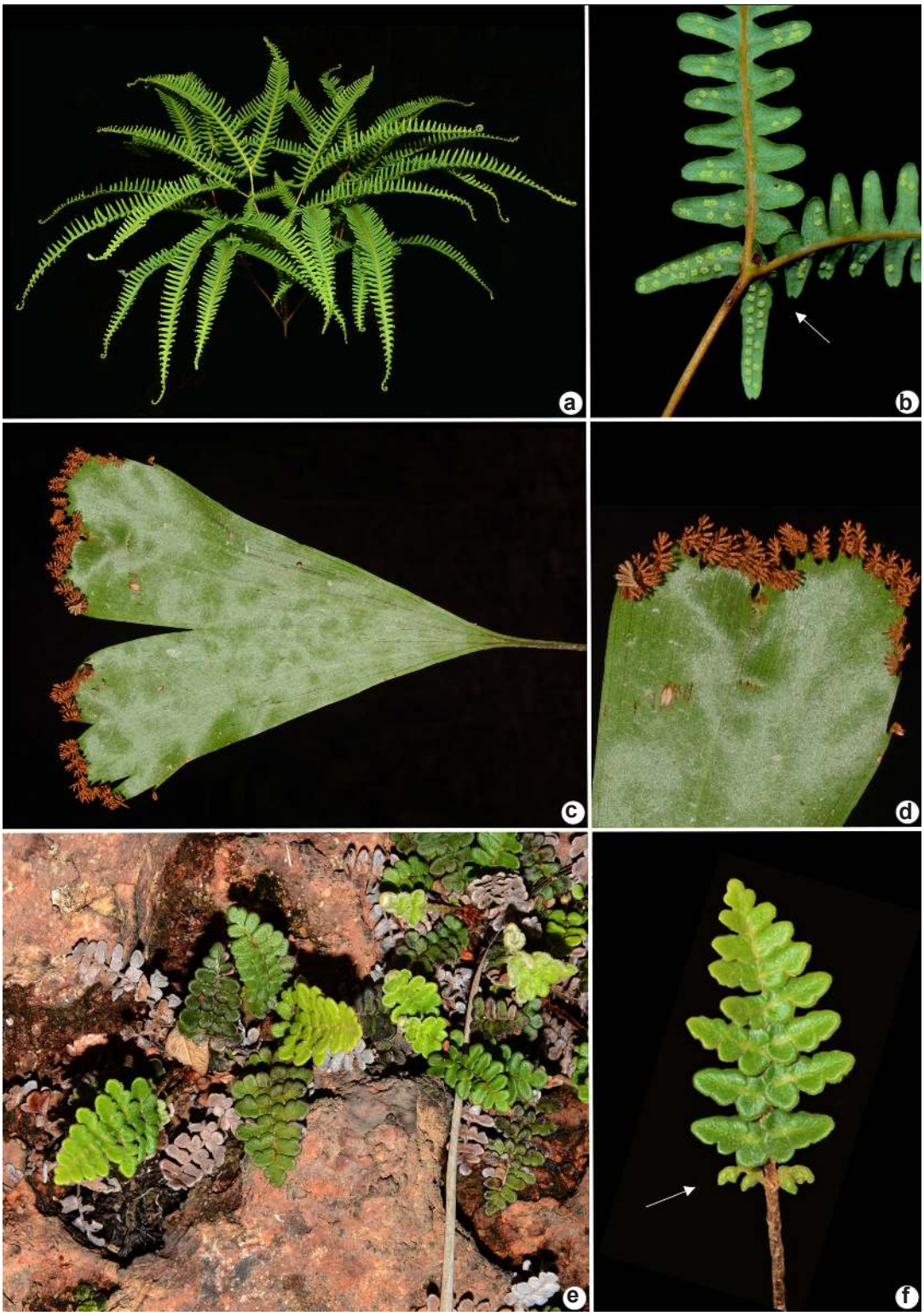

Figure 5 – a-f. Ferns of Estação Ecológica Serra Geral do Tocantins (EESGT) – a-b. *Dicranopteris flexuosa* – a. dichotomous ramifications; b. gem detail with accessory pinnae (arrow); c-d. *Schizaea elegans* – c. lamina; d. detail of sporangiophores on the margin; e-f. *Anemia areniticola* – e. habit; f. detail of sporangiophores on basal pinnae (arrow). (Photographs: M. Figueira & B. Schindler).

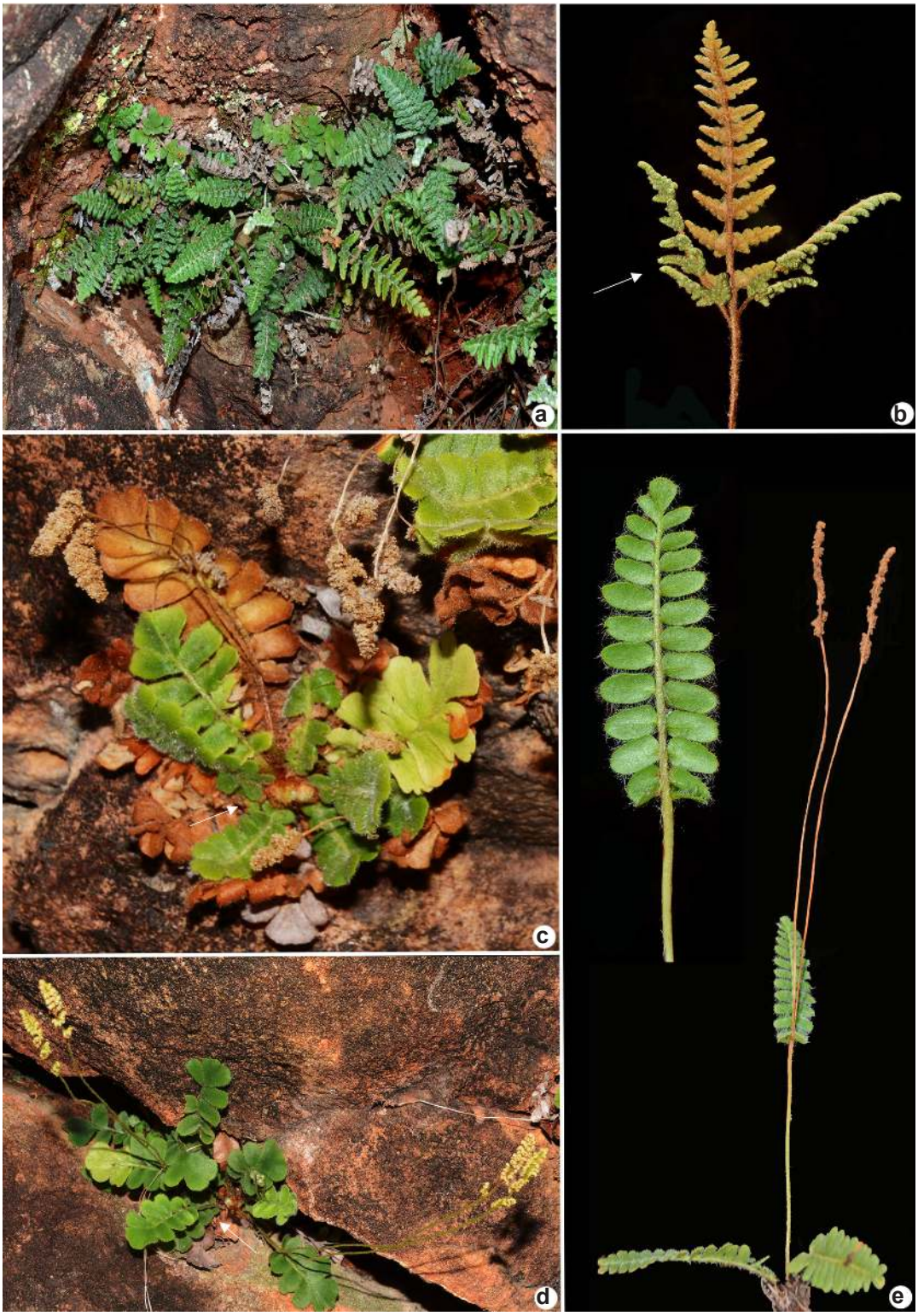

Figure 6 – a-e. Ferns of Estação Ecológica Serra Geral do Tocantins (EESGT) – a-b. *Anemia trichorhiza* – a. habitat; b. laminae and detail of sporangiophores on basal pinnae (arrow); c. *A. humilis* – habitat and detail of laminae decreasing basiscopically (arrow); d. *A. presliana* – habitat and detail of laminae not decreasing basiscopically (arrow); e. *A. andersonii* – detail of lamina. (Photographs: M. Figueira & B. Schindler).

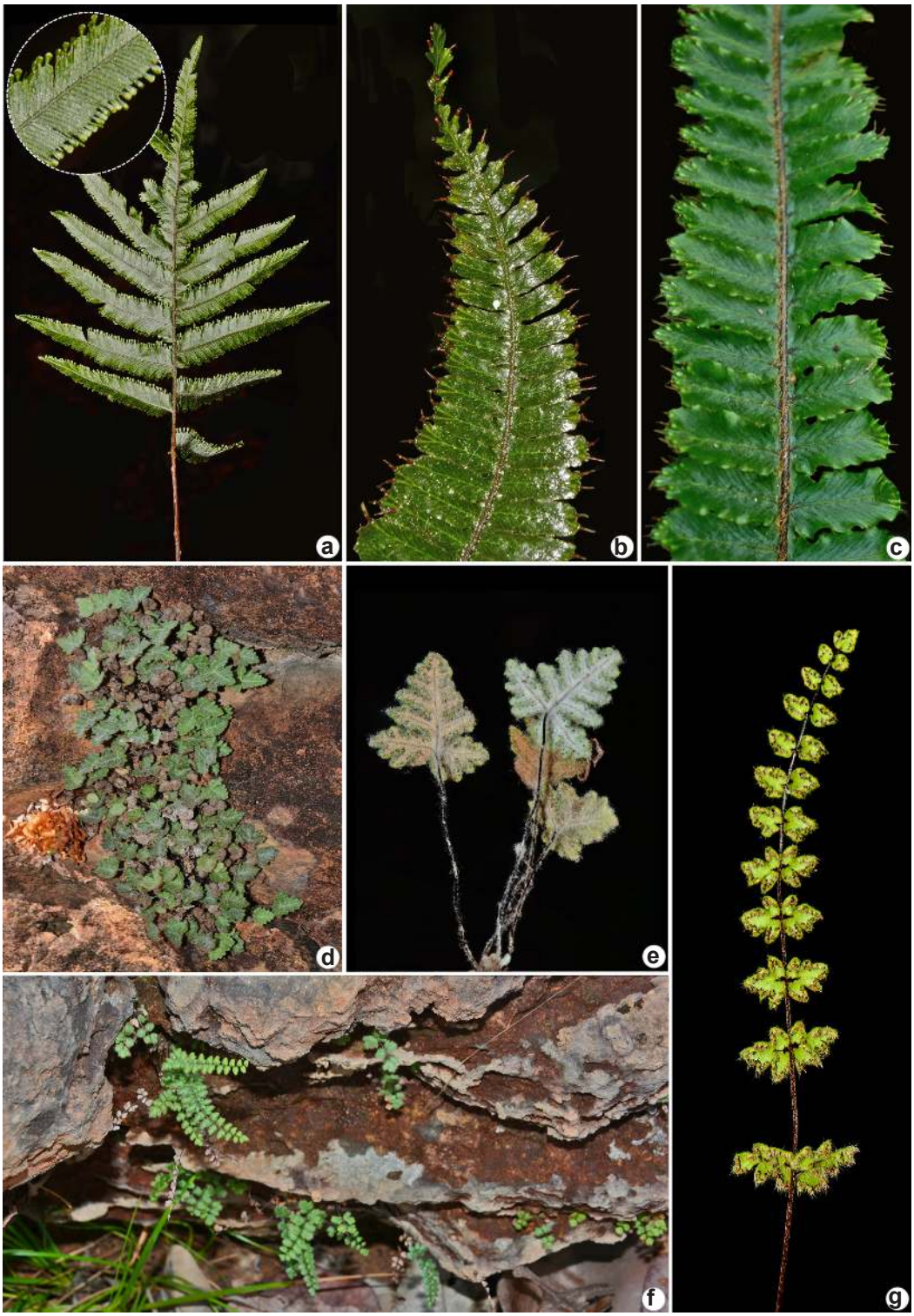

Figure 7 – a-g. Ferns of Estação Ecológica Serra Geral do Tocantins (EESGT) – a. *Trichomanes pinnatum* – detail of conical sori on the margin of pinnae; b. *T. pilosum* – detail of conical sori on the margin of pinnae; c. *T. cristatum* – detail of conical sori on the margin of pinnae; d-e. *Mineirella eriophora* – d. habit; e. detail of the abaxial surface of the laminae; f-g. *Cheilanthes pohliana* – f. habit; g. detail of the abaxial surface of the lamina. (Photographs: a-b, d-g. M. Figueira & B. Schindler; c. Felipe Gonzatti).

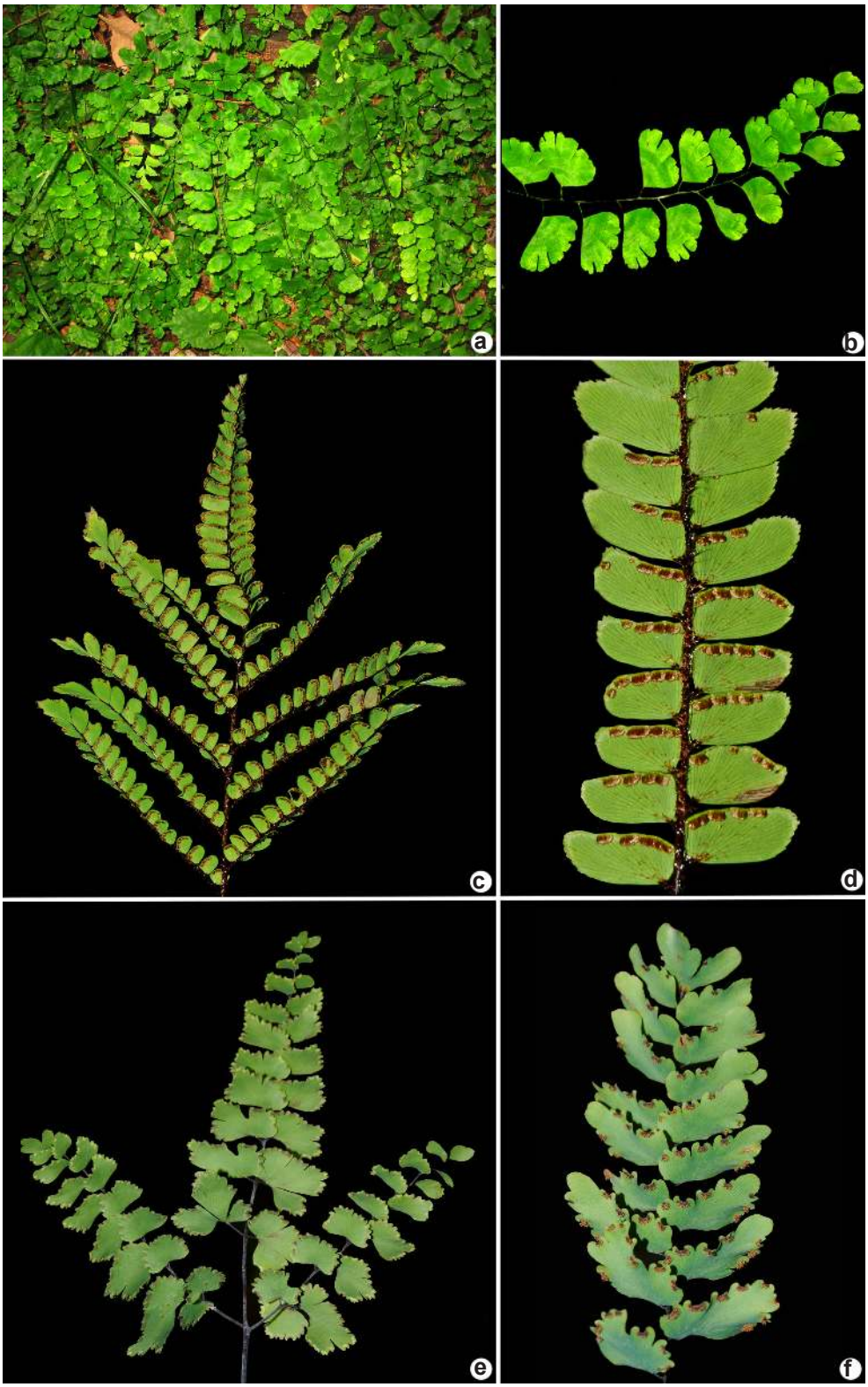

Figure 8 – a-f. Ferns of Estação Ecológica Serra Geral do Tocantins (EESGT) – a-b. *Adiantum deflectens* – a. habit; b. detail of pinnae; c-d. *A. serratodentatum* – c. lamina; d. detail of pinnules with scales and sori; e-f. *A. sinuosum* – e. lamina; f. detail of pinnules with sori. (Photographs: a-b. V.A.O. Dittrich; c-f. M. Figueira & B. Schindler).

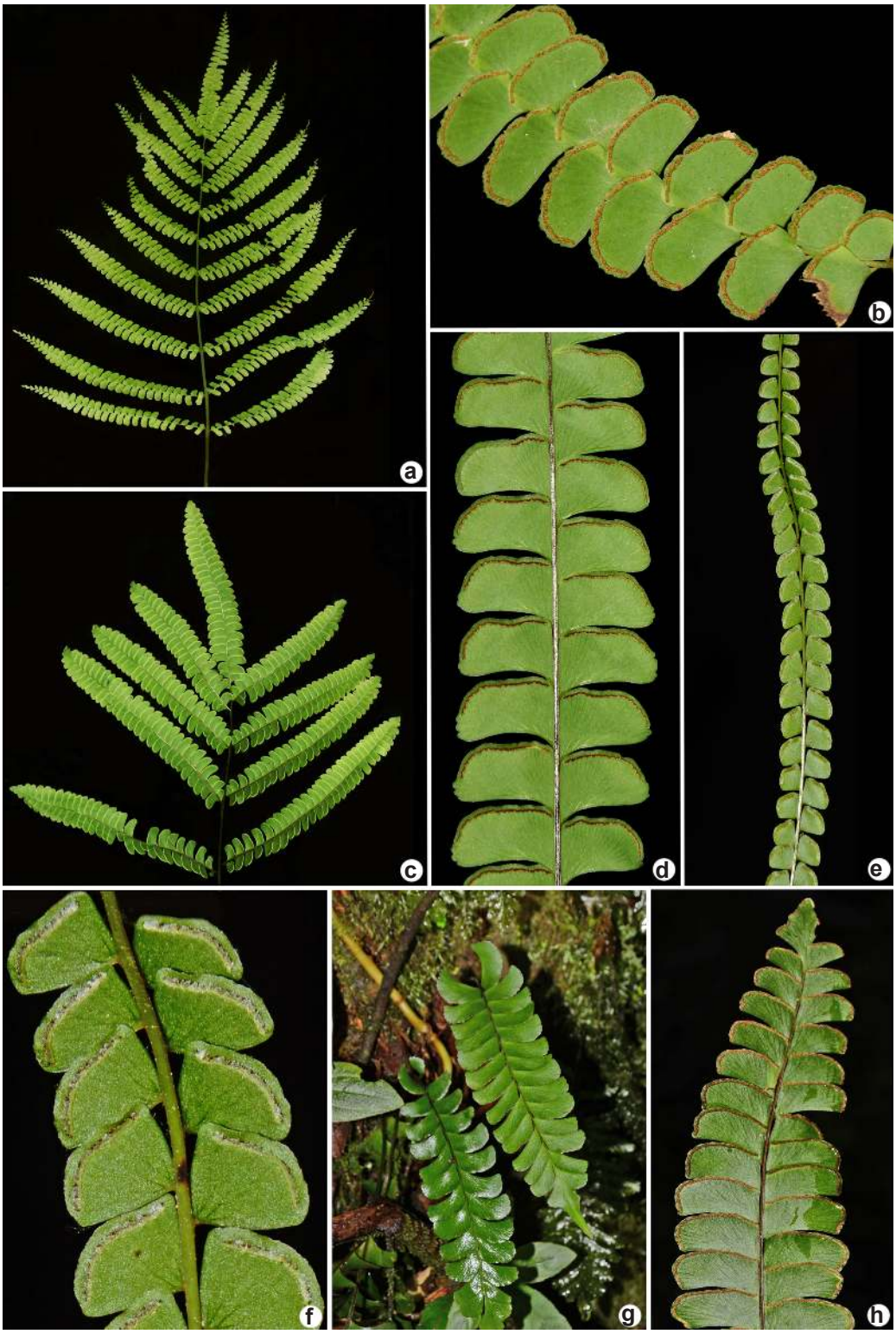

Figure 9 – a-h. Ferns of Estação Ecológica Serra Geral do Tocantins (EESGT) – a-b. *Lindsaea quadrangularis* – a. lamina; b. detail of pinnules with sori; c-d. *L. divaricata* – c. lamina; d. detail of pinnules with sori; e-f. *L. stricta* – e. lamina; f. detail of pinnae with sori; g-h. *L. lancea* – g. habit; h. detail of pinnae with sori. (Photographs: M. Figueira & B. Schindler).

Figure 10 – a-e. Ferns of Estação Ecológica Serra Geral do Tocantins (EESGT) – a-b. *Danaea leprieurii* – a. rhizome, lamina, and details of pulvinus (arrow); b. rachis and detail of veins; c. *Blechnum* sp. – abaxial surface of lamina with sori; d. *Telmatoblechnum serrulatum* – abaxial surface of lamina with sori; e. *Pityrogramma calomelanos* – abaxial surface of lamina with whitish-farinose indument. (Photographs: M. Figueira & B. Schindler).

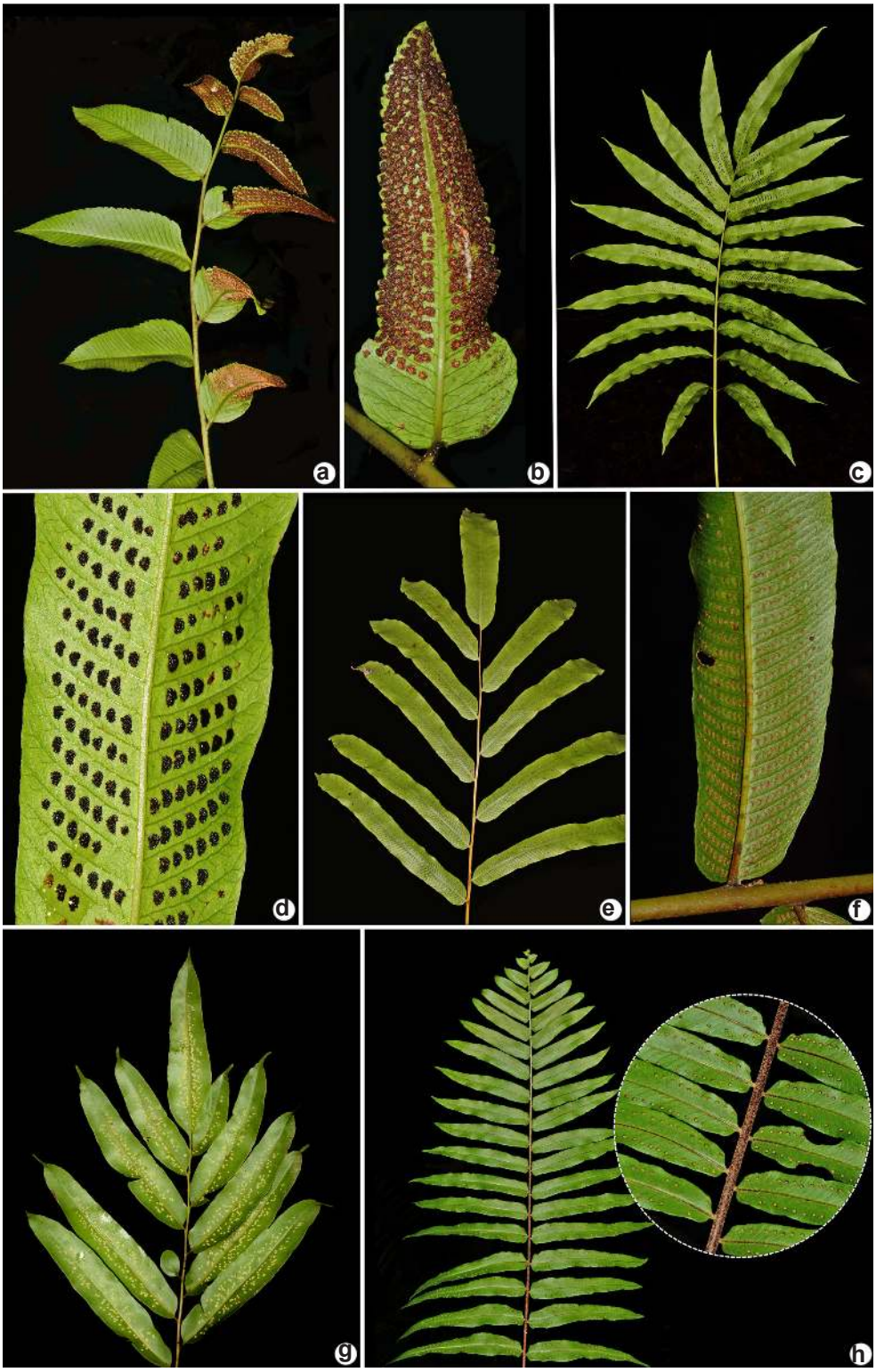

Figure 11 – a-h. Ferns of Estação Ecológica Serra Geral do Tocantins (EESGT) – a-b. *Cyclodium meniscioides* – a. lamina; b. detail of pinnae venation and sori; c-d. *Meniscium arborescens* – c. lamina; d. detail of pinnae venation and sori; e-f. *M. maxonianum* – e. lamina; f. detail of pinnae venation and sori; g. *Metaxya parkeri* – lamina and sori detail; h. *Nephrolepis biserrata,* lamina and sori detail. (Photographs: M. Figueira & B. Schindler).

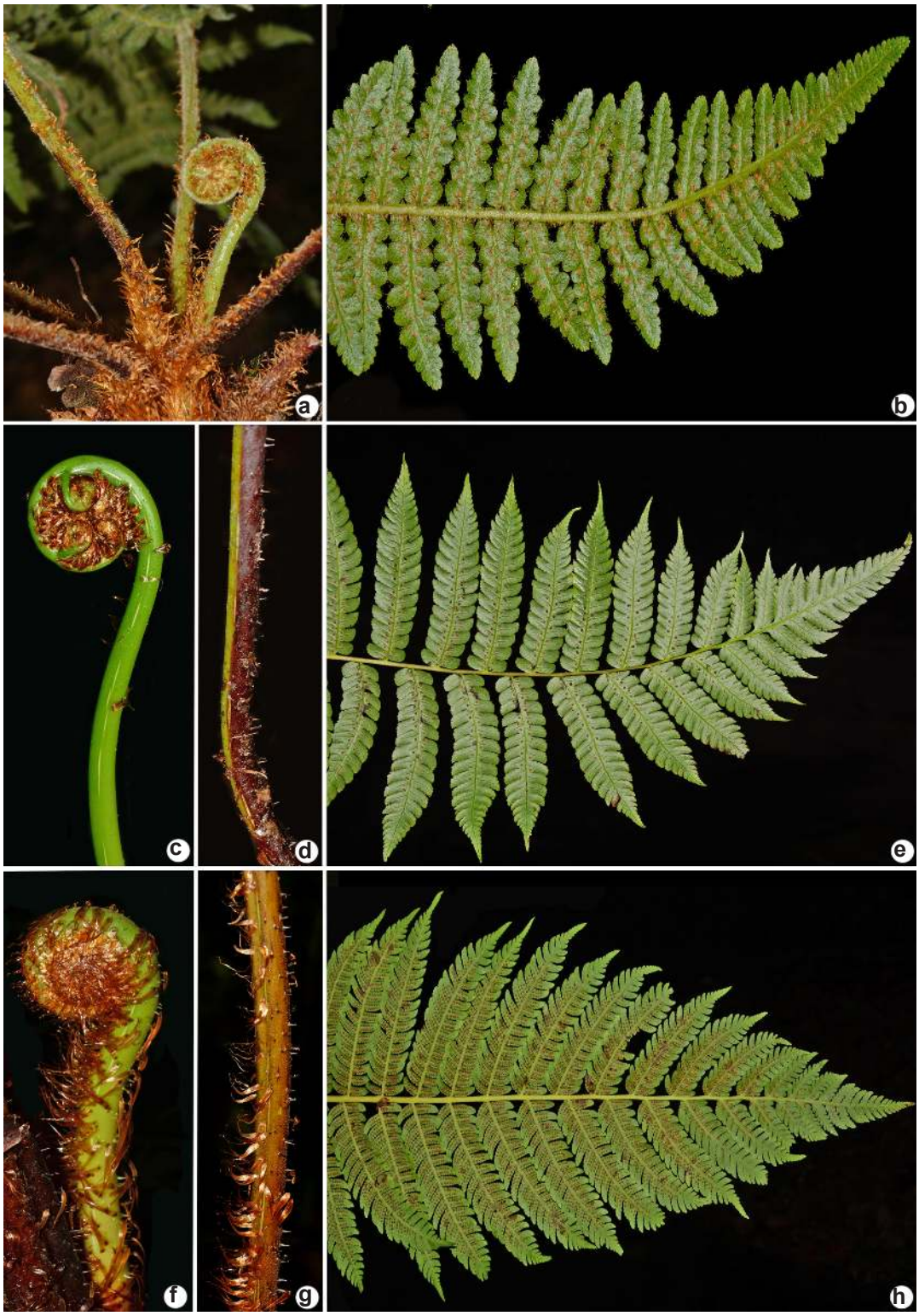

Figure 12 – a-h. Ferns of Estação Ecológica Serra Geral do Tocantins (EESGT) – a-b. *Cyathea myriotricha* – a. detail of fiddlehead and petiole; b. abaxial surface of pinna; c-e. *C. pungens* – c. detail of fiddlehead; d. petiole; e. abaxial surface of pinna; f-h. *C. delgadii* – f. detail of fiddlehead; g. petiole; h. abaxial surface of pinna. (Photographs: M. Figueira & B. Schindler).

Key to the Ferns and Lycophytes of Estação Ecológica Serra Geral de Tocantins, Brazil

1. Plants with microphylls, leaves with one vein, usually up to 1 cm long 2
    2. Microphylls inserted in numerous series, without ligule; plants homosporous 3
        3. Stem erect; strobili pendulous, at the apex of the lateral branches ..... *Palhinhaea camporum* (Fig. 4a)
        3'. Stem prostrate; strobili erect, at the apex of an erect branch ..... *Lycopodiella longipes* (Fig. 4b-c)
    2'. Microphylls inserted in four series, with ligule; plants heterosporous 4
        4. Rhizophores restricted to stem base; stem decumbent to erect; discolored leaf surface ..... *Selaginella radiata* (Fig. 4d-e)
        4'. Rhizophores distributed up to the basal half of the stem; stem prostrate to suberect; concolor leaf surface ..... *Selaginella flexuosa* (Fig. 4f)
1'. Plants with megaphylls, leaves multinerved, longer than 3 cm and reaching several meters in length 5
    5. Laminae branched dichotomously, with a bud and accessory pinnae between the bifurcations ..... *Dicranopteris flexuosa* (Fig. 5a-b)
    5'. Laminae entire or regularly pinnate, without bud and accessory pinnae between the bifurcations 6
        6. Sporangiophores present (pinnae or modified portions of the laminae) 7
            7. Laminae flabelliform; sporangiophores located on the margin of the laminae ..... *Schizaea elegans* (Fig. 5c-d)
            7'. Laminae of other shapes; sporangiophores located in a modified basal pinnae 8
                8. Abaxial surface of the laminae lanose; fertile pinnae horizontal or oblique, not fully erect 9
                9. Fertile pinnae shorter than the sterile; sterile pinnae glabrescent or sparsely lanose on the adaxial surface ..... *Anemia areniticola* (Fig. 5e-f)
                9'. Fertile pinnae longer than the sterile; sterile pinnae densely lanose on the adaxial surface ..... *Anemia trichorhiza* (Fig. 6a-b)
                8'. Abaxial surface of the laminae hirsute; fertile pinnae erect 10
                10. Laminae with ≤ 10 pairs of pinnae; petiole of fertile pinnae approximately the same length as the sterile 11
                11. Sterile laminae decreasing basiscopically ..... *Anemia humilis* (Fig. 6c)
                11'. Sterile laminae not decreasing basiscopically ..... *Anemia presliana* (Fig. 6d)
                10'. Laminae with ≥ 10 pairs of pinnae; petiole of fertile pinnae longer than the sterile ..... *Anemia andersonii* (Fig. 6e)
        6'. Sporangiophores absent 12
            12. Sporangia on the margin of the laminae 13
                13. Sori conical, with involucres immersed in laminar tissue 14
                14. Laminae dimorphic ..... *Trichomanes pinnatum* (Fig. 7a)
                14'. Laminae monomorphic 15
                15. Laminae deltoid, arched or curved ..... *Trichomanes pilosum* (Fig. 7b)
                15'. Laminae linear and erect ..... *Trichomanes cristatum* (Fig. 7c)
                13'. Sori of other formats 16
                16. Laminae pinnatifid, ovate-pentagonal or pentagonal, lanose abaxially ..... *Mineirella eriophora* (Fig. 7d-e)
                16'. Laminae 1–3 pinnate or more, glabrous or the indument of other types 17
                17. Pinnule hirsute, slightly revolute, sori encircling all margin ..... *Cheilanthes pohliana* (Fig. 7f-g)
                17'. Pinnule never hirsute, flat or sinuose, never revolute, sori only on the upper margin (acroscopic) 18

18. Indusia opening toward the costa or segment apex (pseudo-indusia) 19
    19. Laminae 1-pinnate, pinnae glabrous ..... *Adiantum deflectens* (Fig. 8a-b)
    19'. Laminae 1–3 pinnate or more at the base, glabrous or with scales 20
        20. Pinnules flat, scales on abaxial surface ..... *Adiantum serratodentatum* (Fig. 8c-d)
        20'. Pinnules slightly sinuate, glabrous on both surfaces ..... *Adiantum sinuosum* (Fig. 8e-f)
18'. Indusia opening toward the lamina margin 21
    21. Distal pinnules conspicuously smaller in size towards apex of pinnae; spores monolete .... *Lindsaea quadrangularis* (Fig. 9a-b)
    21'. Distal pinnules of equal or slightly reduced size towards the apex of the pinnae (or laminae 1-pinnate); spores trilete 22
        22. Laminae often 1-pinnate, rarely 2-pinnate or more; indusium lacerate .... *Lindsaea stricta* (Fig. 9e-f)
        22'. Laminae 2-pinnate or more; indusium entire 23
            23. Petiole and rachis sub-terete ..... *Lindsaea divaricata* (Fig. 9c-d)
            23'. Petiole and rachis angulose ..... *Lindsaea lancea* (Fig. 9g-h)
12'. Sporangia superficial on the laminae, on the veins or parallel to the main vein 24
    24. Sporangia forming synangium or sori linear and parallel to the costa 25
        25. Petioles with pulvinus; rachis alate; synangia on the veins .... *Danaea leprieurii* (Fig. 10a-b)
        25'. Petioles without pulvinus; rachis non-alate or absent; sori parallel to the main vein 26
            26. Laminae pinnatifid, margin inconspicuously denticulate ..... *Blechnum* sp. (Fig. 10c)
            26'. Laminae pinnate, margin serrate ..... *Telmatoblechnum serrulatum* (Fig. 10d)
    24'. Sporangia forming rounded or oblong sori, or spread on the laminae 27
        27. Abaxial surface of the laminae with a whitish, farinose indument .... *Pityrogramma calomelanos* (Fig. 10e)
        27'. Abaxial surface of the laminae lacking a farinose indument 28
            28. Veins anastomosing 29
                29. Pinnae with crenate to toothed margin ..... *Cyclodium meniscioides* (Fig. 11a-b)
                29'. Pinnae with entire, wavy or slightly crenate margin 30
                30. Abaxial surface of the laminae with glandular trichomes .... *Meniscium maxonianum* (Fig. 11c-d)
                30'. Abaxial surface of the laminae with acicular trichomes .... *Meniscium arborescens* (Fig. 11e-f)
            28'. Veins free 31
                31. Laminae 1-pinnate 32
                32. Pinnae chartaceous, apex long-attenuate to caudate, margins serrate; sori without indusium, one or usually several sori on each side of the costae .... *Metaxya parkeri* (Fig. 11g)
                32'. Pinnae membranous, apex acute, acuminate or emarginate, margin entire to slightly serrate; sori with circular to semicircular indusium, uniseriate on each side of the costae ..... *Nephrolepis biserrata* (Fig. 11h)
                31'. Laminae 2-pinnate or more divided 33
                33. Petiole inermous ..... *Cyathea myriotricha* (Fig. 12a-b)
                33'. Petiole aculeate 34
                34. Pinnules pinnatipartite; indusium absent .... *Cyathea pungens* (Fig. 12c-e)
                34'. Pinnules pinnatisect; indusium present .... *Cyathea delgadii* (Fig. 12f-h)

Species recorded comprise different life forms, ranging from small rupicolous taxa, such as *Anemia* spp., *Cheilanthes pohliana*, and *Mineirella eriophora*, to forest dwelling tree ferns (*Cyathea* spp.). Most listed pteridophytes comprised terrestrial species (18 spp.), followed by rupicolous taxa (12 spp.), while five species were classified as both rupicolous and terrestrial. No epiphytic species were found in the area. Although epiphytes are common in rainforests, they seem to be rare in sites located in regions with seasonal climates (Fernandes *et al.* 2010; Lehn *et al.* 2020; Miguez *et al.* 2013; Xavier *et al.* 2012). However, epiphytic ferns have been registered in *Cerrado* gallery forests. For example, Oliveira & Arcela (2014) found several individuals belonging to four species of Polypodiaceae in a survey of epiphytes in a gallery forest sampled in Distrito Federal.

Pteridophyte occurrence in different habitats within the EESGT

Although open formations, consisting of grasslands and savannas, dominate the landscape within the EESGT, the largest number of species were recorded in forests and humid environments (Tab. 1), predominantly in the understory, where pteridophytes occupy several microenvironments. A predominance of pteridophytes in wet forests (*Mata de galeria* and *Mata cCiliar*) has been reported in other studies in the *Cerrado* (Colli *et al.* 2004; Fernandes *et al.* 2022; Kreutz *et al.* 2016; Miguez *et al.* 2013; Nunes & Labiak 2021). Compared to those studies, the species number reported here is relatively low, considering the expanded size of the EESGT.

It can be argued that the low species richness reported here resulted from undersampling. Indeed, the vast area of the EESGT represents a challenge to comprehensive sampling. However, we were still able to conduct an intensive search for ferns and lycophytes in widely distributed sites within the EESGT, including 15 collection sites located in wet habitats highly suitable for pteridophytes (*Mata ciliar*, *Mata de galeria*, *Vereda*, *Campo úmido*; Figs. 2; 3c). Therefore, we believe that our sampling effort was adequate and enabled the collection of representative samples of local flora. A more likely explanation for the low diversity of pteridophytes in the EESGT, compared to other surveys in the *Cerrado*, is the paucity of suitable habitats. Grasslands and savannas on deep sandy soils, the dominant habitat in the EESGT, are poor in pteridophyte species, possibly owing to a lack of moisture during the dry season. On the other hand, more suitable microhabitats, including wet forests and rocky outcrops (*Cerrado rupestre*), where most species were found, comprise only a small fraction of the landscape.

One spot of high diversity of pteridophytes in the area was the "Cachoeira da Fumaça", a waterfall of the Balsas River located on the southwestern edge of the EESGT (red cell in Figs. 1 and 2f-g), which alone contributed 11 species to the list. That waterfall continuously sends water towards the forest downstream in a gorge, producing a moist environment where several typical ombrophilous species, including ferns, thrive. Pteridophyte diversity in this locality includes large-sized tree ferns, such as *Cyathea* spp. (Fig. 12), as well as rupicolous (*Blechnum* sp., *Danaea leprieurii*; Fig. 10; *Selaginella* spp., Fig. 4) and terrestrial species (*Lindsaea* spp., Fig. 9; *Meniscium maxonianum*, Fig. 11f-g; *Schizaea elegans*, Fig. 5c-d). As far as we know, "Cachoeira da Fumaça" is the only locality where *Cyathea myriotricha* (Fig. 13a-b) and *Cyclodium meniscioides* (Fig. 11a-c) were recorded throughout the entirety of Tocantins state. This habitat sharply contrasts with the seasonally dry grasslands surrounding it, making the site an island of humidity, even during the dry season. The high number of species recorded in the "Cachoeira da Fumaça" is probably associated with this unique and heterogeneous microclimate related to humidity and shade (forest stratification) gradients, as well as the diversity of substrates and high abundance of litter. Indeed, the high species richness of ferns is associated with environmental heterogeneity in *Cerrado* gallery forests (Kreutz *et al.* 2016).

On the other hand, species like *Lycopodiella longipes*, *Palhinhaea camporum*, *Pityrogramma calomelanos,* and *Telmatoblechnum serrulatum* (Figs. 4; 10) were strongly associated with open vegetation on seasonally flooded hydromorphic soils, such as "*Campos úmidos* and *Veredas*", typical of habitats found along watercourses and springs in the EESGT (Fig. 2). However, these same species were reported in similarly poorly-drained environments in other regions (Athayde Filho & Agostinho 2005; Fernandes *et al.* 2022; Zambiase *et al.* 2016), as well as *Veredas* of the EESGT (Silva *et al.* 2017).

We also highlight a few species able to tolerate the dry and nutrient-poor soils of *Cerrado* environments. For example, *Anemia*, *Cheilanthes*, and *Mineirella* species were found in open habitats

and on rocky outcrops and can be classified as xeromorphic (Figs. 5; 6). These small-sized ferns were often found in arenitic slopes and outcrops (*Cerrado rupestre*) growing on sandy soil in pockets and crevices (Fig. 3). To compensate for the xeric conditions, these species have efficient mechanisms for obtaining nutrients, the ability to dry out and become latent during the dry season, and the ability to resprout during the wet season from underground rhizomes that can withstand fire (Benzing 2004; Goetz *et al.* 2012; Hietz 2010). The occurrence of these genera in habitats generally less favorable to ferns can be facilitated by apogamy (Hietz 2010; Moran 2012). Other studies report the occurrence of these genera in similar environments elsewhere (Santos-Silva *et al.* 2023; Castro-Aguiar *et al.* 2022; Fernandes *et al.* 2014; Lehn *et al.* 2020; Mickel 2016; Ponce & Scataglini 2021; Xavier *et al.* 2012).

Our results suggest strong habitat specificity with different pteridophyte assemblages occupying various habitat types in the EESGT. One exception is *Selaginella radiata*, which was recorded growing in sunny, dry rocky outcrops, and in shady and humid places, an ecological observation also reported by Góes-Neto *et al.* (2016).

Overall, we found the highest richness in wet forests on non-flooded soils, whereas comparatively less species were found in open and/or flooded habitats. Habitats with high light incidence, low humidity, seasonally dry microclimates, and sites occurring on poorly-drained soils may represent ecological barriers that prevent colonization by many pteridophyte groups. According to Kessler (2010), environmental conditions can limit the coexistence of different species in the same habitat.

New occurrence records

The 35 species of pteridophytes found in the EESGT represent a considerable fraction of the total number of species recorded for Tocantins and add 11 species to the state's list (Tab. 1). New *Cerrado* records include the first record for the family Marattiaceae with the occurrence of *Danaea leprieurii*, which was only registered to the Amazonian domain (Flora e Funga do Brasil 2022 (continuously updated); Salino & Lima 2017). Another highlight is the record of a recently described species, *Anemia areniticola* cited only for Pará and Maranhão (Pereira *et al.* 2022). In addition to new records, we report the second record of *Anemia andersonii*, *A. trichorhiza* (*B. Schindler et al. 382*), and *Cyathea pungens* from Tocantins.

In the dataset obtained from digital repositories, we found occurrence records of *Metaxya lanosa* A.R. Sm. & Tuomisto (*L.G. Sousa VIC 48791*) and *M. rostrata* (Humb. & Bonpl. *ex* Willd.) C. Presl (*J. Cordeiro et al. 2637*), two species that occur in central and western Amazonia (Cárdenas *et al.* 2016). After examining images of these collections, we preferred not including these species in our checklist since we were not confident in their identifications. A careful examination of the herbarium material would be required to confirm they identity. The specimen *M. rostrata* abovementioned was collected at the "Cachoeira da Fumaça", the same locality where we collected a plant identified as *M. parkeri* based on the work of Cárdenas *et al.* (2016). We do not rule out that these collections could be conspecific. In any case, we recommend a more detailed revision of the material of Metaxyaceae collected in Tocantins, a group that is most diverse in Amazonia.

Prado *et al.* (2015) reported an increase of 210% in the number of species for Tocantins comparing the List of Flora of Brazil 2010 (20 spp.) with the 2015 version (69 spp.). According to the BFG (2022), 82 species are reported for the state. Despite this recent progress in botanical knowledge of Tocantins, the current figures are underestimated. For example, Goiás, a state similar in size to Tocantins but with much better documented flora, has 260 species of ferns and lycophytes. In contrast, Distrito Federal, with an area 50 times smaller, has 148 documented species (BFG 2022). Therefore, increasing collection efforts in Tocantins is essential to improve the state's floristic knowledge and contribute to new species discovery. Increasing occurrence data on ferns and lycophytes in the region would also result in a better understanding of the biogeographic context of Tocantins flora. For example, additional pteridophyte records could provide further evidence for the influence of the Amazon on the flora of riparian forests of the *Cerrado* (Martins *et al.* 2013; Oliveira-Filho & Ratter 2000), such as records of the Amazon-centered species *Danaea leprieurii* and *Selaginella radiata* in the EESGT.

Anemia trichorhiza, a species that inhabits rocky outcrops on the slopes of the Serra Geral, is classified as vulnerable (CNCFlora 2023) and was the single new occurrence record to Bahia reported here.

Overall, our sampling effort, which focused on a single protected area, resulted in a significant improvement in the knowledge of pteridophytes in an otherwise poorly known region, highlighting, in turn, the need for additional botanical surveys that include all groups of vascular plants to fill biodiversity gaps, particularly in Tocantins state. Our results also highlight the importance of forest formations and wet habitats as critical environments for the conservation of pteridophytes within the *Cerrado*. Despite occupying a small fraction of the landscape, these habitats concentrate most pteridophyte diversity. We expect that the checklist presented here, which represents the first compilation of pteridophytes for a protected area in the Jalapão region, will encourage further studies on this often-neglected component of the *Cerrado* flora.

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Data availability statement

In accordance with Open Science communication practices, the authors inform that all data associated with herbarium specimens cited in this study is publicly available in the repository SpeciesLink (CRIA 2022).

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