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Survey of mosses (Bryophyta) along visitor trails in the Parque Nacional de Caparaó, Espírito Santo State, Brazil[1]

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ABSTRACT – (Survey of mosses (Bryophyta) along visitor trails in the Parque Nacional do Caparaó, Espírito Santo State, Brazil). Bryophyta, the mosses, are an abundant plant group in humid environments. In the Atlantic Coastal Forest of Southeastern Brazil, they are found in great richness and diversity, especially in the montane regions. In this context, the Parque Nacional do Caparaó, where our study was conducted, is known for its mountain environment and high altitude. Although a considerable number of moss collections from the western part of the park is already deposited in herbaria, the eastern side belonging to the state of Espírito Santo State had been undersampled until now. For this pioneering work, we covered the park's main visitation trails during three intensive days of collections. We found 59 species of mosses, belonging to 38 genera and 22 families. Nine species are new occurrences for the state and 14 are Brazilian endemics. Most species were found growing on soil. We found more species at altitudes above 1,500 m a.s.l. Sematophyllaceae was the richest moss family.

Keywords: Atlantic Forest, bryophytes, cloud forest, high fields, Ombrophilous Forest

RESUMO – (Levantamento de musgos (Bryophyta) em trilhas de visitação no Parque Nacional do Caparaó, Estado do Espírito Santo, Brasil). No Brasil, os musgos (Bryophyta) são encontrados com maior riqueza e diversidade na Mata Atlântica, especialmente em ambientes montanhosos e úmidos como o encontrado no Parque Nacional do Caparaó. A coleta do material foi realizada durante três dias onde percorremos as principais trilhas de visitação do parque. Foram identificadas 59 espécies pertencentes a 38 gêneros e 22 famílias. Nove espécies são novas ocorrências para o Estado e 14 são endêmicas do país. A família mais rica em espécies foi Sematophyllaceae. As espécies terrícolas são as mais frequentes. A maior riqueza de espécies foi observada em altitudes acima de 1.500 m alt. Embora se tenha considerável número de coletas depositadas nos herbários, oriundos da porção oeste do parque, este é um trabalho pioneiro na região que se estende pelo Espírito Santo.

Palavras chaves: briófitas, campos de altitude, Floresta Ombrófila, Mata Atlântica, mata nebular

Introduction

Bryophytes are nonvascular land plants that include mosses (Bryophyta, Goffinet *et al.* 2009), liverworts (Machantiophyta, Crandall-Stotler *et al.* 2009) and hornworts (Anthocerotophyta, Renzaglia *et al.* 2009). Usually, they are small in size and colonize a wide variety of substrates and ecosystems, except for marine habitats (Costa *et al*. 2010, Vanderpoorten & Goffinet 2009). They are dependent on humidity mainly due to the presence of flagellated gametes and the poikilohydric mechanism, which is why they are more frequent in humid environments, such as the Atlantic Forest. This domain holds almost 90% of the Brazilian bryoflora (Costa *et al*. 2010, Costa & Peralta 2015).

Conservation Units (CU) have great relevance in protecting the biodiversity of forest remnants. The Parque Nacional do Caparaó (PNC) is an important conservation unit located in southeastern Brazil. It includes the third highest peak of the country, the "Pico da Bandeira", rising to 2,892 m above sea level (a.s.l.). Due to its vast extent, the PNC presents a variety of environments and different vegetation compositions, thus possessing great biodiversity that still needs to be discovered and better understood. Furthermore, the park has some waterfalls suitable for swimming, attracting many visitors throughout the year. The last state tourism report, from 2014 to 2017, counted an average of 10,000 visitors per year, with peaks of up to 2,500 visitors per month during high season (Jun-Aug) (ICMBio 2021a; OTE-ES 2018). Therefore, a great ally of conservation is to know the biological diversity of these environments that receive tourists and visitors, as they are as important as the preserved areas.

Even though the Southeast of the country is a well-known and already studied area, there are no published studies related to the bryoflora of the PNC. Only a few records of occasional collections exist (Yano & Peralta 2008, Yano 2010, 2012). For the state of Espírito Santo, scientific works are still scarce and among the most recent we can only mention Costa & Silva (2003) and Yano (2005) in board forests, Silva & Piassi (2010) in restinga, Silva (2011), Silva & Bastos (2012) and Sousa & Faria (2016) and Faria *et al.* (2020) in Ombrophilous Forest. The aim of our study was to carry out a survey of mosses that occur along the PNC visitation trails beginning at the entrance of the Espírito

Santo portion in order to increase the knowledge of the bryophyte flora in the state, of the Atlantic Forest and to contribute to the conservation of ecologically important species, especially threatened ones.

Material and methods

Study site - The Parque Nacional do Caparaó (PNC, figure 1) is located in the Southeast of Brazil along the boundary of the States Minas Gerais and Espírito Santo (20°37' to 20°19'S and 41°43' to 41°55'W). Its territory extends almost 32,000 ha with nearly 80% (the entire eastern portion) of it belonging to the municipalities of Espírito Santo State (ICMBio accessed 06/01/2021a, Coutinho 2015). The Park is entirely immersed in the Atlantic Forest domain with predominance of Dense Mountain Ombrophilous Forest and Dense High Mountain Ombrophilous Forest in the study site (Coutinho 2015). In addition to forests, we can find high elevation grass lands at 1,600 to 1,700 m a.s.l with herbaceous to shrubby vegetation and rocky outcrops (ICMBio accessed 06/01/2021a; Coutinho 2015). The climate is described as tropical in altitude, with average annual temperatures around 19 °C to 22 °C and annual rainfall between 1,000 and 1,500 mm, with higher volumes from November to January (ICMBio accessed 06/01/2021b).

Data collection, identification and analysis - Authorization for the collection of specimens was given by the Instituto Chico Mendes de Conservação da Biodiversidade (number 47090-4). The data collection was carried out during three days in May 2015, along the main access road to the camps and on the trails to some waterfalls. The main road is 9 km long and partially paved, this route can be done by car. We visited the waterfalls “Aurélio” and “Sete pilões” along hiking trails that can be considered narrow and of moderate difficulty, with extensions by 1000 and 210 m, respectively (ICMBio accessed 12/02/2020a). The collection was conducted with the aim to capture the diversity of species at each site, that is, there was no exhaustive search of specimens - species repeated within one site were intentionally not collected again and not abundantly sampled. The plants were collected

manually or with a spatula on all available substrates. In total we collected 125 samples. The samples were stored in paper bags according to the methodology proposed by Yano (1984) also with environmental information such as degree of sun exposure and geographical coordinates. The colonized substrate classification is based on Robbins (1952) with modifications: corticicolous (trunk or living branch), epixilous (trunk, fallen branch or leaves), epiphyllous (upon leaves), rupicolous (upon rocks), terricolous (on soil) and others (e.g. termite mound, anthropized substrates). For identification we used specific literature such as Reese (1993), Sharp *et al.* (1994), Buck (1998), Gradstein *et al.* (2001), Vaz-Imbassahy *et al.* (2008), Peralta & Yano (2010), Costa *et al.* (2010) and Costa (2015). The classification adopted for the mosses in this work is in agreement with Goffinet et al. 2009, except by the Sematophyllaceae family, following Carvalho-Silva *et al.* (2017). Taxa names was checked and corrected using the Tropicos® database (Tropicos 2015). Data of global distribution and of the Brazilian states, as well as the phytogeographic domains are in accordance with the information available in Flora do Brasil 2020 (2021), being verified in the Global Biodiversity Information Facility (Gbif 2021) and Splink (Splink 2021) databases, once the collection information is reliable as, at least, identified by specialist and more than one collected. The information regarding the conservation status and the endemism of the species are in specific literature (Yano & Peralta 2007, Martinelli & Moraes 2013, Flora do Brasil 2020 2021).

We defined four altitudinal zones based on the predominant vegetation type: (I) < 1,500 m a.s.l.; (II) 1,500 to 1,900 m a.s.l.; (III) 1,900 to 2,200 m a.s.l.; (IV) > 2,200 m a.s.l; in order to describe the distribution and richness of families along the sampled sites.

Results

Here, we report 59 species of mosses belonging to 38 genera and 22 families (table 1). Nine species are new occurrences for the state, most notably *Physcomitrium falcifolium* Müll. Hal. ex Broth and *Atractylocarpus brasiliensis* (Müll.Hal.) R.S. Williams which are classified as Vulnerable and Endangered, respectively, in the last red list available for Brazil (Martinelli & Moraes 2013). In the

red list of Espírito Santo (Fraga *et al.* 2019), *Brittonodoxa lithophila* (Hornsch.) W.R. Buck, P.E.A.S.Câmara & Carv.-Silva, *Itatiella ulei* (Broth. ex Müll. Hal.) G.L.Sm. (Yano & Peralta 2007, Fraga *et al.* 2019) and *Schizymenium campylocarpum* (Hook. & W.-Arn.) Shaw are treated as Vulnerable, Vulnerable and Critically Endangered, respectively. The richest families were the Sematophyllaceae (8 species), Leucobryaceae (6spp.), Polytrichaceae and Bryaceae (5 spp.) (figure 2). We found that the most species which is about 53% are unique to the Atlantic Forest and among the others occurrences observed, the most related biome was the Cerrado and Amazon Forest with 37% and 35%, respectively. When considering the global distribution presented by the species, 31% of them have a neotropical, 15% a pantropical, 15% a cosmopolitan distribution, while 24% are endemic to Brazil and the others (15%) have disjunct distributions. Most of our samples were colonizing terricolous substrate (47%) followed by rupicolous ones (28%) (figure 3).

Altitudinal zones II and III exhibited the largest number of families, 12 and 17, respectively (figure 4). Some of the families were only present in one altitudinal zone: Pterobryaceae (1sp) in zone I; Orthotrichaceae (2sp), Calymperaceae and Rhacocarpaceae (1 sp) in zone II; Mniaceae (2 sp), Phyllogoniaceae, Pilotrichaceae and Neckeraceae (1 sp) in zone III; Hedwigiaceae (1 sp) in zone IV. The family Bryaceae was the most common, being present in all zones, but with greater richness in zone III with a total of four species. Below is a diagnostic characterization for endemic and new citations (*), listed in alphabetical order by family.

Bartramiaceae

**Philonotis longiseta* (Michx.) E. Britton, The Bryologist 14(3): 44. 1911.

Figure 6 f

Autoecious plants, tomentose stem, leaves narrow triangular-lanceolate with papillae at the distal extremities of the laminal cell and sporophyte with the long seta. Rupicolous in the Atlantic Forest (montane and high montane) and the Cerrado, formerly recorded in states of BA, CE and RS, as well as in other parts of the Americas.

Brachytheciaceae

Oxyrrhynchium clinocarpum (Taylor) Broth., Die Natürlichen Pflanzenfamilien I (3): 1154. 1909.

Figure 6 e

Stem leaves ovate, acuminate apex, serrate margins; costae strong. Branch leaves distant, erect to wide-spreading, lanceolate to ovate, apex acute to short acuminate. Corticolous, rupicolous and terricolous in the Atlantic Forest, recorded in the states of ES, RJ, PR, RS, SC and SP, as well as throughout the Neotropics.

Bryaceae

**Rhodobryum aubertii* (Schwägr.) Thér., Recueil Publ. Soc. Havraise D'études Diverses 89(2): 128. 1922.

Figure 7 b

Reddish plants, leaves equally spaced, upper crowded, obovate to ovate, serrulate margin toward the apex, bordered by 3-5 rows of long cells, upper cells rombic and basals quadrate; costae percurrent to excurrent. Corticolous, epixilous and terricolous in the Atlantic Forest (lowlands to montane), recorded in the states of BA, MG and RJ, throughout South America and Africa. In this work, we prefer to use the accepted name for the species according to Flora do Brasil 2020 (2021).

Dicranaceae

Aongstroemia julacea (Hook.) Mitt., J. Linn. Soc., Bot. 12: 27. 1869.

Figure 5 a

Slender and small plants, leaves julaceous, concave and ovate-lanceolate to short ovate, with margins crenulate in the upper portion and apex erect. Our samples were found on soil and rocks near to the waterfall, in general occurs as rupicolous in the Atlantic Forest (high montane), recorded in the states of ES, MG and RJ, throughout the tropics.

Ditrichaceae

Cladastomum ulei Müll.Hal., Bull. Herb. Boissier 6: 21. 1898.

Figure 5 f

Leaves distally in cluster, erect above, ovate to oblate-lanceolate; costae short excurrent or ending in an apiculate apex; Easily detached capsula without stomata. Similar to *Crumuscus vitalis* Bück & Snider is differentiated by the presence of julaceous sterile shoots (Schäfer-Verwimp 1996). Our samples were collected in high field, occurs as rupicolous in Atlantic Forest (montane to high montane), recorded in the states of ES, MG, PR, RJ and SC; Brazilian endemic.

Ditrichum crinale (Taylor) Kuntze, Revis. Gen. Pl. 2: 835 1891.

Figure 5 g

Dioecious plants are recognized by erect leaves, base amplectant, justacostal cells weakly to not porose Terricolous in Atlantic Forest (high montane), recorded in the Brazilian states of ES and MG, throughout South America.

**Ditrichum itatiaiae* (Müll.Hal.) Paris, Index Bryol. Suppl. 131. 1900.

Figure 5 h

Long leaves, narrowly acuminate, subulate from an ovate base; thickened laminal cells, basal cells long to retangulate; strong costae, percurrent to excurrent; cylindric capsule strongly sulcate. Terricolous in Atlantic Forest (montane), recorded in states of MG, RJ and SP; Brazilian endemic.

Funariaceae

**Physcomitrium falcifolium* Müll. Hal. ex Broth., Hedwigia 34: 127. 1895.

Figure 6 g

Falcate leaves, lanceolate to linear, apex apiculate, with the upper margin denticulate; long cells at margin and median portion of the lamina. Our samples were found on rocks near to the stream, in general occurs as terricolous in Atlantic Forest (montane), recorded in states of GO, MG, PR, RJ, RS and SP; Vulnerable and Brazilian endemic. This specie was not in the Flora do Brasil 2020 (2021), so we used the Dias, Peralta & Neto (2018) work to complement necessaries information.

Leucobryaceae

**Atractylocarpus brasiliensis* (Müll.Hal.) R.S. Williams, Bryologist 31: 110. 1928.

Figure 5 d

The most distinctive character is the costae excurrent, ridged dorsally and in cross section with stereids in both of sides. The identification of the species depends on the presence of the sporophyte because it is distinguished from others by the exothecial oval cells and peristome teeth with 2-3 teeth split in 2/3. Our samples were found on rocks near to the stream, in general occurs as terricolous in Atlantic Forest (high montane), recorded in the states of BA, RJ, RS and SP Endangered and endemic to Brazil.

Mniaceae

**Schizymenium brevicaule* (Hornsch.) A.J. Shaw & S.P. Churchill, Trop. Bryol. 1: 111. 1989.

Figure 7 c

Long linear leaves, erect to erect-patent, apex acute, upper serrulate margin, smooth cells, linear to fusiform; costae often sub percurrent. Long and pyriform capsule. Our samples were found on rocks and soil as commonly occurs in Atlantic Forest (montane), recorded in the states of RJ, SP and PR; also, throughout Colombia and Bolivia.

Schizymenium campylocarpum (Arn. & Hook.) A.J. Shaw, Bryologist 88: 29. 1985.

Figure 7 d

Leaves erect-patent, oblong-lanceolate, apex acuminate. Distinguished by cylindrically curved capsule, especially when dry or empty; single peristome, with apendiculate at the tips. In our samples were found along the roadside as terricolous, in general occurs as rupicolous in Atlantic Forest (montane), recorded in the state of ES, MG, RJ and RS; cosmopolitan. Critically Endangered in the Espírito Santo State.

Pilotrichaceae

Brymela fluminensis (Hampe) W.R. Buck, Brittonia 39: 217. 1987.

Figure 5 e

Leaves plane, lanceolate to falcate, long acuminate, serrate margin in apical region with simple teeth. Our samples were found in rocks very close to the stream, sometimes submerged, in general occurs as terricolous in Atlantic Forest (sub montane and montane), recorded in the states of ES, PR, RJ, RS and SP. Brazilian endemic.

Polytrichaceae

Itatiella ulei (Broth. ex Müll. Hal.) G.L. Sm., Mem. New York Bot. Gard. 21(3): 52. 1971.

Figure 6 b

Involute leaf margin at the apex, leaves oblong-lanceolate, dentate margin, cells quadrate to hexagonal, smooth and costae percurrent. In transverse section lamellas occupying costae and lamina. According to Peralta & Yano (2010), the species resembles *Pogonatum campylocarpum* (Müll. Hal.) Mitt., but differing by the simple and rhombic lamellae apical cell. Terricolous in Atlantic Forest (montane and high fields), recorded in the states of ES, MG, PR, RJ and SP. Vulnerable in the Espírito Santo State and Brazilian endemic.

Polytrichum angustifolium Mitt., J. Linn. Soc., Bot. 12: 622. 1869.

Figure 6 i

Leaves rigid, imbricate when dry and erect when moist, lanceolate-linear, acuminate. Characterized by pyriform and smooth apical lamellae cell, Peralta and Yano (2010) consider this plant the biggest species in the family. Terricolous in Atlantic Forest (montane) and Pampa, recorded in the states of BA, ES, MG, PR, RJ, RS, SC and SP; Brazilian endemic.

Pottiaceae

**Leptodontium filicola* Herzog., Biblioth. Bot. 87: 34. 9 f. 2. 1916.

Figure 6 c

Leaves incurvate, oblong-lanceolate and denticulate margin, papillose cells with papilla on the lumen. Corticolous, rupicolous and terricolous in Atlantic Forest, recorded in the states of MG, RJ, RS and SC. Vulnerable in Atlantic Forest occurs throughout Tropical America.

Leptodontium stellatifolium (Hampe) Broth., Nat. Pflanzenfam. I (3): 400. 1902.

Figure 6 d

Plants yellowish to golden, leaves crowded, oblong-lanceolate to lingulate, apex short-acuminate to apiculate, crenulate margin; inner basal cells reddish-yellow; costae percurrent. This species was frequent in the study's high elevation grasslands. Rupicolous and terricolous in Atlantic Forest, recorded in the states of ES, MG, RJ, SP and SC; Brazilian endemic.

Rhacocarpaceae

Rhacocarpus inermis (Müll.Hal.) Broth., Acta Soc. Sci. Fenn. 19(5): 22 1891.

Figure 7 a

Robust plants with oblong-lanceolate leaves, apex short acute or cuspidate, margin unbordered and entire. Our samples were found as rupicolous in a humid environment. Occurs throughout the Atlantic Forest (montane and high montane) recorded in the states of ES, MG, RJ, RS and SC. Brazilian endemic.

Sematophyllaceae

Aptychopsis estrellae (Müll. Hal.) P.E.A.S. Câmara, W.R. Buck & Carv.-Silva, J. Bryol. 37(4): 289. 2015.

Figure 5 b

Long, narrowly lanceolate and recurved leaves, gradually acuminate; 2-3 oblong-inflated alar cells obliquely arranged. Corticicolous and - in our samples - rupicolous, in Atlantic Forest, recorded in the states of AL, BA, CE, DF, ES, GO, MG, MT, PA, PE, PR, RJ, RS, SC and SP. Brazilian endemic.

Aptychopsis pyrrhophylla (Müll.Hal.) Wijk & Margad., Taxon 8: 71. 1959.

Figure 5 c

Asymmetrics to falcates leaves when dry, stem leaves ovate or oblong-lanceolate; branch leaves lanceolate, apex cuspidate; inflated alar cells and 2-3 rows of supra-alar cells. Our samples were found on rocks exposed to the sun in an open environment, in general, occurs as corticolous and epixilous in Atlantic Forest common in high altitudes, recorded in the states of AM, BA, ES, MG, PR, RJ, SC AND SP. Brazilian endemic.

**Donnellia lagenifera* (Mitt.) W.R. Buck, Bryologist 91: 134. 1988.

Figure 6 a

Squarrose to erect-patent leaves, concave at the base, ovate from a larger base, smaller cells on the upper laminal, supra-alar cells larger than alar cells. Capsules often sub erect and bigger than *D. commutata* (Müll.Hal.) W.R. Buck as described by Buck (1994). Corticolous in Amazon Forest and Atlantic Forest, recorded in the states of PA, MG, RJ, RS, SC and SP; throughout the Neotropics.

Vitalia galipensis (Müll. Hal.) P.E.A.S. Câmara, Carv.-Silva & W.R. Buck, Taxon 66(4): 825. 2017.

Figure 7 f

Recognized by erect to expanded leaves, oblong to oblong-lanceolate, strongly concave, apex long acuminate, apical cells longer, alar and supra-alar cells larger. Our samples were found in rocks near to the stream. Terricolous, corticolous and rupicolous in Amazon Forest, Atlantic Forest and Cerrado, recorded in the states of BA, DF, ES, GO, MG, MT, MS, PA, PE, PR, RJ, RO, RR, RS, SC, SP and TO. Brazilian endemic. Despite the nomenclatural conflict existing in Flora do Brasil 2020 (2021), *V. galipense* is homotypic synonym for *Sematophyllum galipense* (Müll.Hal.) Mitt., based on Carvalho-Silva et al. (2017).

**Trichosteleum glaziovii* (Hampe) W.R. Buck, Nova Hedwigia 66: 243.1998.

Figure 7 e

Distinguished by lanceolate and strongly falcate leaves, denticulate margin, inflated alar cells slightly oblique arranged, conspicuous or almost imperceptible papillae in the leaf cells. Coticicolous and epixilous in Atlantic Forest, recorded in the states of MG, PE, PR, RJ, RS, SC and SP; Brazilian endemic.

Discussion

The diversity recently recorded for the state of Espírito Santo is 492 bryophyte species (486, Costa & Peralta 2015), out of which 263 are mosses (Flora do Brasil 2020,2021). However, Yano (2012) cataloged for the state 531 taxa of which 286 are mosses, distributed in 134 genera and 50 families. Despite the significant decrease in the number of species, which may come from synonymous taxa or misidentifications, our state remains among the 10 richest states in the country (Costa & Peralta 2015, Flora do Brasil 2020 2021). Over the years, studies conducted in the state have demonstrated the bryoflora's biodiversity potential, for example: Peralta & Yano (2011) have listed 89 moss species in the Mello Leitão Museum herbarium and 21 new records for the state. Silva (2011) found 126 moss species, with 35 new occurrences in Dense Montane and Upper Montane Ombrophylous Forest. Yano (2016) listed 67 moss taxa in the state "Tabuleiro" Forests, with 15 new occurrences. And recently,

Faria *et al.* (2020) published a work carried out in an Ombrophylous Forest, reporting 102 moss species with 33 species as new occurrences. In this study, we found almost 1/4 of the recorded moss diversity for Espírito Santo State (Flora do Brasil 2020 2021) as well as 9 new citations.

Regarding the observed families, Gradstein *et al.* (2001) describe that Sematophyllaceae, Leucobryaceae and Bryaceae are among the richest families in the Neotropics, also in Brazil and in the Atlantic Forest corroborated by Costa & Peralta (2015) Sematophyllaceae is quite common in the Atlantic Forest (Silva Rodrigues & Valente 2015, Silva 2012, Valente *et al*. 2009, Costa & Lima 2005) and is considered the fifth richest family in Brazil as well as Bryaceae. The Leucobryaceae family has a wide distribution in the globe and is commonly found in open environments in montane rain forests, especially the genus *Campylopus* (Gradstein *et al.* 2001), that have adaptations to luminosity and desiccation, such as hyalocysts (hyaline cells) and hair points (Glime 2007). In fact, there is a great diversity of bryophytes registered in the Atlantic Forest, mainly in montane environments.

The composition of bryoflora in our work proved to be more related to that occurring in the Cerrado and in the Amazon Forest. Between the two biomes, the Cerrado is the closest to the Atlantic Forest, however, the Amazon Forest is the second richest biome in the country (Costa & Peralta 2015, Flora do Brasil 2020 2021), it also has great affinity with the flora observed in the Atlantic Forest, since they have an evolutionary historical relationship. Many listed taxa, with the exception of the exclusive ones, has distribution both in the Cerrado and in the Amazon Forest. Corroborating with other studies carried out in the state, such as Sousa & Faria (2016) and Faria *et al.* (2020).

A large number of species (46%) was recorded occurring on terricolous substrate, in fact, it is common to find bryophytes colonizing along the roadside with increasing altitude (Frahm 2003) and even with the increased occurrence of exposed rocks. Even though our collections were carried out mainly along partially open trails, we find a diversity of habitats along these paths providing us with a considerable representativeness of species, including diverse substrates.

Corroborating this, we found greater diversity of mosses and a higher number of families exclusive to one altitudinal zone between 1,500m - 2,100m altitude. As also observed in others remains of the Atlantic Forest, such as in Rio de Janeiro (Costa & Lima 2005), in the Serra de Ibitipoca (Siviero 2010), an area in transition with the Cerrado, in the Serra do Cipó (Yano & Peralta 2011) and in the north of São Paulo (Visnadi 2005). The diversity of microhabitats and microclimates found in these areas favors the establishment of a high richness of bryophytes (Costa & Lima 2005). Therefore, studies such as this one must be continued in this domain, especially in the Espírito Santo State, which has a diversity of environments still unexplored. The importance of the data for the state is demonstrated in the high number of new records and the connected expansion in knowledge for the group. In the case of the PNC, it is urgent to survey the liverworts, which, like mosses, will certainly demonstrate a considerable taxonomic richness. Also, taxonomic revision studies, species list or new occurrences reports should be continuous and frequently updated. In this way, we will be able to pave the way for new issues and thus contribute to the group's knowledge and consequently strengthen the preservation of the Atlantic Forest and its remnants.

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Author Contributions

Thamara Arão Feletti: Contribution to collected the data; Contribution to the identifications of specimes; Contribution to data analysis and interpretation; Contribution to manuscript preparation and wrote.

Denilson Fernandes Peralta: Substancial contribution to manuscript wrote; Substancial contribution to identifications; Contribution to critical revision.

Juliana Rosa do Pará Marques de Oliveira: Contribution to collected the data; Substancial contribution to manuscript preparation; Substancial contribution to identifications; Contribution to critical revision.

Conflicts of interest

There is no conflict of interest.

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Table 1: Mosses list from the Parque Nacional de Caparaó main visitations trails, Espírito Santo State, Brazil. Subs.: substrate. TE: terricolous. RU: rupicolous. CO: corticicolous. EX: epixilous. Phyt. Dom.: Phytogeographic Domain. AF: Atlantic Forest. AM: Amazon Forest. CA: Caatinga. CE: Cerrado. PM: Pampa. PN: Pantanal. Dist.: Brazilian Distribution.

Taxon	Subs.	Phyt. Dom.	Dist.	Voucher
Bartramiaceae				
Breutelia subdisticha (Hampe) A. Jaeger	TE	AF	ES, MG, PR, RJ, RS, SC, SP	MLF 19 (CAP 5927) MLF 21 (CAP 5929)
Breutelia tomentosa (Sw. ex Brid.) A. Jaeger	RU, TE	AF	BA, ES, MG, RS, SP, SC	MLF 52 (CAP 5960) MLF 111 (CAP 6019)
* *Philonotis longiseta* (Michx.) E. Britton	RU	AF	BA, CE, RS	MLF 92 (CAP 6000)
Brachytheciaceae				
Meteoridium remotifolium (Müll. Hal.) Manuel	CO, RU	AF, AM, CE	AL, BA, ES, GO, MG, MT, RR, PB, PE, PR, RJ, RS, SP, SC	MLF 107 (CAP 6015) MLF 116 (CAP 6024) MLF 122 (CAP 6030)
Oxyrrhynchium clinocarpum (Taylor) Broth.	TE	AF	ES, RJ, PR, RS, SC, SP	MLF 120 (CAP 6028)
Squamidium brasiliense (Hornsch.) Broth.	CO	AF, AM, CE	AL, BA, ES, MG, PR, PE, RJ, RS, SC, SP	MLF 62 (CAP 5970)
Squamidium leucotrichum (Taylor) Broth.	CO, RU	AF	AC, AM, AL, BA, CE, ES, MG, PA, PE, RJ, RO, RR, PR, RS, SC, SP	MLF 65 (CAP 5973) MLF 118 (CAP 6026)
Bryaceae				
Bryum argenteum Broth.	RU	AF, AM, CA, CE, PM	AM, AL, BA, ES MA, MG, PA, PE, PB, PR, RJ, RS, SC, SP, TO	MLF 10 (CAP 5918)
Bryum densifolium Brid.	TE	AF, AM, CA, CE, PM	BA, ES, MG, MT, PE, PR, RJ, RS, SC, SE, SP	MLF 119 (CAP 6027)
* *Rhodobryum auberti* (Schwägr.) Thér.	TE	AF	BA, MG, RJ	MLF 43 (CAP 5951)
Rhodobryum beyrichnianum (Hornsch.) Müll. Hal.	TE	AF, AM, CE	BA, DF, ES, GO, MG, MT, RJ, PE, PR, RO, RR, RS, SC, SP	MLF 20 (CAP 5928) MLF 22 (CAP 5930) MLF 54 (CAP 5962)
Calymperaceae				
Syrrhopodon gaudichaudii Mont.	CO	AF, AM, CA, CE, PN	AM, AP, BA, DF, ES, GO, MA, MG, MT, MS, PA, PE, PR, RJ, RR, RS, SE, SC, SP, TO	MLF 94 (CAP 6002)
Dicranaceae				
Aongstroemia julacea (Hook.) Mitt.	RU, TE	AF	ES, MG, RJ	MLF 114 (CAP 6022) MLF 8 (CAP 5916)
Cladastomum ulei Müll. Hal.	TE	AF	ES, MG, PR, RJ, SC	ATS 05 (CAP 6038) ATS 06 (CAP 6039)
Ditrichum crinale (Taylor) Kuntze	TE	AF	ES, MG	MLF 16 (CAP 5924) MLF 17 (CAP 5925)
* *Ditrichum itatiaiae* (Müll.Hal.) Paris	TE	AF	MG, RJ, SP	MLF 23 (CAP 5931)
Funariaceae				
* *Physcomitrium falcifolium* Müll. Hal. ex Broth.	RU	AF	GO, MG, PR, RJ, RS, SP	MLF 36 (CAP 5944)

Taxon	Subs.	Phyt. Dom.	Dist.	Voucher
Hedwidiaceae				
Hedwigidium integrifolium (P. Beauv.) Dixon	TE, EX	AF	ES, MG, PE, PR, RJ, RS, SC, SP	ATS 02 (CAP 6035) ATS 03 (CAP 6036)
Hypnaceae				
Isopterygium tenerifolium Mitt.	TE	AF	AM, BA, CE, DF, GO, MG, MT, PA, PR, RJ, RO, RS, SC, SP	MLF 55 (CAP 5963)
Isopterygium tenerum (Sw.) Mitt.	TE	AF, AM, CA, CE, PM, PN	AC, AM, BA, CE, DF, ES, GO, MA, MG, MS, MT, PA, PB, PE, PI, PR, RJ, RO, RR, RS, SC, SP, TO	MLF 120 (CAP 6028)
Chryso-hypnum elegantulum (Hook.) Hampe	RU	AF, AM, CA, CE, PN	AC, AM, AP, BA, DF, ES, GO, MG, MS, MT, PE, PR, RJ, RO, RR, RS, SC, SP	MLF 113 (CAP 6021)
Lembophyllaceae				
Pilotrichella flexilis (Hedw.) Ångström	CO, EX	AF, AM, CE, PN	AP, BA, ES, MG, MT, MS, PE, PR, RJ, RS, SC, SP	MLF 33 (CAP 5941) MLF 53 (CAP 5961) MLF 37 (CAP 5945) MLF 71 (CAP 5979) MLF 106 (CAP 6014)
Leucobryaceae				
* *Atractylocarpus brasiliensis* (Müll.Hal.) R.S. Williams	RU	AF	BA, RJ, RS, SP	MLF 40 (CAP 5948)
Campylopus arctocarpus (Hornsch.) Mitt.	CO	AF, CA, CE, PM	AM, BA, ES, GO, MG, MT, PE, PI, PR, RJ, RS, SC, SP	MLF 97 (CAP 6005)
Campylopus fragilis (Brid.) Bruch & Schimp.	RU, TE	AF	BA, ES, MG, RJ, RS	MLF 05 (CAP 5913) MLF 59 (CAP 5967)
Campylopus lamellinervis (Müll.Hal.) Mitt.	RU	AF, CA, PM	BA, ES, MG, PE, PI, PR, RJ, RS, SC, SP	MLF 83 (CAP 5991)
Campylopus occultus Mitt.	TE	AF, AM, CE, PM, PN	AP, BA, GO, DF, ES, MA, MG, MT, MS, PA, PE, PR, RJ, RR, RS, SC, SP	MLF 02 (CAP 5910) MLF 13 (CAP 5921) MLF 15 (CAP 5923) MLF 60 (CAP 5968)
Campylopus pilifer Brid.	TE	AF, AM, CA, CE, PM	AM, PA, RR, AL, BA, CE, PE, DF, MT, ES, RJ, MG, SP, PR, RS	MLF 07 (CAP 5915) MLF 08 (CAP 5916) MLF 25 (CAP 5926) MLF 26 (CAP 5927) ATS 04 (CAP 6037)
Pilopogon guadalupensis (Brid.) J.-P.Frahm	TE	AF	BA, ES, MG, PR, RJ, RS, SC, SP	MLF 58 (CAP 5966)
Mniaceae				
Plagiomnium rhynchophorum (Hook.) T.J.Kop.	RU	AF, AM, CE	AP, ES, GO, MG, PR, RJ, RS, SC, SP	MLF 115 (CAP 6023)
* *Schizymenium brevicaule* (Hornsch.) A.J. Shaw & S.P.Churchill	TE, RU	AF	RJ, SC, SP	MLF 04 (CAP 5912) MLF 46 (CAP 5954)
Schizymenium campylocarpum (Arn. & Hook.) Shaw	TE	AF	ES, MG, RJ, RS	MLF 03 (CAP 5911) MLF 33 (CAP 5941)
Neckeraceae				
Thamnobryum fasciculatum (Hedw.) I.Sastre	CO	AF	ES, MG, PR, RJ, RS, SC, SP	MLF 37 (CAP 5945)
Orthotricaceae				

Taxon	Subs.	Phyt. Dom.	Dist.	Voucher
Macromitrium cirrosum (Hedw.) Brid.	CO	AF, AM	AM, AP, BA, CE, DF, ES, GO, MG, PA, PR, RJ, RS, SC, SP	MLF 96 (CAP 6004) MLF 105 (6013)
Macromitrium podocarpi Müll. Hal.	CO	AF, AM, CE	AC, AM, BA, CE, ES, MG, MT, PA, PE, RJ, PR, RO, RR, SE, SP	MLF 63 (CAP 5971)
Phyllogoniaceae				
Phyllogonium viridae Brid.	CO	AF	AL, BA, CE, ES, MG, MT, PE, PR, RJ, RS, SC, SP	MLF 37 (CAP 5945)
Pilotrichaceae				
Brymela fluminensis (Hampe) W.R. Buck	RU	AF	ES, PR, RJ, RS, SP	MLF 38(CAP 5946)
Polytrichaceae				
Itatiella ulei (Broth. ex Müll. Hal.) G.L.Sm.	TE	AF	ES, MG, PR, RJ, SP	MLF 117 (CAP 6025) ATS 06 (CAP 6039)
Polytrichadelphus pseudopolytrichum (Raddi) G.L.Sm.	TE	AF	ES, MG, RJ, PR, RS, SC, SP	MLF 12 (CAP 5920)
Polytrichum juniperinum Willd. ex Hedw.	TE, RU	AF, AM, CE	BA, DF, ES, GO, MG, PR, RJ, RO, RR, RS, SC, SP, TO	MLF 44 (CAP 5952) ATS 01 (CAP 6034)
Polytrichum commune L. ex Hedw.	TE	AF, AM, CA, CE, PM	AM, BA, DF, ES, GO, MG, PR, RJ, RO, RR, RS, SC, SP	MLF 33 (CAP 5941) ATS 06 (CAP 6039)
Polytrichum angustifolium Mitt.	TE	AF, PM	BA, ES, MG, PR, RJ, RS, SC, SP	MLF 24 (CAP 5932)
Pottiaceae				
* *Leptodontium filicola* Herzog.	TE	AF	MG, RJ, RS, SC	MLF 14 (CAP 5922) MLF 28 (CAP 5936)
Leptodontium viticulosoides (P. Beauv.) Wijk & Margad.	TE, CO	AF	BA, ES, MG, PE, PR, RJ, RS, SC, SP	MLF 51 (CAP 5959) MLF 53 (CAP 5961)
Leptodontium stellatifolium (Hampe) Broth.	RU	AF	ES, MG, RJ, SC, SP	ATS 07 (CAP 6040)
Tortella humilis (Hedw.) Jenn.	RU	AF, CA, CE, PM, PN	BA, DF, ES, GO, MA, MG, MS, PE, PR, RJ, RS, SC, SP	MLF 10 (CAP 5918) MLF 118 (CAP 6026)
Prionodontaceae				
Prionodon densus (Hedw.) Müll.Hal.	CO	AF, PM	ES, MG, PR, RJ, RS, SC, SP	MLF 116 (CAP 6024)
Rhacocarpaceae				
Rhacocarpus inermis (Müll.Hal.) Lindb.	TE, RU	AF	ES, MG, RJ, RS, SC	MLF 87 (CAP 5995) MLF 89 (CAP 5997) MLF 91 (CAP 5999)
Sematophyllaceae				
Aptychopsis estrellae (Hornsch.) Ångström	RU, CO	AF	AL, BA, CE, DF, ES, GO, MG, MT, PA, PE, PR, RJ, RS, SC, SP	MLF 98 (CAP 6006) MLF 102 (CAP 6010) MLF 41 (CAP 5949)
Aptychopsis pyrrhophylla (Müll.Hal.) Wijk & Margad.	RU	AF	AM, BA, ES, MG, PR, RJ, SC, SP	MLF 85 (CAP 5993)
Brittonodoxa lithophila (Hornsch.) W.R. Buck, P.E.A.S.Câmara & Carv.-Silva	RU	AF, AM, CE	ES, MT, MG, PR, RJ, RS, SP	MLF 36 (CAP 5944)
Brittonodoxa subpinnata (Brid.) W.R. Buck, P.E.A.S.Câmara & Carv.-Silva	RU	AF, AM, CA, CE, PN, PM	AC, AL, AM, AP, BA, CE, DF, ES, GO, MA, MG, MS, MT, PA, PB, PE,	MLF 41 (CAP 5949)

Taxon	Subs.	Phyt. Dom.	Dist.	Voucher
* *Donnellia lagenifera* (Müll.Hal.) W.R. Buck	CO	AF, AM	PR, RJ, RO, RR, RS, SC, SP, TO MG, PA, RJ, RS, SC, SP	MLF 45 (CAP 5953)
Sematophyllum swartzii (Schwägr.) W.H.Welch & H.A.Crum	CO	AF	BA, ES, MG, RJ, RS, SC, SP	MLF 77 (CAP 5985)
* *Trichosteleum glaziovii* W.R. Buck	EX	AF	MG, RJ, PE, PR, RS, SC, SP	MLF 93 (CAP 6001)
Vitalia galipensis (Müll. Hal.) P.E.A.S.Câmara, Carv.-Silva & W.R. Buck	RU	AF, AM, CE	BA, DF, ES, GO, MG, MT, MS, PA, PE, PR, RJ, RO, RR, RS, SC, SP, TO	MLF 39 (CAP 5947) MLF 89 (CAP 5997)
Sphagnaceae				
Sphagnum aciphyllum Müll. Hal.	TE	AF, PM	BA, ES, MG, PR, RJ, RS, SC, SP	MLF 30 (CAP 5938) MLF (CAP 5951)
Thuidiaceae				
Thuidium delicatulum (Hedw.) Schimp.	TE, CO, EX	AF, AM, CE	AM, BA, ES, GO, MG, MT, PA, PR, RJ, RS, SC, SP	MLF 43 (CAP 5951) MLF 105 (CAP 6013) MLF 107 (CAP 6015) MLF 108 (CAP 6016)
Thuidium tomentosum Schimp.	TE	AF, AM, CE, PN	AL, AM, BA, ES, GO, MG, MS, MT, PA, PE, PR, RJ, RO, RR, RS, SC, SP	MLF 42 (CAP 5950)

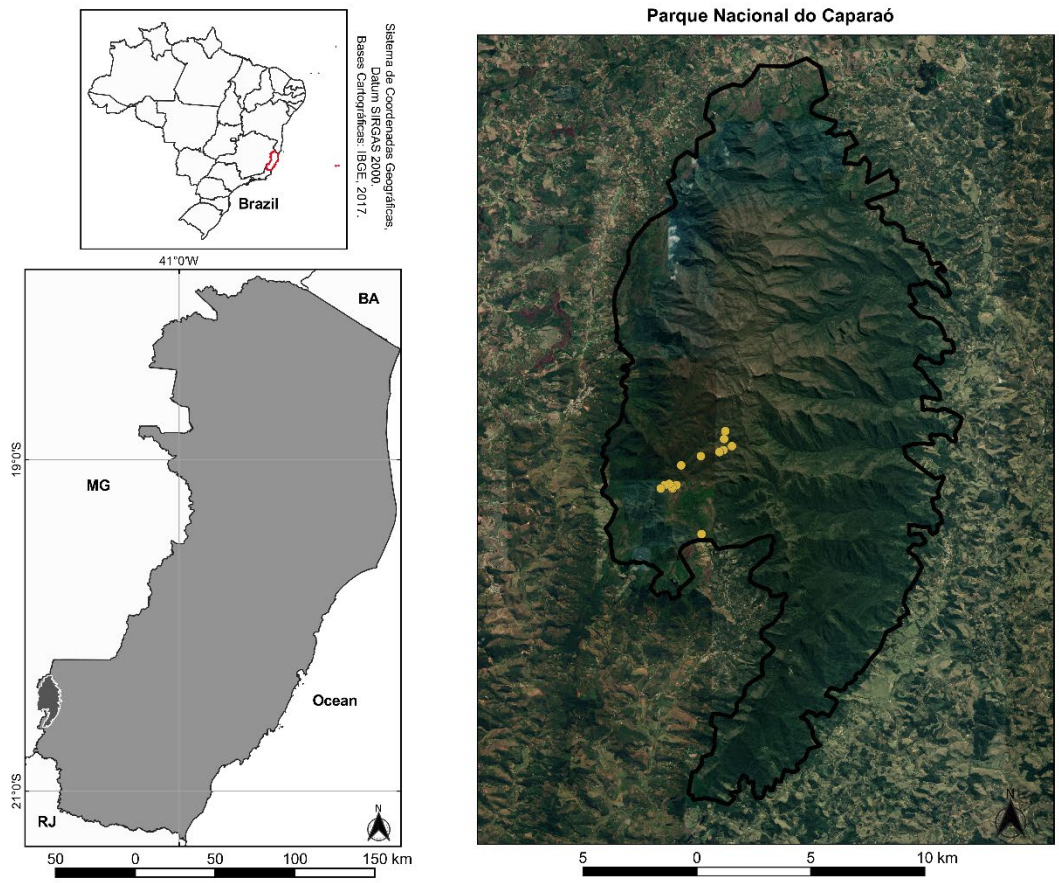

Figure 1. Localization map of the Parque Nacional do Caparaó, Espírito Santo State, Brazil.

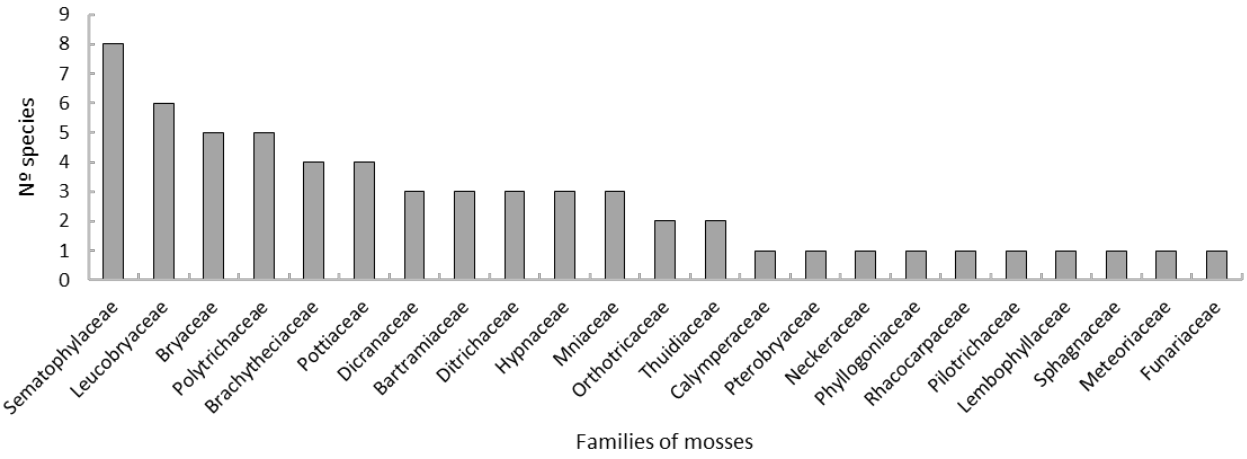

Figure 2. Richness families occurring in the Parque Nacional do Caparaó, Espírito Santo State, Brazil.

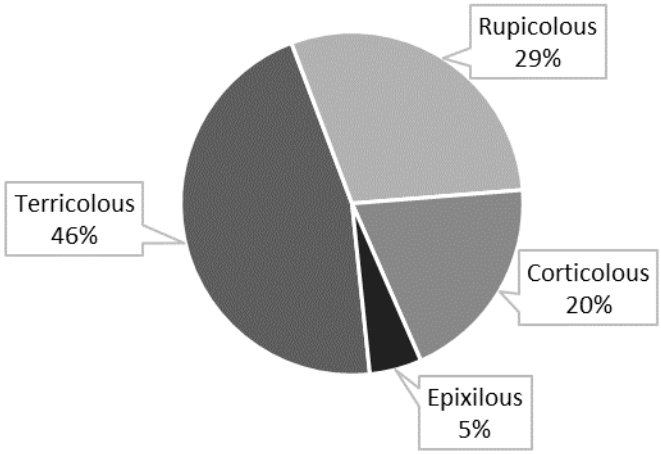

Figure 3. Percentage of substrates colonized by moss species occurring in the Parque Nacional do Caparaó, Espírito Santo State, Brazil.

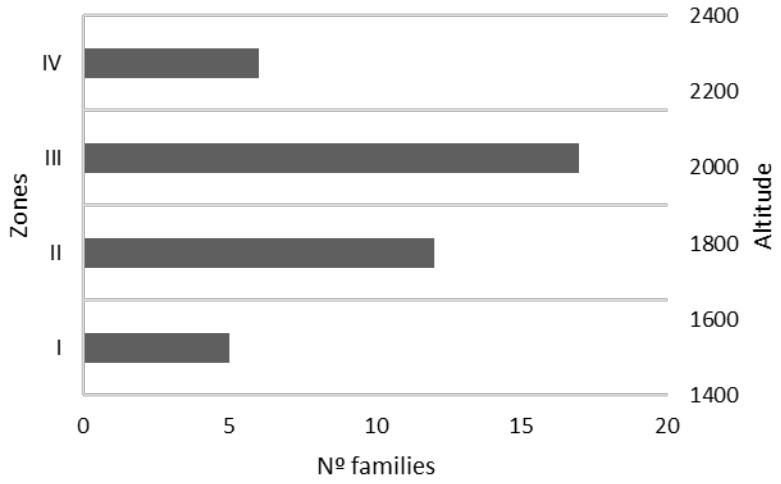

Figure 4. Richness of mosses families in four altitudinal zones in the Parque Nacional do Caparaó, Espírito Santo State, Brazil.

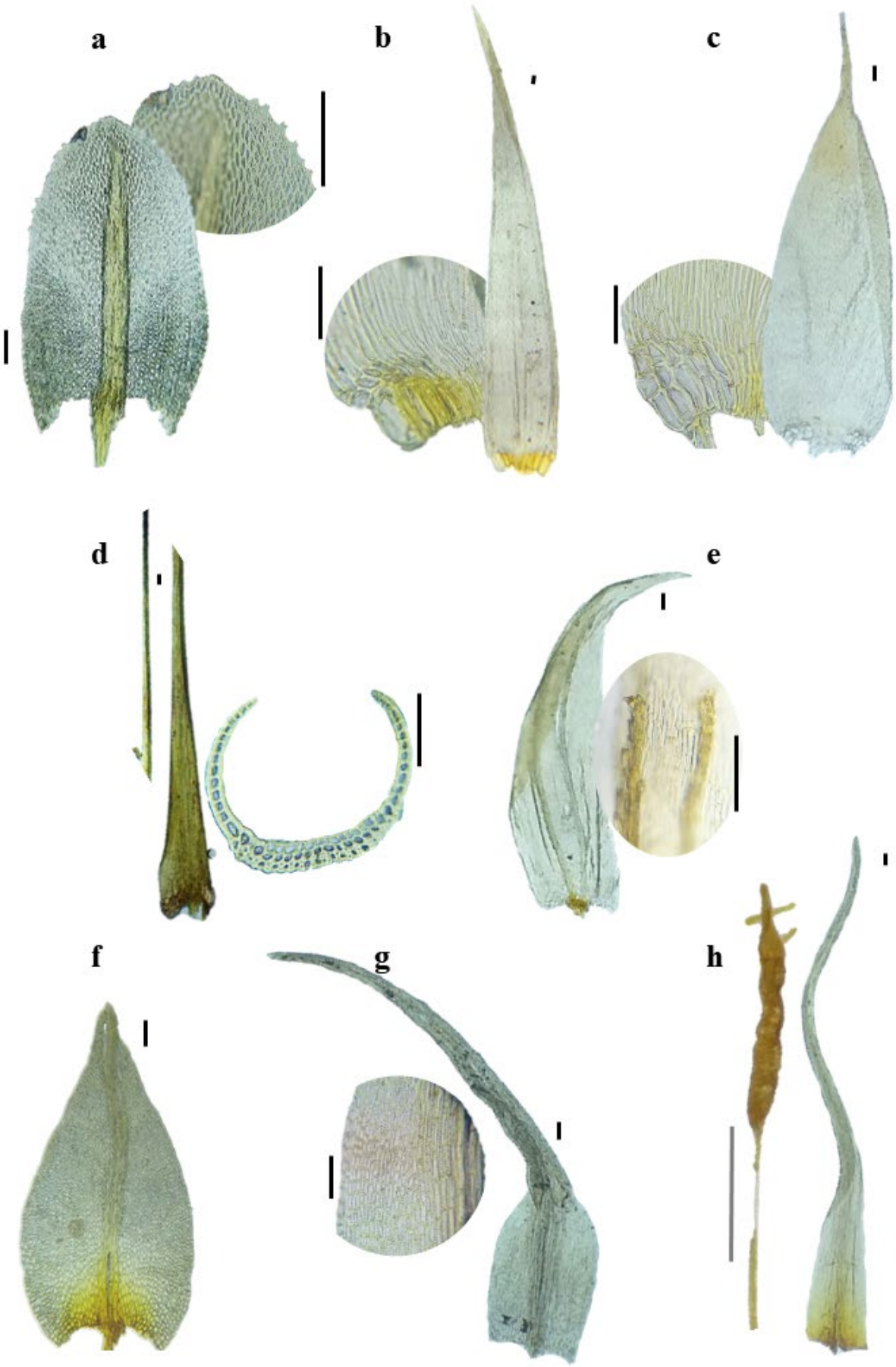

Figure 5. Mosses (Bryophyta) in the Parque Nacional de Caparaó, Espírito Santo State, Brazil. a. *Aongstroemia julacea* (Hook.) Mitt. b. *Aptychopsis estrellae* (Hornsch.) Ångström. c. *Aptychopsis pyrrhophylla* (Müll.Hal.) Wijk & Margad. d. *Atractylocarpus brasiliensis* (Müll.Hal.) R.S. Williams. e. *Brymela fluminensis* (Hampe) W.R. Buck. f. *Cladastomum ulei* Müll. Hal. g. *Ditrichum crinale* (Taylor) Kuntze. h. *Ditrichum itatiaiae* (Müll.Hal.) Paris. Black scale: 200um. Gray scale: 1cm. (a. Fornazier 114. b. Fornazier 98. c. Fornazier 85. d. Fornazier 40. e. Fornazier 38. f. Da Silva 06. g. Fornazier 16. h. Fornazier 23).

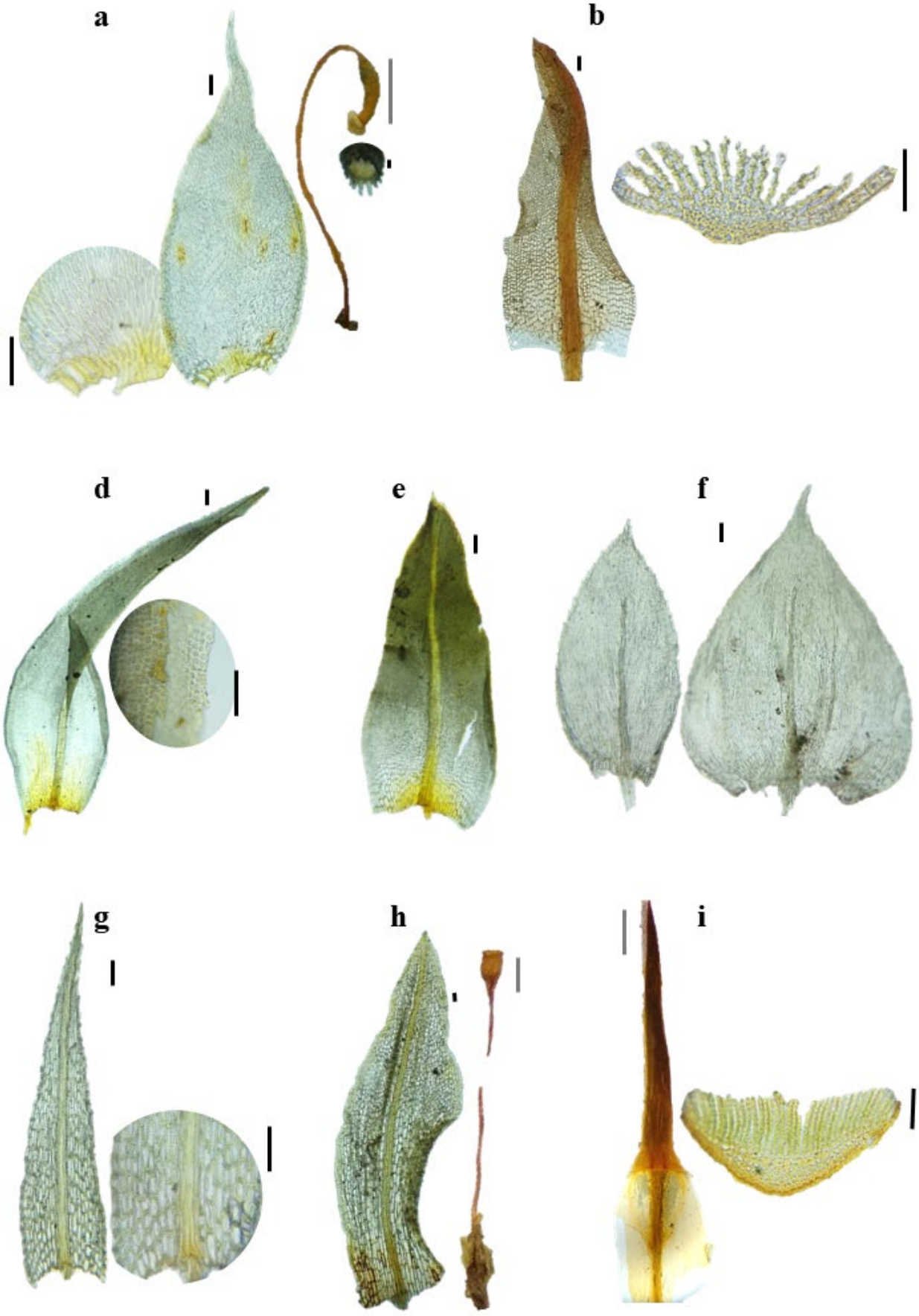

Figure 6. Mosses (Bryophyta) in the Parque Nacional de Caparaó, Espírito Santo State, Brazil. a. *Donnellia lagenifera* (Müll.Hal.) W.R. Buck. b. *Itatiella ulei* (Broth. ex Müll. Hal.) G.L.Sm. c. *Leptodontium filicola* Herzog. d. *Leptodontium stellatifolium* (Hampe) Broth. e. *Oxyrrhynchium clinocarpum* (Taylor) Broth. f. *Philonotis longiseta* (Michx.) E. Britton. g. *Physcomitrium falcifolium* Müll. Hal. ex Broth. i. *Polytrichum angustifolium* Mitt. Black scale: 200um. Gray scale: 1cm. Black scale: 200um. Gray scale: 1cm. (a. Fornazier 45. b. Da Silva 06. c. Fornazier 28. d. Da Silva 07. f. Fornazier 120. g. Fornazier 92. h. Fornazier 36. i. Fornazier 24).

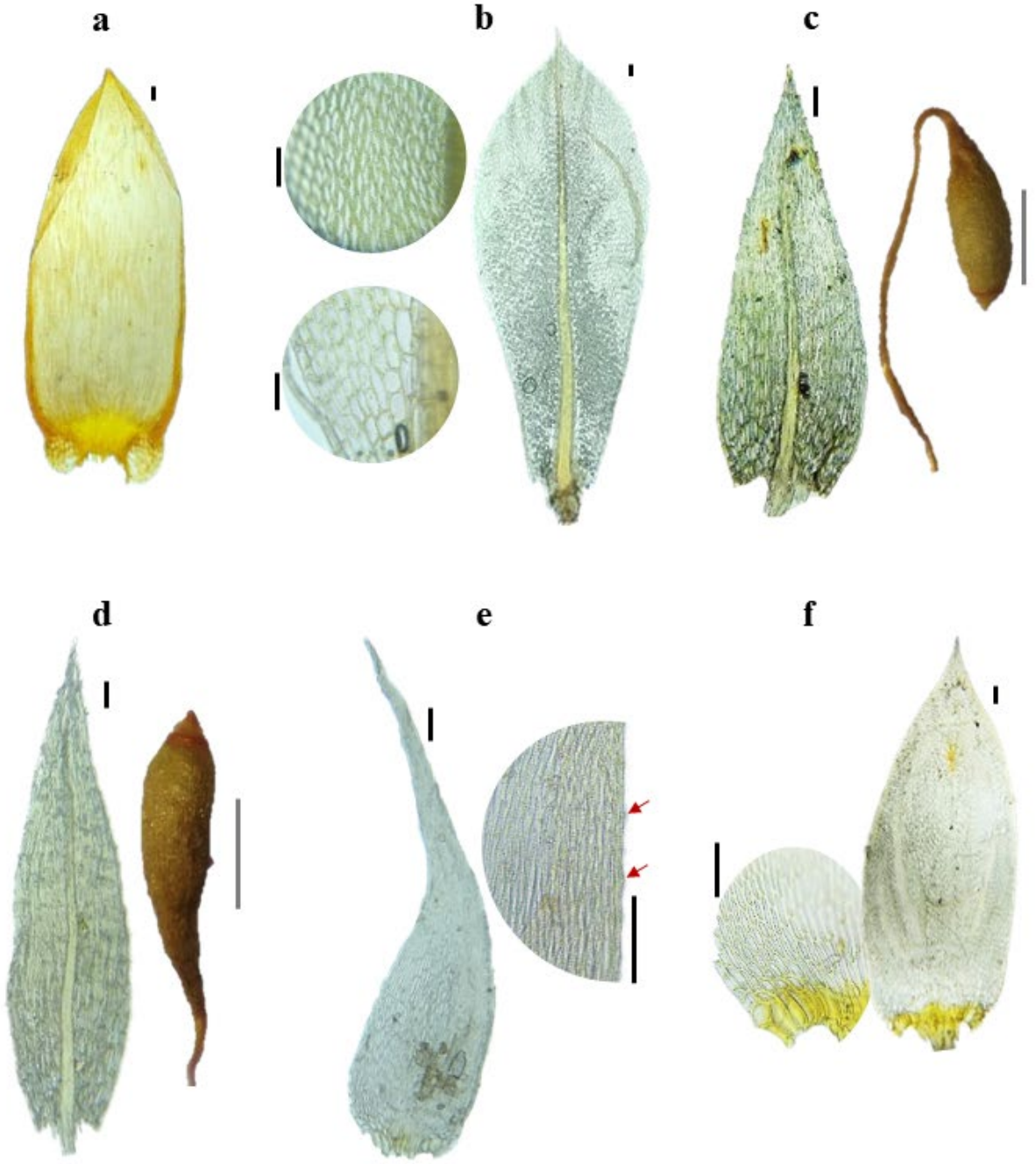

Figure 7. Mosses (Bryophyta) in the Parque Nacional de Caparaó, Espírito Santo State, Brazil. a. *Rhacocarpus inermis* (Müll.Hal.) Lindb. b. *Rhodobryum aubertii* (Schwägr.) Thér. c. *Schizymenium brevicaule* (Hornsch.) A.J. Shaw & S.P.Churchill. d. *Schizymenium campylocarpum* (Arn. & Hook.) Shaw. e. *Trichostelium glaziovii* W.R. Buck. f. *Vitalia galipensis* (Müll. Hal.) P.E.A.S.Câmara, Carv.-Silva & W.R. Buck. Black scale: 200um. Gray scale: 1cm. (a. Fornazier 89. b. Fornazier 43. c. Fornazier 46. d. Fornazier 03. e. Fornazier 93. f. Fornazier 89).

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