



## Angiosperms from rocky outcrops of Pedra do Elefante, Nova Venécia, Espírito Santo, Brazil

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### Abstract

We provide a floristic inventory of Angiosperms from rocky outcrops of the Área de Proteção Ambiental Pedra do Elefante, Espírito Santo, Brazil. Fieldwork was performed monthly from March/2015 to July/2016. A checklist with 302 species belonging to 219 genera and 74 families is provided. Bromeliaceae, Orchidaceae, Fabaceae, Euphorbiaceae, Apocynaceae, Asteraceae, Cactaceae, Convolvulaceae, Rubiaceae, Bignoniaceae and Cyperaceae are the richest families with around 50% of the listed species. One hundred forty seven species are exclusively rupicolous, 125 spp. exclusively terricolous, 26 spp. are epiphytes, and six species are found as both rupicolous and terricolous. Phanerophytes and chamaephytes were predominant life forms. Our results added 18 new records to the Espírito Santo state, indicated the occurrence of nine endemic species for the state and noticed that only 55 taxa of the total of species have threat assessments according to IUCN.

**Key words:** Atlantic rainforest, floristic inventories, inselberg, neotropics.

### Resumo

O objetivo deste trabalho foi realizar o inventário florístico das Angiospermas dos afloramentos rochosos da Área de Proteção Ambiental Pedra do Elefante, Espírito Santo, Brasil. Expedições de coleta foram realizadas mensalmente de março/2015 a julho/2016. Um total de 302 espécies pertencentes a 219 gêneros e 74 famílias foram encontradas. Bromeliaceae, Orchidaceae, Fabaceae, Euphorbiaceae, Apocynaceae, Asteraceae, Cactaceae, Convolvulaceae, Rubiaceae, Bignoniaceae e Cyperaceae são as famílias mais ricas com cerca de 50% de representatividade das espécies listadas. Os táxons exclusivamente rupícolas são representados por 147 espécies enquanto 125 spp. São exclusivamente terrícolas, 26 spp. são epífitas e seis espécies são encontradas como tanto como rupícolas quanto terrícolas. As formas de vida predominantes foram fanerófitas e as caméfitas. Nossos resultados adicionaram 18 novos registros ao estado do Espírito Santo, indicaram a ocorrência de nove espécies endêmicas para o estado e indicam que apenas 55 táxons do total de espécies encontradas possuem avaliações de quanto às categorias de ameaça de acordo com a IUCN.

**Palavras-chave:** Mata Atlântica, inventário florístico, afloramentos rochosos, neotrópicos.

### Introduction

Rocky outcrops can be found mainly in tropical and subtropical regions of the world (Barthlott *et al.* 1993). Due to peculiarities in the floristic composition, they turned into spotlights in different parts of the world (Hurault 1963; Ibisch *et al.* 1995; Meirelles *et al.* 1999; Porembski *et al.* 1997). They are constituted by granite and/or gneiss composition, and are a remarkable component in the landscapes (Porembski & Barthlott 2000). The lack of continuous soil coverage is an important factor

that induces environmental conditions such as high rates of sun exposition and evaporation, leading to specific adjustments and thereby generating a very distinct species composition (Porembski 2000).

In Brazil, the extra-Amazonian rocky outcrops that exhibit higher elevations may be found in the South and Southeast regions with special attention to the Serra do Mar, the Serra Geral, the Serra da Mantiqueira, and the Cadeia do Espinhaço (Oliveira-Filho *et al.* 2013). With increasing altitude and peculiar topography, rocky outcrops have great

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diversity of habitats and native vegetation reflects directly to this heterogeneity, forming mosaics with high levels of endemism (Porembski *et al.* 1997; Oliveira-Filho *et al.* 2013).

Espírito Santo is one of the richest states in Brazil when considering Angiosperm diversity. It possesses 6,364 recorded taxa (Dutra *et al.* 2015) which represents around 32% of the species from the Atlantic Rainforest Domain (BFG 2015). Such richness may be easily treated as underestimated, especially by the lack of information in poorly sampled areas and fairly low number of available taxonomic studies (Dutra *et al.* 2015).

The floristic knowledge in ES were improved by studies conducted in the last decades (*e.g.*, Peixoto & Gentry 1990; Fabris & César 1996; Pereira & Zambom 1998; Pereira *et al.* 1998; Pereira & Araújo 2000; Assis *et al.* 2004; Fraga *et al.* 2007; Esgario *et al.* 2009; Fabris & Peixoto 2013; Chagas *et al.* 2014; Saiter & Thomaz 2014; Sarnaglia Junior *et al.* 2014; Pertele *et al.* 2015; Dutra *et al.* 2015; Lubner *et al.* 2016; Souza *et al.* 2016). These studies, however, included a few rocky outcrops

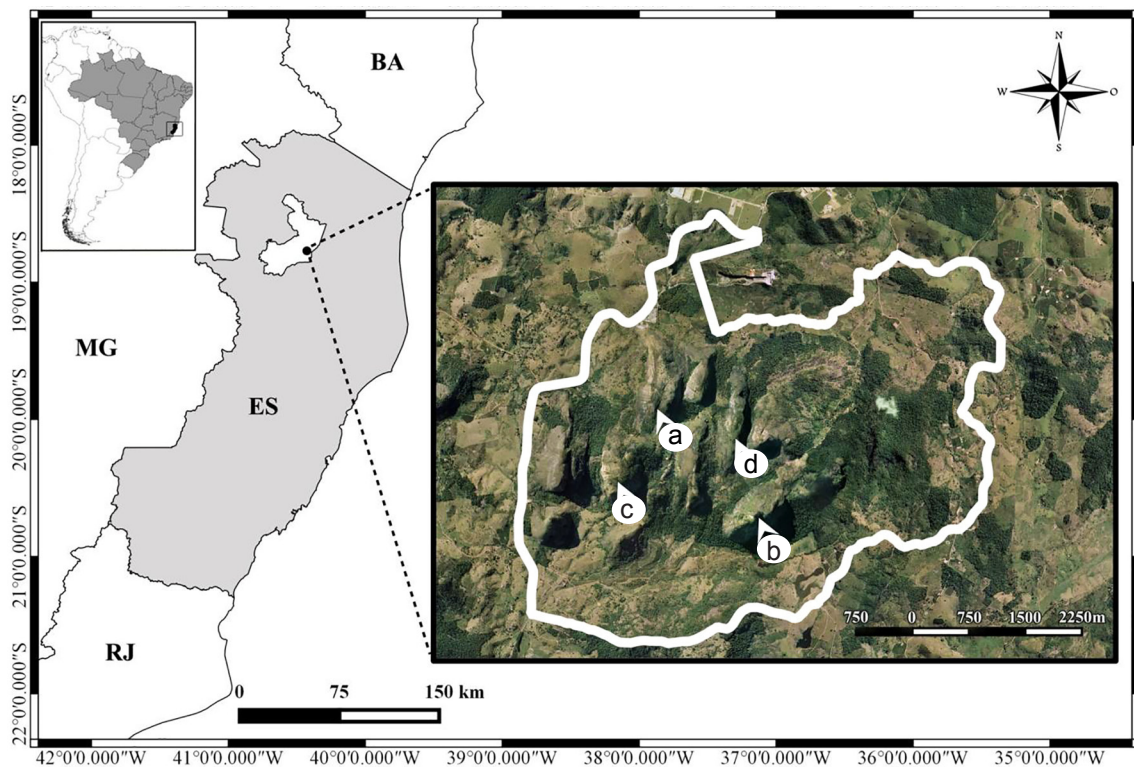
of the state. Therefore, data regarding native and adapted species from rocky outcrops from the State are scarce. To achieve a fair comprehension aiming conservation of this very unique vegetation, floristics and comparison analysis are extremely important (Caiafa & Silva 2005).

Low sampling efforts, habitat loss for many reasons (as cattle raising, fire and granite exploration), and unauthorized collection of plants cause negative impacts on the preservation of the rocky outcrops native vegetation, and affect the diversity of species in the Northern Espírito Santo. Thus, the objective of this study is to identify the Angiosperms flora from the rocky outcrops of the Área de Preservação Ambiental Pedra do Elefante, Nova Venécia, Espírito Santo, Brazil.

## Material and Methods

### Study site

The Área de Preservação Ambiental Pedra do Elefante (PE) belongs to the Nova Venécia municipality, Northwestern Espírito Santo state (ES), Brazil (18°46'30"S, 40°27'42"W) (Fig. 1).



**Figure 1** – Location map of APA Pedra do Elefante, Espírito Santo, Brazil – a. Pedra do Elefante rocky outcrop; b. Pedra da Dona Ecila (da Torre) rocky outcrop; c. rocky outcrop to the left to Pedra do Elefante rocky outcrop; d. rocky outcrop to the right to Pedra do Elefante rocky outcrop.

It has 2,562,31 ha with granitic rocky outcrops ranging 50–500 above sea level and associated to slope forests. Vegetation type is classified as Seasonal Semi-deciduous Submontane forest and is entirely inserted in the Atlantic Rainforest domain (IBGE 2012). Temperature and annual rainfall averages are 25°C and 800 mm, respectively (INCAPER 2016).

The study encompassed four rocky outcrops (Fig. 2a-d): Pedra do Elefante (18°45'59"S, 40°27'24,8"W) (Fig. 2a); Pedra da Dona Ecila (da Torre) (18°46'57,9"S, 40°26'46,5"W) (Fig. 2b); Pedra to the left of Pedra do Elefante (18°46'40"S, 40°27'46,6"W) (Fig. 2c); and Pedra to the right of Pedra do Elefante (18°46'9,6"S, 40°26'51,6"W) (Fig. 2d). They were chosen based on accessibility and presence of remaining native vegetation criteria. This work considers as start point of sampling those with very clearly exposed rock areas and shallow soils from the bottom to the top of the rocky outcrops.

### Sampling and general information

Sampling expeditions were carried out monthly from March/2015 to July/2016. Fertile specimens exclusively from the rocky outcrops were collected randomly and processed according to usual methods in plant taxonomy (Bridson & Forman 1998). All collected samples are deposited at VIES herbarium (Thiers, continuously updated) and family circumscriptions follow APG IV (2016).

Additional data from previously collected samples were gathered from JABOT - Banco de Dados da Flora Brasileira (2016). Only specimens with complete environmental information (locality and substrate data obtained from exsiccate labels) were included. Author names and specific epithets were confirmed after consulting The International Plant Names Index (IPNI 2016).

Only taxa from rocky outcrops were gathered and classified as: (a) rupicolous (*i.e.*, organisms fixed directly onto the rock, solitary or in vegetation



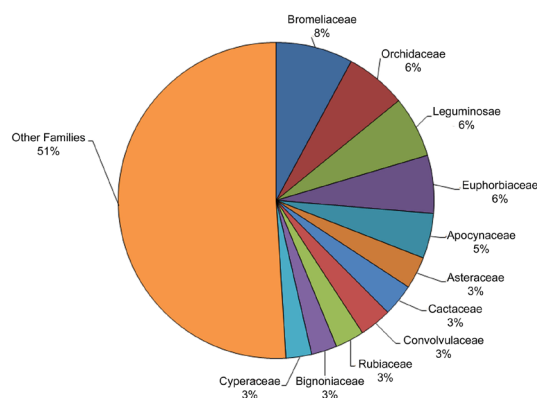
**Figure 2** – Rocky outcrops shown in APA Pedra do Elefante, Espírito Santo, Brazil – a. Pedra do Elefante rocky outcrop; b. Pedra da Dona Ecila (da Torre) rocky outcrop; c. rocky outcrop to the left to Pedra do Elefante rocky outcrop; d. rocky outcrop to the right to Pedra do Elefante rocky outcrop.

islands essentially formed by herbaceous species); (b) terricolous (*i.e.*, organisms occurring on shallow soils in vegetation islands essentially formed by shrubs, treelets or trees species); and (c) epiphytes (*i.e.*, Plants that use as support organisms that occur on shallow soils in vegetation islands essentially formed by shrubs, treelets or trees species). Life forms were based on Raunkiaer's (1934) and the species conservation statuses were consulted in IUCN (based on CNCF flora 2017). The first records for ES were assessed using Flora do Brasil 2020 (<<http://floradobrasil.jbrj.gov.br/>>).

## Results

A total of 302 species belonging to 219 genera and 74 families were recorded from PE rocky outcrops (see supplementary material <<https://figshare.com/s/8bb98b0d9e36e045bafa>>). Bromeliaceae (24 spp.), Orchidaceae and Fabaceae (19 spp., each), Euphorbiaceae (18 spp.), Apocynaceae (14 spp.), Asteraceae, Cactaceae, Convolvulaceae and Rubiaceae (10 spp., each), Bignoniaceae and Cyperaceae (eight spp., each) are the richest families with around 50% of the listed species (Fig. 3). On the other hand, 32.5% of the recorded families (24 families) are represented by a single taxon.

*Peperomia* Ruiz & Pav. (Piperaceae) with seven spp., *Acianthera* Scheidw. (Orchidaceae), *Mandevilla* Lindl. (Apocynaceae), and *Tillandsia* L. (Bromeliaceae) with five spp. (each), *Aechmea* Ruiz & Pav. (Bromeliaceae), *Borreria* G.Mey. (Rubiaceae), and *Solanum* L. (Solanaceae) with four spp. (each) are the most representative genera regarding species number. Besides, they together totaled around 20% of the recorded *taxa*.



**Figure 3** – Representation of the richest families from APA Pedra do Elefante, Espírito Santo, Brazil.

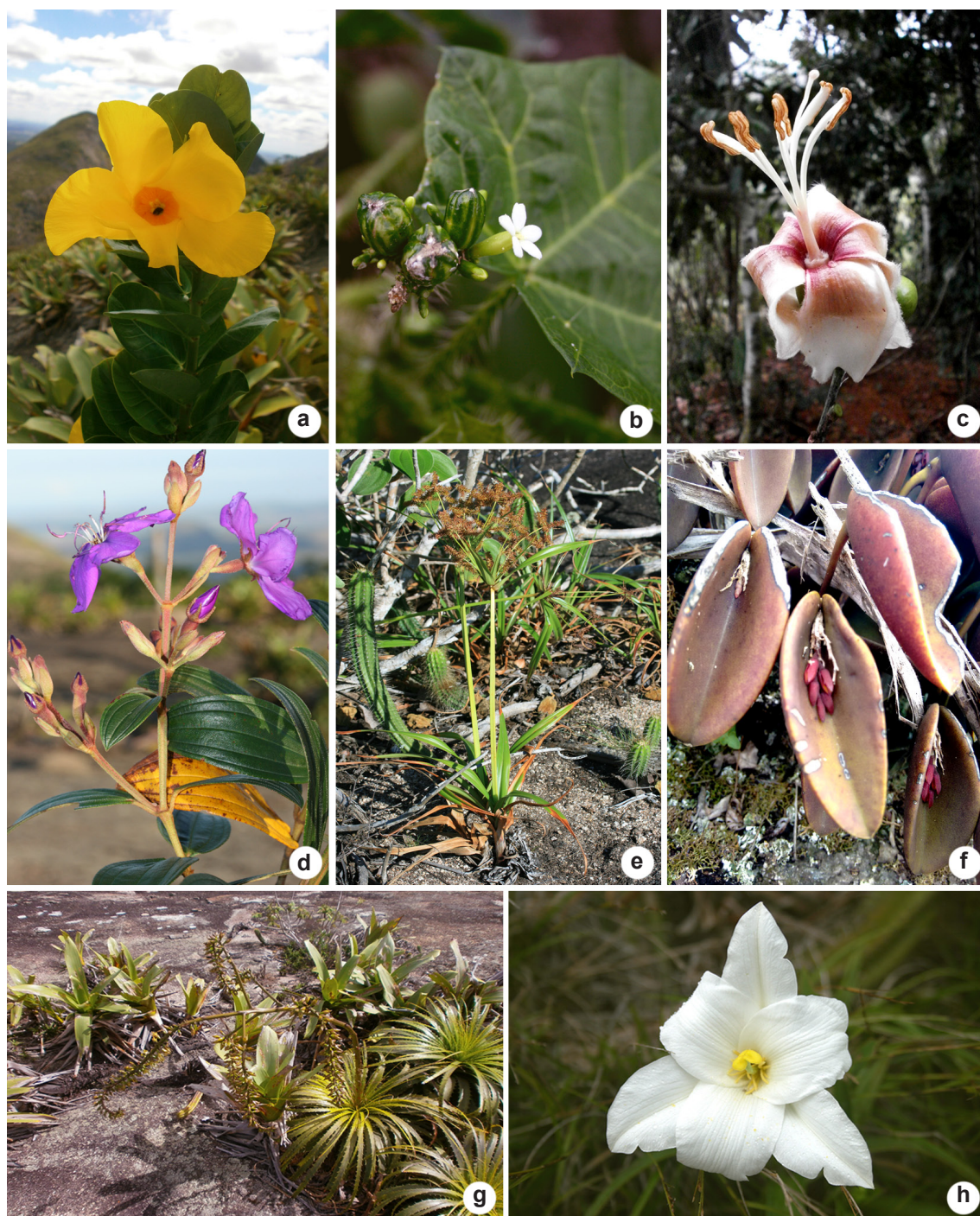
One hundred forty seven species are exclusively rupicolous, followed by 125 spp. exclusively terricolous, epiphytes with 26 spp., and six species are found as both rupicolous and terricolous: *Handroanthus selachidentatus* (A.H. Gentry) S.Grose (Bignoniaceae); *Dichorisandra hexandra* (Aubl.) C.B. Clarke, *D. thyrsiflora* J.C. Mikan (Commelinaceae); *Aosa parviflora* (Schrader) Weigend (Loasaceae); *Prescottia plantaginifolia* Lindl. ex Hook. (Orchidaceae); and *Randia armata* (Sw.) DC. (Rubiaceae).

Amongst exclusively rupicolous species (Fig. 4), Bromeliaceae (14 spp.), Euphorbiaceae (11 spp.), Fabaceae (eight spp.), Cactaceae, Cyperaceae and Melastomataceae (seven spp., each) have the highest values of richness and the most common life forms, in this order, are chamaephytes (72 spp.), phanerophytes (70 spp.), hemicryptophytes [*Anthurium jilekii* Schott, *Anthurium parasiticum* (Vell.) Stellfeld, *Philodendron edmundoi* G.M. Barroso (Araceae) and *Utricularia subulata* L. (Lentibulariaceae)]; and Geophytes (*Hippeastrum* sp. - Amaryllidaceae).

Exclusively terricolous species (Fig. 5a-f) are represented by Fabaceae (11 spp.), Convolvulaceae (nine spp.), Apocynaceae (spp.), Euphorbiaceae (spp.), and Bignoniaceae (five spp.) as the richest families. On the contrary compared to the rupicolous plants, the most common life forms are phanerophytes (94 spp.), followed by chamaephytes (27 spp.), and the Hemicryptophyte species: *Tridax procumbens* L. (Asteraceae). One single taxon, *Philodendron pedatum* (Hook) Kunth (Araceae), was registered as both rupicolous and terricolous and is an hemiepiphyte plant.

Epiphytes (Fig. 5h) are represented by species of Orchidaceae (10 spp.), Bromeliaceae and Piperaceae (six spp., each), Cactaceae (three spp.), and Araceae [*Lepismium cruciforme* (Vell.) Miq.]. They are usually found occurring associated to the vegetation islands formed essentially by shrubs, treelets and trees on the shallow soils. The predominant life forms were, in general, phanerophytes and chamaephytes, representing 54% and 33%, respectively (Fig. 6).

Eighteen new records for Espírito Santo are listed below (see supplementary material <<https://figshare.com/s/8bb98b0d9e36e045bafa>>): *Alternanthera bahiensis* Pedersen (Amaranthaceae); *Cereus hildmannianus* K.Schum. subsp. *hildmannianus* (Cactaceae); *Kielmeyera coriacea* Mart. & Zucc. (Calophyllaceae); *Maytenus ilicifolia* Mart. ex Reissek (Celastraceae); *Evolvulus*



**Figure 4** – Rupicolous species from APA Pedra do Elefante – a. *Mandevilla fistulosa* (Apocynaceae); b. *Cnidoscolus urentissimus* (Euphorbiaceae); c. *Ceiba erianthos* (Malvaceae); d. *Pleroma fissinervia* (Melastomataceae); e. *Cyperus pohlii* (Cyperaceae); f. *Acianthera limae* (Orchidaceae); g. *Encholirium horridum* (Bromeliaceae); h. *Vellozia candida* (Velloziaceae).



**Figure 5** – Terrestrial and epiphyte species from APA Pedra do Elefante rocky outcrops – a. *Syagrus pseudococos* (Areaceae); b. *Aristolochia gracilipedunculata* (Aristolochiaceae); c. *Pyrostegia venusta* (Bignoniaceae); d. *Jacquemontia martii* (Convolvulaceae); e. *Aechmea saxicola* (Bromeliaceae); f. *Cryptanthus venecianus* (Bromeliaceae); g. *Gurania eriantha* (Cucurbitaceae); h. *Tillandsia gardneri* (Bromeliaceae).

*lithospermoides* Mart., *Ipomoea bahiensis* Willd. ex Roem. & Schult. (Convolvulaceae); *Fevillea bahiensis* G. Rob. & Wunderlin, *Momordica charantia* L. (Cucurbitaceae) [naturalized]; *Cnidocolus urens* var. *neglectus* (Pohl) Lourteig, *Manihot leptopoda* (Müll.Arg.) D.J.Rogers & Appan, *Stillingia argutedentata* Jabl. (Euphorbiaceae); *Erythroxyllum nummularia* Peyr. (Erythroxyllaceae); *Anadenanthera peregrina* var. *falcata* (Benth.) Altschul, *Senna oblongifolia* (Vogel) H.S.Irwin & Barneby (Fabaceae); *Strychnos brasiliensis* Mart. (Loganiaceae); *Sida cerradoensis* Krapov. (Malvaceae); *Cissampelos pareira* L. (Menispermaceae); *Portulaca pilosa* L. (Portulacaceae); and *Borreria virgata* Cham. & Schltdl. (Rubiaceae).

Nine endemic taxa were registered: *Philodendron stenolobum* E.G.Gonç. (Araceae); *Begonia aguibrancensis* L.Kollmann (Begoniaceae); *Alcantarea trepida* Versieux & Wand., *Cryptanthus venecianus* Leme & L.Kollmann (Bromeliaceae); *Kielmeyera rupestris* Duarte (Calophyllaceae); *Clusia spiritusanctensis* G.Mariz & B.Weinberg (Clusiaceae); *Merianthera parvifolia* R.Goldenb., Fraga & A.P. Fontana (Melastomataceae); *Cattleya hoehnei* Van den Berg (Orchidaceae); and *Peperomia ciliato-caespitosa* Carv.-Silva & E.F.Guim (Piperaceae).

Only 55 species from the list are assigned under IUCN categories (based on CNCFlora 2016): Least Concern - LC (40 spp.); Near Threatened - NT [*Handroanthus selachidentatus* (A.H. Gentry) S.Grose (Bignoniaceae), *Rodriguezia obtusifolia* (Lindl.) Rehb.f. (Orchidaceae)]; Vulnerable - VU [*Chrysophyllum splendens* Spreng. (Sapotaceae), *Orthophytum foliosum* L.B.Sm. (Bromeliaceae), *Syagrus ruschiana* (Bondar) Glassman

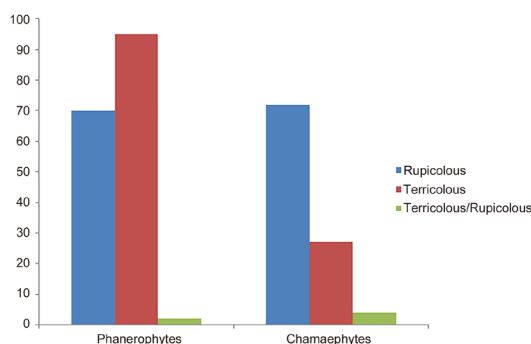
(Arecaceae)]; Endangered - EN [*Cololobus rupestris* (Gardner) H.Rob. (Asteraceae), *Begonia ibitiocensis* E.L.Jacques & Mamede (Begoniaceae), *Encholirium* cf. *gracile* L.B.Sm. *E. horridum* L.B.Sm. (Bromeliaceae), *Sinningia aghensis* Chautems (Gesneriaceae), *Stigmaphyllon crenatum* C.E.Anderson (Malpighiaceae), *Cattleya hoehnei* Van den Berg, *Pseudolaelia citrina* Pabst (Orchidaceae), and *Solanum sycocarpum* Mart. & Sendtn. (Solanaceae)]; and Critically endangered - CR [*Kielmeyera rupestris* Duarte (Calophyllaceae)].

## Discussion

Results provided different values for species richness against previously investigations carried out in Brazil (e.g., França *et al.* 1997; Meirelles *et al.* 1999; Caiafa & Silva 2005, 2007; Conceição *et al.* 2007; Araújo *et al.* 2008; Esgario *et al.* 2009; Gomes & Alves 2009, 2010; Gomes *et al.* 2011; Gomes & Sobral-Leite 2013). This could be explained by methodological aspects adopted. In general, studies which bring vegetation structural analysis show lower species richness (e.g., Kurtz & Araújo 2000; Thomas *et al.* 2009). However, considering only studies with similar sampling methods, the number of species increases from 15% (e.g., França *et al.* 1997) to around 30% (e.g., Araújo *et al.* 2008). Regarding Atlantic Rainforest Domain, investigations such as Caiafa & Silva (2005), Esgario *et al.* (2009), and Gomes & Sobral-Leite (2013) indicated Angiosperms richness for different areas with 75, 172, and 138 species, respectively, elucidating that depending on the type of floristic compositions present in the area under study, different taxonomic richness will be presented.

The most representative families in PE reflect a floristic composition pattern for rocky outcrops found both in the Brazilian Atlantic forest and in the Northeastern semi-arid. Compared to the other floras, it was noticed there is an alternation among the top six richest families, for instance: Asteraceae, Bromeliaceae, Cyperaceae, Euphorbiaceae, Fabaceae, and Orchidaceae (e.g., Meirelles *et al.* 1999; Conceição *et al.* 2007; Esgario *et al.* 2009; Gomes & Alves 2009, 2010; Gomes & Sobral-Leite 2013).

Porembski & Barthlott (1997) highlight some Angiosperm families as the most commonly found for rock outcrops in South America with great specific diversity like Melastomataceae, Orchidaceae, Cactaceae, and Bromeliaceae. Melastomataceae, however, is represented



**Figure 6** – Representation of the predominant life forms from APA Pedra do Elefante rocky outcrops, Espírito Santo, Brazil.

only by seven species in PE, which does not corroborate with the authors. On the contrary, the significant number of families represented here by a single species (32.5%) indicates that PE fits in a characteristic pattern of high diversity areas (Ratter *et al.* 2003).

Taxonomic groups typically cited as occurring on rocky outcrops like Alstroemeriaceae, Droseraceae and Eriocaulaceae were not found occurring in PE. This could be likely associated to the lack of water pools on the inselberg surface or even to the severe dry season that lasts over three years in the region. But, it is not a surprise when considered the stated by Porembski (2007), where the author asserts that vegetation of inselbergs in southeastern Brazil is extremely rich in dry resistant perennial species whereas annuals are relatively rare.

There is also alternation amongst top six richest genera when compared to the lists made by Gomes & Alves (2009; 2010) and Gomes & Sobral-Leite (2013): *Acianthera* (Orchidaceae), *Aechmea* and *Tillandsia* (Bromeliaceae), *Erythroxylum* P.Browne (Erythroxylaceae), *Ipomoea* L. (Convolvulaceae) and *Mandevilla* (Apocynaceae). *Peperomia* (Piperaceae) stands out as the richest genus in PE and this could be explained by considering terricolous species. Six out seven *Peperomia* species found are epiphytes and depend on the shrubs and trees for fixation.

High values of rupicolous species richness (147 spp.) were expected, and this life form represents almost half (48%) of the recorded *taxa*. They have adaptive strategies such as water accumulation in pools on leaf sheaths, specialized trichomes, and presence of bulbs or pseudobulbs, which turn them able to survive in this kind of environmental conditions (Porembski & Barthlott 1997). Vegetation islands formed by herbaceous species or the “monocotyledonous mats”, according to Barthlott *et al.* (1993), are visually frequent in PE, especially those formed by *Alcantarea trepida* Versieux & Wand. This species is easily seen and usually has the majority of rupicolous species associated to it (personal observation).

Terricolous plants totaled 41% of the registered species in PE (126 spp.) and they correspond to those *taxa* which form shrubby/tree vegetation islands. They occur on shallow soils and/or on rock fissures that could accumulate water and organic soils. Those vegetation islands are constituted by important landscape

elements [*Kielmeyera coriacea* Mart. & Zucc. (Calophyllaceae), *Anadenanthera peregrina* var. *falcata* (Benth.) Altschul (Fabaceae), and *Myrsine coriacea* (Sw.) R.Br. ex Roem. & Schult. (Primulaceae)], which might be colonized by epiphytes and hemi-epiphytes species.

Even found associated to terricolous plants, some epiphytes species have adaptive strategies which make them able to colonize rocks (Benzing 1987). *Epidendrum* L. species (Orchidaceae) are thought to be one of them. For instance, *Epidendrum campaccii* Hágsater & L.Sánchez was found occurring both on monocotyledonous mats and on shrub/tree vegetation islands in the studied site. The same was observed by Gomes and Sobral-Leite (2013) with other two species: *Epidendrum cinnabarinum* Salzm. ex Lindl. and *Epidendrum rigidum* Jacq.; where both could be found in the canopy of tropical forests. Although epiphytes species were not mentioned by Raunkiaer (1934), some studies bring this information considering them as phanerophytes.

In general, phanerophytes was the predominant life form followed by Chamaephytes in the analyzed site. Although chamaephytes is the second most important life form, they are the group who covers most of the area. Almost the same was found by Gomes and Alves (2010), with phanerophytes in the first place but therophytes rising up as the second group in two sites in the semi-arid region of Brazil. Additionally, Gomes and Sobral-Leite (2013) asserted the inverse order, in two different areas in the Atlantic forest of the Northeastern Brazil, with therophytes as the most important life form followed by phanerophytes. The authors inferred that therophytes are rarely restricted to rupicolous environments, with few exceptions. Yet, floristic composition likely underwent interferences by the surrounding forests (Gomes & Sobral-Leite 2013). Our results corroborate the stated by Porembski & Barthlott (1997) where they assigned phanerophytes as the most representative group in South America, whereas therophytes are less important.

New records and presence of endemic species in PE is likely related to the singularities of floristic composition from rocky outcrops in the Northern ES. Our results add new records to the listed by Dutra *et al.* (2015) extending the known geographic distribution for some *taxa*, including those widely distributed in Brazil but not previously cited as occurring in ES, for instance: *Anadenanthera peregrina* var. *falcata*



(Benth.) Altschul, *Senna oblongifolia* (Vogel) H.S.Irwin & Barneby (Fabaceae), *Cissampelos pareira* L. (Menispermaceae), *Cnidocolus urens* var. *neglectus* (Pohl) Lourteig (Euphorbiaceae), *Ipomoea bahiensis* Willd. ex Roem. & Schult. (Convolvulaceae), *Kielmeyera coriacea* Mart. & Zucc. (Calophyllaceae), *Momordica charantia* L. (Cucurbitaceae) [naturalized], *Portulaca pilosa* L. (Portulacaceae), *Sida cerradoensis* Krapov. (Malvaceae), and *Strychnos brasiliensis* Mart. (Loganiaceae). In addition, investigating areas like PE might reveal taxonomic novelties, e.g., *Cryptanthus venecianus* Leme & L.Kollmann (Bromeliaceae) (Leme *et al.* 2010), *Erythroxyllum* sp. nov. (Erythroxyllaceae) (James L. Costa Lima, personal communication) and *Pseudobombax* sp. nov. (Malvaceae) (Jefferson Sobrinho, personal communication). Moreover, that region is known by higher levels of diversity and endemism found in the Atlantic Forest (Dutra *et al.* 2015).

Several human activities such as cattle raising, fire and granite exploration has increased dramatically on rocky outcrops, causing habitat loss and sometimes irreversible damage to their vegetation. Facing our results (high number of species, new records to the State and the record of endemic species), performing regional inventories is highly recommended to improve the quality of the knowledge and consequently the efforts for conservation of rocky outcrops vegetation.

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