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Vascular plants on inselberg landscapes in Espírito Santo state: bases for the creation of a protected area in southeastern Brazil

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ABSTRACT. Inselbergs are granitic or gneissic rocky outcrops prevalent in the landscape of southeastern Brazil. These ecosystems represent islands of isolated habitats that harbor a peculiar flora with high richness and endemism. The present study lists the species of vascular plants occurring in the Pedra da Andorinha Complex, located in the municipality of Jerônimo Monteiro/Cachoeiro de Itapemirim, southern Espírito Santo state, aiming to generate subsidies for the creation of a protected area. The survey was performed between July 2017 and October 2018, resulting in a record of 121 species, 96 genera, and 40 families. Bromeliaceae (17), Orchidaceae (12) and Fabaceae (10) were the richest families. The phytophysiognomy of exposed rock vegetation comprises a greater number of species (79 species) compared to the woody rupicolous communities (42). Eighteen of the collected species are threatened by extinction; a new species was discovered; and five were described based on materials previously collected in the studied location — *Alcantarea patriae, Anthurium martinellii, Coleocephalocereus uebelmanniorum, Stigmatodon attenuatoides* and *Pitcairnia azouryi*, the first four being endemic to the region. We also found *Tabebuia reticulata,* a rare species among Brazilian flora. Our results highlight the biological importance of the Pedra das Andorinhas Complex and reinforce the need to create a protected area to preserve biodiversity and the regional natural heritage.

Keywords: Atlantic rainforest; conservation; rocky outcrops; taxonomy; vegetation island.

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Introduction

In Atlantic Forest of southeastern Brazil occurs a special class of residual landforms, composed predominantly by plutonic (granite) and metamorphic (gneiss) rocks, that are ecologically known as inselbergs (from German, *insel* = island, *berg* = mountain). They can occur isolated or in groups, separated by a few or many kilometers, forming inselberg landscapes (Hmeljevski, Nazareno, Bueno, Reis, & Forzza, 2017). These ecosystems differ greatly from the surrounding matrix, having unique edaphic-climatic characteristics that select for a specialized vegetation with high endemicity (see Safford & Martinelli, 2000; Porembski & Barthlott, 2000; Porembski, 2007; de Paula, Forzza, Neri, Bueno, & Porembski, 2016). However, inselberg flora is frequently overlooked in favor of other ecosystems of the Atlantic domain.

Southeastern Brazil is one of three important regions recognized globally as hotspots of plant diversity in inselberg ecosystems, alongside Madagascar and southwestern Australia (Porembski, 2007). In this context, it is worth mentioning that the inselbergs located in southern Espírito Santo, recognized for their significant biological importance, are a priority for floristic studies and ought to be prioritized for the creation of protected areas (Martinelli, 2007; Couto, Dias, Pereira, Fraga, & Pezzopane, 2016a; Couto, Francisco, Manhães, Machado, & Pereira, 2017; Kessous, Couto, Uribbe, & Costa, 2018).

Although inselbergs are not suitable for agriculture, and therefore escape its impacts, the mining industry poses the greatest threat to the flora of these environments worldwide (Porembski et al., 2016). Espírito Santo has a highly developed ornamental rock mining industry- one of the state's main economic activities- and is among the world's leaders in mineral exploration (Sardou Filho, Matos, Mendes, & Iza, 2013). On the other hand, mining is threatening the endemic and endangered flora of the region's inselbergs. For any proposal of conservation, sustainable use, management, and restoration of inselberg ecosystems, knowledge of their biota is essential. Thus, there is an urgent need for studies on the biodiversity of these unique environments.

This study aimed to inventory the species of vascular plants that grow on the inselbergs of the Pedra das Andorinhas Complex. We aimed to contribute to the knowledge of inselberg flora in southeastern Brazil, and document the occurrence of endemic and endangered species, to support the creation of a protected area in the locality.

Material and methods

Study site

The present study took place on private land (center point: 20° 47' 24'' S and 41° 23' 19.6'' W) between the municipalities of Cachoeiro de Itapemirim and Jerônimo Monteiro, southern state Espírito Santo, Brazil, in a region denominated by the Pedra das Andorinhas Complex (PAC) (Figure 1 and 2). Covering an area of approximately 360 ha, the study site features large rocky outcrops with patches of Submontane Seasonal Semideciduous Forest (*Instituto Brasileiro de Geografia e Estatística* [IBGE], 2012) at the base and summit, forming inselberg landscapes.

The PAC ranges from 150 to 500 m in elevation. It is surrounded by agricultural activities (cattle ranching and coffee, eucalyptus and orange plantations), mineral extraction and forest fragments. The climate has been classified as CwA, with dry winters and rainy summers, a mean annual temperature of about 24°C, and a mean annual rainfall of 1,450 mm (Couto et al., 2016b).

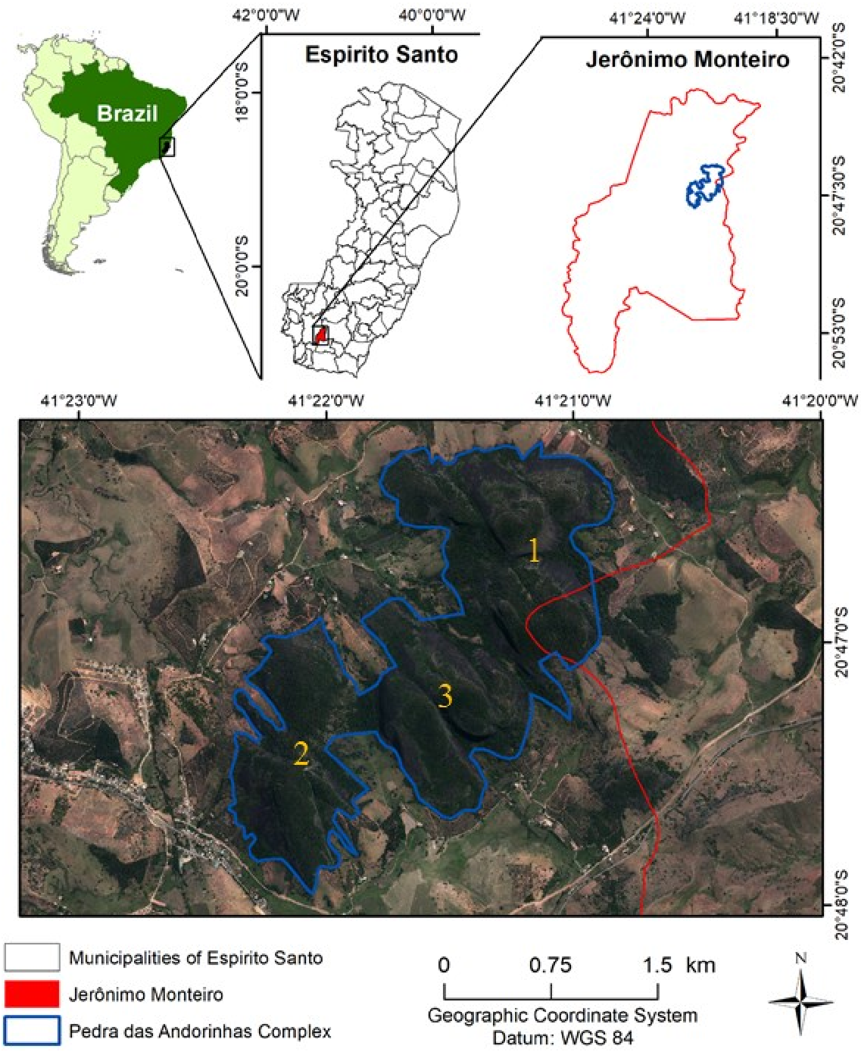

Figure 1. Location of the study area Pedra das Andorinhas Complex, an inselberg landscape located in Jerônimo Monteiro and Cachoeiro de Itapemirim, Espírito Santo State, southeastern Brazil. 1 = Pedra das Andorinhas, 2 = Parada Cristal and 3 = Pedra Três Irmãs.

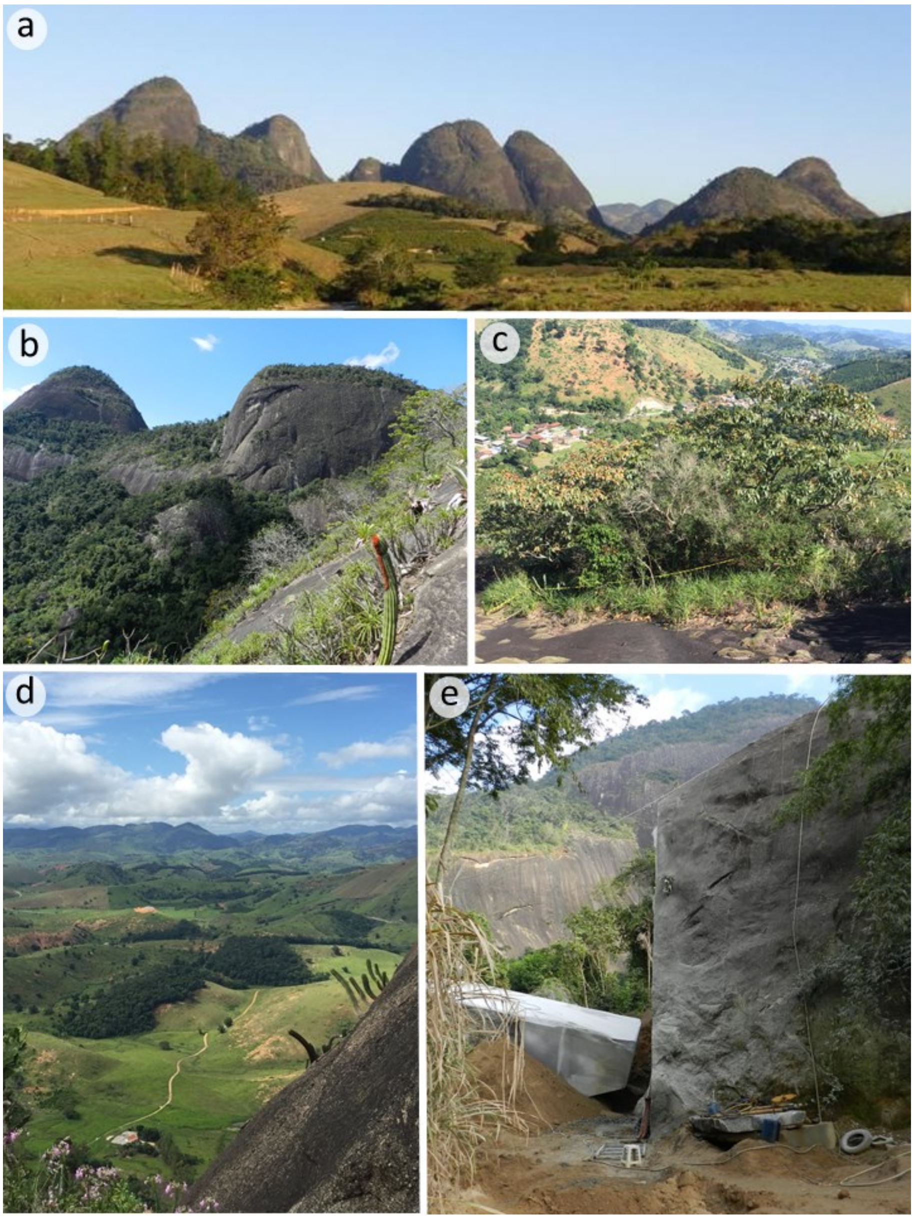

Figure 2. a. General view of the inselberg landscape Pedra das Andorinhas Complex, in the Jerônimo Monteiro and Cachoeiro de Itapemirim county, Espírito Santo State, southeastern Brazil; b. phytophysiognomy of vegetation on exposed rock; c. woody rupicolous communities; d. surrounding matrix of the Pedra das Andorinhas Complex; e. rock mining activities in surrounding. (Photos by: A. Marcelo Dan Scardua; B: Dayvid R. Couto; C-D-E: João Mário C. Covre).

According to reports from local residents, the PAC has a history of bushfires (between 15 and 20 years ago) and some mineral exploration. The rocky complex consists of several inselbergs, which are generally difficult to access (Figure 2). In this study, we investigated three rock outcrops, one between Cachoeiro de Itapemirim/ Jerônimo Monteiro, known as Pedra das Andorinhas (1) (20° 46' 19" S; 41° 21' 12" W), and two others in Jerônimo Monteiro: Parada Cristal (2) (20° 47' 39" S; 41° 22' 20" W), Pedra Três Irmãs (3) (20° 46' 19" S; 41° 21' 12" W).

Data collection

Floristic surveys of the rock outcrops in the PAC were conducted during monthly field expeditions between July 2017 and October 2018. Sampling was restricted to inselberg vegetation, which is characterized by rupicolous species that inhabit the rocky surfaces.

Fertile specimens were collected randomly, using the walk-over survey method (Filgueiras, Brochado, Nogueira, & Guala, 1994), and processed according to Mori, Berkov, Gracie, and Hecklau (2011). We accomplished taxonomic identification by consulting specialized taxonomic literature (e.g., regional and local flora monographs), images of exsiccatae available in virtual herbaria Jabot (jabot.jbrj.gov.br/) and Reflora (reflora.jbrj.gov.br/reflora/herbarioVirtual/), and experts on each taxon, to whom we sent exsiccate. The circumscription adopted for angiosperm families are in accordance with APG IV (The Angiosperm Phylogeny Group, 2016). For monilophytes and lycophytes, we followed PPG I (Pteridophyte Phylogeny Group [PPG], 2016). Accepted names, synonymy, and authors were confirmed by reference to Flora do Brasil 2020 (http://floradobrasil.jbrj.gov.br/), Missouri Botanical Garden (http://tropicos.org) and International Plant Names Index (IPNI, 2020). Additional specimens collected at other times were identified through consultation of the database of Brazilian flora.

In general, the rocky outcrops of the PAC can be organized into two main phytophysiognomies: (i) vegetation on exposed rock and (ii) woody rupicolous communities. All species were organized according to their occupation within these two rocky phytophysiognomies.

Vegetation on the exposed rock is groups of plants growing directly on and bounded by the rocky surfaces, with no or very shallow soil (epilithic or saxicolous plants respectively) (Conceição, Pirani, & Meirelles, 2007). This phytophysiognomy is composed mainly of monocot mats (Bromeliaceae and Velloziaceae mainly) and epilithic vegetation, covering large expanses of the rock outcrops. The woody rupicolous communities are composed predominantly by shrubs and small trees less than 10 m high, growing in poorly developed soil (up to 20 cm deep) in large depressions and fissures on the slopes of the inselbergs. Woody species typical of the matrix, such as epiphytes, vines, and herbs, can also occur (Couto et al., 2017).

Species were classified according to vegetative habit as trees, shrubs, subshrubs, climbing plants and herbaceous, following Couto et al. (2017). The endangered species were cited according to the official list of *Centro Nacional de Conservação da Flora* (cncflora.jbrj.gov.br), Red List of Espírito Santo state (Fraga, Peixoto, & Leite, 2019) and IUCN Red List (https://www.iucnredlist.org/).

Collections of botanical material were carried out for all species recorded in the study and voucher specimens were deposited in the CAP herbarium (acronym according to Thiers – continuously updated), of the *Universidade Federal do Espírito Santo*, in Jerônimo Monteiro, state Espírito Santo.

Results and discussion

A total of 121 species, belonging to 96 genera and 40 families, were recorded for the PAC (see supplementary material). Eudicotyledons represented the most diverse evolutionary lineage (65 spp., 54% of the total), with 25 families (62.5%), followed by Monocotyledons with 45 spp. (37%) and 10 families (25%), Monilophytes (8 spp., 6.6%) with 3 families (7.5%), Lycophytes (2 spp., 1.6%) with 1 family (2.5%), and Magnoliids (1 spp., 0.8%) with 1 family (2.5%).

The richest families in the PAC were Bromeliaceae (17 spp.), Orchidaceae (12), Fabaceae (10), Asteraceae and Euphorbiaceae (6 spp. each), Cactaceae and Pteridaceae (5 spp. each), Gesneriaceae and Myrtaceae (4 spp. each), Solanaceae and Commelinaceae (3 spp. Each) (Figure 3). These families accounted for 75 species (i.e. 62% of the total) (Table S1).

The genera represented by the most species were *Tillandsia* (Bromeliaceae), with five species, *Pitcairnia* (Bromeliaceae) and *Sinningia* (Gesneriaceae), both with four species each. *Selaginella* (Selaginellaceae), *Doryopteris* (Pteridaceae), *Cyrtopodium* (Orchidaceae), *Eugenia* (Myrtaceae), *Centrosema, Macroptilium* (Fabaceae), *Cyperus* (Cyperaceae), *Alcantarea* (Bromeliaceae), *Anthurium* (Araceae), *Anemia* (Anemiaceae), *Ipomoea* (Convolvulaceae), *Dioscorea* (Dioscoreaceae), *Vellozia* (Velloziaceae) and *Solanum* (Solanaceae) were represented by two species each (Figure 4).

A new species of Araceae (*Anthurium* genus) recorded during fieldwork (voucher: J. M. C. Covre 93), is in description phase. On the other hand, *Alcantarea patriae* Versieux & Wand (Versieux & Wanderley, 2007), *Anthurium martinellii* Nadruz & Theófilo (Coelho & Valadares, 2019), *Coleocephalocereus uebelmanniorum* (Braun & Esteves) Braun, Esteves & Hofacker, *Pitcairnia azouryi* Martinelli & Forzza (Martinelli & Forzza, 2006), and *Stigmatodon attenuatoides* (Couto, Manhães & Costa, 2020) were described from collections obtained in the PAC. Of these species, *Alcantarea patriae, Anthurium martinellii, Coleocephalocereus uebelmanniorum* and *Stigmatodon attenuatoides* are endemic to the inselbergs of Jerônimo Monteiro and Cachoeiro de Itapemirim.

As for the distribution of species according to vegetative habit (supplementary material), herbaceous species were predominant, with 72 species (60%), followed by climbing plants with 15 species (12%), shrubs with 14 species (12%), trees with 13 species (11%) and subshrubs with 6 species (5%). The occurrence of species according to phytophysiognomy showed a higher prevalence of species in exposed rocky vegetation than in woody rupicolous communities, with 79 species (65.29%) and 42 species (34.71%), respectively. In total, 18 species (15%) are included on official endangered species lists (Table 1).

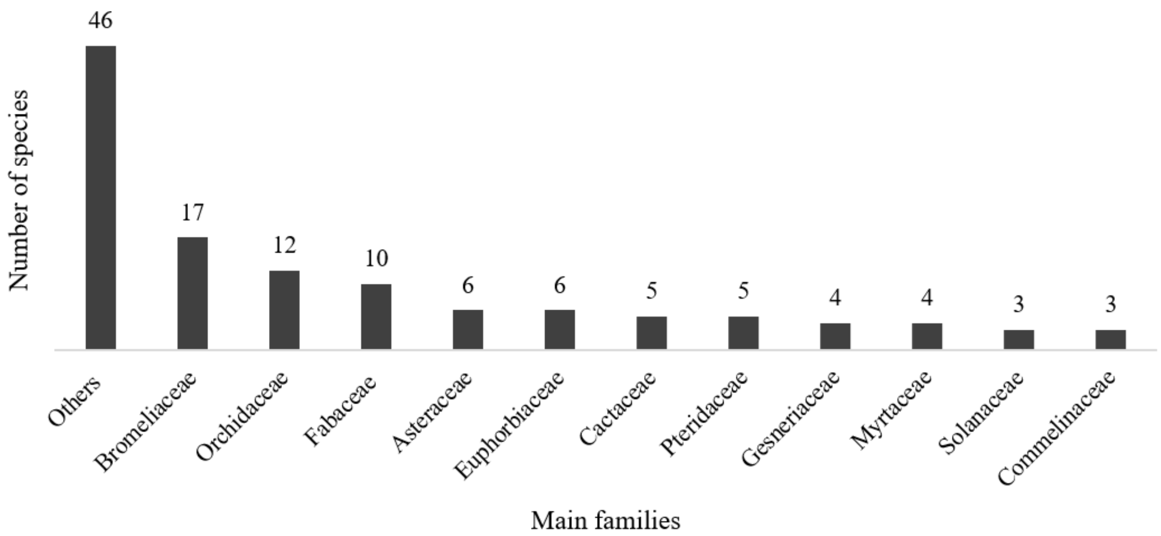

Figure 3. Number of species for the main families for the Pedra das Andorinhas Complex.

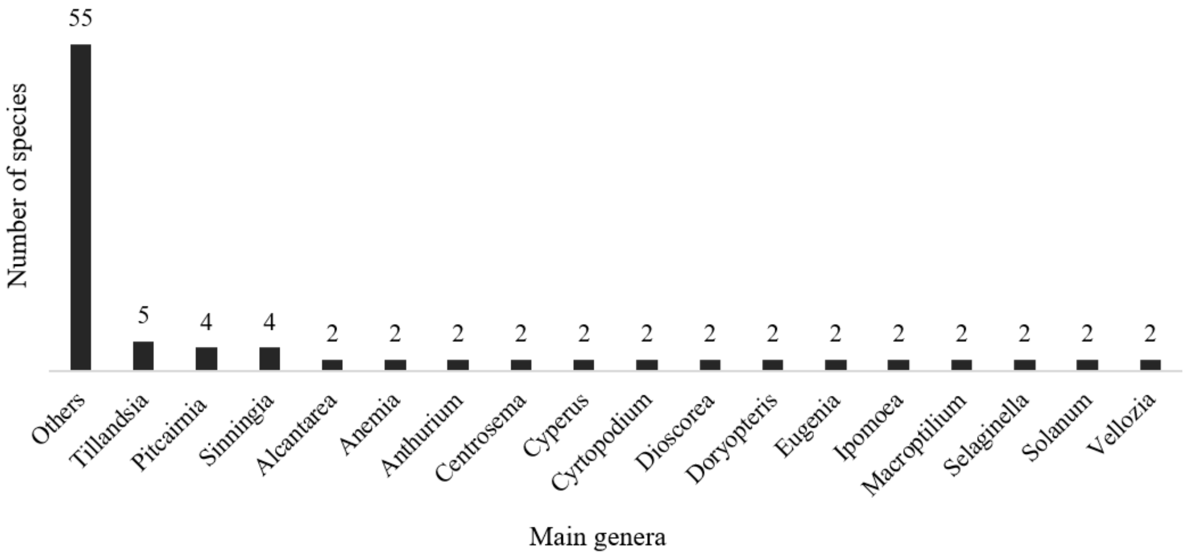

Figure 4. Number of species for the main genera for Pedra das Andorinhas Complex.

Table 1. Endangered species collected on the Inselbergs of the Pedra das Andorinhas Complex, Jerônimo Monteiro/Cachoeiro de Itapemirim, ES, Brazil. Species categorized according to different national and international databases. Categories: VU = vulnerable; EN = endangered; CR = critically endangered.

Family	Species	ES	Brazil	IUCN
Anemiaceae	*Anemia retroflexa* Brade	VU		
Amaryllidaceae	*Hippeastrum striatum* (Lam.) Moore	VU	EN	
Asteraceae	*Wunderlichia azulensis* Maguire & Barroso		EN	
Bromeliaceae	*Alcantarea patriae* Versieux & Wand.	VU		
Bromeliaceae	*Encholirium horridum* L. B. Sm.	VU		
Bromeliaceae	*Neoregelia diversifolia* Pereira	EN	EN	
Bromeliaceae	*Pitcairnia azouryi* Matinelli & Forzza	EN		
Bromeliaceae	*Pitcairnia decidua* L. B. Sm.		EN	
Bromeliaceae	*Vriesea saltensis* Leme & Kollmann	CR		
Cactaceae	*Coleocephalocereus uebelmanniorum* (Braun & Esteves) Braun, Esteves & Hofacker			EN
Gesneriaceae	*Sinningia bragae* Chautems, Peixoto & Rossini	EN		
Gesneriaceae	*Sinningia speciosa* (Lodd.) Hiern	VU		
Malpighiaceae	*Stigmaphyllon vitifolium* A. Juss.	CR	CR	
Moraceae	*Ficus cyclophylla* (Miq.) Miq.	VU	VU	
Orchidaceae	*Cattleya cernua* (Lindl.) van den Berg	VU		
Orchidaceae	*Cyrtopodium gigas* (Vell.) Hoehne	EN		
Pteridaceae	*Cheilanthes geraniifolia* (Weath.) Tryon & Tryon	VU		
Pteridaceae	*Doryopteris rediviva* Fée		VU	

The flora of the Pedra da Andorinha Complex is characterized by genera typical of the inselbergs of southeastern Brazil, such as *Alcantarea*, *Coleocephalocereus*, *Encholirium*, *Selaginella* and *Vellozia* (Porembski, Martinelli, Ohlemüller, & Barthlott, 1998; Meirelles, Pivello, & Joly, 1999; Couto et al., 2017; de Paula, Mota, Viana, & Stehmann, 2017), and includes endemic and endangered species. The survey results corroborate previous studies that recognize the southeastern region of Brazil as one of the global centers of richness and endemism among inselberg plants, a distinction shared by Madagascar and eastern Australia (Porembski, 2007).

The survey results differ from some other studies conducted previously in various regions of Brazil (Table 2). In general, the number of species was higher, especially in comparison to inselbergs in the Caatinga Domain, but it was lower compared to inselbergs of the Atlantic Forest, with rare exceptions. These variations can be explained, according to Porembski (2007), by the clear pattern of distinction between different geographic regions, in which environmental filtering differentially shapes inselberg species composition and structure (Yates et al., 2019).

When compared to other inselbergs researched in Espírito Santo, the species richness recorded for the PAC was inferior (Table 2). Compared to montane inselbergs, such as Alto Misterioso (Esgario, Fontana, & Silva, 2009) in the state's midwestern region, and Pedra dos Pontões (Couto et al., 2017) in its south, the differences in climate (temperature and precipitation) and altitudinal gradient may be the main causes of this distinction. The PAC is a submontane inselberg under the influence of the surrounding Submontane Seasonal Semideciduous Forest and its dry climate. Alto Misterioso and Pedra dos Pontões are situated between a seasonal and humid (ombrophilous) phytophysiognomy and patches of cloud forest (Esgario et al., 2009; Couto et al., 2017).

Table 2. Studies conducted on inselberg vegetation in Brazil, showing the phytogeographic domain (*sensu* Flora Brasil 2020), family, and genera richness. Organized by the areas of greatest species richness (Rich.).

References	Location (state)	Domain	Elevation	Rich.	Fam.	Gen.
Pena et al., 2017	Pedra do Elefante (ES)	Atlantic Forest	50 to 500 m	302	74	219
Couto et al., 2017	Pedra dos Pontões (ES)	Atlantic Forest	700 to 1400 m	211	51	130
Gomes & Alves, 2010	Brejo de Agrestina (PE)	Caatinga	620 to 740 m	211	69	168
Esgario et al., 2009	Alto Misterioso (ES)	Atlantic Forest	850 to 1143 m	170	44	109
Gomes & Sobral-Leite, 2013	Pedra do Trevo and Lajedo do Uruçu (PE)	Atlantic Forest	307 m/451 m	142	51	116
Porto et al., 2008	Esperança (PB)	Caatinga	-	127	53	101
This study	Pedra da Andorinha Complex (ES)	Atlantic Forest	150 to 500 m	121	40	96
Lopes-Silva et al., 2019	Morro do Carioca (PB)	Caatinga	250 to 376 m	120	46	101
Paulino et. al., 2018	Monólitos Quixadá (CE)	Caatinga	-	107	45	81
Lucena, Lucena, Sousa, Silva, & Souza, 2015	Espinho Branco (PB)	Caatinga	250 to 415 m	101	45	84
Tölke et al., 2011	Inselberg Puxinanã (PB)	Caatinga	-	97	35	69
de Paula et al., 2017	Mucuri (MG)	Atlantic Forest	306 to 676 m	89	37	73

However, the distinction in species richness was most notable concerning submontane inselbergs of Pedra do Elefante in northern Espírito Santo (Pena & Alves-Araújo, 2017). Although the Pedra do Elefante complex covers a large area (2,562.31 ha), its higher species richness compared to the PAC seems to be due only to the greater collection effort in that locality. Historically, it was subject to mineral extraction, but it is now a Protected Area (Conservation Unit – Law 9985/00 SNUC).

Among the richest families found in the PAC, six (Fabaceae, Orchidaceae, Asteraceae, Bromeliaceae, Myrtaceae, and Euphorbiaceae) were also among the richest families in the Atlantic Forest (The Brazil Flora Group [BFG], 2015) and are well represented in inselberg vegetation in Brazil (e.g. França, Melo, & Santos, 1997; Esgario et al., 2009; Couto et al., 2017; Pena & Alves-Araújo, 2017). Fabaceae, for example, has a species richness in the PAC similar to that found on inselbergs in the Caatinga Domain (Araújo, Oliveira, & Lima-Verde, 2008; Tölke, Silva, Pereira, & Melo, 2011; Paulino, Silveira, & Gomes, 2018). This finding contradicts the results of other floristic surveys conducted in Espírito Santo, in which the most-represented families were Orchidaceae, Bromeliaceae, Asteraceae, Melastomataceae, Cyperaceae, Poaceae, Polypodiaceae, Cactaceae and Araceae (Esgario et al., 2009; Couto et al., 2017). Porto, Almeida, Pessoa, Trovão, and Felix (2008) explained this high number of Fabaceae species in Caatinga as evidence of greater variation in its species' survival strategies in xeric environments. Porembski and Barthlott (2000), in studies conducted in African inselbergs, also showed this family's ability to adapt effectively to rocky environments.

Of the 96 genera recorded in the present study, 66% were represented by a single species. This finding contradicts results found in floristic surveys conducted on the African continent, where 48% of the collected species belonged to genera represented by a single species (e.g. Porembski & Brown, 1995; for Costa do Marfim). We found a total of 40 families, 16 of which were represented by a single species. This large number has also been observed in other floristic surveys of rocky outcrops in Espírito Santo (Esgario et al., 2009; Couto et al., 2017; Pena & Alves-Araújo, 2017) and is characteristic of high diversity sites (Ratter, Bridgewater, & Ribeiro, 2003). Families such as Bromeliaceae and Orchidaceae were more relevant in terms of species richness among the rock outcrops studied here, possibly due to adaptive strategies that contribute to their survival in these environments, such as the presence of systems that accumulate water, specialized trichomes, thick and crass leaves and the presence of bulbs or pseudobulbs (Porembski, Seine, & Barthlott, 1997; Benzing & Bennett, 2000; Menini Neto, Forzza, & van den Berg, 2013).

Many of the plant species specific to inselberg ecosystems are known as 'resurrection plants' because of their desiccation tolerance, a common survival strategy in these environments. In the present study, this survival mechanism was observed in the Velloziaceae (*Vellozia candida* and *Vellozia variegata*) family and the monilophytes and lycophytes genera *Anemia*, *Cheilanthes*, *Doryopteris*, and *Selaginella*. All of these genera have been described as desiccation tolerant in previous studies (Porembski & Barthlott, 2000; Porembski, 2007). Species identified as *Encholirium horridum* (Bromeliaceae), *Coleocephalocereus uebelmanniorum* (Cactaceae) and *Cyrtopodium glutiniferum* (Orchidaceae) possessed adaptive mechanisms such as stems that store water or an underground caudex (Porembski, 2007).

Typical genera of Bromeliaceae, such as *Alcantarea*, *Encholirium*, *Pitcairnia*, *Stigmatodon,* and *Tillandsia*, were found on rocky outcrops. These genera have been found in high abundance in Brazil's inselberg landscapes (de Paula et al., 2016; Couto et al., 2017). We also recorded *Coleocephalocereus* (Cactaceae), *Sinningia* (Gesneriaceae) and *Vellozia* (Velloziaceae), which, despite comprising only a few species, are equally important genera typical of South American inselbergs (Porembski, 2007).

In this study, we observed that the woody rupicolous species - *Ceiba erianthos* (Malvaceae), *Eugenia punicifolia* (Myrtaceae), *Pseudobombax* aff. *petropolitanum* (Malvaceae), *Tabebuia reticulata* (Bignoniaceae) and *Wunderlichia azulensis* (Asteraceae) - hosted 12 species of vascular epiphytes, mainly Bromeliaceae (*Tillandsia gardneri*, *T. loliacea*, *T. recurvata*, *T. stricta* and *T. usneoides*), and Orchidaceae (*Brassavola tuberculata*, *Cattleya cernua* and *Laelia gloriosa*). Of the phorophytes mentioned, *Pseudobombax* aff. *petropolitanum* is recognized as an important facilitator tree in inselberg vegetation of Espírito Santo (Couto et al., 2016a; Francisco, Couto, Evans, Garbin, & Ruiz-Miranda, 2018). Owing to its architecture and size, including the large roots exposed on the rock surface, this phorophyte hosts an impressive diversity of vascular epiphytes, particularly on montane inselbergs (Couto et al., 2016a; Couto et al., 2019). Although these woody rupicolous communities are an important component of inselberg vegetation, they are scarcely studied (Couto et al., 2017; Francisco et al., 2018). More research ought to be focused on these communities, as they are an essential component in restoration strategies for globally threatened inselberg ecosystems (Porembski et al., 2016).

Conservation of Pedra das Andorinhas complex

PAC has a high diversity of known species, some of which are endemic to the complex itself and nearby outcrops. Some of those species have been described only recently, using botanical materials from the site. Collection efforts are fundamental to filling research gaps and expanding the floristic and phytogeographic knowledge of the rocky outcrops in the Atlantic Forest in the state of Espírito Santo. Also, conservation policies are essential for protecting this unique vegetation, including many endangered species, some of which are rare (e.g. *Tabebuia reticulata*; see Lohmann & Silva-Castro, 2009) or restricted to rock outcrops (e.g. *Pitcairnia decidua*, *Pitcairnia azouryi*, *Coleocephalocereus uebelmanniorum*, *Encholirium horridum*). These species are recognized worldwide as prevalence indicators for the creation of protected areas (Brooks et al., 2006).

Because the PAC is an outcrop of granite origin and close to one of Brazil's most important ornamental stone beneficiation industries (Xavier, Azevedo, Alexandre, Monteiro, & Pedroti, 2019), the locale is extremely vulnerable to speculative mining. Despite the importance of the mining sector for the Espírito Santo economy, mining activity is the biggest threat to inselberg vegetation, not only in Brazil but also around the world (Porembski et al., 2016). Historically, inselberg vegetation has been neglected by environmental agencies during the environmental licensing of mining activities, causing irreparable damage to these important ecosystems of the Atlantic Forest (Couto et al., 2019). Now, the populations of many inselberg plant species (e.g. *Pitcairnia azouryi*) are under serious threat of extinction (Manhães, Couto, Miranda, & Carrijo, 2016). For these reasons, we call the attention of public authorities to the importance of inselberg vegetation.

Furthermore, the PAC is surrounded by an anthropized matrix, where exotic grasses, mainly Panicoideae genera (e.g. *Panicum* and *Urochloa*) (observed), grow extensively and are used widely for cattle grazing. The existence of these grasses, their persistence, and high abundance in seed banks (Correia & Martins, 2015) is worrying. Wherever they manage to colonize natural areas, these grasses impair the development and establishment of native monocotyledons on rocky outcrops due to their hardiness in competition for resources. Another aggravation associated with colonization by grass species is the deposition of combustible material, which leaves the PAC high susceptible to fire. Inselberg fires modify community structure and composition and lead to the loss of endemic species, resulting in homogenization of the flora of these important refuges (Hunter, 2017).

Occurrence and distribution data on invasive alien species are essential for developing appropriate control measures and management strategies for natural areas protected under Brazilian law 9985/00. Much of the work on protected areas neglect this information despite invasive species being a major cause of global biodiversity loss (Haddad et al., 2015). Therefore, to guide conservation policy makers, we have incorporated the occurrence of exotic species with invasive potential into our plant list.

Finally, a few characteristics and particularities of the existing flora in the PAC justify and support the creation of a Protected Area that would preserve a significant portion of the flora in the South Espírito Santo region, mainly the inselberg vegetation.

Conclusion

This study provides important knowledge about the flora of the Pedra da Andorinha Complex and justifies the need to create a Conservation Unit in the locality, defining it as a priority for conservation due to the recorded wealth, the number of endangered, endemic species and new species that are being described for this location.

It is worth mentioning that the carrying out of more regional inventories is highly recommended to improve the quality of knowledge and, consequently, the efforts to conserve the vegetation of these singular areas and the Atlantic Forest.

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SUPPLEMENTARY MATERIAL

Table S1. List of vascular plants from Pedra da Andorinha Complex, Espírito Santo State, Brazil. Life form: Climb. = climbing; Herb = herbaceous; Subsh = subshrubs. PHYTO = Phytophysiognomy: VER = vegetation on exposed rock; WRC = woody rupicolous communities.

Evolutionary Lineages (species number)	Family/ Species	Life form	PHYTO		Vouchers (Herbaria)
			VER	WRC	
Lycophytes (2)	SELAGINELLACEAE (2)				
1 family	*Selaginella convoluta* (Arn.) Spring	Herb	X		J.M.C. Covre 90; D.R. Couto 3670, 3998 (CAP)
	Selaginella sellowii Hieron.	Herb	X		J.M.C. Covre 89; D.R. Couto 3668, 3669 (CAP)
Monilophytes (8)	ANEMIACEAE (2)				
3 families	*Anemia retroflexa* Brade	Herb	X		D.R. Couto 4003 (CAP)
	Anemia tomentosa (Sav.) Sw.	Herb	X		J.M.C. Covre 120 (CAP)
	POLYPODIACEAE (1)				
	Pleopeltis minima (Bory) J. Prado & R.Y. Hirai	Herb		X	J.M.C. Covre 161 (CAP); D.R. Couto 3996 (CAP)
	PTERIDACEAE (5)				
	Adiantum sp.	Herb	X		J.M.C. Covre 199 (CAP); D.R. Couto 3986 (CAP)
	Cheilanthes geraniifolia (Weath.) R.M.Tryon & A.F.Tryon	Herb	X		D.R. Couto 4004 (CAP)
	Doryopteris collina (Raddi) J.Sm.	Herb	X		D.R. Couto 3997 (CAP)
	Doryopteris rediviva Fée	Herb	X		J.M.C. Covre 86 (CAP)
	Hemionitis tomentosa (Lam.) Raddi	Herb	X		J.M.C. Covre 106; D.R. Couto 3679, 3680 (CAP)
Magnoliids (1)	PIPERACEAE (1)				
1 family	*Peperomia* cf. *spiritus-sancti* E.F. Guim. & Carv.-Silva	Herb	X		J.M.C. Covre 75 (CAP); D.R. Couto 3664. 3665 (CAP)
Monocots (45)	AMARYLLIDACEAE (1)				
10 families	*Hippeastrum striatum* (Lam.) Moore	Herb	X		J.M.C. Covre 165 (CAP)
	ARACEAE (3)				
	Anthurium martinellii Nadruz & Theófilo	Herb		X	J.M.C. Covre 57 (CAP); G. Martinelli 15975 (RB)
	Anthurium sp.	Herb	X		J.M.C. Covre 93 (CAP)
	Philodendron edmundoi G.M.Barroso	Herb	X		Observed
	BROMELIACEAE (17)				
	Aechmea saxicola L.B.Sm.	Herb		X	J.M.C. Covre 119 (CAP)
	Alcantarea extensa (L.B.Sm.) J.R.Grant	Herb	X		Observed
	Alcantarea patriae Versieux & Wand.	Herb	X		J.M.C. Covre 215 (CAP); Versieux 365 (SP, RB)
	Billbergia iridifolia (Nees & Mart.) Lindl.	Herb	X		D.R. Couto 2347 (R)
	Encholirium horridum L.B.Sm.	Herb	X		Observed
	Neoregelia diversifolia E. Pereira	Herb		X	G. Martinelli 15751 (RB)
	Pitcairnia azouryi Martinelli & Forzza	Herb	X		J.M.C. Covre 173 (CAP); G. Martinelli 15977 (RB); V.C. Manhães 287 (VIES); D.R. Couto 4010 (CAP)
	Pitcairnia decidua L.B.Sm.	Herb	X		J.M.C. Covre 30 (CAP), D.R. Couto 2345 (R)
	Pitcairnia flammea Lindl.	Herb	X		J.M.C. Covre 122 (CAP); V.C. Manhães 495 (VIES); D.R. Couto 2346 (R)
	Pitcairnia flammea var. *macropoda* L.B.Sm. & Reitz	Herb	X		J.M.C. Covre 102 (CAP)
	Tillandsia gardneri Lindl.	Herb		X	J.M.C. Covre 189; D.R. Couto 3990, 3994, 4011 (CAP)
	Tillandsia loliacea Mart. ex Schult. & Schult.f.	Herb		X	J.M.C. Covre 5 (CAP); D.R. Couto 2343 (R); D.R. Couto 2155; V.C. Manhães 292 (VIES)
	Tillandsia recurvata (L.) L.	Herb		X	D.R. Couto 3989 (CAP); V.C. Manhães 289 (VIES)
	Tillandsia stricta Sol.	Herb		X	D.R. Couto 4006 (CAP), D.R. Couto 2353 (R)
	Tillandsia usneoides (L.) L.	Herb		X	D.R. Couto 2344 (R)
	Stigmatodon attenuatoides D.R. Couto, Manhães & A.F. Costa	Herb	X		D.R. Couto 2330 (R); D.R. Couto 3971 (CAP)
	Vriesea saltensis Leme & L. Kollmann	Herb		X	J.M.C. Covre 105 (CAP); D.R. Couto 3304 (R)
	COMMELINACEAE (3)				
	Aneilema brasiliense C.B.Clarke	Herb	X		J.M.C. Covre 207 (CAP)
	Dichorisandra procera Mart. ex Schult & Schult.f.	Herb		X	J.M.C. Covre 53 (CAP)
	Gibasis geniculata (Jacq.) Rohweder	Herb	X		J.M.C. Covre 160 (CAP)
	COSTACEAE (1)				

Evolutionary Lineages (species number)	Family/ Species	Life form	PHYTO VER	PHYTO WRC	Vouchers (Herbaria)
	Costus spiralis (Jacq.) Roscoe	Herb		X	J.M.C. Covre 15 (CAP)
	CYPERACEAE (4)				
	Cyperus coriifolius Boeckeler	Herb	X		D.R. Couto 4005 (CAP)
	Cyperus sp.	Herb	X		J.M.C. Covre 4 (CAP)
	Scleria sp.	Herb		X	J.M.C. Covre 45 (CAP)
	Trilepis lhotzkiana Nees ex Arn.	Herb	X		J.M.C. Covre 214 (CAP)
	MARANTACEAE (1)				
	Maranta divaricata Roscoe	Herb		X	J.M.C. Covre 72 (CAP)
	ORCHIDACEAE (12)				
	Pabstiella sp.	Herb	X		J.M.C. Covre 82; D.R. Couto 3657 (CAP)
	Brassavola tuberculata Hook.	Herb		X	J.M.C. Covre 184 (CAP)
	Cattleya cernua (Lindl.) Van den Berg	Herb		X	Observed
	Christensonella pumila (Hook.) Szlach. et al.	Herb	X		D.R. Couto 3658 (CAP)
	Cyclopogon argyrifolius Barb.Rodr.	Herb	X		J.M.C. Covre 174 (CAP)
	Cyrtopodium gigas (Vell.) Hoehne	Herb		X	H.M.Dias 528 (CAP)
	Cyrtopodium glutiniferum Raddi	Herb	X		J.M.C. Covre 12; D.R. Couto 3993 (CAP)
	Eltroplectris triloba (Lindl.) Pabst	Herb		X	J.M.C. Covre 158; D.R. Couto 3992 (CAP)
	Laelia gloriosa (Rchb.f.) L.O.Williams	Herb		X	J.M.C. Covre 1 (CAP)
	Prescottia plantaginifolia Lindl. ex Hook.	Herb		X	J.M.C. Covre 107; D.R. Couto 2361 (CAP)
	Specklinia grobyi (Batem. ex Lindl.) F.Barros	Herb	X		D.R.Couto 3656, 3661 (CAP)
	Trichocentrum pumilum (Lindl.) M.W.Chase & N.H.Williams	Herb		X	D.R.Couto 220 (MBML)
	TALINACEAE (1)				
	Talinum paniculatum (Jacq.) Gaertn.	Herb	X		J.M.C. Covre 66 (CAP)
	VELLOZIACEAE (2)				
	Vellozia candida Mart.	Herb	X		J.M.C. Covre 44 (CAP)
	Vellozia variegata Goethart & Henrard	Herb	X		H.M. Dias 529 (VIES)
Eudicots (65) 25 families	APOCYNACEAE (2)				
	Aspidosperma gomezianum A. DC.	Tree	X		J.M.C. Covre 188 (CAP)
	Mandevilla sp.	Subsh	X		J.M.C. Covre 187 (CAP)
	ASTERACEAE (6)				
	Baccharis serrulata (Lam.) Pers.	Subsh	X		D.R. Couto 3991 (CAP)
	Bidens sp.	Herb	X		J.M.C. Covre 225 (CAP)
	Cyrtocymura scorpioides (Lam.) H.Rob.	Subsh	X		J.M.C. Covre 126 (CAP); D.R. Couto 3995 (CAP)
	Emilia fosbergii Nicolson	Herb	X		J.M.C. Covre 231 (CAP)
	Praxelis clematidea (Griseb.) R.M.King & H.Rob.	Herb	X		J.M.C. Covre 230 (CAP)
	Wunderlichia azulensis Maguire & G.M.Barroso	Tree	X		J.M.C. Covre 194 (CAP)
	BIGNONIACEAE (2)				
	Anemopaegma setilobum A.H.Gentry	Climb.		X	J.M.C. Covre 41 (CAP)
	Tabebuia reticulata A.H.Gentry	Tree	X		J.M.C. Covre 162 (CAP)
	BORAGINACEAE (1)				
	Tournefortia bicolor Sw.	Climb.	X		J.M.C. Covre 197 (CAP)
	CACTACEAE (5)				
	Brasiliopuntia brasiliensis (Willd.) A.Berger	Shrub	X		J.M.C. Covre 16 (CAP)
	Cereus fernambucensis Lem.	Shrub	X		J.M.C. Covre 28 (CAP); D.R. Couto 1730 (VIES)
	Coleocephalocereus uebelmanniorum (P.J.Braun & Esteves) P.J.Braun, Esteves & Hofacker	Shrub	X		J.M.C. Covre 2 (CAP); D.R. Couto 1729 (VIES)
	Pereskia aculeata Mill.	Climb.	X		J.M.C. Covre 6 (CAP)
	Rhipsalis lindbergiana K.Schum.	Herb		X	J.M.C. Covre 51 (CAP)
	CALOPHYLLACEAE (1)				
	Kielmeyera membranacea Casar.	Tree		X	J.M.C. Covre 50 (CAP)
	CLEOMACEAE (1)				
	Tarenaya rosea (Vahl ex DC.) Soares Neto & Roalson	Herb		X	J.M.C. Covre 112 (CAP)
	CONVOLVULACEAE (3)				
	Ipomoea quamoclit L.	Climb.	X		J.M.C. Covre 209 (CAP)
	Ipomoea sp.	Climb.		X	J.M.C. Covre 222 (CAP)
	Jacquemontia sp.	Climb.		X	J.M.C. Covre 109 (CAP)
	DIOSCOREACEAE (2)				
	Dioscorea glandulosa (Griseb.) Kunth	Climb.	X		J.M.C. Covre 208 (CAP)
	Dioscorea subhastata Vell.	Climb.	X		J.M.C. Covre 212 (CAP)
	ERYTHROXYLACEAE (1)				
	Erythroxylum sp.	Tree	X		J.M.C. Covre 192 (CAP)
	EUPHORBIACEAE (6)				

Evolutionary Lineages (species number)	Family/ Species	Life form	PHYTO		Vouchers (Herbaria)
			VER	WRC	
	Acalypha amblyodonta (Müll.Arg.) Müll.Arg.	Shrub		X	J.M.C. Covre 100 (CAP)
	Astraea gracilis (Müll.Arg.) O.L.M. Silva & Cordeiro	Herb	X		J.M.C. Covre 211 (CAP)
	Cnidoscolus oligandrus (Müll.Arg.) Pax	Tree		X	J.M.C. Covre 176 (CAP)
	Euphorbia comosa Vell.	Herb		X	J.M.C. Covre 232 (CAP)
	Manihot sp.	Shrub	X		J.M.C. Covre 205 (CAP)
	Romanoa tamnoides (A.Juss.) Radcl.-Sm.	Climb.	X		J.M.C. Covre 115 (CAP)
	FABACEAE (10)				
	Albizia polycephala (Benth.) Killip ex Record	Tree		X	J.M.C.Covre 235 (CAP)
	Aeschynomene sp.	Herb	X		J.M.C. Covre 181 (CAP)
	Calliandra sp. Benth.	Tree		X	J.M.C. Covre 234 (CAP)
	Camptosema isopetalum (Lam.) Taub.	Climb.	X		J.M.C. Covre 64 (CAP)
	Centrosema sp.	Subsh	X		J.M.C. Covre 218 (CAP)
	Centrosema arenarium Benth.	Subsh	X		J.M.C. Covre 164 (CAP)
	Machaerium sp.	Climb.		X	J.M.C. Covre 138 (CAP)
	Macroptilium atropurpureum (Sessé & Moc. ex DC.) Urb.	Climb.	X		J.M.C. Covre 143 (CAP)
	Macroptilium erythroloma (Mart. ex Benth.) Urb.	Climb.	X		J.M.C. Covre 229 (CAP)
	Sigmoidotropis speciosa (Kunth) A. Delgado	Climb.	X		J.M.C. Covre 99 (CAP)
	GESNERIACEAE (4)				
	Sinningia bragae Chautems,M. Peixoto & Rossini	Herb	X		J.M.C. Covre 171 (CAP)
	Sinningia brasiliensis (Regel & Schmidt) Wiehler & Chautems	Herb	X		J.M.C. Covre 191 (CAP)
	Sinningia speciosa (Lodd.) Hiern	Herb		X	J.M.C. Covre 216 (CAP)
	Sinningia sp.	Herb	X		J.M.C. Covre 88 (CAP)
	LOASACEAE (1)				
	Aosa parviflora (Schrad. ex DC.) Weigend	Herb	X		J.M.C. Covre 65 (CAP)
	MALPIGHIACEAE (1)				
	Stigmaphyllon vitifolium A.Juss.	Herb	X		J.M.C. Covre 210 (CAP)
	MALVACEAE (2)				
	Ceiba erianthos (Cav.) K.Schum.	Tree		X	Observed
	Pseudobombax aff petropolitanum A.Robyns	Tree	X		J.M.C. Covre 141; D.R. Couto 2362, 4000 (CAP)
	MELASTOMATACEAE (1)				
	Pleroma heteromallum D. Don (D.Don)	Shrub	X		J.M.C. Covre 98 (CAP)
	MORACEAE (1)				
	Ficus cyclophylla (Miq.) Miq.	Tree		X	J.M.C. Covre 198 (CAP)
	MYRTACEAE (4)				
	Eugenia punicifolia (Kunth) DC.	Shrub		X	J.M.C. Covre 43 (CAP)
	Eugenia sp.	Shrub	X		J.M.C. Covre 55 (CAP)
	Myrciaria floribunda (H.West ex Willd.) O.Berg	Shrub	X		J.M.C. Covre 183 (CAP)
	Sp. 1	Shrub	X		J.M.C. Covre 144 (CAP)
	RUTACEAE (2)				
	Esenbeckia sp.	Tree		X	J.M.C. Covre 48 (CAP)
	Pilocarpus spicatus A.St.-Hil.	Tree	X		J.M.C. Covre 206 (CAP)
	SOLANACEAE (3)				
	Physalis peruviana L.	Shrub	X		J.M.C. Covre 129 (CAP)
	Solanum americanum Mill.	Herb	X		J.M.C. Covre 110 (CAP)
	Solanum asperum Rich.			X	H.M. Dias 520 (VIES)
	URTICACEAE (2)				
	Laportea aestuans (L.) Chew	Herb		X	J.M.C. Covre 92 (CAP)
	Urera baccifera (L.) Gaudich. ex Wedd.	Shrub		X	J.M.C. Covre 54 (CAP)
	VERBENACEAE (2)				
	Lantana camara L.	Shrub		X	J.M.C. Covre 154 (CAP)
	Lippia origanoides Kunth	Subsh	X		J.M.C. Covre 46 (CAP)
	VITACEAE (1)				
	Cissus erosa Rich.	Climb.	X		J.M.C. Covre 233 (CAP)
	VOCHYSIACEAE (1)				
	Qualea sp.	Shrub	X		J.M.C. Covre 148 (CAP)