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Flora of Espírito Santo, Brazil

Plants in the clouds: vascular epiphytes of Pedra Azul, a mountain top in Espírito Santo, Southeastern Brazil

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Abstract

Cloud forests usually occur at high-altitude sites of the Atlantic Forest in eastern Brazil, albeit scattered and fragmented along the mountain tops. In this habitat, the vegetation occurs at low-temperature conditions and is usually provided by additional water sources that arise due to the horizontal precipitation of the frequent fogs. Together with the more considerable air movement and higher luminosity, these factors are conditioning for singular floras at high elevations, mainly the vascular epiphytes, which are macro and microclimate dependent. In the mountains range at the center of the Espírito Santo state, Southeastern Brazil, some mountain tops such as Pedra Azul (PA) hold these environmental features. Here, we aimed to present the first checklist of vascular epiphytes in the Pedra Azul State Park and surroundings based on fieldwork and herbarium specimens. The checklist comprises 152 species, 65 genera, and 17 families, the main families being Orchidaceae, Bromeliaceae, and Polypodiaceae, with the main genera represented by *Vriesea*, *Acianthera*, and *Peperomia*. The holoepiphytes were the main category among the epiphytes, although an unusually high number of facultative epiphytes were recorded. *Asplenium theciferum* and *Octomeria cucullata* are recorded in Espírito Santo for the first time, and we confirmed the occurrence of *Rhipsalis cereuscula* in the state. Overall, the richness recorded in PA is amongst the highest of the Atlantic Forest cloud forests. Six species are threatened at the national level and 32 at the state level. These results support the importance of the protected area for conserving the flora; however, several species - including threatened - were only recorded in the surroundings, demonstrating that the buffer zone of the Pedra Azul State Park must be included in the management plans.
Key words: Atlantic Forest, cloud forest, endangered species, floristic, inselberg, Pedra Azul State Park.

Resumo

As florestas nebulares ocorrem em locais de altitude elevada na Floresta Atlântica do leste do Brasil, embora dispersas e fragmentadas no topo das montanhas. Neste habitat, a vegetação ocorre em condições de baixa temperatura e geralmente é suprida por fontes de água adicionais que surgem devido à precipitação horizontal oriundas de nevoeiros, que são frequentes nesses locais. Ademais, os maiores movimentos de ar e a luminosidade, constituem fatores condicionantes a floras singulares que ocorrem em altitudes elevadas, principalmente as plantas epifíticas, que são sensíveis ao macro e microclima. Na região serrana do centro do estado do Espírito Santo, no Sudeste do Brasil, alguns locais mais elevados, como a Pedra Azul (PA), possuem essas características ambientais. Aqui, objetivamos apresentar a primeiro inventário de epífitas vasculares no Parque Estadual de Pedra Azul e arredores com base em trabalhos de campo e espécimes de herbário. Nós registramos 152 espécies, 65 gêneros e 17 famílias, sendo as principais famílias Orchidaceae, Bromeliaceae e Polypodiaceae, com os principais gêneros representados por *Vriesea*, *Acianthera* e *Peperomia*. As holoepífitas constituem a categoria principal entre as epífitas, embora um número incomumente alto de epífitas facultativas tenha sido registrado. *Asplenium theciferum* e *Octomeria cucullata* foram registradas pela primeira vez no

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Espírito Santo, e confirmamos a ocorrência de Rhipsalis cereuscula no estado. No geral, a riqueza registrada em PA está entre as mais altas das da Floresta Atlântica. Seis espécies estão ameaçadas em nível nacional e 32 em nível estadual. Esses resultados corroboram a importância da área protegida para a conservação da flora; entretanto, várias espécies - inclusive ameaçadas - foram registradas apenas no entorno, demonstrando que a zona de amortecimento do Parque Estadual da Pedra Azul deve ser incluída nos planos de manejo.
Palavras-chave: Floresta Atlântica, floresta nebular, espécies ameaçadas, florística, inselberg, Parque Estadual da Pedra Azul.

Introduction

The Atlantic Forest, which occurs in eastern Brazil, northern Argentina, and eastern Paraguay, is a phytogeographic domain comprising the second largest forest massif of South America, only smaller than the Amazon (Oliveira-Filho & Fontes 2000; Fiaschi & Pirani 2009). It occurs in the most mountainous region of Brazil, thus having a rugged relief and, consequently, a physiognomy conditioned by several environmental factors (*e.g.*, climatic and edaphic), resulting in different types of vegetation (*e.g.*, Semideciduous and Deciduous Seasonal Forests, Dense and Mixed Rain Forest, and Coastal Plain Forest (*Restinga*) (Oliveira-Filho & Fontes 2000; Fiaschi & Pirani 2009).

At high altitudes, primarily in southern and southeastern Brazil, some particular vegetation types occur in the Atlantic Forest, such as the cloud forests, Araucaria forests, and high-altitude grasslands (Safford 1999; Costa *et al.* 2018). The main mountain ranges are the Serra da Mantiqueira and the Serra do Mar, with elevations reaching nearly 3,000 m above sea level (*e.g.*, Pico da Bandeira, at 2,890 m) (Costa *et al.* 2018). Besides these, in the state of Espírito Santo, southeastern Brazil, there is a mountain range locally called Montanhas Capixabas or Serra do Castelo (Chiron & Bolsanello 2015). Although it does not reach elevations as high as the former ones, with the highest peak reaching about 2,000 m on the highest mountain top of the Serra do Castelo (Chiron & Bolsanello 2015; Garbin *et al.* 2017), it is one of the least botanically studied of the Atlantic Forest mountain ranges, with few floristic studies available.

The vegetation of these highlands, nowadays restricted and scattered on mountain tops, was likely widespread in the past due to the cold climate during the Pleistocene glaciations, forcing them to occur at lower elevations and latitudes (Luna-Vega *et al.* 2001; Behling *et al.* 2002). Thus, this vegetation represents vestiges of the past cold climate physiognomies that are nowadays reduced to fragments on the mountain tops (Koehler *et al.* 2002; Bertoncello *et al.* 2011) and harbor important and threatened species with restricted distributions and which may disappear with the increase of global temperatures (Foster 2001; Colwell *et al.* 2008).

High-altitude environments hold peculiar environmental conditions such as the presence and persistence of clouds and mist, influencing edaphic and microclimatic conditions (Bertoncello *et al.* 2011) and, consequently, the distribution of the flora and vegetation (Gentry & Dodson 1987; Oliveira-Filho & Fontes 2000; Blum *et al.* 2011a; Leitman *et al.* 2015).

At the Serra do Castelo, high-altitude vegetation, like occurs in the Pedra Azul, is associated with the granite-gneiss dome-shaped rock massifs (inselberg) (Garbin *et al.* 2017; de Paula *et al.* 2020). In such environments, according with the topography, in the rock slopes occurs scattered mats with herbaceous plants, and where patches of shallow soil are formed, a shrub vegetation occurs; also, in flat areas, deepest soils are formed and a scattered dwarf cloud forests developed (Rizzini 1997; Garbin *et al.* 2017; de Paula *et al.* 2020). Furthermore, surrounding the inselbergs, taller montane and high-montane cloud forests may occur (Magnago *et al.* 2007; Thomaz 2010). Such forests are characterized by low temperatures and abundant fog that substantially increase the humidity and may provide water during drought periods (Stadtmüller 1987; Bruijnzeel *et al.* 2010; Bertoncello *et al.* 2011; Arcova *et al.* 2016). Hence, vascular epiphytes, which are greatly dependent of humidity, are favored by the horizontal precipitation provided by the clouds, resulting in great diversity and biomass of epiphytes in cloud forests (Nadkarni 1984; Clark *et al.* 1998; Freiberg & Freiberg 2000; Köhler *et al.* 2007).

In Brazil, few floristic surveys of vascular epiphytes have been carried out in cloud forests (*e.g.*, Bianchi *et al.* 2012; Bonnet *et al.* 2013;

Alves & Menini Neto 2014; Furtado & Menini Neto 2016, 2018). In Espírito Santo, only two studies of vascular epiphytes were performed in high-altitude sites (Couto *et al.* 2016; Francisco *et al.* 2019). Gaps in biodiversity knowledge are one of the biggest problems for conservation (*e.g.*, Almeida & Mamede 2014; Giaretta *et al.* 2015). Therefore, it is essential to carry out floristic studies in areas that have been little studied and present environmental heterogeneity, aiming to direct the conservation efforts (Kessler 2001), besides the great relevance of understanding the origin, maintenance, distribution patterns, and processes to which biodiversity is subject (Werneck *et al.* 2011; Santos *et al.* 2014; Zizka & Antonelli 2018).

Here, we aim to present the first checklist of the composition of vascular epiphytes at a mountain top in the center of the state of Espírito Santo (Serra do Castelo), Southeastern Brazil, specifically in the Pedra Azul State Park and surroundings.

Material and Methods

Study site

The Pedra Azul (PA) is situated in the mountainous region of Espírito Santo, which occupies the central-south portion of the state (IPEMA 2005). These mountains are known locally as Serra do Castelo (Castelo Mountain Chain) (Chiron & Bolsanello 2015) and delimited to the North by the Doce River valley, to the East by the coastal plain, to the South by the Itapemirim River valley, to the Southwest by the Serra do Caparaó, and to the Northwest by the state of Minas Gerais and the Serra da Chibata, with an average altitude of 700 m reaching up to 2,050 m (Chiron & Bolsanello 2015). In the collection sites of the PA, the elevation ranges between 1,100 m and 1,600 m.

According to the Köppen classification, the climate in the PA is Cfb, with an average temperature from 14 °C to 16 °C, average precipitation of 1,200 mm to 1,500 mm, and seasonal drought in the winter (May to October), with six months with less than 100 mm of rain (Alvares *et al.* 2013; INCAPER 2020). In the PA, the occurrence of fogs is usual (personal observations), with an estimated mean annual cloud cover of 80 % (Wilson & Jetz 2016).

In PA, the vegetation is usually classified as montane to high-montane cloud rainforest (dense ombrophilous forest) (Magnago *et al.* 2007; Garbin *et al.* 2017). However, there are six months of drought (Alvares *et al.* 2013; INCAPER 2020), so it is better fitted as a seasonal forest (IBGE 2012). In the collection sites, the vegetation ranges from tall montane and high-montane cloud forests to dwarf high-montane cloud forests, including riverine formations of both. The first occur in the deep valleys, slopes, and some patches among the inselberg drainages, while the latter in the high-altitude inselbergs, between Pedra das Flores and Pedra Azul.

The study site comprises part of the Pedra Azul State Park (PASP) and a valley in the Buffer Zone (BF) (central coordinate 20°25'05"S and 41°00'25"W) (Fig. 1), situated in the district of Aracê, which belongs to the municipality of Domingos Martins, in the state of Espírito Santo (ES), Southeastern Brazil. The PASP was created in 1960 originally named Pedra Azul Forest Reserve (State Decree No. 312, of October 31st, 1960), comprising the steepest areas usually with little or no interest for crop cultivation or pastures (IDAF 2004). Consequently, the protected area includes the high-altitude inselbergs (Pedra Azul at 1,822 m, Pedra das Flores at 1,909 m) and adjacent mountain tops, comprising about 1,240 hectares, surrounded by private properties. The PASP has a well-developed tourism activity.

Collections were made on the touristic trail from the natural pools up to the foothill of Pedra das Flores and Pedra Azul (ranging from 1,350 m to 1,600 m a.s.l., covering about 12 hectares of dwarf cloud forest), in the secondary forest surrounding the research lodge (1,300 m to 1,400 m, covering about 20 ha), and in an area contiguous to the Park, in the slopes and riverine forests, in the headwaters of the Jucu River, which crosses a private property (1,100 m to 1,230 m, covering about 5 ha) (Fig. 1).

Data collection

The floristic inventory of vascular epiphytes was carried out over seven expeditions lasting about one to tree days each, in January, May, and September of 2018, February, August, and October of 2019, and November of 2020. Fertile specimens were deposited at the Herbarium Rioclarense (HRCB), and duplicates were sent to the herbaria BHCB, CESJ, RB, and UNOP (acronyms follow Index Herbariorum, continuously updated). Sterile specimens collected mainly from fallen trees and branches were kept at a greenhouse in Rio Claro until flowering and subsequently processed. To complement the floristic inventory, we used the SpeciesLink network (CRIA 2020) and Reflora

- Virtual Herbarium (2020) to analyze previous collections carried out within the Park and deposited at the herbaria MBML, RB, and VIES (acronyms follow Index Herbariorum, continuously updated).

During the expeditions to the field, we observed the habits of the epiphytes and classified them into ecological categories according to their relationship with the phorophytes, following Benzing (1990): characteristic

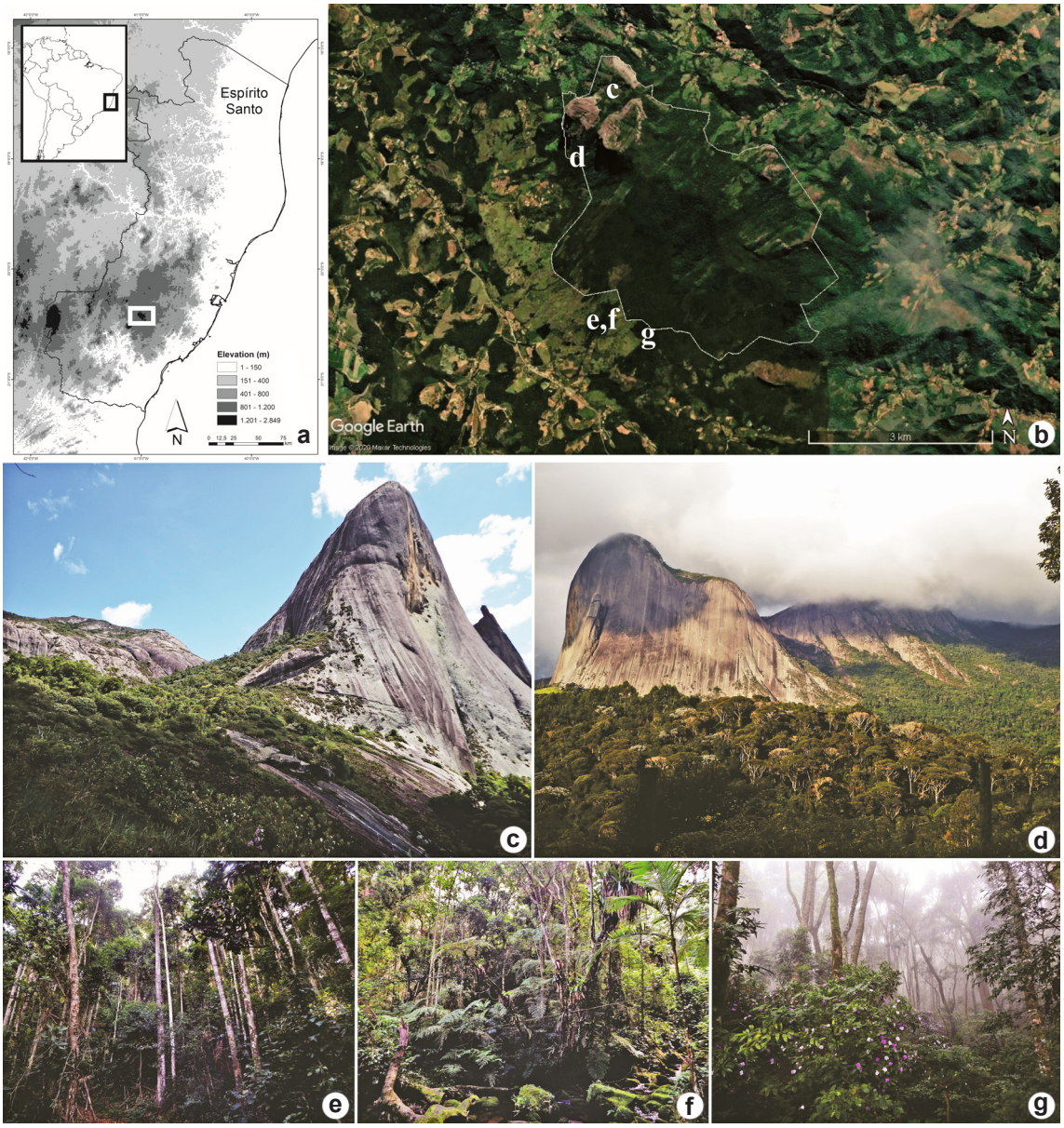

Figure 1 – a-b. Geographical location of Pedra Azul and the delimitation of the Pedra Azul State Park (PASP) in white, in Domingos Martins municipality, Espírito Santo, Brazil – a. Espírito Santo state, highlighting the location of Pedra Azul; b. delimitation of PASP (the letters are according to the photos). c-d. showing the interior of the PASP – c. Pedra Azul, dwarf cloud forest and Pedra das Flores in the background; d. Pedra Azul and Pedra das Flores covered by the clouds showing the tall montane forest in the slopes. e-g. the buffer zone sampled in this study – e. tall montane cloud forest; f. alluvial cloud montane forest; g. secondary montane cloud forest. (a. prepared by Henrique Lauand Ribeiro; b. adapted from Google Earth Pro; c-g. photos of Gabriel Mendes Marcusso).

holoepiphytes, facultative holoepiphytes, primary hemiepiphytes, and secondary hemiepiphytes. It was preferred to use this classification instead of that of Zotz (2013a) to facilitate comparison with other studies since most used the former. Terrestrial species occasionally found growing as epiphytes were not considered in this study, as they are deemed ephemeral epiphytes (Kersten 2010; Zotz 2016).

Taxonomic identification was made using taxonomic literature and herbarium collections at HRCB and MBML, as well as by consulting specialists (mentioned in the acknowledgments). The taxonomic classification is according to APG IV (2016) for angiosperms and PPG I (2016) for monilophytes and lycophytes. Species names, synonymy, authors, and distributions are used according to Flora do Brasil 2020 (BFG 2018). The conservation statuses were obtained at national (Martinelli & Moraes 2013; CNC Flora 2020) and, at the state level (Fraga *et al.* 2019).

Results

In the PA, we recorded 152 species of vascular epiphytes belonging to 65 genera and 17 families (Figs. 2-3; Tab. S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.17161412.v1>). Ferns and Lycophytes account for 37 of the recorded species, and flowering plants represent the vast majority (115 species). In the PASP 104 species were recorded, in the BF, of the 73 species, 48 were not recorded inside the protected area; 25 of them were recorded in both (Tab. S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.17161412.v1>). Overall, the richest families were Orchidaceae (56 species), Bromeliaceae (29), Polypodiaceae (16), Cactaceae and Piperaceae (9 each), and Araceae (7). The richness genera were *Vriesea* (11 species), *Acianthera* and *Peperomia* (9 each), *Gomesa* (7), *Asplenium* (6), and *Hymenophyllum*, *Nidularium*, *Octomeria*, *Rhipsalis*, and *Tillandsia* (5 each). The main ecological category is the characteristic holoepiphytes (88 species), followed by the facultative holoepiphytes (58) and the secondary hemiepiphytes (6).

Six species are reported as threatened at the national level, one critically endangered, two endangered, and three vunerable. At state level 32 are cited in the list, four are critically endangered, six endangered, and 22 vunerable (Tab. S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.17161412.v1>). Furthermore, 10 species are Data Deficient (DD) at the state level.

Discussion

We presented the first checklist of the vascular epiphytes of the Pedra Azul, including part of the Pedra Azul State Park and a river valley in the buffer zone. We found new records for the state and species threatened of extinctions at both state and national level. Overall, the number of species is outstanding for the cloud forests of the AF. The great number of facultative epiphytes is a characteristic feature of forest in rockness matrix, like the mountain's summits. Furthermore, the peculiar climatic conditions -with the prevalence of cloud cover inputing water in the vegetation and the low temperature- are the main drive for the singular flora found in this high-altitude site.

In Brazil, few floristic studies regarding vascular epiphytes have been carried out in mountainous sites above 1,000 m of elevation (Tab. 1). These studies registered a richness ranging from 50 to 312 species, although they used different sample efforts and areas (Tab. 1). The richness recorded in the PA agrees with the data on vascular epiphytes in mountainous sites of the Atlantic Forest. The PA only stands below studies that carried out more comprehensive sampling, considering several years of collections, and those in areas with a wider altitude range (*e.g.*, Fontoura *et al.* 1997; Furtado & Menini Neto 2016). Furthermore, considering the area sampled in the present study (about 37 hectares) and the entire area of the State Park (1,240 hectares), we may consider that the PA harbors a rich vascular epiphyte flora. Undoubtedly, additional species are expected to occur in the area since most pristine forest patches of the PA are of difficult access due to the mountainous relief and there being few trails that cross such areas. Some species are not mentioned in the list because they were not found fertile [*e.g.*, *Acianthera nemorosa* (Barb.Rodr.) F.Barros, *Epidendrum paranaense* Barb.Rodr. (Orchidaceae), *Spirotheca rivieri* (Decne.) Ulbr. (Malvaceae), and *Nematanthus* sp. (Gesneriaceae)].

Low temperatures and frost are constraining factors that affect vascular epiphyte diversity in high-altitude habitats (Gentry & Dodson 1987;

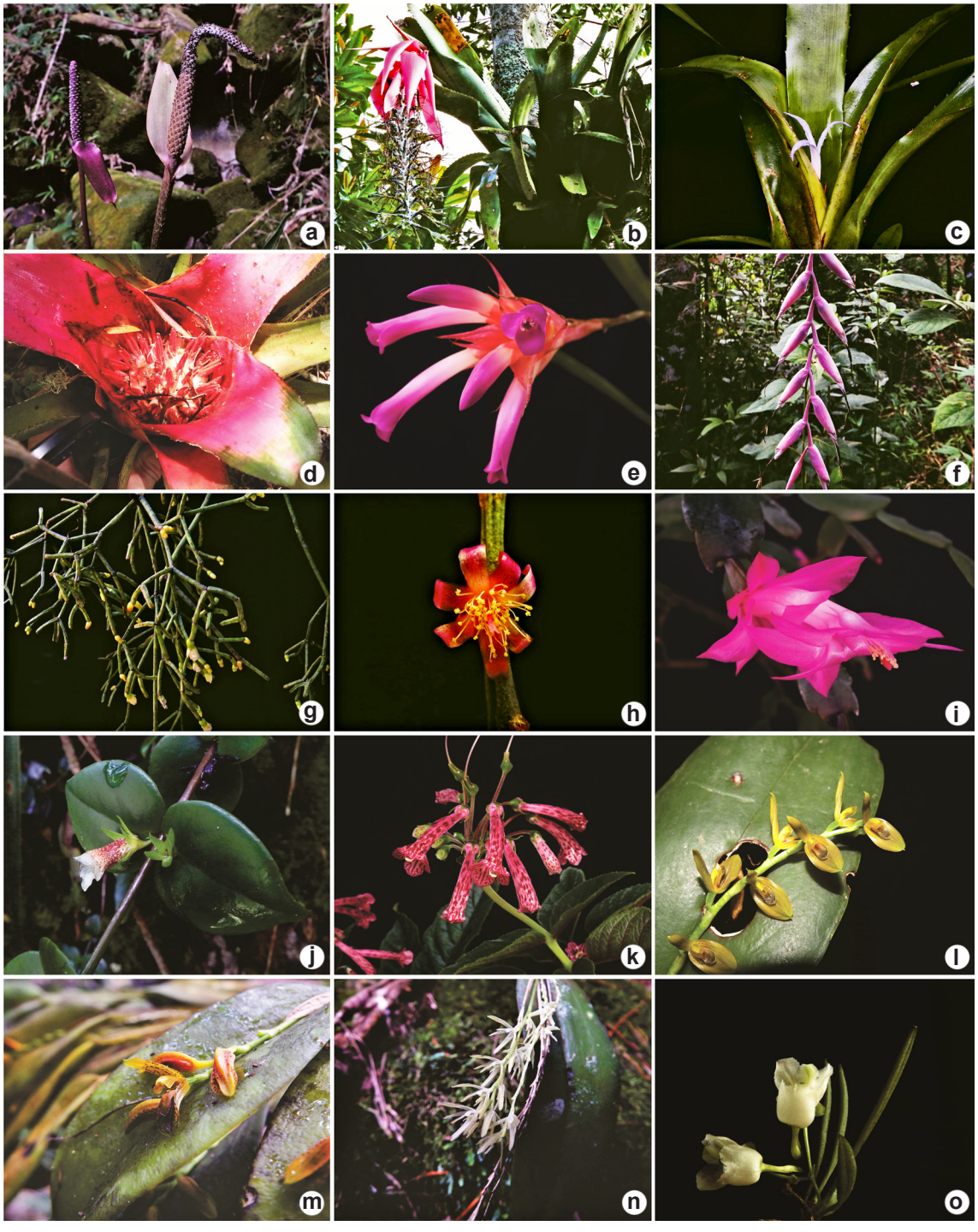

Figure 2 – a-o. Vascular epiphytes representatives of Pedra Azul State Park and a neighbor particular area, Domingos Martins, Espírito Santo, Brazil, highlighting new records to Espírito Santo, threatened and data deficient species – a. *Anthurium fragae* (Araceae); b-f. Bromeliaceae – b. *Billbergia zebrina*; c. *Neoregelia diversifolia*; d. *Neoregelia farinosa*; e. *Quesnelia kautskyi*; f. *Vriesea capixabae*; g-i. Cactaceae – g. *Rhipsalis cereuscula*; h. *Rhipsalis hoelleri*; i. *Schlumbergera kautskyi*; j-k. Gesneriaceae – j. *Codonanthe cordifolia*; k. *Sinningia douglasii*; l-o. Orchidaceae – l. *Acianthera binotii*; m. *Acianthera heringeri*; n. *Anathallis radialis*; o. *Centroglossa macroceras*.

Figure 3 – a-o. Vascular epiphytes representatives of Pedra Azul State Park and a neighbor particular area, Domingos Martins, Espírito Santo, Brazil, highlighting new records to Espírito Santo, threatened and data deficient species – a-m. Orchidaceae – a. *Dichaea cogniauxiana*; b. *Epidendrum chlorinum*; c. *Gomesa gomezoides*; d. *Gomesa imperatoris-maximiliani*; e. *Gomesa praetexta*; f. *Gomesa uhlii*; g. *Hadrolaelia pumila*; h. *Lankesterella ceracifolia*; i. *Miltonia spectabilis*; j. *Octomeria cucullata*; k. *Octomeria palmyrabellae*; l. *Pabstia jugosa*; m. *Pabstiella leucopyramis*; n-o. Piperaceae – n. *Peperomia catharinae*; o. *Peperomia pilicaulis*.

Table 1 – Local floristic surveys exclusively of vascular epiphytes in the high-altitude [above (880–)1,000 m] pluvial to seasonal cloud forests in the Brazilian Atlantic Forest organized in descending order of species richness. Spp = number of species; Gen = number of genera; Fam = number of families; m = meters above sea level; mm = millimeters, ha = hectares; NI = data not informed at the source; * = excluded mistletoes.

Location	State	Spp.	Gen.	Fam.	Altitude (m)	Precipitation (mm)	Area (ha)	Source
Macaé de Cima	RJ	312	87	26	880-1720	2128	7200	Fontoura *et al.* (1997)*
Ibitipoca	MG	224	81	22	1000-1800	1532	300	Furtado & Menini Neto (2018)
Pedra Azul	ES	152	65	17	1100-1600	1200-1500	37	Present study
Serra do Papagaio	MG	138	66	25	1800-2000	NI	NI	Furtado & Menini Neto (2016)
Serra do Cruz	MG	135	62	16	1100-1500	1200-1500	NI	Alves & Menini Neto (2014)
Marumbi	PR	127	59	21	1000	1384	1	Bianchi *et al.* (2012)
Serra da Prata	PR	121	64	23	1000-1100	2290	0.2	Blum *et al.* (2011b)
Ponte Alta	SC	84	47	16	1131	NI	2.01	Bonnet *et al.* (2013)
Cubatão, Joinville	SC	73	44	16	1168	NI	2.01	Bonnet *et al.* (2013)
Pedra dos Pontões	ES	66	34	10	1150	NI	1	Francisco *et al.* (2019)
Pedra Roxa	ES	62	46	15	1114	1391	2	Couto *et al.* (2016)
Guarapuava	PR	54	32	13	1100-1200	NI	NI	Kersten *et al.* (2009)
Campos do Jordão	SP	51	31	11	1030-2007	NI	NI	Mania (2013)
Nova Trento	SC	50	34	13	1097	NI	2,01	Bonnet *et al.* (2013)

Krömer *et al.* 2005; Blum *et al.* 2011b; Hsu *et al.* 2014). In turn, the occurrence of fogs acts as a source of humidity (Arcova *et al.* 2012) and is positively associated with the epiphytic assemblage, thus being one of the most important factors conditioning the occurrence of vascular epiphytes (Gentry & Dodson 1987; Laube & Zotz 2003; Ding *et al.* 2016). This additional humidity has great importance in the driest periods, mitigating the drought due to the "horizontal precipitation" (Vogelmann 1973; Arcova *et al.* 2012). Unfortunately, quantitative climatic data (*e.g.*, on water input by cloud condensation) are scarce in the Brazilian mountains, mainly in Espírito Santo. In the PA, fog at the mountain is common, especially from nightfall to morning (personal observations).

In the PA, the richest families reported follow the expected for cloud forests of eastern Brazil (Alves & Menini Neto 2014; Furtado & Menini Neto 2016, 2018), for the Atlantic Forest in particular (Kersten 2010; Freitas *et al.* 2016), and to the global patterns, except for the more considerable importance of the Bromeliaceae family, which is a near endemic Neotropical family (Zotz 2013b, 2016). About 80 % of the vascular epiphytes are concentrated in the greatly diversified Orchidaceae family, resulting in the significant taxonomic importance of this family in this synusia (Kersten 2010; Zotz 2013b, 2016). The low representativity of the Araceae family in high-altitude habitats is expected in the Neotropical Region (Krömer *et al.* 2005; Ortiz *et al.* 2019), and the Atlantic Forest (Menini Neto *et al.* 2009; Rogalski *et al.* 2016), with a better contribution in lowland forests (Coelho 2010), mainly in the Amazon (Irume *et al.* 2013; Obermuller *et al.* 2014).

Few ferns and lycophytes were recorded in the PA (21.7 % of the total). This pattern is not usually observed in higher-altitude forests in the Neotropical Region, which usually is richer at high-altitude sites (Krömer *et al.* 2005, 2013; Cardelús *et al.* 2006). The pattern appears to be different

in the Atlantic Forest, with lycophytes and ferns decreasing in richness when the altitude increases (Paciencia 2008; Blum *et al.* 2011b; Nóbrega 2013; Couto *et al.* 2016).

Regarding the distribution, the vast majority of the identified species (95 spp., 62.5% overall) are endemic of the Atlantic Forest, and seven are restricted to Espírito Santo (*Anthurium fragae*, *Gomesa uhlii*, *Neoregelia diversifolia*, *Nidularium cariacicaense*, *Vriesea capixabae*, *V. pereirae*, and *Rhipsalis hoelleri*). *Octomeria cucullata* and *Asplenium theciferum* are being reported for the first time in Espírito Santo and represent the first collections for Brazil after over 50 years, according to Dutra *et al.* (2015), CRIA (2020), and REFLORA (2020). We recorded the occurrence of *Rhipsalis cereuscula* in Espírito Santo; the only collection previously reported of it (Dutra *et al.* 2015) was in the city of Espírito Santo do Pinhal, in the state of São Paulo. Furthermore, 22 species are being recorded in cloud forests of the Southeastern Brazil for the first time (Furtado 2020).

The predominance of holoepiphyte characteristics is an expected pattern (Freitas *et al.* 2016; Zotz 2016). On the other hand, the great number of facultative holoepiphytes recorded is outstanding (38.1 % overall) when compared with some sites of the Atlantic Forest (Bonnet *et al.* 2011; Padilha *et al.* 2015; Couto *et al.* 2016; Marcusso & Monteiro 2016; Rolim *et al.* 2016). This different pattern could be explained by the abundance of rock outcrops in the studied area (Biral & Lombardi 2012; Perleberg *et al.* 2013; Couto *et al.* 2016). The rocks show a level of ecological equivalence with the trunks and branches of trees, such as the few nutrients available and the higher water drainage (Zotz 2016). Also, when situated below the forest cover, they may hold light conditions similar to those of the lower trunk and inner tree crown (Zotz 2016). These features have demonstrated a high habitat equivalence, allowing the occurrence of epiphytes, mainly accidental, in the trees (Perleberg *et al.* 2013; Couto *et al.* 2019). In our study, few accidental epiphytes' species, not included in the checklist, were observed in forks and horizontal branch (*e.g.*, *Bifrenaria tyrianthina* (Lodd. *ex* Loudon) Rchb.f., *Epidendrum secundum* Jacq. and the exotic Crassulaceae, *Kalanchoe fedtschenkoi* Raym.-Hamet & H.Perrier. However, several of the facultative species recorded, grows on the rocks. The presence of trees with horizontal and exposed roots perhaps is a determinant factor for the colonization of a high number of typical rupicolous species, like *Pseudobombax* (Couto *et al.* 2019), not observed in the PA.

The hemiepiphytes were represented by few species in the PA, in agreement with the low representativity of families with a great prevalence of this habit, such as the Araceae, corroborating the previous data on vascular epiphytes at high altitudes or in rocky outcrop habitats (Alves & Menini Neto 2014; Couto *et al.* 2016; Furtado & Menini Neto 2016; 2018; Rogalski *et al.* 2016).

The records of 31,6 % of the species only outside the protected area argue for the conservation issues in the BZ of the PASP, which must be considered in conservationist policies. Special attention regarding the threatened species recorded only outside the PASP are need: three of them are threatened at national level - *Acianthera heringeri* (Hoehne) F.Barros being critically endangered - and nine at state level - *Schlumbergera kautskyi* (Horobin & McMillan) N.P.Taylor and *Sinningia douglasii* (Lindl.) Chautems being critically endangered. On the other hand, the sampling of the inaccessible areas inside the PASP could locate these threatened taxa inside its area. Therefore, a first step is to reach the inaccessible areas of the PASP by means of trails, to monitor and allow new studies in the areas not visited by tourists. Plus, monitoring the populations inside the PASP and the BF is needed, to avoid the illegal collections, the illegal suppression of the vegetation and the occurrence of the fire. In this way, we encourage more botanical collections and studies within the boundaries of this protected area.

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References

Almeida RA & Mamede MCH (2014) Checklist, conservation status, and sampling effort analysis of Malpighiaceae in Espírito Santo state, Brazil. Brazilian Journal of Botany 37: 329-337.

Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM & Sparovek G (2013) Köppen's climate classification map for Brazil. Meteorologische Zeitschrift 22: 711-728.

Alves FE & Menini Neto L (2014) Vascular epiphytes in a forest fragment of Serra da Mantiqueira and floristic relationships with Atlantic high altitude areas in Minas Gerais. Brazilian Journal of Botany 37: 187-196.

APG IV - Angiosperm Phylogeny Group (2016) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society 181: 1-20.

Arcova FCS, Galvani E, Cicco V & Ranzini M (2012) Captação de água de nevoeiros por coletores cilíndricos instalados na Serra Do Mar, Cunha - SP. Revista Geonorte, Edição Especial 2: 1204-1229.

Arcova FCS, Galvani E, Ranzini M & Cicco V (2016) Ocorrência de nevoeiros em uma microbacia experimental na Serra do Mar, Cunha, SP. Revista Brasileira de Climatologia 18: 327-348.

Behling H, Arz HW, Pätzold J & Wefer G (2002) Late quaternary vegetational and climate dynamics in southeastern Brazil, inferences from marine cores GeoB 3229-2 and GeoB 3202-1. Palaeogeography, Palaeoclimatology, Palaeoecology 179: 227-243.

Benzing DH (1990) Vascular epiphytes. General biology and related biota. Cambridge University Press, Cambridge. 354p.

Bertoncello R, Yamamoto K, Meireles LD & Shepherd GJ (2011) A phytogeographic analysis of cloud forests and other forest subtypes amidst the Atlantic forests in south and southeast Brazil. Biodiversity and Conservation 20: 3413-3433.

BFG - The Brazil Flora Group (2018) Brazilian Flora 2020: innovation and collaboration to meet Target 1 of the Global Strategy for Plant Conservation (GSPC). Rodriguésia 69: 1513-1527.

Bianchi JS, Bento CM & Kersten RA (2012) Epífitas vasculares de uma área de ecótono entre as Florestas Ombrófilas Densa e Mista, no Parque Estadual do Marumbi, PR. Estudos de Biologia: Ambiente e Diversidade 34: 37-44.

Biral L & Lombardi JA (2012) Flora vascular da mata da Pavuna, Botucatu, SP, Brasil. Rodriguésia 63: 441-450.

Blum CT, Roderjan CV & Galvão F (2011a) O clima e sua influência na distribuição da floresta ombrófila densa na Serra Da Prata, Morretes, Paraná. Floresta 41: 589-598.

Blum CT, Roderjan CV & Galvão F (2011b) Composição florística e distribuição altitudinal de CHs vasculares da Floresta Ombrófila Densa na Serra da Prata, Morretes, Paraná, Brasil. Biota Neotropica 11: 141-159.

Bonnet A, Curcio GR, Lavoranti OJ & Galvão F (2011) Flora epifítica vascular em três unidades vegetacionais do Rio Tibagi, Paraná, Brasil. Rodriguésia 62: 491-498.

Bonnet A, Caglioni E, Schmitt JL, Cadorin TJ, Gasper AL, Andrade S, Grosch B, Cristofolini C, Oliveira CPL, Lingner DV, Uhlmann A, Sevegnani L & Vibrans AC (2013) Epífitos vasculares da Floresta Ombrófila Densa de Santa Catarina. *In*: Vibrans AC, Bonnet A, Caglioni E, Gasper AL & Lingner DV (eds.) Epífitos vasculares da Floresta Ombrófila Densa. Vol. 5. Edfurb, Blumenau. Pp. 23-67.

Bruijnzeel LA, Scatena FN & Hamilton L (2010) Tropical Montane Cloud Forests: science for conservation and management. Cambridge University Press.

Cardelús CL, Colwell RK & Watkins Jr JE (2006) Vascular epiphyte distribution patterns: explaining the mid-elevation richness peak. Journal of Ecology 94: 144-156.

Chiron GR & Bolsanello RX (2015) Orchidées du Brésil - as orquídeas da Serra do Castelo (Espírito Santo - Brasil). Vol. 1. Tropicalia, Voreppe. 371p.

CNC Flora - Centro Nacional de Conservação da Flora (2020) Instituto de Pesquisas Jardim Botânico do Rio de Janeiro. Available at <http://cncflora.jbrj.gov.br/portal>. Access on 10 March 2021.

Coelho MAN (2010) A família Araceae na Reserva Natural Vale, Linhares, Espírito Santo, Brasil. Boletim do Museu de Biololgia Mello Leitão 28: 41-87.

Colwell RK, Brehm G, Cardelús CL, Gilman AC & Longino JT (2008) Global warming, elevational range shifts, and lowland biotic attrition in the wet tropics. Science 322: 258-261.

Costa DP, Couto GP, Siqueira MF & Churchill SP (2018) Bryofloristic affinities between Itatiaia National Park and tropical Andean Countries. Phytotaxa 346: 203-220.

Couto DR, Dias HM, Pereira MCA, Fraga CN & Pezzopane JEM (2016) Vascular epiphytes on *Pseudobombax* (Malvaceae) in rocky outcrops (inselbergs) in Brazilian Atlantic Rainforest: basis for conservation of a threatened ecosystem. Rodriguésia 67: 583-601.

Couto DR, Francisco TM, Garbin ML, Dias HM, Pereira MCA, Menini Neto L & Pezzopane JEM (2019) Surface roots as a new ecological zone for occurrence of vascular epiphytes: a case study on *Pseudobombax* trees on inselbergs. Plant Ecology 220: 1071-1084.

CRIA (2020) Centro de Referência em Informação Ambiental. Available at <http://www.cria.org.br>. Access on 1 March 2020.

de Paula LFA, Azevedo LO, Mauad LP, Cardoso LJT, Braga JMA, Kollmann LJC, Fraga CN, Menini Neto L, Labiak PH, Mello-Silva R, Porembski S, Forzza RC (2020) Sugarloaf Land in south-eastern Brazil: a tropical hotspot of lowland inselberg plant diversity. Biodiversity Data Journal 8: e53135. <https://doi.org/10.3897/BDJ.8.e53135>

Ding Y, Liu G, Zang R, Zhang J, Lu X & Huang J (2016) Distribution of vascular epiphytes along a tropical elevational gradient: disentangling abiotic and biotic determinants. Scientific Reports 6: 19706.

Dutra VF, Alves-Araújo A & Carrijo TT (2015) Angiosperm checklist of Espírito Santo: using electronic tools to improve the knowledge of an Atlantic Forest biodiversity hotspot. Rodriguésia 66: 1145-1152.

Fiaschi P & Pirani JR (2009) Review of plant biogeographic studies in Brazil. Journal of Systematics and Evolution 47: 477-496.

Fontoura T, Sylvestre LS, Vaz AMS & Vieira CM (1997) Epífitas vasculares, hemiepífitas e hemiparasitas da Reserva Ecológica de Macaé de Cima. *In*: Lima HC & Guedes-Bruni RR (eds.) Serra de Macaé de Cima: diversidade florística e conservação em Mata Atlântica. Editora do Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rio de Janeiro. Pp. 89-102.

Foster P (2001) The potential negative impacts of global climate change on tropical montane cloud forests. Earth-Science Reviews 55: 73-106.

Fraga CN, Peixoto AL, Leite YLR, Santos ND, Oliveira JRPM, Sylvestre LS, Schwartsburd PB, Tuler AC, Freitas J, Lírio EJ, Couto DR, Dutra VF, Waichert C, Sobrinho TG, Hostim-Silva M, Ferreira RB, Bérnils RS, Costa LP, Chaves FG, Formigoni MH, Silva JP, Ribeiro RS, Reis JCL, Capellão RT, Lima RO, Saiter FZ, Lopes AS, Paglia AP, Chautems A, Braz AG, Mônico AT, Salino A, Firmino AD, Chagas AP, Colodetti AF, Krahl AH, Sousa AAC, Pavan ACDO, Castello ACD, Loss AC, Srbek-Araujo AC, Scudeler AL, Farro APC, Feijó A, Machado AFP, Ferreira ALN, Fontana AP, Freitas AVL, Cabral A, Bolzan AAS, Weigand A, Frazão A, Neto ACR, Almeida AP, Brescovit AD, Argôlo AJS, Soares AS, Gonçalves AM, Santiago ACP, Giaretta A, Rosa AHB, Katz AM, Gomes BM, Øllgaard B, Silva BCB, Canestraro BK, Melo BF, Evaldt BHC, Pimentel CR, Possamai CB, Ferreira CDM, Guidorizzi CE, Silva CBM, Ferreira CD, Zocca C, Miranda CV, Duca C, Kameyama C, Vilar CC, Canedo C, Sampaio CA, Carneiro CE, Mynssen CM, Pessoa CS, Cunha CJ, Sá CFC, Imig DC, Sampaio D, Monteiro D, Moreira DO, Robayo DS, Machado DF, Peralta DF, Silva DF, Gonzaga DR, Zeppelini D, Silva EMP, Lozano ED, Melo E, Chiquito EA, Rossetto EFS, Smidt EC, Martins ER, Neto EAS, Júnior EMSS, Massariol FC, Firetti F, Novelli FZ, Dario FD, Gonzatti F, Guimarães FV, Cabral FN, Fraga FRM, Matos FB, Dagosta FCP, Vaz-de-Mello FZ, Souza FS, Leite FT, Molina FB, Barroso FG, Alves FM, Salles FF, Mendonça GC, Siqueira GS, Pinto GO, Romão GO, Antar GM, Rosa GAB, Hasseme G, Heiden G, Shimizu GH, Caitano HA, Lima HC, Resende HC, Pichler HA, Bergallo HG, Fernandes HQB, Secco HKC, Costa HC, Dias HM, Filho HJD, Silva HL, Ornellas IS, Bergher IS, Pinheiro IEG, Koch I, Rodrigues IMC, Passamani JA, Delabie JHC, Oliveira JCF, Luber J, Prado J, Lopes JC, Christ JA, Nodari JZ, Tonini JFR, Zorzanelli JPF, Condack JPS, Lacerda JVA, Adelir-Alves J, Jardim JG, Santander-Neto J, Trezena JS, Schoereder JH, Gomes JML, Silva JN, Trarbach J, Rossini J, Kulkamp J, Pereira JBS, Prado JR, Guarnier JC, Paula-Souza J, Alevi KCC, Furieri KS, Costa KG, Alves KP, Pederneiras LC, Cardoso LJT, Geise L, Mathias LB, Ingenito LFS, Merçon L, Contaifer LS, Bissoli LB, Aona LYS, Silva LTP, Freitas LT, Calazans LSB, Marinho LC, Silva LA, Silva LEF, Lima LV, Martins LR, Kollmann LJC, Bernacci LC, Mayorga LFSP, Sarmento-Soares LM, Góes-Neto LAA, Duboc LF, Fonseca LHM, Faria LRRJr, Beyer M, Vianna Filho MDM, Devecchi MF, Passamani M, Britto MR, Pereira MR, Simonelli M, Trovó M, Fukuda MV, Verdi M, Pellegrini MOO, Coelho MAN, Lehnert M, Alves MAS, Kierulffl MCM, Loiola MIB, Marchioretto MS, Saka MN, Rodrigues MR, Zanin M, Facco MG, Zortéa M, Freitas MO, Pastore M, Camelo MC, Milward-de-Azevedo MA, Ribeiro M, Teixeira MDR, Klautau M, Kaehler M, Menezes NA, Bigio NC, Pena NTL, Shibatta OA, Silva OLM, Gonçalves PR, Santos PM, Grossi PC, Buckup PA, Chaves PB, Paiva PC, Windisch PG, Barros PHD, Evangelista PHL, Gonella PM, Fiaschi P, Cardoso PH, Peloso PLV, Santos PMLA, Taucce PPG, Cardoso PCA, Almeida RF, Barbosa-Silva RG, Trad RJ, Vanstreels RET, Macieira RM, Monteiro RF, Viveros RS, Ribeiro RTM, Romanini RP, Hirai RY, Betzel RL, Pereira RCA, Rurtado R, Sousa-Lima RS, Pagotto RV, MelloSilva R, Goldenberg R, Vicente RE, Lourenço-de-Moraes R, Couto RS, Bianchi RC, Paresque R, Valadares RT, Guimarães RR, Ribon R, Martins-Pinheiro RF, Marquete R, Subirá RJ, Siciliano S, Recla SS, Ribeiro S, Nunes SF, Mendes SL, Oliveira TPR, Carrijo TT, Silva TG, Volpi TA, Almeida TE, Flores TB, Kloss TG, Castro TM, Silva-Soares T, Barbosa TDM, Tavares

VC, Fagundes V, Verdade VK, Amaral VS, Orrico VGD, Vale V, Caldara VJr, Dittrich VAO, Freitas VC, Giglio VJ, Perte W, Colombo WD, Cardoso WC & Nóbrega YC (2019) Lista da fauna e flora ameaçadas de extinção no estado do Espírito Santo. *In*: Fraga CN, Formigoni MH & Chaves FG (eds.) Fauna e flora ameaçadas de extinção no estado do Espírito Santo. Instituto Nacional da Mata Atlântica, Santa Teresa. Pp. 342-419.

Francisco TM, CoutoDR, Garbin ML, Muylaert RL & Ruiz-Miranda CR (2019) Low modularity and specialization in acommensalistic epiphyte-phorophyte network in a tropical cloud forest. Biotropica 51: 509-518.

Freiberg M & Freiberg E (2000) Epiphyte diversity and biomass in the canopy of lowland and montane forests in Ecuador. Journal of Tropical Ecology 16: 673-688.

Freitas L, Salino A, Menini Neto L, Almeida TE, Mortara SR, Stehmann JR, Amorim AM, Guimarães EF, Coelho MN, Zanin A & Forzza RC (2016) A comprehensive checklist of vascular epiphytes of the Atlantic Forest reveals outstanding endemic rates. PhytoKeys 58: 65-79.

Furtado SG & Menini Neto L (2016) Vascular epiphytic flora of a high montane environment of Brazilian Atlantic Forest: composition and floristic relationships with other ombrophilous forests. Acta Botanica Brasilica 30: 422-436.

Furtado SG & Menini Neto L (2018) Diversity high up: a cloud forest of the Serra da Mantiqueira as a vascular epiphyte hotspot. Rodriguésia 69: 263-279.

Furtado SG (2020) Biogeografia de epífitas vasculares na Serra da Mantiqueira, Sudeste do Brasil. Tese de Doutorado. Universidade Federal de Juiz de Fora.

Garbin ML, Saiter FZ, Carrijo TT & Peixoto AL (2017) Breve histórico e classificação da vegetação capixaba. Rodriguesia 68: 1883-1894.

Gentry AH & Dodson CH (1987) Diversity and biogeography of Neotropical vascular epiphytes. Annals of the Missouri Botanical Garden 74: 205-233.

Giaretta A, Menezes LFT & Peixoto AL (2015) Diversity of Myrtaceae in the southeastern Atlantic forest of Brazil as a tool for conservation. Brazilian Journal of Botany 38: 175-185.

Hsu RCC, Wolf JHD & Tamis WLM (2014) Regional and elevational patterns in vascular epiphyte richness on an East Asian island. Biotropica 46: 549-555.

IDAF - Instituto de Defesa Agropecuária e Florestal do Espírito Santo (2004) Plano de manejo do Parque Estadual da Pedra Azul. Vitória. 446p.

Index Herbariorum [continuously updated] Index herbariorum: a worldwide index of 3,100 herbaria and 12,000 associated staff where a total of 390 million botanical specimens are permanently housed. New York Botanical Garden, New York. Available at <http://sweetgum.nybg.org/ih/>. Access on 28 February 2020.

IPEMA - Instituto de Pesquisas da Mata Atlântica (2005) Conservação da Mata Atlântica no Espírito Santo: cobertura florestal e unidades de conservação. IPEMA, Conservação Internacional, Vitória. 142p.

IBGE - Instituto Brasileiro de Geografia e Estatística (2012) Manual técnico da vegetação brasileira. 2ª ed. IBGE, Rio de Janeiro. 276p.

INCAPER (2020) Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural. Available at <https://meteorologia.incaper.es.gov.br/mapas-de-chuva-normal-climatologica-album>. Acess on 3 May 2020.

Irume MV, Moraes MCLS, Zartman CE & Amaral IL (2013) Floristic composition and community structure of epiphytic angiosperms in a terra firme forest in central Amazonia. Acta Botanica Brasilica 27: 378-393.

Kersten RA, Kuniyoshi YS & Roderjan CV (2009) Epífitas vasculares em duas formações ribeirinhas adjacentes na bacia do Rio Iguaçu - terceiro planalto paranaense. Iheringia - Série Botânica 64: 33-43.

Kersten RA (2010) Epífitas vasculares - histórico, participação taxonômica e aspectos relevantes, com ênfase na Mata Atlântica. Hoehnea 37: 9-38.

Kessler M (2001) Patterns of diversity and range size of selected plant groups along an elevational transect in the Bolivian Andes. Biodiversity and Conservation 10: 1897-1921.

Koehler A, Galvão F & Longhi SJ (2002) Floresta Ombrófila Densa Altomontana: aspectos florísticos e estruturais de diferentes trechos na Serra do Mar, PR. Ciência Florestal 12: 27-39.

Köhler L, Tobón C, Frumau KF & Bruijnzeel LA (2007) Biomass and water storage dynamics of epiphytes in old-growth and secondary montane cloud forest stands in Costa Rica. Plant Ecology 193: 171-184.

Krömer T, Kessler M, Gradstein SR & Acebey A (2005) Diversity patterns of vascular epiphytes along an elevational gradient in the Andes. Journal of Biogeography 32: 1799-1809.

Krömer T, Acebey A, Kluge J & Kessler M (2013) Effects of altitude and climate in determining elevational plant species richness patterns: a case study from Los Tuxtlas, Mexico. Flora 208: 197-210.

Laube S & Zotz G (2003) Which abiotic factors limit vegetative growth in a vascular epiphyte? Functional Ecology 17: 598-604.

Leitman P, Amorim AM, Sansevero JBB & Forzza RC (2015) Floristic patterns of epiphytes in the Brazilian Atlantic Forest, a biodiversity hotspot. Botanical Journal of the Linnean Society 179: 587-601.

Luna-Vega I, Morrone JJ, Ayala AO & Organista DE (2001) Biogeographical affinities among Neotropical cloud forests. Plant Systematics and Evolution 228: 229-239.

Magnago LFS, Assis AM & Fernandes HBQ (2007) Floresta ombrófila densa submontana, montana e alto-montana. *In*: Fraga CN & Simonelli M (eds.)

Espécies da flora ameaçadas de extinção no estado do Espírito Santo. IPEMA, Vitória. Pp. 45-50.

Mania LF (2013) Composição florística de comunidades epifíticas vasculares em unidades de conservação no estado de São Paulo. Doctoral Thesis, Universidade Estadual Paulista, Rio Claro. 129p.

Marcusso GM & Monteiro R (2016) Composição florística das epífitas vasculares em duas fisionomias vegetais no município de Botucatu, estado de São Paulo, Brasil. Rodriguésia 67: 553-569.

Martinelli G & Moraes MA (2013) Livro vermelho da flora do Brasil. Vol. 1. Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rio de Janeiro. 1100 p.

Menini Neto L, Forzza RC & Zappi D (2009) Angiosperm epiphytes as conservation indicators in forest fragments: a case study from southeastern Minas Gerais, Brazil. Biodiversity and Conservation 18: 3785-3807.

Nadkarni NM (1984) Epiphyte biomass and nutrient capital of a neotropical elfin forest. Biotropica 16: 249-256.

Nóbrega GA (2013) Licófitas e samambaias em um gradiente altitudinal da Mata Atlântica, SP: diversidade, distribuição e aspectos ecofisiológicos. Doctoral Thesis. Universidade Estadual de Campinas, Campinas. 231p.

Obermuller FA, Freitas L, Daly DC & Silveira M (2014) Patterns of diversity and gaps in vascular (hemi-) epiphyte flora of Southwestern Amazonia. Phytotaxa 166: 259-272.

Oliveira-Filho AT & Fontes MAL (2000) Patterns of floristic differentiation among Atlantic forests in southeastern Brazil and the influence of climate. Biotropica 32: 793-810.

Ortiz OO, Stapf SF & Croat TB (2019) Diversity and distributional patterns of aroids (Alismatales: Araceae) along an elevational gradient in Darién, Panama. Webbia 74: 339-352.

Padilha PT, Santos Junior R, Custódio SZ, Oliveira LC, Santos R & Citadini-Zanette V (2015) Comunidade epifítica vascular do Parque Estadual da Serra Furada, sul de Santa Catarina, Brasil. Ciência e Natura 37: 64-78.

Paciencia MLB (2008) Diversidade de pteridófitas em gradientes de altitude na Mata Atlântica do estado do Paraná, Brasil. Doctoral Thesis. Universidade de São Paulo, São Paulo. 229p.

Perleberg TD, Garcia EM & Pitrez SR (2013) Epífitos vasculares em área com floresta estacional semidecidual, Pelotas, Rio Grande do Sul, Brasil. Ciência e Natura 35: 65-73.

PPG I - The Pteridophyte Phylogeny Group (2016) A community-derived classification for extant lycophytes and ferns. Journal of Systematics and Evolution 54: 563-603.

REFLORA- Herbário Virtual (2020) Available at <http://floradobrasil.jbrj.gov.br/reflora/herbarioVirtual/>. Access on 20 March 2020.

Rizzini CT (1997) Tratado de fitogeografia do Brasil. 2ª ed. Âmbito Cultural Edições, Rio de Janeiro. 748p.

Rogalski JM, Reis A, MS Reis & Queiroz MH (2016) Spatial distribution of Araceae on phorophytes in different areas of submontane rainforest, Santa Catarina Island (SC), Southern Brazil. Brazilian Journal of Botany 39: 1077-1086.

Rolim SG, Sylvestre L, Franken EP & Coelho MAN (2016) Epífitas vasculares nas fisionomias vegetais da Reserva Natural Vale, Espírito Santo. *In*: Rolim SG, Menezes LFT & Srbek-Araujo AC (eds.) Floresta Atlântica de Tabuleiro: diversidade e endemismos na Reserva Natural Vale. Pp. 269-281.

Safford HD (1999) Brazilian páramos I. Introduction to the physical environment and vegetation of the campos de altitude. Journal of Biogeography 26: 693-712.

Santos ND, Costa DP, Kinoshita LS & Shepherd GJ (2014) Windborne: can liverworts be used as indicators of altitudinal gradient in the Brazilian Atlantic Forest? Ecological Indicators 36: 431-440.

Stadtmüller T (1987) Cloud forests in the humid tropics: a bibliographic review. United Nations University, Tokyo, and CATIE, Turrialba. 82p.

Thomaz LD (2010) A Mata Atlântica no estado do Espírito Santo, Brasil: de Vasco Fernandes Coutinho ao século 21. Boletim do Museu de Biologia Mello Leitão 27: 5-20.

Vogelmann HW (1973) Fog precipitation in the cloud forests of eastern Mexico. Bioscience 23: 96-100.

Zizka A & Antonelli A (2018) Mountains of diversity. Nature 555: 173-174.

Zotz G (2013a) "Hemiepiphyte": a confusing term and its history. Annals of Botany 111: 1015-1020.

Zotz G (2013b) The systematic distribution of vascular epiphytes - a critical update. Botanical Journal of the Linnean Society 171: 453-481.

Zotz G (2016) Plants on plants - the biology of vascular epiphytes. Fascinating Life Sciences. Springer International Publishing. 282p.

Werneck MS, Sobral MEG, Rocha CTV, Landau EC & Stehmann JR (2011) Distribution and endemism of angiosperms in the Atlantic Forest. Natureza & Conservação 9: 188-193.

Wilson AM & Jetz W (2016) Remotely sensed high-resolution global cloud dynamics for predicting ecosystem and biodiversity distributions. PLoS Biol 14: e1002415. DOI: 10.1371/journal. pbio.1002415

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