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Flora of Espírito Santo, Brazil

Angiosperm checklist and conservation of one the richest restingas in southeastern Brazil

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Abstract

The Paulo César Vinha State Park (PEPCV), an important conservation unit in the state of Espírito Santo, has one of the richest angiosperm communities of any restinga area in Brazil, making it a priority area for biodiversity conservation. In this study, we perform an inventory of the PEPCV flora through an exploratory collection over the park area and compilation of data from botanical collections available in virtual herbaria. A total of 634 species were listed, distributed into 367 genera and 111 families of angiosperms, representing 43.75% of the species documented in the restingas of Espírito Santo. The richest families were Fabaceae (54 spp.), Cyperaceae (40 spp.), Orchidaceae (40 spp.), Myrtaceae (36 spp.), and Poaceae (30 spp.). Six species were recorded for the first time in the park, ten are endemic to the Espírito Santo, and about 10% of the species are threatened with extinction. We provide data on the habit, species distribution in phytophysiognomies, and endangered species. Finally, we discussed the importance of broad knowledge about the park's plants, exposing points to conserve specific areas with high antopic rate, and plans to preserve the biodiversity of this ecosystem.

Key words: angiosperms, Atlantic Forest, Espírito Santo, Paulo César Vinha State Park, phytophysiognomies.

Resumo

O Parque Estadual Paulo César Vinha (PEPCV) é uma importante Unidade de Conservação do estado do Espírito Santo, e está entre as áreas de restinga mais ricas em espécies de angiospermas do Brasil, sendo considerado uma área prioritária para conservação da biodiversidade. Neste estudo inventariamos a flora do PEPCV, por meio de coletas exploratórias ao longo da área do parque e compilação de dados de coleções botânicas disponíveis em herbários virtuais. Foram listadas 634 espécies, reunidas em 367 gêneros e 111 famílias de angiospermas para o parque, o que representa 45,5% das espécies citadas para as restingas capixabas. As famílias mais ricas em espécies foram Fabaceae (54 spp.), Cyperaceae (40 spp.), Orchidaceae (40 spp.), Myrtaceae (36 spp.) e Poaceae (30 spp.). Seis espécies são novos registros para a flora do parque, 10 são endêmicas do estado do Espírito Santo e cerca de 10% das espécies são consideradas ameaçadas de extinção. São apresentados dados sobre o hábito, a distribuição das espécies nas fitofisionomias e as espécies ameaçadas. Por fim, discutimos a importância de um amplo conhecimento sobre as plantas do parque, expondo pontos para a conservação de áreas específicas com altos índices de antropização e planos de preservação da biodiversidade desse ecossistema.

Palavras-chave: angiospermas, Floresta Atlântica, Espírito Santo, Parque Estadual Paulo César Vinha, fitofisionomias.

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Introduction

The Atlantic Forest is recognized as a global biodiversity hotspot, with high biological richness and a large number of threatened species (Mittermeier *et al.* 2004). The biome is made up of distinct phytoecological regions, distributed along an extensive latitudinal range with extremely heterogeneous geomorphological and climatic characteristics (Azevedo 1962; Veloso *et al.* 1991). Its coastal area has seen varied and extensive economic uses since Brazil's colonial period (Dean 1995), resulting in a fragmented natural landscape of only 11.73% of its original coverage (Ribeiro *et al.* 2009; Fundação SOS Mata Atlântica & INPE 2019).

Despite a well-documented literature on the reforestation of the Atlantic Forest (Atlantic Forest Restoration Pact 2009), the recovery of some of its ecosystems - such as the restinga - has presented a challenge. Restinga vegetation occurs on coastal sandy deposits, which extend along the Brazilian coast (Cerqueira 2000). This vegetation occurs on a quaternary plain (IBGE 2012) and is remarkable for the richness of its plant communities, which grow on nutrient-poor, sandy sediments that are usually of marine origin and rarely fluvial (Pereira 2003).

In Espírito Santo state, the restinga was originally present along 411 km of the coastline on the state (Albino *et al.* 2016), its continuous nationwide decline is especially pronounced in this region (*e.g.*, Pereira 2007; Brasil 2018a; Espírito Santo 2013). The coast has a geomorphological peculiarity that directly influences the restingas ecosystem of the state. In the northern region, we observe more extensive restingas and are composed of a small variety of habitats - a characteristic derived from the influence of the Tabuleiro Forest located on the Northeast Coast. In the southern region, below the Rio Doce delta, we observe more preserved restingas with more variety of habitats - the result of the influence of the Precambrian Crystalline Complex located on the Southeast Coast (Silveira 1968). The vegetation is composed of different phytophysiognomies made up of established herbaceous, shrub, or tree communities, with the makeup depending on the level of the water table, among other factors (Pereira 2003; Magnago *et al.* 2011a).

The Paulo César Vinha State Park (PEPCV) in Espírito Santo contains most of the restinga phytophysiognomies identified in the literature (Pereira 2003). This was the first conservation unit created to preserve the restinga ecosystem in the state and is home to vegetation with little anthropic interference (Chagas *et al*. 2014). In addition, it represents the main restinga area in the south of Espírito Santo and represents one of the richest restingas in terms of angiosperm species along the Brazilian coast (Guarnier 2019).

Although PEPCV is recognized as a priority area for conservation, continued impacts persist, such as illegally set fires (Espírito Santo 2010; Narciso 2012; Brasil 2018a). These environmental variations, in addition to the ecosystem services provided by the restinga environment, underpin decisions to direct resources to the PEPCV and local environmental authorities (Espírito Santo 2009). In particular, floristic surveys are important for land managers and help to identify and conserve remnants with unique vegetation cover (Chaves *et al.* 2013). Online platforms are increasingly being used to assist with these floristic surveys and provide information on species richness within Brazilian conservation units (Moreira *et al.* 2020). In spite of the volume of research that has been carried out in PEPCV (*e.g.*, Behar & Viegas 1992; Martins *et al.* 1999; Assis *et al.* 2003, 2004; Fraga & Peixoto 2004; Silva & Piassi 2010; Valadares *et al.* 2010; Gomes & Silva 2013; Chagas *et al.* 2014; Peterle *et al.* 2015), no study has yet been able to present an exhaustive list of the park's angiosperms.

Therefore, the purpose of this study is to provide an updated floristic list of PEPCV, with information on the occurrence of phytophysiognomies and conservation status. By doing this, we aim to assist researchers and environmental authorities in their efforts to enact policies aimed at the conservation of restingas.

Material and Methods

Study area

The PEPCV was created by decree nº 2.993-N in 1990, with initial denomination of Setiba's Park. Through the Law nº 4.903 in 1994, became known as Paulo César Vinha State Park. Is situated on a coastal plain with an area of about 1,500 ha, located within the Environmental Protection Area of Setiba in the Guarapari municipality, metropolitan region of Grande Vitória, on the southern coast of Espírito Santo (Fig. 1). The area is located between 20°32'13" and 20°37'41" S and between 40°22'58" and 40°25'39"W (CEPEMAR 2007). According to the Köppen classification (Alvares *et al*. 2014), the region's climate is classified as Aw tropical, with an

annual average temperature between 24 °C and 26 °C and average annual precipitation of 1,160 mm (INCAPER 2019). The vegetation is predominantly composed of restinga, and eight plant formations can be identified (Fig. 2) according to Pereira (2003). The mapping of typologies identified was prepared using QGIS v 2.18 software (2016). PEPCV also has a rocky outcrop adjacent to the intermittent mouth of the Caraís Lagoon, which is its main water body.

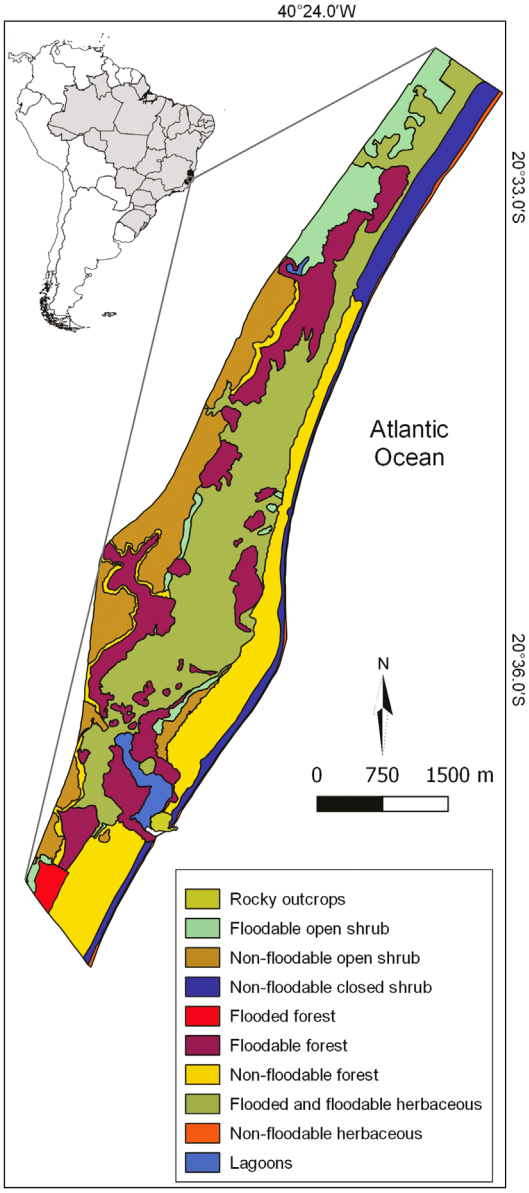

Figure 1 – Location of the Paulo César Vinha State Park, Guarapari, Espírito Santo, southeastern Brazil, showing the phytophysiognomies present, according to Pereira (2003). The non-floodable herbaceous formation, although not represented due to the scale, occurs along the entire length of the park following the beach line.

Collection and preparation of the database

Fertile samples (flowers and/or fruits) of angiosperms were collected between May 2016 and August 2020 using the walking method (Filgueiras *et al.* 1994). The collected material was processed according to the usual methods of specimen preservation (Fidalgo & Bononi 1989), and then deposited at the VIES Herbarium in the Federal University of Espírito Santo, Vitória, Brazil. The identification of the collected specimens was performed using dichotomous keys, by the comparison with specimens deposited in the VIES Herbarium collection, consultation with the INCT-HVFF (<http://inct.splink.org.br/>) and REFLORA (2020) virtual herbaria, as well as by consulting with specialists on different botanical families.

We also consulted virtual herbarium collections to help prepare our database of the specimens collected in the PEPCV. Our search included the key terms "Parque de Setiba", "Lagoa do Milho", and "Lagoa de Caraís" to include materials collected before the current nomenclature of the park and without geographical coordinates. The data from this research included specimens from the following herbariums: ALCB, BHCB, BOTU, CEN, CEPEC, CESJ, EAC, FLOR, HRCB, HUCS, HUEFS, HURB, IAC, ICN, JPB, MBM, MBML, MO, NY, OUPR, RB, RBR, RFA, SAMES, SP, SPF, SPSF, TEPB, UEC, UFP, UPCB, VIC, and VIES (Thiers, continuously updated). We considered dried specimens with identification by specialists to be reliably determined for inclusion in the database.

The third source of data included material from articles with floristic, phytosociological, and taxonomic surveys carried out in the PEPCV area: Martins *et al.* 1999; Assis *et al.* 2003, 2004; Valadares *et al.* 2010, 2020; Chagas *et al.* 2014; Peterle *et al.* 2015). All names were validated by consulting BFG (2018). The information from the three data acquisition sources was organized in a floristic list following the classification proposed by APG IV (2016).

Figure 2 – a-f. Phytophysiognomies observed at the Paulo César Vinha State Park, Guarapari, Espírito Santo, southeastern Brazil – a,b. flooded herbaceous; c. open non-floodable shrub; d. open floodable shrub; e. floodable forest; f. non-floodable forest.

The species habit assessment was carried out following the design proposed in the Technical Manual of Brazilian Vegetation (IBGE 2012). Data were obtained by observing specimens in the field and from the labels of material consulted in the herbaria.

Finally, data on the geographic distribution of the species were obtained from BFG (2018). The species' conservation status at national and state level was consulted in the Red Book of Brazilian Flora (Martinelli & Moraes 2013) and the List of Endangered Species in Espírito Santo (Fraga 2019; Fraga *et al.* 2019), respectively.

Results

A total of 634 species were found, distributed into 367 genera and 111 families of angiosperms in the PEPCV (Tab. S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.17192903.v1>). The following ten families had the highest number of species: Fabaceae (54 spp.), Cyperaceae (40 spp.), Orchidaceae (40 spp.), Myrtaceae (36 spp.), Poaceae (30 spp.), Rubiaceae (27 spp.), Bromeliaceae (25 spp.), Apocynaceae (23 spp.), Asteraceae (22 spp.), and Melastomataceae (18 spp.). Together, these families make up approximately 50% of the species richness of the PEPCV.

The most representative genera in numbers of taxa were *Eugenia* (12 spp.), *Cyperus* (9 spp.), *Rhynchospora* (9 spp.), *Myrcia* (8 spp.), *Aechmea* (8 spp.), *Solanum* (7 spp.), *Chamaecrista* (7 spp.), *Paspalum* (6 spp.), *Eleocharis* (6 spp.), and *Miconia* (6 spp).

The most representative species habits were herbs (202 spp.), followed by trees (157 spp.), shrubs (101 spp.), climbers/liana (77 spp.), subshrubs (45 spp.), epiphytes (34 spp.), palm (7spp.), hemiparasite (6spp.) and hemiepiphytes (5 spp.) (Figs. 3-4).

The phytophysiognomies more richness in species are the non-floodable forest formation (263 spp.), followed by the flooded and floodable herbaceous formations (161 spp.), floodable forest formation (101 spp.), non-floodable open shrub (90 spp.), floodable open shrub (69 spp.), rocky outcrops (30 spp.), non-floodable herbaceous (22 spp.), and flooded forest (17 spp.) (Fig. 5). The sum of the species values in the formations is higher than the total species that occur in the PEPCV due to the fact that some species occur in different phytophysiognomies (Tab. S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.17192903.v1>).

Forest phytophysiognomies (floodable and non-floodable) showed a greater number of species habits than the shrub and herbaceous phytophysiognomies. Only the flooded forest formation had lower numbers. Herbaceous plants predominated on the rocky outcrops, though most of the species habits evaluated were also present.

Our study found records of six species that had not been previously reported in the PEPCV, as follows: *Ageratum conyzoides* L. (Asteraceae), *Lemna minuta* Kunth. (Araceae), *Lepidaploa coulonioides* (H.Rob.) H.Rob. (Asteraceae), *Peltaea obsita* (Mart. *ex* Colla) Krapov (Malvaceae), *Rourea gardneriana* Planch. & Cristóbal (Connaraceae), and *Stachytarpheta angustifolia* (Mill.) Vahl (Verbenaceae).

Ten species endemics to Espírito Santo were identified [*Aechmea fosteriana* L.B. Sm., *A. roberto-seidelii* E. Pereira, *Cryptanthus maritimus* L.B. Sm, *Neoregelia macrosepala* L.B. Sm. (Bromeliaceae), *Clusia spiritu-sanctensis* Mariz & Weinberg (Clusiaceae), *Rhynchospora plusquamrobusta* Luceño & M.Martins (Cyperaceae), *Ocotea arenicola* L.C.S. Assis & Mello-Silva (Lauraceae), *Rhodostemonodaphne capixabensis* Baitello & Coe-Teix. (Lauraceae), *Callianthe inaequalis* (Link &Otto) Donnel. (Malvaceae), and *Dichanthelium peristypum* (Zuloaga & Morrone) Zuloaga (Poaceae)]. Among them, two species are restricted to restingas of this state: *Rhynchospora plusquamrobusta* e *Rhodostemonodaphne capixabensis.*

A total of 64 threatened species were found (Tab. S2, available on supplementary material

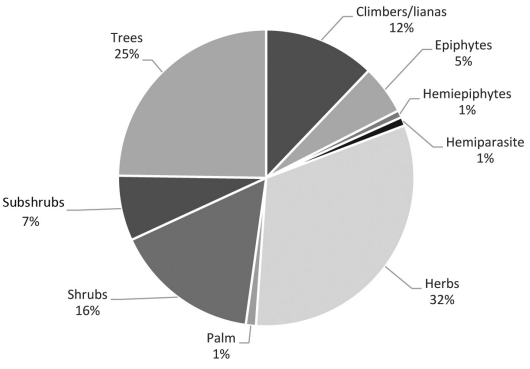

Figure 3 – Percentage of species habits in the Paulo César Vinha State Park, Guarapari, Espírito Santo, southeastern Brazil.

Figure 4 – a-f. Species with different habits sampled at the Paulo César Vinha State Park, Guarapari, Espírito Santo, southeastern Brazil – a. *Ouratea cuspidata* (tree); b. *Actinocephalus ramosus* (herb); c. *Phyllanthus klotzschianus* (subshrub); d. *Marcetia taxifolia* (shrub); e. *Tillandsia stricta* (epiphyte); f. *Passiflora alata* (climbers/liana).

<https://doi.org/10.6084/m9.figshare.17192903.v1>), corresponding to 10.4% of the species present in the PEPCV. Of these, 26 species are present in the Red Book of Brazilian Flora (Martinelli & Moraes 2013), with half at the vulnerable state (VU) and the other half endangered (EN). At the state level, 55 species are present in the List of Endangered Species of Espírito Santo (Fraga *et al.* 2019b), with 6% critically endangered (CR), 34% EN, and 60% VU.

Most threatened species occur in the non-floodable forest formation (31 spp.), followed by the non-flooded open shrub formation (14 spp.). The remaining phytophysiognomies account for less than 15% of all threatened species (Fig. 6).

Discussion

According to BFG (2018), the restinga in Espírito Santo has 1,447 species of angiosperms. This study indicates that PEPCV contains the richest restinga in terms of Angiosperms species statewide, with 43.75% of all known angiosperm species in the state's restinga (Fig. 7). The PEPCV is followed by the Itaúnas State Park in Conceição da Barra at the extreme northern end of the state, which has 562 species of angiosperms, accounting for 40.1% of the known angiosperm species in the restingas of Espírito Santo (Souza *et al.* 2016). The significant contribution of the families Fabaceae, Myrtaceae, Poaceae, Bromeliaceae, Rubiaceae, and Asteraceae to the species richness of restingas has been documented in other studies carried out in different sites in northeastern (Queiroz *et al.* 2012; Oliveira *et al.* 2014; Santos-Filho *et al.* 2015), southeastern (Martins *et al.* 2007; Araújo *et al.* 2009), and southern (Scherer *et al*. 2005) Brazil.

The peculiarity of angiosperms list presented here can be explained in two ways. The first is due to the diversity of phytophysiognomies present in the area, which offers a greater variety of niches than other restingas on the coast of Espírito Santo (*e.g.*, restinga de Camburi; Pereira & Assis 2000). The second factor involves the geographic positioning of the PEPCV. Espírito Santo is geomorphologically unique as it is located between two coastal regions (Silveira 1968) the Eastern coast is made up of the Barreiras Formation, to the north of the Doce River delta; to the south of the Doce River delta, the Southeast Coast is cut by the presence of the escarpments of the Precambrian Crystalline Complex.

The plants of the restinga are heavily affected by neighboring ecosystems (Matias & Nunes 2000), which has an effect on species distributions. The flora of the PEPCV is influenced by the nearby forests of the Crystalline Complex, with a predominance of the Atlantic Forest species (Assis *et al*. 2004). However, statistical tests that include medium-altitude forests in the Southeast Coast are necessary to support the influence hypothesis.

This study shows that forest formations have the highest richness of species and life habits in the PEPCV. Some authors (Freiberg 1994; Parker 1995) argue that this richness in forest formations occurs due to the greater stratification in comparison to other phytophysiognomies, which causes microclimate differences due to the heterogeneity of strata and provides a greater number of niches for plant species. However, there is an evident decrease in richness between non-floodable forest formations and those with a higher degree of flooding. This result has been associated with species selection caused by seasonal water

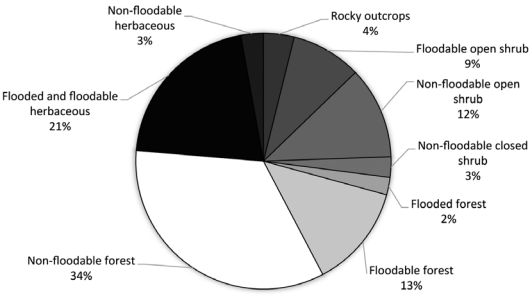

Figure 5 – Percentage distribution of flora species among the phytophysiognomies of the Paulo César Vinha State Park, Guarapari, Espírito Santo, southeastern Brazil.

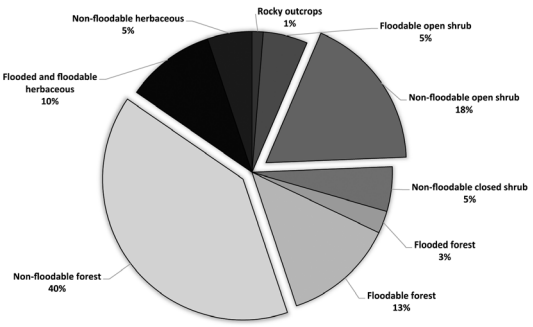

Figure 6 – Distribution of threatened species among the phytophysiognomies of the Paulo César Vinha State Park, Guarapari, Espírito Santo, southeastern Brazil.

saturation in flooded restinga formations (Magnago *et al.* 2010, 2013).

Some of the species listed here are characteristic of forest formations within the PEPCV. Assis *et al*. (2003; 2004) cite *Alchornea triplinervia* (Spreng.) Mull. Arg., *Jacaranda puberula* Cham., *Myrciaria floribunda* O.Berg, *Protium heptaphyllum* (Aubl.) Marchand, and *Tapirira guianensis* Aubl. as the most representative taxa of non-floodable forest formations in the park. Other species listed here for flooded forests, *Bactris setosa* Mart., *Geonoma schottiana* Mart., and *Symphonia globulifera* L.f.), are also characteristic of these formations in other restinga areas of the Espírito Santo (Magnago *et al.* 2011b).

Some authors indicate floristic differences between flooded and non-flooded open shrub formations (Kuster *et al.* 2019). Although the water table outcrop has not been observed in the flooded areas mapped here, species like *Abildgaardia baeothryon* A.St.-Hil. found in areas between thickets were associated with stretches with observed humidity. Species like this can be indicators for such areas, supporting the hypothesis that proximity to the water table is a regulatory factor in the development of some species (Magnago *et al*. 2011a). Species inherent to these formations, such as *Allagoptera arenaria* (Gomes) Kuntze, *Byrsonima sericea* DC., *Cupania emarginata* Cambess., *Paullinia weinmanniifolia* A.Gray, and *Schinus terebinthifolia* Raddi, are routinely found in the literature of the restinga flora in Espírito Santo (Pereira 1990; Magnago *et al*. 2011b; Bove *et al.* 2003; Kuster *et al.* 2019).

Our findings on the species richness of flooded and floodable herbaceous formations significantly exceeded previous estimates (Pereira 1990). The present results show that Cyperaceae and Poaceae were the most representative of these formations, in line with previously findings. The representativeness of these families in the PEPCV can be linked to two important factors: the great extent of herbaceous formations in the park area (Fig. 1) and the capacity of the species of these families to colonize open environments with flood pulses (Bove *et al.* 2003; Valadares *et al.* 2020). Previous studies also indicated the strong contribution of these families to species richness in similar areas (Araújo & Henriques 1984; Sá 1992; Araújo *et al.* 1998). Although the data may indicate a strong effect caused by the taxonomic study of Cyperaceae in PEPCV (Martins *et al.* 1999), taxonomic efforts that include Poaceae in the future are expected to further increase the richness of flooded and floodable herbaceous formations.

It is a general rule that non-floodable herbaceous formation has lower richness species than other restinga phytophysiognomies (Araújo & Henriques 1984; Thomaz & Monteiro 1993; Magnago *et al.* 2011b; Bove *et al.* 2003; Souza *et al.* 2016). All species related to this formation are

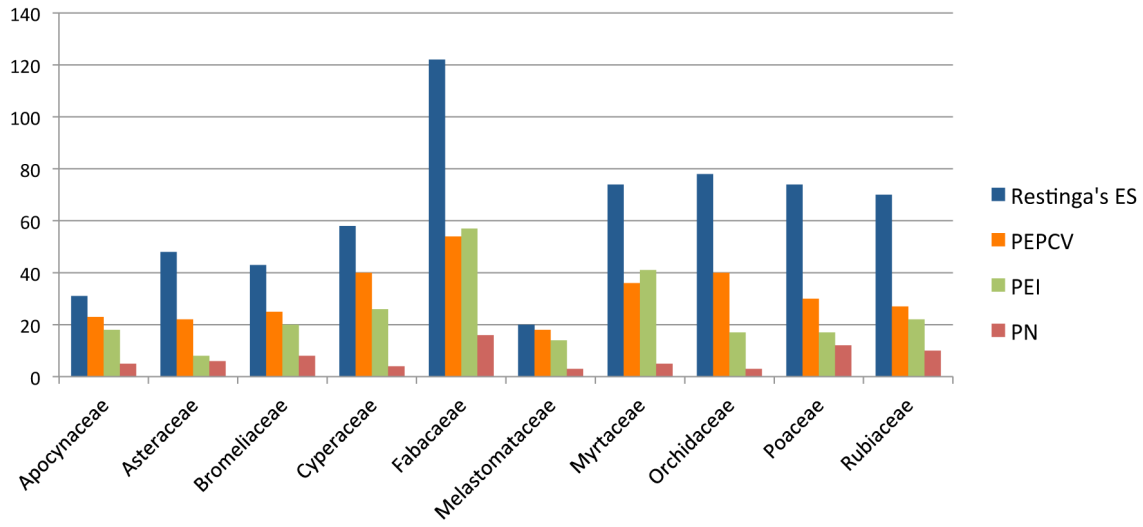

Figure 7 – Comparison of the most representative families in terms of species richness cited for restingas, as follows: Restingas's ES (BFG 2018); PEPCV - Paulo César Vinha State Park (present study); PEI - Itaúnas State Park (Souza *et al*. 2016); PN - Praia das Neves (Braz *et al*. 2013).

resilient and widely distributed along the Brazilian coast (BFG 2018). However, some species that are present in lower frequencies (*e.g.*, *Scaevola plumieri* (L.) Vahl and *Sporobolus virginicus* (L.) Kunth) can serve as indicators of native vegetation on the beach, as a consequence of conservation of the area.

The threatened angiosperm checklist of the PEPCV has a representative percentage of species, even though it is a fully protected Conservation Unit inserted in a biodiversity hotspot (Mittermeier *et al.* 2004). The park has been designated a "Sítio-BAZE" (MMA 2018) since it shelters several species threatened with extinction within a declining ecosystem. In the park, even historically poorly studied phytophysiognomies, as the flooded and floodable herbaceous formation, have endangered species (*e.g.*, *Rhynchospora plusquamrobusta* Luceño & M. Martins) subjected to continued impacts. Despite legal recognition, impacts associated with the extraction of ornamental and threatened species (Caitano *et al*. 2020) indicate the need to implement inspection measures that include technology capable of monitoring the limits of the park.

The location of the PEPCV within the metropolitan region of Espírito Santo is a long-term problem, but it should also be seen as an opportunity for targeting resources. Future studies focusing on threatened species will be able to assess the size of the species distribution within the park. This will shed light on the importance of conservation of the park, and expands the study of threatened species in other areas of the state. A similar scenario has been analyzed in a previous study involving restingas close to large urban centers in Rio de Janeiro state (Calazans *et al.* 2018).

Although the PEPCV has been extensively studied, floristic lists never completely fill the knowledge gaps of the local flora. Future studies should focus on field expeditions, especially on poorly studied phytophysiognomies as the non-floodable open shrub, floodable open shrub, and non-floodable closed shrub formations. Projects involving the mapping of populations of species with ornamental potential in easily accessible phytophysiognomies, require urgent measures for the conservation of native vegetation. In addition, new taxonomic studies are needed to increase and refine the knowledge of the richness of species present in the park.

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