Acta Botanica Brasilica, 2022, 36: e2021abb0038
doi: 10.1590/0102-33062021abb0038

Original article

Floristic inventory and conservation of one of the most striking coastal mountains in the Brazilian Atlantic Forest

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Received: February 1, 2021
Accepted: August 31, 2021

ABSTRACT

The Atlantic Forest is made up of different vegetation types over extensive latitude. Most of its remnants are in mountain ranges, which are responsible for the maintenance of most endemic and threatened species in this domain. Here we present the floristic composition of the Área de Proteção Ambiental Mestre Álvaro (APAMA), a coastal massif at Espírito Santo State with expressive altitudinal amplitude (100-800 a.s.l.) containing remnants never floristically studied. Knowing the composition of this protected area is important because it includes an altitudinal range not yet evaluated in floristic comparisons involving highland and lowland forests between the latitudes 18-21° S. We found 493 species (in 292 genera and 91 families): ten are regional endemic species, nine are new records of occurrence for the state, and 52 are under some degree of threat of extinction. Our results indicate the presence of flora elements' typical of both highland and lowland forests, which makes the APAMA essential in a scenario extremely fragmented. Finally, our data provide an unprecedented floristic list for regional forest restoration projects, as well as an invaluable source of data for biogeographic studies that seek to understand the effect caused by neighboring vegetation types on the composition of lowland forests.

Keywords: APA Mestre Álvaro, Atlantic Forest, ravine forest, endangered species, protected areas

Introduction

> "It will probably be many years before, with some exceptions, other Brazilian flora other than herbs and shrubs are known."
>
> Auguste de Saint-Hilaire, when visiting the "Monte Mestre Alvo" (1818)

The Atlantic Forest plays multiple roles in climate regulation (Brasil 2018). Even recognizing the damage caused by its devastating history, this biome is still continuously shrinking (Dean 1996; Brasil 2012a; 2017; SOS Mata Atlântica & INPE 2020). Currently, it is represented by ca. 11% of its original coverage (Ribeiro *et al.* 2009) and most of its remnants are in mountain ranges (*e.g.*, Serra do Mar, Serra da Mantiqueira). These geomorphological sectors

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are responsible for the maintenance of most endemic and threatened species in the Atlantic Forest domain (see Loyola *et al.* 2014; BFG 2018).

In the state of Espírito Santo, for example, the northern portion of Serra da Mantiqueira is home to numerous endemic taxa (Dutra *et al.* 2015) and new species from this region are continuously being described (Fraga *et al.* 2019). Further, there are still difficult access to contiguous forest remnants that guarantee the preservation of regional diversity (Assis 2007). However, most of the diversity in this region only began to be cataloged in the 1990s. Floristic inventories covering different life-forms are scarce for this state (*e.g.*, Assis *et al.* 2004; Luber *et al.* 2016; Souza *et al.* 2016) and are greatly needed for the biome (see Menini-Neto *et al.* 2009).

The present study was carried out in an area of dense ombrophilous forest in the state (see Garbin *et al.* 2017). This type of vegetation was divided into different ecological formations according to altitudinal criteria (Veloso *et al.* 1991). In Espírito Santo, there have been some local studies restricted to a single ecological formation that only include research about the arboreal structure (Thomaz & Monteiro 1997; Saiter *et al.* 2011; Saiter & Thomaz 2014). However, floristic inventories in an altitudinal gradient that include more than one formation are non-existent for this region.

Considering these gaps, we aimed to perform a floristic inventory of angiosperms of the Área de Proteção Ambiental Mestre Álvaro (APAMA), a protected area within the scenario discussed. In addition, we classified the life-forms of the species recorded to the area, verify the conservation status of these and discuss the richness of the more representative families compared to other areas located at similar altitudinal ranges or under the distinct degree of regeneration and anthropic disturbances in the state.

Materials and methods

Study area

APAMA is a mountain area in Grande Vitória, in the south-central region of Espírito Santo State, in an extension of the Serra da Mantiqueira Setentrional (Gatto *et al.* 1983; Mendes *et al.* 1987). It is between 20°08'32"–20°11'28" S and 40°07'42"–40°19'44" W, with a total area of 2,389 ha, with an elevation gradient ranging from 50 to 833 m (Espírito Santo 2018) (Fig. 1). The climate is humid subtropical, with a dry winter and hot summer from 50–500 m a.s.l. and temperate summer from 500–800 m a.s.l. (Koppen classification), annual precipitation of 1300–1600 mm and a dry season from May to August, when the average precipitation is only 63 mm (Alvares *et al.* 2013). The vegetation type is submontane dense ombrophilous forest from 50–500 m a.s.l. and montane dense ombrophilous forest above 500 m a.s.l. (Veloso *et al.* 1991), where rise inselbergs interspersed with forest ecosystems. The vegetation is currently under different degrees of regeneration, but still contains well-preserved areas (Fig. 2), such as ravine forest (*sensu* Menini-Neto *et al.* 2009) and inselberg vegetation (Porembski 1998). The area is of high conservation priority due to the presence of well-maintained fragments that house endemic and rare species (see Giulietti *et al.* 2009; Espírito Santo 2010a; Iglesias *et al.* 2016; Pereira-Silva *et al.* 2019).

Floristic survey

The angiosperms floristic survey was carried out through field trips conducted between 2012–2016 during the project Diversidade Florística da Área de Proteção Ambiental do Mestre Álvaro, using the walking method (Filgueiras *et al.* 1994). The specimens were processed using standard techniques (Fidalgo & Bononi 1989) and deposited in the herbarium VIES. A database was constructed based on the following: i) our field data and ii) herbarium records (CVRD, HUEFS, IPA, MBML, RB, SPF, SP, VIES – acronyms according to Thiers 2021), using only specimens identified by specialists.

The life-forms of each species were classified through direct field observations using the concepts proposed by Font Quer (2000). Additionally, we used data from herbarium labels to evaluate the morphological plasticity of the species. Venn diagrams were employed to identify unique and shared life-forms among species (Bardou *et al.* 2014).

We also used previously published lists for some angiosperm families in the area (Sarnaglia-Junior *et al.* 2014a; Iglesias & Dutra 2017). The final list obtained was compared to the Brazilian and Espírito Santo State Red Lists of Plants (Martinelli & Moraes 2013; Fraga *et al.* 2019) to verify the conservation status of the species of APAMA. We assume species not listed in Flora do Brasil 2020 (2020) and Dutra *et al.* (2015) as new occurrence records for the state of Espírito Santo.

Results

A total of 493 angiosperm species (Figs. S1-S3 in supplementary material) belonging to 292 genera and 91 families were recorded in APAMA (Tab. S1 in supplementary material). The richest families are Fabaceae (45 spp.), Malvaceae (28), Melastomataceae (27), Piperaceae (25), Rubiaceae (21), Orchidaceae (21), Araceae (19), Bromeliaceae (19), Asteraceae (15), Myrtaceae (15), Cactaceae (13) and Malpighiaceae (13). These accounted for 48 % of the species sampled. The most speciose genera are *Piper* (16 spp.), *Miconia* (10 spp.), *Peperomia* (9), *Anthurium* (8), *Begonia* (8), *Solanum* (8), *Philodendron* (7), *Psychotria* (7) and *Sida* (7).

Regarding the life-forms (Fig. 3), many species (79 spp.) exhibit more than one form (*e.g.*, *Randia armata*, *Davilla rugosa*). The proportion of herbs was 37 %, followed by trees (20 %), shrubs (16 %), subshrubs (15 %) and lianas or

climbers (12%). Within the herbs, the families Orchidaceae (20 spp.), Araceae (19), and Bromeliaceae (16) stand out. Among the trees, the richest family are Fabaceae (19 spp.), followed by Myrtaceae (15) and Melastomataceae (06). Among the shrub species, the families Melastomataceae (18 species), Myrtaceae (15), Fabaceae (13) and Rubiaceae (9) stand out for having the greatest richness. Subshrub species predominantly belong to Malvaceae (13 spp.), followed by Fabaceae (7 spp.) and Asteraceae (5 spp.). Among the lianas and climbers, the most representative family is Malpighiaceae (9 spp.), followed by Bignoniaceae (6). Lianas and climbers are concentrated in the most concave portions of the relief, where numerous trees up to 25 m house several species of epiphytes and hemiepiphytes, especially from the families Bromeliaceae, Orchidaceae and Araceae.

Our study recorded 10 regional endemic species (2.3%) from the state of Espírito Santo: *Aphelandra maximiliana*, *Begonia espiritosantensis*, *Clusia spiritu-sanctensis*, *Cryptanthus maritimus*, *Dalechampia margarethiae*, *Dichaea elianae, Huberia mestrealvarensis*, *Kuhlmanniodendron apterocarpum*, *Leandra triantha*, *Rudgea mucronata*, and *Tillandsia kautskyi*.

The inventory added seven new records of occurrence for the state of Espírito Santo: *Gurania pseudo-spinulosa* (Cucurbitaceae), *Mimosa debilis* (Fabaceae), *Peperomia martiana* (Piperaceae), *Pavonia fruticosa*, *Sida spinosa*, *Triumfetta rhomboidei* (Malvaceae) and *Ziziphus undulata* (Rhamnanceae).

Among the species found in APAMA, 52 (10.5%) are under some degree of threat of extinction according to the Brazilian Red List and Espírito Santo Red List. Twenty-nine species were exclusive to the regional list, for example, *Erythroxylum nobile* (CR – critically endangered), *Bertolonia duasbocaensis* (CR), and *Huberia mestrealvarensis* (CR). Another seven species were only cited on the country's red list: *Aechmea depressa* (VU - vulnerable), *Aphelandra maximiliana* (VU), *Begonia itaguassuensis* (VU), *Begonia novalombardiensis* (VU), *Griffinia espiritensis* (VU), *Hippeastrum striatum* (VU), and *Zeyheria tuberculosa* (EN – endangered). Few species presented distinct categories in the two red lists: *Begonia kuhlmannii*, *Cariniana ianeirensis*, *Cryptanthus maritimus*, *Handroanthus riodocensis*, and *Sinningia aghensis*.

Other important species include taxa defined as the following: data deficient (DD), *Myrciaria tenella* and *Chondrodendron platiphyllum*; and near threatened (NT), *Philodendron hatschbachii*, *Pilosocereus brasiliensis* and *Mollinedia lamprophylla*.

Some naturalized species have been found associated with anthropized areas, such as *Menilis repens*, *Hedychium coronarium*, *Oeceoclades maculata* and *Impatiens walleriana*.

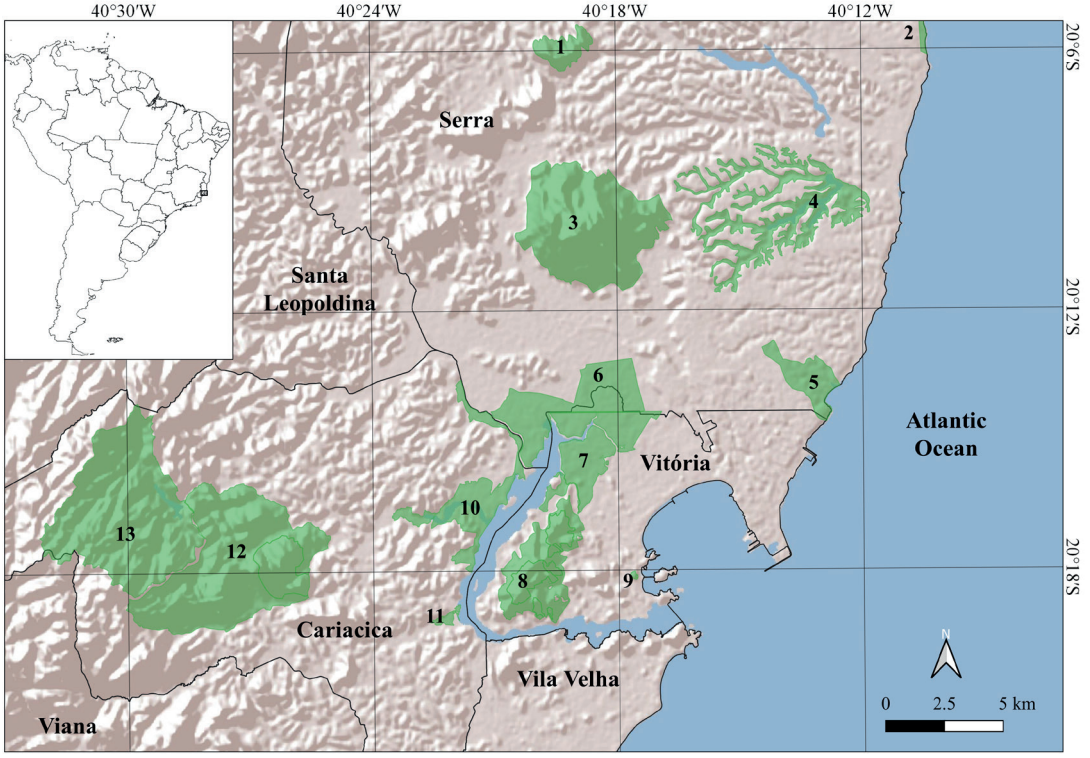

Figure 1. Location of Area de Preservação Ambiental do Mestre Álvaro (APAMA) and surrounding protected areas. 1: Área de Proteção Ambiental do Morro do Vigilante; 2: Área de Proteção Ambiental Costa das Algas; 3: Área de Proteção Ambiental do Mestre Alvaro; 4: Área de Proteção Ambiental Municipal da Lagoa Jacunem; 5: Área de Proteção Ambiental de Praia Mole; 6: Área de Proteção Ambiental Manguezal Sul da Serra; 7: Estação Ecológica do Lameirão; 8: Área de Proteção Ambiental do Maciço Central; 9: Parque Natural Municipal Von Schilgen; 10: Reserva de Desenvolvimento Sustentável Municipal do Manguezal de Cariacica; 11: Parque Natural Municipal do Manguezal de Itangua; 12: Área de Proteção Ambiental Municipal do Monte Mochuara; 13: Reserva Biológica Duas Bocas.

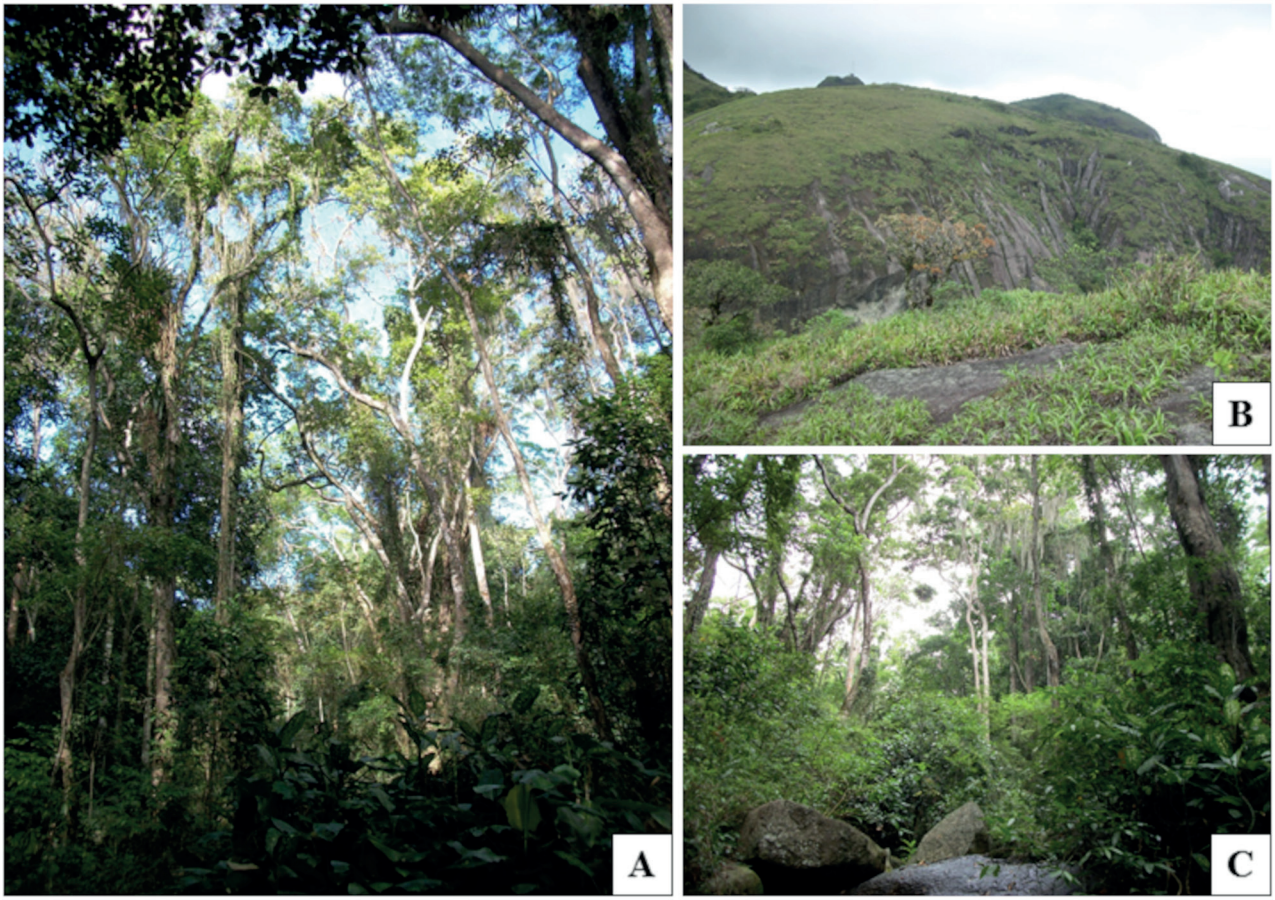

Figure 2. Conserved vegetation areas in Área de Proteção Ambiental do Mestre Álvaro. **A.** Forest in an advanced stage of regeneration on a convex portion of the relief; **B.** Rocky outcrop vegetation; **C.** Ravine forest.

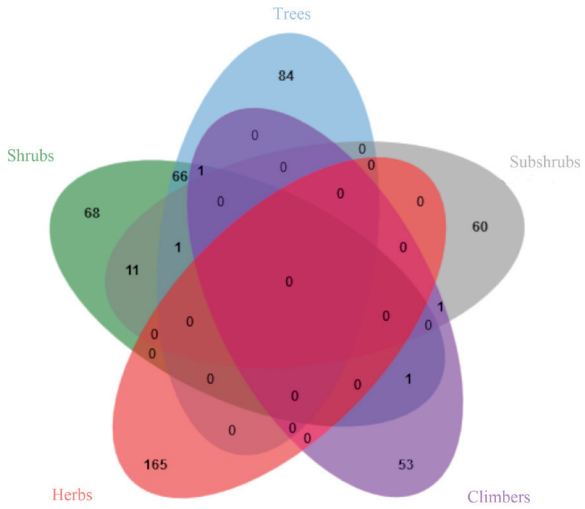

Figure 3. Venn diagram showing the number of life-forms expressed by species for Área de Proteção Ambiental do Mestre Álvaro.

Discussion

This study aimed to inventory the vegetation of APAMA, an important and poorly studied phytoecological region in the state of Espírito Santo. Initial indicators, such as the description of new species (*e.g.*, Valadares & Sakuragui 2014; Iglesias *et al.* 2016; Valadares & Coelho 2017; Pereira-Silva *et al.* 2019), demonstrated the floristic importance of this area. Our results demonstrate a richness superior to initial estimates for similar altitudinal ranges in the state (see Luber *et al.* 2016). However, we agree with Menini-Neto *et al.* (2009) that we should not rule out the scarcity of studies focused on different life-forms in dense ombrophilous forest as a factor when making difficult comparisons.

Despite historical disturbances and current land use (IBC 1970), APAMA has well-preserved vegetation in regions with the most concave relief (ravine forest). Terrestrial and epiphytic herbaceous species are concentrated in ravines. The high humidity in these environments has been reported as an important factor for the maintenance of these life-forms (Benzing 1990; Menini-Neto 2009). APAMA is notable for the presence of perennial and seasonal streams that are often associated with ravines. The steepness of these ravine forests probably made it difficult to extract wood in the past, resulting in a much more expressive richness than in forests in convex areas. For example, some elements restricted to ravines include individuals of species with a diameter at breast height (DBH) greater than 79.5 cm that has recognized economic

value, such as *Pouteria venosa*, *Cariniana legalis*, *Lecythis pisonis*, *Actinostemon klotzschii*, *Handroanthus riodocensis*, and *Ocotea aniboides* (Lorenzi 2008; 2009; 2013).

It is interesting to note that the most representative families found in APAMA were also the focus of works within the project Diversidade Florística da Área de Proteção Ambiental do Mestre Álvaro: including unpublished data as Araceae, Cactaceae, Fabaceae, Malvaceae, Malpighiaceae and, Melastomataceae (Iglesias & Dutra 2017). This effect was also pointed out by Luber *et al.* (2016) as an important variable in a similar study. Even so, our data follow the expected trend for the families that are the most diverse lineages in the Atlantic Forest (BFG 2018): Asteraceae, Fabaceae, Melastomataceae, Myrtaceae, Bromeliaceae and Orchidaceae.

The family Fabaceae, for example, is also prominently reported in other studies involving the same phytoecological region (Luber *et al.* 2016), even when restricted to the arboreal component (Carvalho *et al.* 2007; Solórzano *et al.* 2007; Saiter *et al.* 2011). When comparing the species of this family in APAMA with other phytoecological regions of this state, we find more species shared with tabuleiro forest (*e.g.*, *Abarema langsdorffii* and restinga (*e.g.*, *Albizia polycephala*, *Chloroleucon extortum*) than with montane ombrophilous forest (*Inga marginata* and *Senna macranthera*). This result may be associated with a greater sampling effort made in the first two regionally well-studied vegetation types (Pereira *et al.* 1998; 2000; Pereira & Zambom 1998; Assis *et al.* 2004; Rolim *et al.* 2016), and also to the high amount of endemism found in forests above 800 m altitude (Thomaz & Monteiro 1997). Among the registered species, *Leucochloron incuriale* has a wide distribution, but within the state of Espírito Santo its occurrence is limited to APAMA, which is possibly associated with the scarcity of collections (Chagas *et al.* 2017).

In the case of Melastomataceae, species typical of dense montane ombrophilous forest accounted for ca. 70 % of the species collected in APAMA (Iglesias & Dutra 2017); the remainder are typically at altitudes below 500 m. Perhaps, this view is the best definition of APAMA's floristic identity, which has elements from both phytoecological regions. Although expected for the altitudinal range analyzed, the union between these elements is a relictual distribution in a sharply fragmented landscape.

Other significant families in APAMA have centers of diversity in the Atlantic Forest. This is the case for Araceae, which contains the conspicuous genera *Anthurium* and *Philodendron*. Their representativeness in APAMA supports Krömer *et al.* (2005) and Furtado & Menini-Neto (2018), who assume that up to 800 m of these genera are under optimal developmental conditions. Besides this, they are particularly remarkable for having dense populations along streams and on boulders in forests.

For Cactaceae, the center of diversity of the epiphytic tribe Rhipsalideae is in the Atlantic Forest, which contributes to it being one of the most representative vascular epiphyte families in this domain (Calvente *et al.* 2011; Freitas *et al.* 2016). The diversity and abundance of these cacti in humid environments could be an indicator of the degree of regeneration of Atlantic Forest (Taylor & Zappi 2004). Some species, such as *Hatiora salicornioides*, *Lepismium cruciforme* and *Rhipsalis elliptica*, were recorded for the first time for the Grande Vitória Metropolitan Region, since they are associated with elevated areas in Espírito Santo, at submontane and montane forests (Cardoso *et al.* 2022) .

The cases of Malpighiaceae and Malvaceae in APAMA are typical examples of representativeness as a reflection of the collection effort because both families generally do not appear prominent in floristic studies. Malpighiaceae, for example, only show significant representativeness in the state in a study by Pereira & Zambom (1998) conducted in restinga. Nevertheless, about 35 % of the Malpighiaceae genera recorded for Espírito Santo also occur in APAMA (see Almeida & Mamede 2014). The record of *Amorimia maritima* is the first for this species for ombrophilous forest in Espírito Santo.

For Malvaceae, there is a strong link of *Malvastrum*, *Sida*, *Sidastrum*, *Triumfetta* and *Waltheria* to altered environments (*e.g.*, Bovini *et al.* 2001; Bovini & Baumgratz 2016), which occur in APAMA as pastures, roads, and landfills. These genera represent 73 % of the species sampled for the family. It is important to highlight that even though these species are ruderal (Moro *et al.* 2012), they contribute to APAMA's natural regeneration process and should be included in similar studies.

The representativity of Piperaceae in similar phytoecological regions in Espírito Santo was previously associated with disturbances of anthropic origin (Luber *et al.* 2016). However, in APAMA the richness of the family is well represented by *Peperomia*, which is a conspicuous element of dense ombrophilous forest (Carvalho-Silva & Guimarães 2008; Sarnaglia-Junior *et al.* 2014b). As previously noted by Sarnaglia-Junior *et al.* (2014a), *Piper* is common on the margins of well-preserved streams in ravines.

It is important to note the considerable lack of collections for some groups, such as Myrtaceae, Sapotacaeae and Lauraceae, which are often representative components in Tertiary/Quaternary forests (Fabris & Cesar 1996; Fabris 2011; Fabris & Peixoto 2013; Giaretta & Peixoto 2015; Moraes & Vergne 2018; Moraes & Vergne 2019), as well as montane forests of Espírito Santo (Thomaz & Monteiro 1997; Barbosa *et al.* 2012; Giaretta *et al.* 2015; Monico & Alves-Araujo 2019). This makes clear the next gap to be filled regarding APAMA's flora, which will potentially result in additional information about the floristics of the area.

The richness found in APAMA is a positive example of what conservation units with different phytoecological regions contribute to the maintenance of ecological corridors. This study also provides a new source of data for biogeographic studies that seek to understand the effect caused by neighboring vegetation types on the composition of restinga vegetation (see Giaretta *et al.* 2013). In the state of Espírito Santo, the submontane dense ombrophilous

forest has never been studied in this scenario and APAMA's coastal location makes this possible.

Finally, it is important to note that, despite the significant number of species found in APAMA, floristic comparisons with other similar areas would be premature considering the current knowledge of their floras. This is because our results indicate a tendency for subsampling some representative families of the Atlantic Forest. However, this gap serves as a trigger to conduct new taxonomic studies involving these families.

We have shown the conservation of protected areas in large urban centers allows the maintenance of target species for conservation. This study can contribute to maintaining the conservation unit by providing information about the presence of endemic and endangered species. It is of paramount importance that decision-makers can obtain indicators as a metric for resource allocation. The presence of new records is indicative of the negligence this significant forest remnant has experienced until now and highlights the need to improve the research there.

Knowing the vegetation of APAMA is an important tool for restoration projects designed to meet the Brazilian Native Vegetation Protection Law (Brasil 2012b). We demonstrate that, despite the history of use, the study area guarantees the maintenance of a significant number of endemic and threatened species, as well as important ecosystem services. Our study presents an unprecedented documented floristic list for the altitudinal gradient (100–800 m) in the priority area for the conservation of Grande Vitória (Espírito Santo 2010b). This list will support forest restoration projects in line with the region's natural regeneration potential (Martins *et al.* 2014) and legally recognized ecological corridors (Espírito Santo 2010a).

Acknowledgements

We thank to Luana Calazans for providing valuable comments on this manuscript. This work was supported through a research grant from the Fundação de Amparo à Pesquisa do Espírito Santo (FAPES, Processo 57226334/12).

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