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Original Paper

Flora and Phytophysiognomies of an Atlantic Forest remnant on the coast of Southeast Brazil

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Abstract

The present work describes the phytophysiognomies and inventories the remaining floristic diversity of the Brisas Environmental Protection Area, which is located on the coast of Sepetiba Bay in the state of Rio de Janeiro, Brazil, covering approximately 101 hectares. Three phytophysiognomies were identified and described, namely *Restinga*, the Lowland Dense Ombrophylous Forest and the Mangrove. Different types of vegetation can be recognized for *Restinga*, such as beaches and dunes, those located on sandy ridges, in this case represented by Low and High *Restinga* forests, and the vegetation associated with depressions, such as the Swampy *Restinga* and Swampy forest. The floristic survey identified 311 species, distributed in 231 genera and 86 families. Herbaceous plants represent 29.26% of the flora, followed by vines (27.75%), trees (27.33%), shrubs (14.46%) and epiphytes (4%). *Restinga* is home to 81% of the flora, followed by the Lowland Dense Ombrophylous Forest (28.30%) and the Mangrove (2.25%). The most representative families were Fabaceae (38 spp.), Euphorbiaceae (15 spp.), Asteraceae (14 spp.) and Sapindaceae (14 spp.). The area has low floristic similarity with other areas of the state of Rio de Janeiro, but it has a greater grouping with restingas from the state of Rio de Janeiro.

Key words: Brisas EPA, floristic, Lowland Dense Ombrophylous Forest, *Restinga*, Mangrove.

Resumo

O presente trabalho descreve as fitofisionomias e inventaria a diversidade florística remanescente da Área de Proteção Ambiental das Brisas, que se localiza no litoral da Baía de Sepetiba, no estado do Rio de Janeiro, possuindo cerca de 101 hectares. Foram identificadas e descritas três fitofisionomias, a saber, Restinga, a mais predominante, a Floresta Ombrófila Densa de Terras Baixas e o Manguezal. Para a Restinga pode-se reconhecer diferentes tipos de vegetação, como a de Praias e Dunas, as situadas sobre Cordões Arenosos, neste caso representadas por Florestas Baixa e Alta de Restinga, e a vegetação associada às depressões, como o Brejo de Restinga e a Floresta Paludosa. O levantamento florístico identificou 311 espécies, distribuídas em 231 gêneros e 86 famílias. As plantas herbáceas representam 29,26% da flora, seguido das trepadeiras (27,75%), arbóreas (27,33%), arbustivas (14,46%) e epífitas (4%). A Restinga abriga 81% da flora, seguida pela Floresta Ombrófila Densa de Terras Baixas (28,30%) e o Manguezal (2,25%). As famílias mais representativas foram Fabaceae (38 spp.), Euphorbiaceae (15 spp.), Asteraceae (14 spp.), Sapindaceae (14 spp.) e Malvaceae (13 spp). A área tem baixa similaridade florística com outras áreas do estado do Rio de Janeiro, porém apresenta maior agrupamento com restingas fluminenses.

Palavras-chave: APA das Brisas, florística, Floresta Ombrófila de Terras Baixas, Restinga, Manguezal.

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Introduction

There are different physiographic units along the Brazilian coast which are characterized by climatic, oceanographic and continental aspects (Silveira 1964), presenting features of bays, estuaries, cliffs, dunes and coasts, among others (Zickel *et al*. 2004). The vegetation of the Brazilian coastal plains is quite heterogeneous in its floristic and structural composition, characterizing different formations (Silva & Britez 2005), such as mangroves, *restingas* and lowland forests, among others.

According to Lino (1992) and Negrelle (2002), lowland vegetation and coastal plain forests are those which suffer the most from anthropic disturbances along the Brazilian coast, especially due to accessibility and real estate speculation. Despite being located in easily accessible areas, they are also the least preserved and studied areas (Lino 1992; Negrelle 2002), mainly because these coastal sandy plains are being rapidly destroyed along almost the entire Brazilian coast without us being aware of their floristic richness, structure and potentialities (Sá & Araujo 2009).

The neighborhoods of Guaratiba and Pedra de Guaratiba on the shores of Sepetiba Bay in the city of Rio de Janeiro resist as a mosaic of unparalleled ecosystems. Based on the current composition of forest remnants in the region, it is assumed that the region from the coastal margin to the interior of the continent was discontinuously composed of a first zone of mangroves, followed by phytophysiognomies of herbaceous, shrubby and arboreal areas from the beaches, in addition to the lowland dense rainforest in the plains close to the slopes, and the dense submontane and montane rainforests in the surrounding hills and massifs, located in what is now the Pedra Branca State Park. Over the years, agro-industrial cycles and disorderly urban expansion have caused significant losses of coastal vegetation along the entire Brazilian coast (Pougy *et al*. 2018; Soares *et al.* 2021), and it was no different on the coast of Sepetiba Bay, in Rio de Janeiro (Mello 2015; Almeida & Izaias 2020). The progressive installation of subdivisions on the coast of this bay caused suppression of the original coastal vegetation (mangroves, sandbanks and lowland forest), but the Brisas Environmental Protection Area (EPA) has resisted time and urbanization as the only representative set of the three remaining coastal ecosystems.

Created by Law 1918 of October 5, 1992, the Brisas EPA, located in the west zone of the city of Rio de Janeiro, is a Municipal Conservation Unit (CU) whose objective is to safeguard the biodiversity of the remaining coastal ecosystems that compose it. It is in a coastal plain on the coast of Sepetiba Bay, and the area encompasses several environments which constitute the phytophysiognomies of mangroves, *restinga* and lowland dense rainforest, which belong to the phytogeographic domain of the Atlantic Forest. Its unique biotic and historical-archaeological components characterize it as an important research area, ranking ninth among the ten main areas of the Atlantic Forest in the city, according to the Pereira Passos Institute (IPP 2018).

The Brazilian *restingas* from the coastal zones are constituted by a complex of vegetation which varies from herbaceous plants specialized in occupying dunes closer to the beach, to shrubs and large trees that occupy more favorable locations with more humid and fertile soils (Sampaio *et al*. 2005). Some preserved stretches of *Restinga* forests are found within conservation units, and the protection of these areas is not only of paramount importance for maintaining biodiversity, but also to be a source of species to recover coastal sandy plain areas (Sugiyama 1998). The *Restinga* forests in the coastal plains often form gradients with the formations of lowland dense rainforest, making it difficult to floristically and structurally distinguish between these phytophysiognomies (BRASIL 2002). However, recent studies have shown that such forest formations are composed of different tree species, sharing a few species with each other (Cerqueira 2000; Scarano 2002; Assis *et al.* 2011).

The *Restinga* forests in the state of Rio de Janeiro are already widely known and present several floristic surveys (Pereira & Araujo 2000; Rocha *et al*. 2007). The state of Rio de Janeiro has 21 *Restinga* remnants, totaling more than 60,000 hectares located in areas undergoing an accelerated urbanization process (Rocha *et al*. 2007); however, the Brisas EPA is not listed as a representative area. The flora and structure of the Lowland Dense Ombrophylous Forest (LDOF) is still little known (Ponçano *et al*. 1981; Assis *et al*. 2011). Because this type of vegetation is associated with the coastal plain and the base of the slopes (Veloso *et al*. 1991), the soil type can be a delimiting factor between the *Restinga* Forest (*Restinga* arborea) and the DLOF, distinguishing them on the coast of São Paulo, as suggested by Assis *et al*. (2011).

The Brisas Environmental Protection Area represents one of the last *Restinga* Forest and Lowland Dense Ombrophylous Forest remnants in the municipality of Rio de Janeiro. It is also noteworthy that this CU is fully inserted in an urban context, being an area with flat relief and easy access, much sought after by real estate speculation.

Knowledge of the biodiversity present in municipal CUs is still deficient, especially in those of sustainable use, which accentuates the many knowledge gaps for the different biological groups (SOS MATA ATLÂNTICA 2017), and makes it difficult to prepare conservation and management actions for their remnants and the species that may occur in them. This is even more serious in municipal CUs as they are located in urban areas which are more vulnerable to various impacts and pressures from the surroundings, despite playing an important role in protecting populations of endemic, rare and/or endangered fauna and flora species (SOS MATA ATLÂNTICA 2017).

Despite its 30 years of creation, the Brisas EPA still does not have a published and disseminated floristic survey, so that the absence of floristic studies represents a serious lack of knowledge about the continental coastal flora of Sepetiba Bay and the state of Rio de Janeiro, in addition to hindering the use of strategies for managing and preserving this conservation unit. In this context, actions which make it possible to carry out a rapid inventory of species are essential to fill these gaps, with the aim of knowing regional and local floras, as well as discovering new and/or endangered species (Lewinsohn & Prado 2006). Thus, the present study sought to expand knowledge about the coastal flora of forest remnants in the state of Rio de Janeiro, especially in Sepetiba Bay.

Material and Methods

Study area

The Brisas EPA is a CU for sustainable use, and is located in the coastal complex of Baía de Sepetiba, facing the *Restinga* da Marambaia, specifically between the neighborhoods of Guaratiba and Pedra de Guaratiba (22°59'03"–23°00'00"S, 43°39'59"W), in the metropolitan region of the city of Rio de Janeiro, and occupies an area of 101.6 ha (Rio de Janeiro (RJ) 1999).

The region's climate is Aw type (tropical rainy climate) according to the Köppen classification system (Alvares *et al.* 2013), with abundant rainfall in summer and scarce in winter. The average annual rainfall in Sepetiba Bay is between 1,000 mm and 2,230 mm, and the average annual temperature ranges from 20º to 27 ºC (SEMADS 2001). The relative humidity of the air is 79% (SMAC 1995 *apud* Pereira 1999).

I. Descriptions of phytophysiognomies, schematic profiles and phytophysiognomic map

First, the study by Veloso *et al*. (1991) and as described in Municipal Law 1918/1992 enacted on the occasion of creating this CU were adopted as the reference to characterize the coastal phytophysiognomies of the Atlantic Forest in the Brisas EPA. The vegetation physiognomy descriptions were taken from field surveys and measurements, using satellite images to complement the terrain measurement by Google Earth Pro. The schematic profiles were subsequently made from these data using the Inkscape® free graphic editing software program (Inkscape 2021). The type of substrate, the presence and height of the litter layer, the height of the strata and their main species were observed in describing the different phytophysiognomies.

The Qgis 3.26® free software program was used to prepare the map of recognized phytophysiognomies, with the application of vector data from the CU and the creation of polygons to delimit and calculate the extension (ha) of each phytophysiognomy based on satellite images and surveys in field of edaphic and floristic components which compose the vegetation.

II. Soil analysis

Soil samples were taken at different points of the three occurring phytophysiognomies, totaling nine samples at three depths (0–5; 5–20; 20–40 cm) for better sampling of soil fertility. Chemical and granulometric analyzes of the collected material were carried out at the Soil Department of the Federal Rural University of Rio de Janeiro. The collections and analyzes were carried out using the usual methods following the protocol of Teixeira *et al.* (2017).

III. Floristic inventory: richness and characterization

The sampled vegetation in the study area was selected by consulting satellite images, local visits and local residents in order to mainly

contemplate the phytophysiognomies in a good state of preservation and with conditions to access the botanical material for collection. The vegetation covers the physiognomic and floristic gradient from the herbaceous communities on the beach passing through the Mangrove, *Restinga* and Lowland forest formations. The classification proposed by CONAMA Resolution No. 7, of July 23, 1996 (BRASIL 1996), for the state of São Paulo was adopted for a more detailed analysis of the *Restinga* vegetation, which enables analyzing the vegetation succession stages. In this case, the vegetation is divided into the following vegetation types: Vegetation on beaches and dunes, Vegetation on sandy ridges (Low *Restinga* forest, High *Restinga* forest) and Vegetation associated with depressions (Swampy *Restinga*, Swampy forest).

Botanical material collections were carried out from September/2021 to November/2022 through monthly unsystematic collections, aiming to cover the largest possible area and sample all physiognomies, including areas degraded by anthropic action. The collected material was herborized and the specimens deposited in the Botanical Garden Research Institute of Rio de Janeiro (RB) herbarium, with duplicates deposited in the Federal Rural University of Rio de Janeiro (RBR) herbarium. The species were identified through specific literature of the taxa, consultation with specialists and comparison with material deposited in the RB and RBR Herbariums. Species were classified according to taxonomic diversity using PPG I (2016) for ferns and lycophytes, and APG IV (2016) for angiosperms. The list of taxa was organized in alphabetical order by family, genus and species, respectively. Verification of the nomenclature, geographical distribution and indication of the biological forms of the species [arboreal (including trees, small trees and palms), shrubs (including shrubs and subshrubs), herbaceous (including terrestrial and aquatic), epiphytes and climbing plants (herbaceous and woody)] were based on data available on the *Flora e Funga do Brasil* website (Flora e Funga do Brasil 2023, continuously updated). The conservation status of the species was indicated based on the Red Book of the Flora of Brazil (Martinelli & Moraes 2013) and on Ordinance MMA No. 148, of June 7, 2022 (BRASIL 2022). The occurrences of species and biological forms were assigned using data from *Flora e Funga do Brasil* (Flora e Funga do Brasil 2023, continuously updated).

Floristic similarity analysis

Works in floristics and phytosociology were used for the floristic comparison between the studied area and other Atlantic Forest remnants in the state of Rio de Janeiro, in addition to consultations with digital databases, such as Specieslink (2023) and JABOT (2017). A matrix of binary data (presence/absence) of species was created in correlation with six areas to generate the Jaccard similarity coefficients (Valentin 2000). In addition, a cluster analysis using the mean group method (UPGMA) was used in order to interpret the floristic similarity between the areas (Valentin 2000). All analyzes were performed using the PAST4 program (Hammer *et al.* 2001).

Results

I. Phytophysiognomies: types, characterization and schematic profiles

Three coastal phytophysiognomies of the Atlantic Forest are recognized in the Brisas EPA, namely Mangrove, *Restinga* and Lowland Dense Ombrophylous Forests. These phytophysiognomies correspond to 76.27% of the study area (Fig. 1), in which *Restinga* is the most predominant corresponding to 34.2% of the area, followed by anthropized areas which correspond to 23.71% of the area.

The *Restinga* can be particularly differentiated into the following vegetation types: beach and dune vegetation, vegetation on sandy ridges (Lower and Upper *Restinga* forests) and Vegetation associated with depressions (Swampy *Restinga*, Swampy forest). Among these, the dune vegetation, Swampy forest and Swampy *Restinga* are the types that occur in the smallest area.

The map shown in Figure 1 presents updates regarding the classification and distribution of phytophysiognomies when compared with the map proposed by the zoning and regulation of the Brisas EPA from 1997 (Fig. 2).

Based on our data, three profiles can be drawn up illustrating the structure and distribution of recognized phytophysiognomies (Fig. 3a-c) in three sections from left to right, and from the coast to the opposite end across the study area. They represent the *lato sensu* phytophysiognomies (*i.e. Restinga*) and the physiognomies with the predominant microenvironments (*e.g.*, apicum, swampy, intermittent lakes, swampy forest).

Mangrove

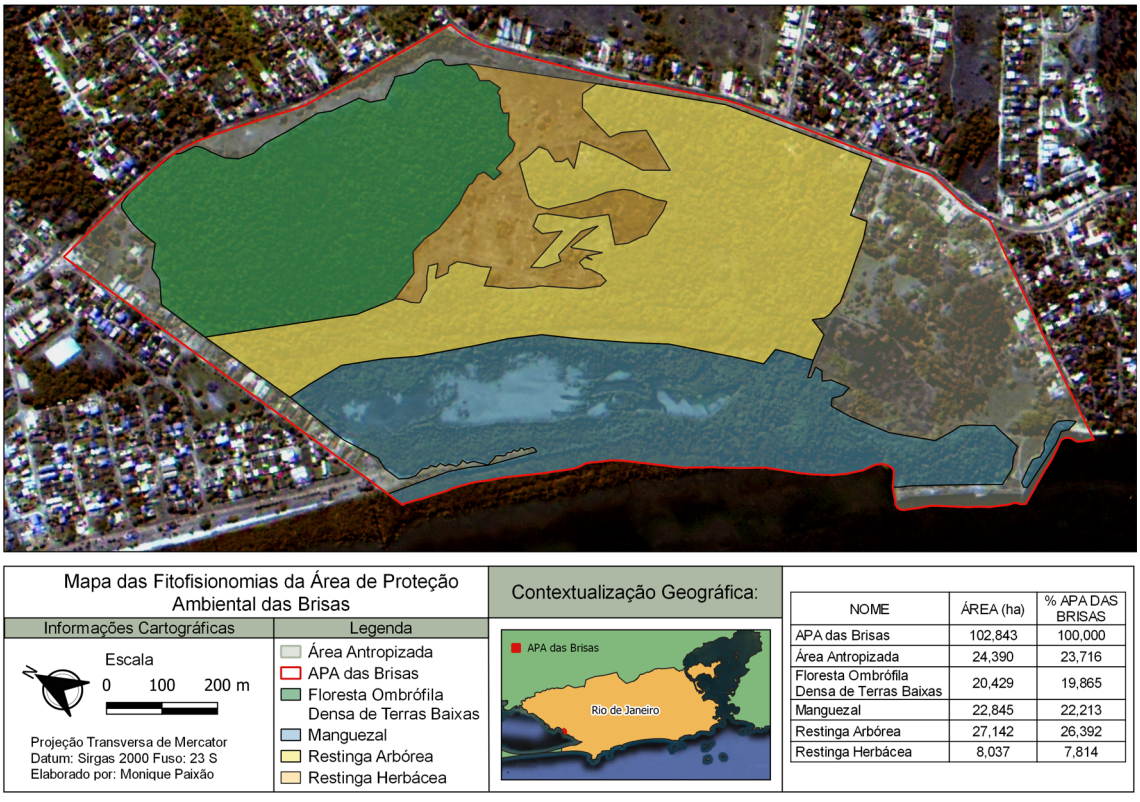
The mangrove occurs on the coastline in contact with Sepetiba Bay. It has a large apex in its central zone predominantly devoid of vegetation, with small green spots marginal to the forest formation, covered by undergrowth of *Salicornia fruticosa* L. The apicum ecosystem is associated with the mangrove, and presents periodic flooding susceptible to the tide, so that in drier periods it is possible to notice the presence of numerous footprints of animals that transit through the area (Fig. 4).

The vegetation of forest formation is characterized by the species of *Laguncularia racemosa* (L.) C.F.Gaertn. (White mangrove) and *Avicennia schaueriana* Stapf & Leechm. *ex* Moldenke (Black mangrove), with medium and large trees that can reach seven meters in height (Fig. 5). *Avicennia schaueriana* Stapf & Leechm. ex Moldenke is the most abundant species, forming monospecific forests.

The soil is muddy and sandy, predominantly covered by pneumatophorous roots. It is possible to find many growing propagules in advanced regeneration stage areas. It is also possible to find some epiphytes and hemiepiphytes in the trees, with an emphasis on *Tillandsia stricta* Sol. and *Selenicereus setaceus* (Salm-Dyck) Berg.

Restinga

It is possible to notice different vegetational mosaics of *Restinga* forming discontinuous microenvironments in the study area. Part of the *Restinga* area shows signs of the exploitation cycle in the region, showing exotic-invasive species in areas that used to have common traffic. The forest canopy is relatively low, ranging from 10 to 20 m in height, and shows no obvious stratification. Based on the classification proposed by CONAMA Resolution No. 7 of July 23, 1996 (BRASIL 1996), the following *Restinga* plant communities were found: 1. Beach and dune vegetation; 2. Vegetation on sandy ridges (2a. Low *Restinga* forest; 2b. High *Restinga* forest); and 3. Vegetation associated with depressions (3a. Swampy *Restinga*; 3b. Swampy forest). A Scrubland formation was not



NOME	ÁREA (ha)	% APA DAS BRISAS
APA das Brisas	102,843	100,000
Área Antropizada	24,390	23,716
Floresta Ombrófila Densa de Terras Baixas	20,429	19,865
Manguezal	22,845	22,213
Restinga Arbórea	27,142	26,392
Restinga Herbácea	8,037	7,814

Figure 1 – Map illustrating the phytophysiognomies of the Brisas Environmental Protection Area, Rio de Janeiro, Brazil (Structuring: Monique Paixão, 2023).

found in the study area. Although it represents the best-preserved stretch of the Pedra de Guaratiba coastline, it still shows changes due to past and recent anthropic interventions, such as the remnants of the activities of the former Caieira Farm, the presence of exotic and invasive plant species, damage due to irregular visitation, arson and garbage accumulation and works of a religious nature (Guimarães 2023).

1. Beach and dune vegetation (herbaceous *Restinga*)

In the area close to the sea, beach and dune vegetation (or herbaceous *Restinga*) is characterized by small vegetation patches with a predominance of creeping species, such as *Sesuvium portulacastrum* (L.) L. and *Canavalia rosea* (Sw.) DC., in addition to some grasses which are constantly susceptible to fires caused by visitors to the waterfront. The central area of the EPA is directly exposed to the sun, and the herbaceous *Restinga* is characterized by typical species such as: *Bulbostylis capillaris* (L.) C.B.Clarke, *Chamaecrista nictitans* (L.) Moench, *Cyperus ligularis* L., *Hexasepalum teres* (Walter) J.H.Kirkbr., *Matourea ocymoides* (Cham. & Schltdl.) Colletta & V.C.Souza, *Sauvagesia erecta* L. and *Stylosanthes viscosa* (L.) Sw. The soil is characteristically sandy, with coarse sand granules and natural dune formations.

2. Vegetation on sandy ridges

Some vegetation is established on late sandy sedimentary deposits. They present drier and more drained soils in relation to the vegetation associated with the depressions. We did not find Scrubland vegetation (shrubby *Restinga*), only the vegetation of the Low and High *Restinga* forest was observed. These two vegetation types are also designated here as *Restinga* Arborea.

2a. Low *Restinga* forest

This is predominantly an arboreal phytophysiognomy that occupies a discontinuous area, being a part between the Swampy forest

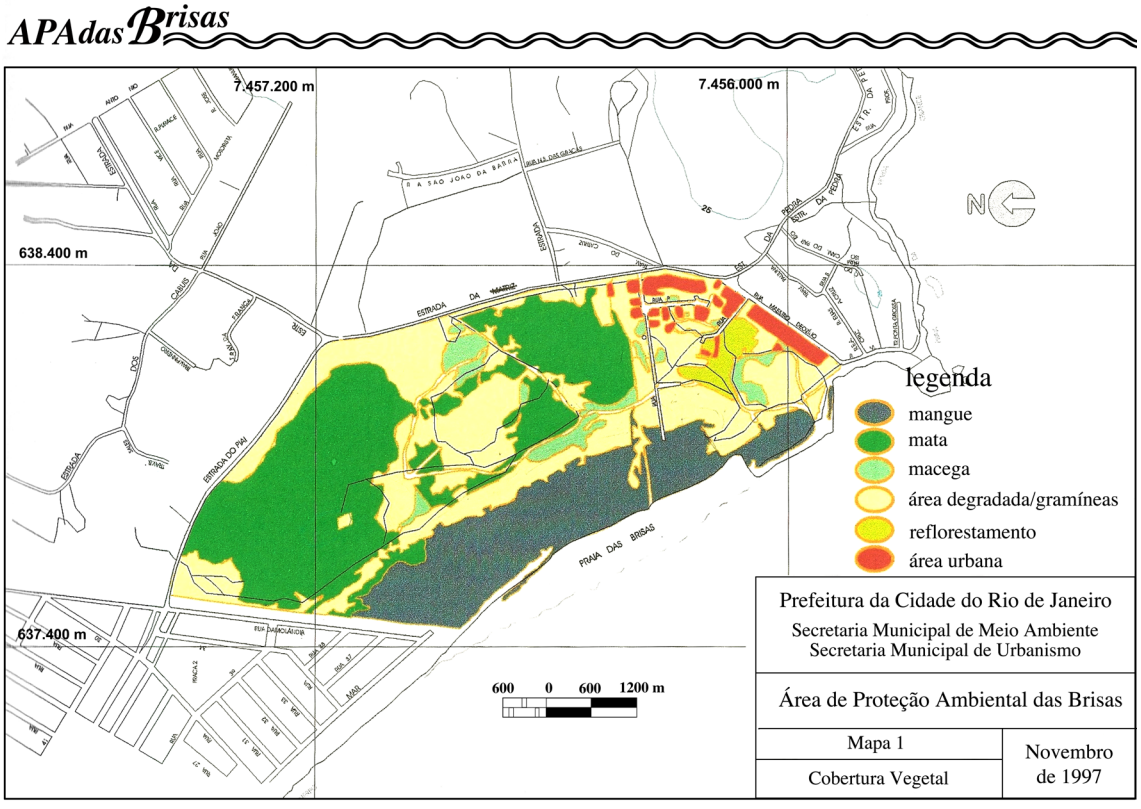


Figure 2 – Physiognomic map of the Brisas Environmental Protection Area (Source: Regulation and Zoning of the Area. 1997).

and the High *Restinga* forest and another part between the Swampy forest and the Lowland Dense Ombrophylous forest. It is characterized by dry sandy soil, with a notable presence of shells (Fig. 6) from middens found there (Rita Scheel-Ybert, personal communication). It has a relatively closed canopy up to 10 meters high, and some emergent trees up to 15 meters high. An understory is present with shrubs in lesser diversity, as well as the presence of some epiphytes and a high diversity of lianas and vines.

Regarding the tree species, the following stand out: *Aegiphila mediterranea* Vell., *Astronium fraxinifolium* Schott, *Cestrum axillare* Vell., *Eugenia uniflora* L., *Guarea guidonia* (L.) Sleumer, *Mollinedia glabra* (Spreng.) Perkins, *Pseudobombax grandiflorum* (Cav.) A. Robyns, *Salacia arborea* (Schrank) Peyr., *Schinus terebinthifolia* Raddi, *Sophora tomentosa* L. and *Trichilia casaretti* C.DC. The understory is represented by *Piper amalago* L. and *Psychotria carthagenensis* Jacq., while the following stand out in the shrub formation: *Celtis*

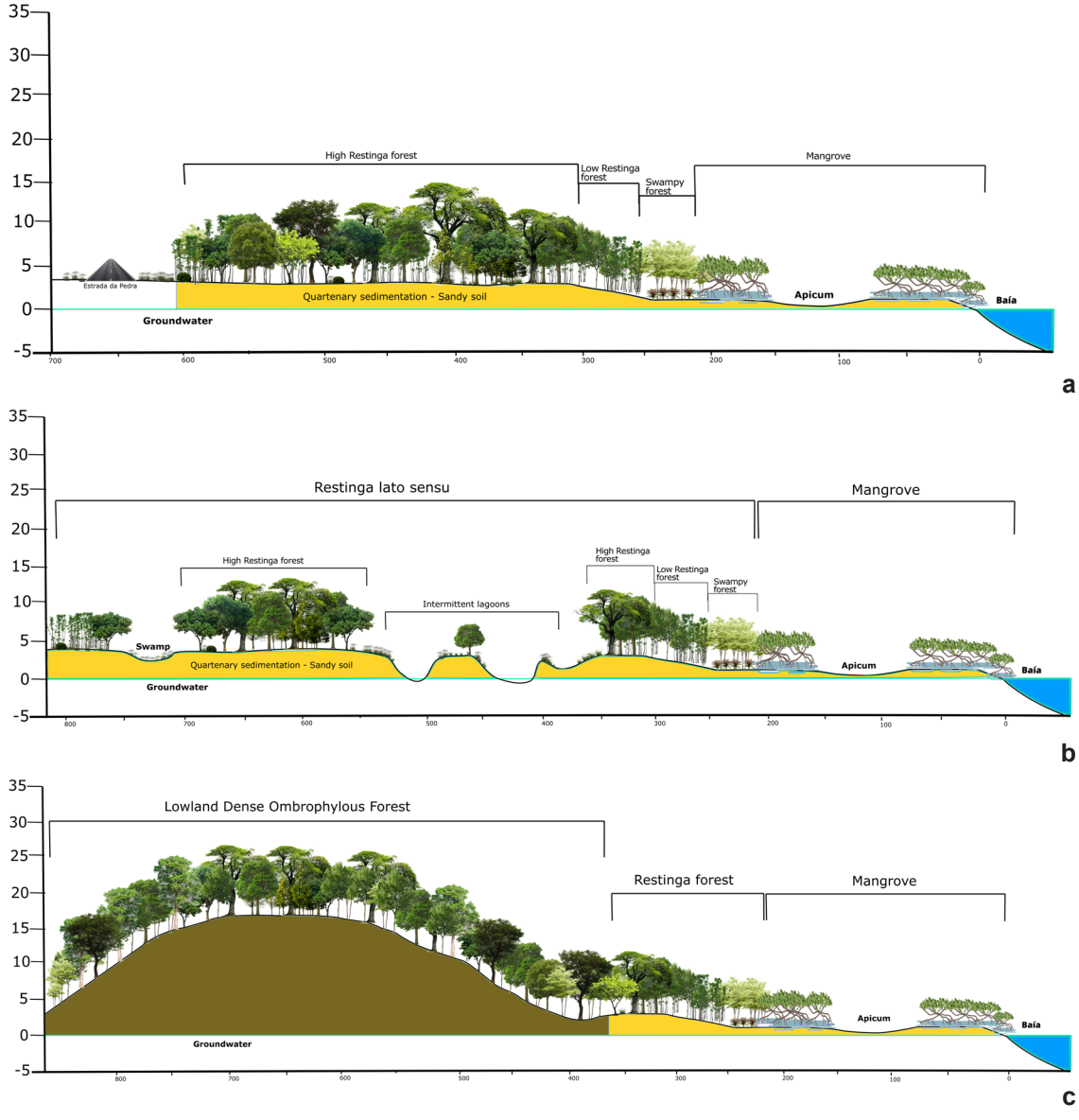


Figure 3 – a-c. Schematic profiles of the phytophysiognomies present in the Brisas Environmental Protection Area, Rio de Janeiro, Brazil. Source: G. S. Guimarães (2023).

brasiliensis (Gardner) Planch., *Cheiloclinium serratum* (Cambess.) A.C.Sm. and *Lantana camara* L. For epiphytes we found: *Billbergia amoena* (Lodd.) Lindl., *Microgramma vacciniifolia* (Langsd. & Fisch.) Copel, *Neoregelia johannis* (Carrière) L.B.Sm., *Neoregelia cruenta* (R.Graham) L.B.Sm. and *Pleopeltis pleopeltifolia* (Raddi) Alston.

Among the vines, the following species stand out: *Abrus precatorius* L., *Anchietea pyrifolia* (Mart.) G.Don., *Antigonon leptopus* Hook. & Arn., *Cardiospermum corindum* L., *Chiococca alba* (L.) Hitchc., *Chondrodendron platiphyllum* (A.St.-Hil.) Miers, *Davilla rugosa* Poir., *Mucuna sloanei* Fawc. & Rendle, *Serjania cuspidata* Cambess., *Serjania dentata* (Vell.) Radlk., *Smilax quinquenervia* Vell., *Smilax rufescens* Griseb. and *Urvillea ulmacea* Kunth.

Figure 4 – Apicum area inside the mangrove in the Environmental Protection Area of Brisas, Rio de Janeiro, showing a dry period, with the presence of animal footprints (arrows) and clusters of *Salicornia fruticosa* (☆) (Photo: G. S. Guimarães).

Figure 5 – Different heights of mangrove tree species in the Brisas Environmental Protection Area, Rio de Janeiro (Photo: G. S. Guimarães).

2b. High *Restinga* forest

This is a predominantly arboreal phytophysiognomy, with sections presenting understory with few herbaceous species. It is characterized by a dry and sandy soil, discontinuous and covered by a thick layer of litter, in addition to having slopes and small dunes inside the forest. The forest canopy is closed with little light penetration. The vegetation is composed of trees which vary from 10 to 15 m in height, with some emerging ones reaching 20 m (Fig. 7), and woody lianas within this formation that reach the treetops and few epiphytes. The presence of lianas and vines, shrubs and small and large herbaceous plants is notable on the edge of the vegetation. For the tree species, the following stand out: *Alchornea triplinervia* (Spreng.) Müll.Arg., *Andira legalis* (Vell.) Toledo, *Aspidosperma pyricollum* Müll.Arg., *Byrsonima sericea* DC., *Cupania emarginata* Cambess.,

Figure 6 – Detail of the sandy soil under a litter layer and with shell deposits in the formation of the Low Restinga forest in the Brisas Environmental Protection Area, Rio de Janeiro (Photo: G. S. Guimarães).

Figure 7 – High Restinga forest with emerging trees amid vegetation in the Environmental Protection Area of Brisas, Rio de Janeiro (Photo: Yuri Borba).

Eugenia florida DC., *Heisteria perianthomega* (Vell.) Sleumer, *Myrcia loranthifolia* (DC.) G.P.Burton & E.Lucas, *Ormosia arborea* (Vell.) Harms, *Protium brasiliense* (Spreng.) Engl., *Tapirira guianensis* Aubl. and *Zanthoxylum caribaeum* Lam.

The understory is represented by species such as: *Coccocypselum capitatum* (Graham) C.B.Costa & Mamede, *Dichorisandra thyrsiflora* J.C.Mikan, *Quesnelia quesneliana* (Brongn.) L.B.Sm. and *Scleria latifolia* Sw. The *Heteropterys chrysophylla* (Lam.) Kunth and *Lantana fucata* Lindl. species can be highlighted for shrubs, while the occurrence of *Microgramma vacciniifolia* (Langsd. & Fisch.) Copel., *Serpocaulon triseriale* (Sw.) A.R.Sm., *Tillandsia stricta* Sol., *Tillandsia tricholepis* Baker and *Vriesea neoglutinosa* Mez. can be noted for epiphytes.

Among the vines, the occurrence of *Aristolochia trilobata* L., *Banisteriopsis sellowiana* (A.Juss.) B.Gates, *Davilla rugosa* Poir., *Doliocarpus sessiliflorus* Mart. and *Fridericia conjugata* (Vell.) L.G.Lohmann are noteworthy.

In addition, the following arboreal plants can be found on the margins of the vegetation (Fig. 8): *Allophylus puberulus* (Cambess.) Radlk., *Cecropia pachystachya* Trécul, *Connarus rostratus* (Vell.) L.B.Sm. and *Trema micranthum* (L.) Blume. Then among the shrubs, the *Celtis fluminensis* Carauta, *Connarus nodosus* Baker, *Opuntia monacantha* Haw. and *Triumfetta bogotensis* DC. species can be observed, while *Coccoloba arborescens* (Vell.) R.A.Howard, *Dioclea virgata* (Rich.) Amshoff, *Fridericia conjugata* (Vell.) L.G.Lohmann and *Fridericia rego* (Vell.) L.G.Lohmann vines can be found on the margins of the vegetation.

3. Vegetation associated to depressions

3a. Swampy *Restinga*

This is an herbaceous formation which occurs in shallow depressions with permanent, predominant or sporadic flooding due to the action of the water table. There is a permanent brackish swamp between the phytophysiognomies of Mangrove and the Low *Restinga* forest that extends horizontally for 200 meters, with a predominance of *Typha domingensis* Pers. in the interior and *Acrostichum danaeifolium* Langsd. & Fisch. on the margins. This same type of phytophysiognomy is found in front of the headquarters of the old Caieira Farm.

Next, there is an herbaceous *restinga* area in the central area between the Lowland Dense Ombrophylous Forest and the Low and High *Restinga* forests, where it is possible to find slopes which approach the water table. The soil is sandy with large granules of white sand (Fig. 9), forming dunes and slopes occupied by herbaceous and shrubby vegetation, in addition to swamps/marshes and intermittent lakes that receive direct sunlight.

It is also observed that the slopes and dunes are present even within the primary and secondary vegetation of arboreal *Restinga*, which denotes the naturalness of the sandy formations resulting from changes in sea level during the Quaternary period.

Three intermittent lakes were found in the area, closed and surrounded by dunes, two of which hold the largest volume of water, and with seasonal floods which are more expressive in the rainy season (Fig. 10). During the field expeditions, it was observed that the lakes flooded for up to four months, passing through a drought of up to one month, until replenishment by the rains.

Figure 8 – Edge of the High Restinga forest in the Brisas Environmental Protection Area, Rio de Janeiro (Photo: Yuri Borba).

Figure 9 – Sandy soil of a dune in the central area of the Brisas Environmental Protection Area, Rio de Janeiro (Photo: G. S. Guimarães).

The central area of the lakes is occupied by low-lying aquatic plants in the less rainy periods (from June to August), such as *Bacopa lanigera* (Cham. & Schltdl.) Wettst. and *Oldenlandia salzmann*i (DC.) Benth. & Hook.f. *ex* B.D.Jacks., in addition to clumps of grasses that serve as shelter for the local herpetofauna which seek more humid environments and protected from the sun.

The presence of aquatic plants stands out during flood periods (October to April), such as *Eleocharis interstincta* (Vahl) Roem. & Schult., *Nymphoides humboldtiana* (Kunth) Kuntze, *Nymphaea pulchella* DC. and *Xyris jupicai* Rich. The presence of these populations (Fig. 11) suggests late establishment of the community, in addition to denoting the naturalness of the intermittent lake ecosystem in the Brisas EPA *Restinga*.

It is possible to find some shallow freshwater swamps in the central and marginal area (towards Estrada da Pedra) where some grasses and other taxa occur, with emphasis on the occurrence of *Bactris setosa* Mart., *Blechnum occidentale* L., *Eleocharis elongata* Chapm and *Xyris jupicai* Rich. As can be seen, these swamps are also ecosystems of great importance for the amphibian and fish species that live there, in addition to being a source of drinking water for the many species of birds that frequent the region during their migratory period.

Figure 10 – Intermittent lagoon in the central area among the vegetation of arboreal Restinga and Lowland forest in the Environmental Protection Area of Brisas, Rio de Janeiro (Photo: G. S. Guimarães).

The occurrence of *Notholebias minimus*, popularly known as *Peixe-das-nuvens*, stands out in the swamps of the Brisas EPA (Araújo & Soares 2022). The species is categorized as Critically Endangered, and was discovered during the expeditions of this work by the team from the Laboratory of Fish Ecology at UFRRJ.

It should be noted that these important microenvironments are located in the Controlled Occupation Zone (COZ 2), which, according to the decree regulating the area, provides for the possibility of urban occupation.

3b. Swampy forest

The Swampy forest occupies a wetland area in the transition between the Mangrove and the Lower *Restinga* forest, with seasonal flooding of brackish water from the tide and the rainy season. The soil is sandy and muddy and the phytophysiognomy is characterized by arboreal vegetation with a semi-open canopy up to 8 m in height and a predominance of *Guapira opposita* (Vell.) Reitz and *Monteverdia obtusifolia* (Mart.) Biral species which form almost homogeneous populations.

There is great abundance and diversity of epiphytes on the trees (Fig. 12), with emphasis on the presence of clumps of *Neoregelia cruenta* (R.Graham) L.B.Sm. and *Neoregelia johannis* (Carrière) L.B.Sm., as well as the occurrence of *Microgramma vacciniifolia* (Langsd. & Fisch.) Copel., *Pleopeltis astrolepis* (Liebm.) E.Fourn., *Tillandsia stricta* Sol. and *Tillandsia tricholepis* Baker.

Of the occurring hemiepiphytes, we can highlight *Selenicereus setaceus* (Salm-Dyck) Berg. and *Thaumatophyllum corcovadense* (Kunth) Sakur., Calazans & Mayo. It is possible to find small clumps of *Neoregelia cruenta* (R.Graham) L.B.Sm. and *Neoregelia johannis* (Carrière) L.B.Sm. in the herbaceous stratum at ground level, in addition to the expressive predominance of *Quesnelia quesneliana* (Brongn.) L.B.Sm in the understory, forming extensive homogeneous colonies between the Swampy forest and the Low *Restinga* forest (Fig. 13).

Lowland Dense Ombrophylous Forest

This is predominantly an arboreal phytophysiognomy with large trees ranging from 10 to 15 meters in height, with some emerging trees reaching up to 20 m. The forest canopy is closed with little light penetration, understory

present with seedlings of tree species, few shrubs and herbaceous plants, low diversity of vascular epiphytes and high number of woody vines (lianas) on the banks and in its interior. The number of lianas is so expressive that it makes access to the vegetation difficult (Fig. 14). What externally seems to be a flat physiognomy, it was discovered that the vegetation is on an ascending hill, which reaches up to 15 meters in altitude. The soil is composed of red podzolic covered by a thin layer of litter.

The presence of shrubs and small and large herbaceous plants on the edge of the vegetation is notable. The following interior trees stand out: *Anadenanthera colubrina* (Vell.) Brenan, *Sparattosperma leucanthum* (Vell.) K.Schum., *Piptadenia gonoacantha* (Mart.) J.F.Macbr., *Swartzia apetala* Raddi and *Syagrus romanzoffiana* (Cham.) Glassman; while for the understory we can highlight *Casearia commersoniana* Cambess. and *Trichilia casaretti* C.DC. *Ditaxis simoniana* Casar, which can also be found in the flatter areas of the understory.

The following species stand out in relation to the vines in the interior: *Cheiloclinium serratum*

Figure 11 – a-i. Aquatic species associated with the intermittent lagoons of the Brisas Environmental Protection Areas, Rio de Janeiro – a. *Oldenlandia salzmanni*; b. *Nymphaea pulchella*; c. *Bacopa lanigera*; d. *Matourea ocymoides;* e. *Xyris jupicai*; f. *Ludwigia longifolia*; g. *Xyris jupicai*; h. *Eleocharis interstincta*; i. *Nymphoides humboldtiana*. (Photos: G. S. Guimarães).

Figure 12 – High abundance of vascular epiphytes in the Swampy Restinga forest of the Brisas Environmental Protection Area, Rio de Janeiro (Photo: G. S. Guimarães).

Figure 13 – *Quesnelia quesneliana* population in the understory of the Swampy Restinga forest of the Environmental Protection Area of Brisas, Rio de Janeiro (Photo: G. S. Guimarães).

Figure 14 – High abundance of woody vines within the vegetation of the Lowland Dense Ombrophylous Forest of the Environmental Protection Area of Brisas, Rio de Janiro. (Photograph: G. S. Guimarães).

(Cambess.) A.C.Sm., *Chondrodendron platiphyllum* (A.St.-Hil.) Miers, *Hebanthe erianthos* (Poir.) Pedersen and *Smilax rufescens* Griseb.

It is possible to notice the presence of characteristic tree species in the marginal vegetation, such as: *Casearia obliqua* Spreng., *Helicteres macropetala* A.St.-Hil., *Solanum argenteum* Dunal and *Swartzia apetala* Raddi. Moreover, *Croton allemii* G.L.Webster stands out regarding the marginal shrubby species, and *Stachytarpheta cayennensis* (Rich.) Vahl for the herbaceous species. In addition, the following marginal vines stand out: *Aristolochia rumicifolia* Mart. & Zucc., *Baccharis trinervis* Pers., *Dalechampia brasiliensis* Lam., *Lygodium volubile* Sw., *Operculina macrocarpa* (L.) Urb., *Macropsychanthus violaceus* (Mart. *ex* Benth.) L.P.Queiroz & Snak and *Reissekia smilacina* (Sm.) Steud.

II. Soil analysis of phytophysiognomies

The soil of *Restinga* is predominantly sandy, with a high content of total and coarse sand, while presenting the lowest values for natural and total clay. The soil of the Lowland Dense Ombrophylous Forest and the Mangrove is sandy-clay; however, as a physical distinction, the mangrove has the highest concentrations of fine sand and natural clay.

The Lowland Ombrophylous Forest and the *Restinga* forest have a pronounced acidic pH, unlike the mangrove soil, which has a more basic pH. Collections at greater depth for the Lowland Forest have a lower pH than collections closer to the surface, unlike the mangrove area, which presented a more basic pH at greater depths. The Lowland Ombrophylous Forest showed higher aluminum concentrations at greater depths. The mangrove has a high concentration of potassium.

Table 1 below presents the physicochemical properties of the soil layers (0–40 cm) of the phytophysiognomies recognized in the Brisas EPA.

III. Floristic inventory: richness and characterization

A total of 311 species and one variety were sampled for the set of different physiognomies found in the Brisas EPA, distributed in 231 genera and 86 families (Annex S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.24867507.v1), which represent 303 species of angiosperms and eight species of

Table 1 – Analysis of the chemical and granulometric components of the soil of the phytophysiognomies of the Brisas EPA, Rio de Janeiro (LDOF = Lowland Dense Ombrophylous Forest).

Chemical analysis										
Ident.		**LDOF**	**LDOF**	**LDOF**	**Restinga**	**Restinga**	**Restinga**	**Mangrove**	**Mangrove**	**Mangrove**
Profund.		**0-5**	**5-20**	**20-40**	**0-5**	**5-20**	**20-40**	**0-5**	**5-20**	**20-40**
pH		4,63	4,15	3,98	4,56	4,55	4,6	7,2	7,53	7,76
P	mg/dm	10	2	80	78	22	8	4	0	2
K		50	32	18	36	13	14	4160	3988	3108
Na	cmol/dm	0,06	0,08	0,09	0,26	0,06	0,33	150	154	154
Ca		2,3	1	0,7	2,5	0,5	0,7	8,7	8,3	12
Mg		1,9	0,7	0,7	1,2	1,7	0	5,6	5,5	5,1
K		0,13	0,18	0,05	0,09	0,03	0,04	10,5	10,2	7,95
Al		0,3	1	1,5	0	0,5	0,3	0	0	0
H+Al		7,76	9,41	8,09	6,6	6,44	3,96	1,65	2,15	1,32
S		4,39	1,86	1,54	4,05	2,29	1,07	174,8	178	179,05
T		12,15	11,27	9,63	10,65	8,73	5,03	176,45	180,15	180,37
V%	%	36	17	16	38	26	21	99	99	99
m		6,4	34,94	49,41	0	17,9	21,97	0	0	0
n		0,49	0,71	0,93	2,44	0,69	6,57	85,01	85,48	85,38
t	cmol/dm	4,69	2,68	3,04	4,05	2,79	1,37	174,8	178	179,05

Granulometric analysis								
Ident.	**Profund.**	**Natural clay**	**Total clay**	**Total sand**	**Fine sand**	**Coarse sand**	**Silt**	**G.F.**
		g/kg						**%**
LDOF	0-5	80	200	750	60	690	50	60
LDOF	5-20	150	280	650	100	540	70	46
LDOF	20-40	170	330	600	90	510	70	48
Restinga	0-5	10	70	860	70	790	70	86
Restinga	5-20	10	70	890	60	830	40	86
Restinga	20-40	20	60	910	90	820	30	67
Mangrove	0-5	120	210	700	300	400	90	43
Mangrove	5-20	150	190	670	440	230	140	21
Mangrove	20-40	280	330	500	180	320	170	15

pteridophytes. Moreover, 13 of the total number of registered species were not identified to the specific level.

Families with the highest species richness were: Fabaceae (38), Euphorbiaceae (15), Asteraceae (14), Sapindaceae (14), Malvaceae (13), Cyperaceae (11), Malpighiaceae (11), Myrtaceae (9), Bromeliaceae (8), Rubiaceae (8) and Apocynaceae (8), which together represent 48% of the floristic diversity of the area (Fig. 15), while 34 families contribute with only one species. The most representative genera are: *Cyperus* (5), *Piptadenia* (5), *Eugenia* (4), *Heteropterys* (4), *Mimosa* (4), *Stigmaphyllon* (4) and *Solanum* (4).

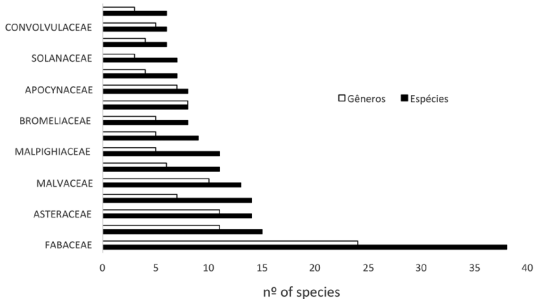


Figure 15 – The 16 families with the greatest species richness in the Brisas Environmental Protection Area, Rio de Janeiro, Brazil.

The herbaceous habit was predominant (29.26%) (Fig. 16), followed by creeping/climbing (27.75%) (Fig. 17), arboreal (27.33%) (Fig. 18), shrubby (14.46%) (Fig. 19) and epiphyte (4%) (Tab. 2; Fig. 20). Compared to the life forms of the *restingas* of Rio de Janeiro (Araujo 2000), the Brisas EPA has a higher percentage of herbs, vines and trees, with a smaller representation of shrubs and epiphytes.

Regarding the endemism of the species occurring in the study area, 97 species (31.18%) were endemic to Brazil, 51 (16.39%) endemic to the Atlantic Forest, 14 (4.50%) endemic to Southeast Brazil, and five (1.92%) endemic to the state of Rio de Janeiro (Fig. 21).

Anthurium harrisii (Graham) G.Don, *Doliocarpus sessiliflorus* Mart., *Piptadenia trisperma* (Vell.) Benth. and *Vriesea neoglutinosa* Mez. can be highlighted among the inventoried species as endemic to *restingas* in the state of Rio de Janeiro; *Stigmaphyllon vitifolium* A.Juss, which is critically endangered, is endemic to the Dense Ombrophilous and *Restinga* forests of the states of Espírito Santo and Rio de Janeiro; and *Ditaxis simoniana* Casar., which is endemic to the coastal areas of the Rain Forest in the state of Rio de Janeiro (Martinelli & Moraes 2013; Flora e Funga do Brasil 2023, continuously updated). According to the Flora e Funga do Brasil 2023 (continuously updated), the Brisas EPA still harbors 12 species that only occur in *restingas*, being them: *Anthurium harrisii* (Graham) G.Don, *Aspidosperma pyricollum* Müll.Arg., *Blutaparon portulacoides* (A.St.-Hil.) Mears, *Canavalia rosea* (Sw.) DC., *Doliocarpus sessiliflorus* Mart., *Guapira pernambucensis* (Casar.) Lundell, *Passiflora mucronata* Lam., *Piptadenia trisperma* (Vell.) Benth., *Stigmaphyllon vitifolium* A.Juss., *Tarenaya rosea* (Vahl *ex* DC.) Soares Neto & Roalson, *Temnadenia odorifera* (Vell.) J.F. Morales, *Vriesea neoglutinosa* Mez.

Among the 311 inventoried species, 281 (90.35%) are native, while 21 are exotic (6.75%), including: *Antigonon leptopus* Hook. & Arn., *Arundo donax* L., *Crotalaria pallida* Aiton, *Cyperus rotundus* L., *Euphorbia cyathophora* Murray, *Heliconia bihai* (L.) L., *Kalanchoe pinnata* (Lam.) Pers., *Lantana camara* L., *Mimosa caesalpiniifolia* Benth. *Murraya paniculata* (L.) Jack, *Ocimum gratissimum* L., *Oeceoclades maculata* (Lindl.) Lindl., *Ricinus communis* L., *Rivina humilis* L., *Salicornia fruticosa* L., *Sesuvium portulacastrum* (L.) L., *Solanum diphyllum* L.; *Syzygium cumini* (L.) Skeels, *Triplaris americana* L., *Terminalia catappa* L. and *Thunbergia alata* Bojer *ex* Sims.

For the occurrence of species by phytophysiognomy, the "*lato sensu*" *restinga* has 252 species, of which 207 are exclusive to this phytophysiognomy. In addition, 88 species are registered for the LDOF, of which 46 are exclusive to this phytophysiognomy, while seven species are registered for the Mangrove, three of which are exclusive (Tab. 3; Fig. 22).

Regarding the threat category, *Banisteriopsis sellowiana* (A.Juss.) B.Gates stands out as VU (Vulnerable), *Scutia arenicola* (Marry.) Reissek as EN (Endangered) and *Stigmaphyllon vitifolium* A.Juss. as CR (Critically Endangered). Of the total, 266 species have not yet been evaluated, 29 are classified as LC (Least Concern) and *Chondrodendron platiphyllum* (A.St.-Hil.) Miers and *Ipomoea cynanchifolia* Meisn. are classified as DD (data deficient). The occurrence of three species with threat categories in a small urban fragment shows the need for efforts to conserve remnants of the coast of Rio de Janeiro.

IV. Floristic similarity

The floristic similarity analysis between the studied area and eight other areas in the state of Rio de Janeiro (Fig. 23; Tab. 4) showed a greater relationship between locations which share the same phytophysiognomy and the geographic proximity between them. The Brisas EPA was grouped with *restinga* areas. However, even though they are grouped together and geographically close (*i.e.*, Brisas EPA and Marambaia *Restinga*), the analyzed formations showed low floristic similarity

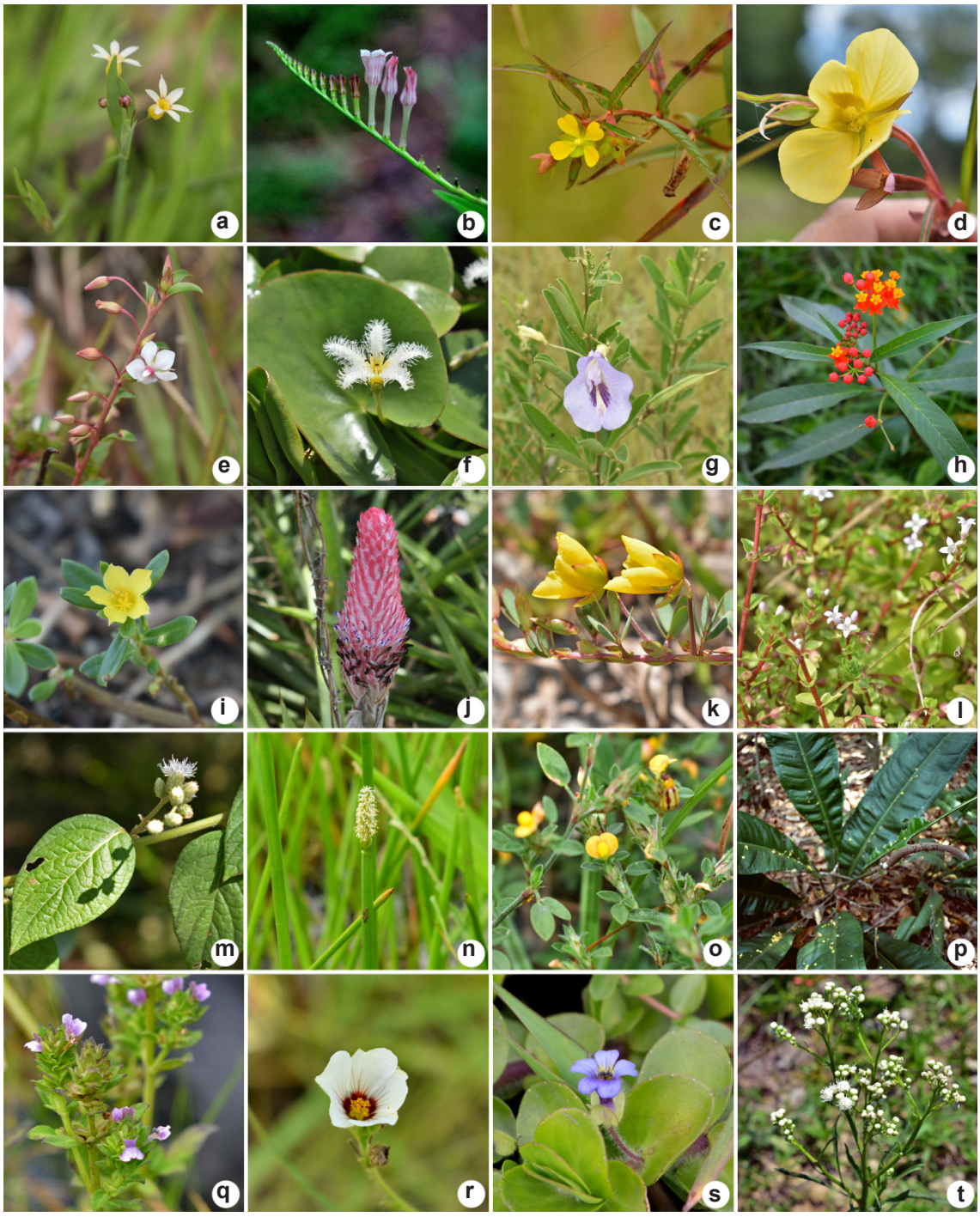


Figure 16 – a-t. Herbaceous species occurring in the Brisas EPA, Rio de Janeiro, Brazil – a. *Sisyrinchium micranthum*; b. *Spigelia beyrichiana*; c. *Ludwigia leptocarpa*; d. *Ludwigia longifolia*; e. *Sauvagesia erecta*; f. *Nymphoides humboldtiana*; g. *Clitoria laurifolia*; h. *Asclepias curassavica*; i. *Portulaca mucronata*; j. *Quesnelia quesneliana*; k. *Chamaecrista desvauxii*; l. *Oldenlandia salzmannii*; m. *Lepidaploa sororia*; n. *Eleocharis interstincta*; o. *Stylosanthes viscosa*; p. *Anthurium harrisii*; q. *Matourea ocymoides*; r. *Sida linifolia*; s. *Bacopa lanigera*; t. *Baccharis glutinosa*. Photos: a, s. Diego Monsores; b, c. Yuri Borba; other photos: G. S. Guimarães.

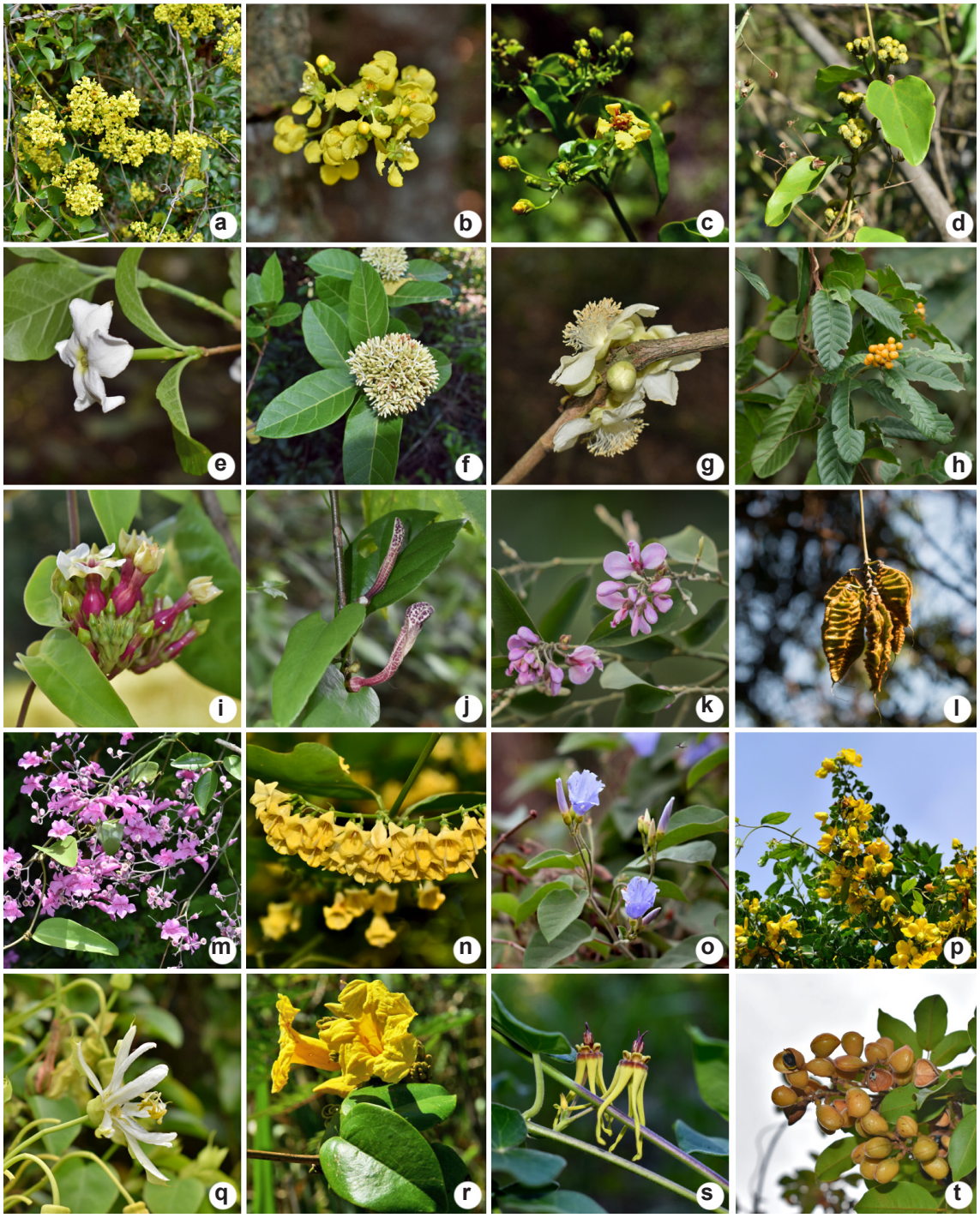


Figure 17 – a. *Banisteriopsis sellowiana*; b. *Heteropterys fluminensis*; c. *Stigmaphyllon arenicola*; d. *Randia armata*; e. *Forsteronia cordata*; f. *Doliocarpus sessiliflorus*; g. *Davilla rugosa*; h. *Temnadenia odorifera*; i. *Aristolochia rumicifolia*; j. Securidaca diversifolia; k. *Mucuna sloanei*; l. *Fridericia conjugata*; m. *Chiococca alba*; n. *Jacquemontia holosericea*; o. *Senna angulata* var. *miscadena*; p. *Passiflora mucronata*; q. *Adenocalymma marginatum*; r. *Oxypetalum banksii*; s. *Connarus nodosus*. Photos: h, k, l, o, r. Diego Monsores; other photos: G. S. Guimarães.

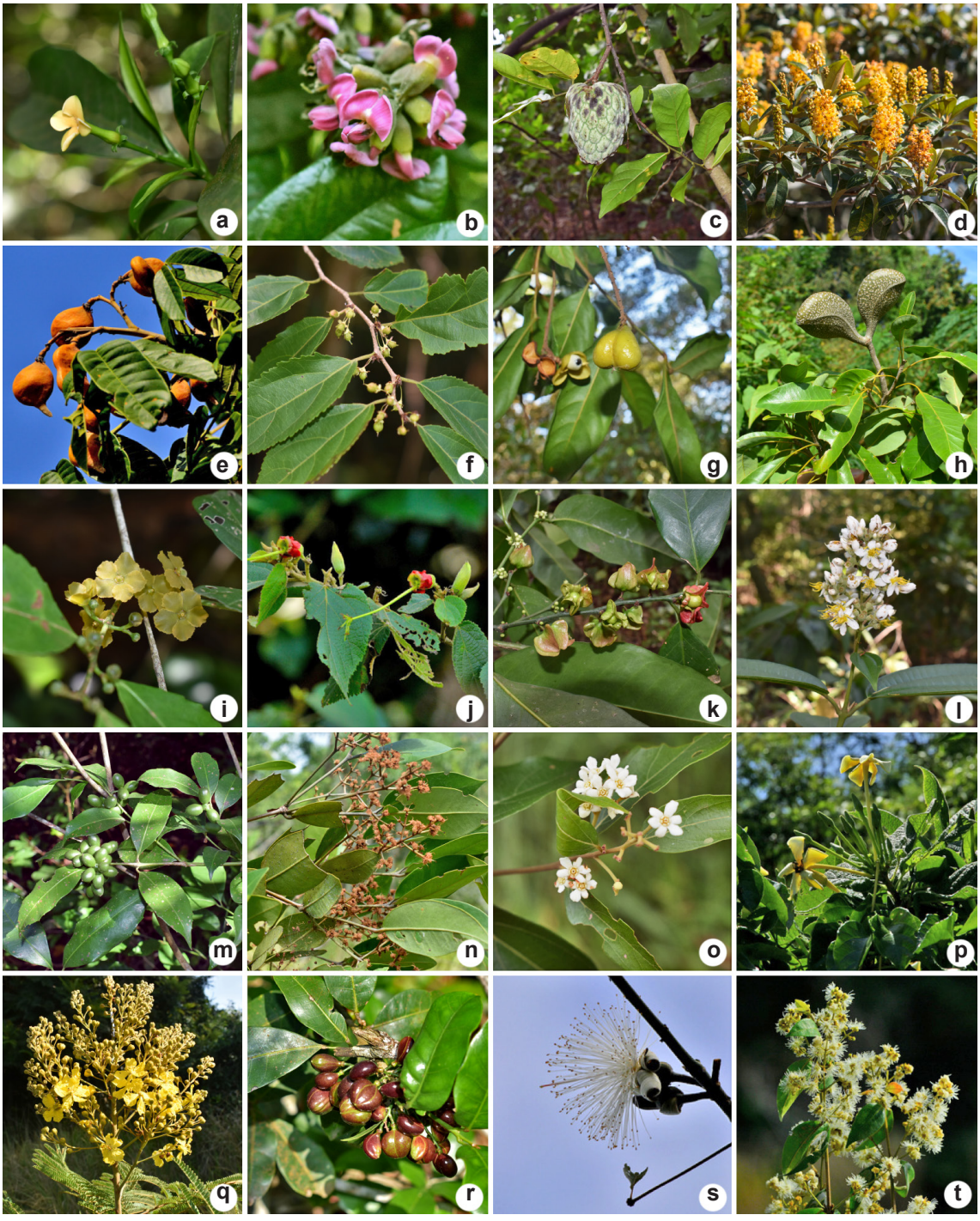


Figure 18 – a-t. Tree species occurring in the Brisas EPA, Rio de Janeiro, Brazil – a. *Tabernaemontana hystrix*; b. *Andira legalis*; c. *Annona acutiflora*; d. *Byrsonima sericea*; e. *Ormosia arborea*; f. *Casearia obliqua*; g. *Cupania emarginata*; h. *Aspidosperma pyricollum*; i. *Salacia arborea*; j. *Helicteres macropetala*; k. *Heisteria perianthomega*; l. *Miconia staminea*; m. *Mollinedia glabra*; n. *Myrcia loranthifolia*; o. *Nectandra* sp; p. *Tocoyena formosa*; q. *Peltophorum dubium*; r. *Protium brasiliense*; s. *Pseudobombax grandiflorum*; t. *Myrcia splendens*. Photos: d. Diego Monsores; e, j, p, s, t. Yuri Borba; other photos: G. S. Guimarães.

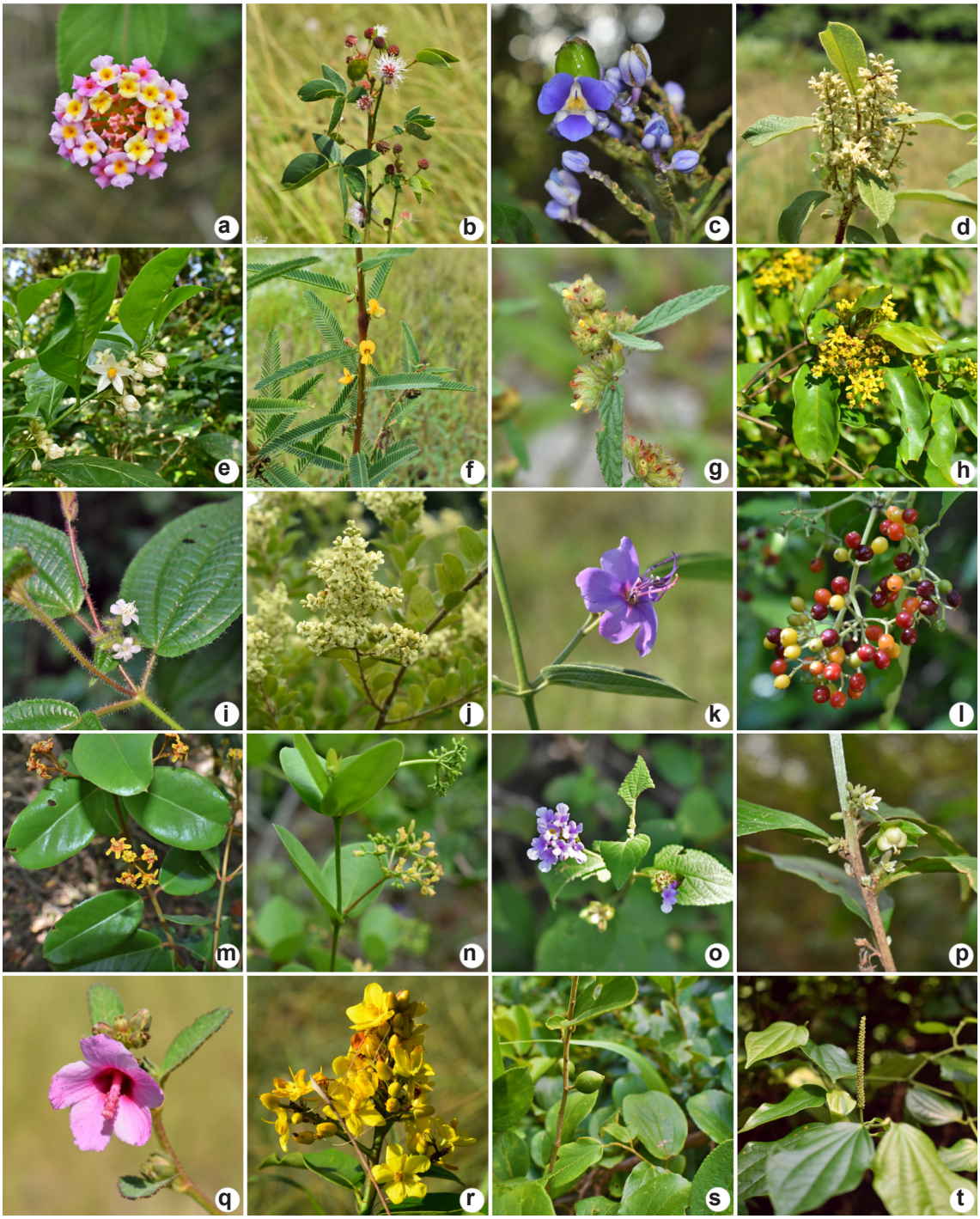


Figure 19 – a-t. Shrub species occurring in the Brisas EPA, Rio de Janeiro, Brazil – a. *Lantana camara*; b. *Mimosa velloziana*; c. *Dichorisandra thyrsiflora*; d. *Trigonia villosa*; e. *Solanum pseudoquina*; f. *Chamaecrista nictitans*; g. *Waltheria indica*; h. *Bronwenia ferruginea*; i. *Clidemia hirta*; j. *Bredemeyera hebeclada*; k. *Pleroma* sp; l. *Psychotria carthagenensis*; m. *Heteropterys chrysophylla*; n. *Guapira pernambucensis*; o. *Lantana fucata*; p. *Ditaxis simoniana*; q. *Urena lobata*; r. *Ouratea cuspidata*; s. *Celtis brasiliensis*; t. *Piper amalago*. Photos: G. S. Guimarães.

Table 2 – Total species, genera and families by life forms in the Brisas Environmental Protection Area, Rio de Janeiro, Brazil.

Life forms	Species	Genres	Families
Herbaceous	91	72	45
Climbing plants	86	62	36
Trees	85	66	35
Shrubs	45	36	21
Epiphytes	13	9	3

Figure 20 – Richness of species, genera and families by life forms in the Brisas Environmental Protection Area, Rio de Janeiro, Brazil.

to each other, allowing to infer the existence of high floristic heterogeneity in the phytophysiognomies of the analyzed *restingas*.

The Dense Ombrophylous forest areas compared (CAMB, SCG and PDA) were grouped separately and also showed low similarity, probably due to the different phytophysiognomies (Lowlands and Submontane), in addition to the different sampling efforts. For the analysis, the cophenetic correlation was 0.9252.

Discussion

According to the IPP (2018), the Brisas EPA is categorized as the ninth area among the ten main areas of Atlantic Forest in the city; however, there were no published floristic surveys. The Brisas EPA comprises one of the last arboreal *restinga* and lowland dense rainforest areas for the city of Rio de Janeiro. Including the mangrove, the area also represents the only Conservation Unit for the municipality of Rio de Janeiro with the three representations of coastal forest phytophysiognomies (Guimarães 2023).

Fraga *et al*. (2012) investigated some soil elements of the Marambaia *Restinga* dunes, also confirming higher aluminum levels, acidic pH and poor nutrients (oligotrophy). A similar result was obtained in the works of Henriques *et al.* (1986), Guedes *et al.* (2006), Montezuma & Araujo (2007), Sacramento *et al.* (2007), Silva *et al.* (2008) and Almeida *et al.* (2009), which were also all carried out in *Restinga* phytophysiognomies. Bonilha *et al.* (2012) describes that the *Restinga* forest is maintained by nutrient cycling, with phytomass being its main reserve. This demonstrates that ecosystem vulnerability is directly related to vegetation removal, which interrupts the addition of nutrients and organic matter to the soil. Martins (2010) also evaluated the soil elements of the *Restinga* and Lowland phytophysiognomies, showing that both areas had acidic and nutrient-poor soils (like the present study). These relationships were also seen by Cestaro & Soares (2004), who indicated soil fertility, aluminum content and water regime as the main elements that possibly determine the small floristic and structural differences of the vegetation.

The five angiosperm families with the greatest species richness for the flora of Rio de Janeiro are: Orchidaceae, Fabaceae, Asteraceae, Bromeliaceae and Melastomataceae (BFG 2015; Coelho *et al.* 2017). These families are also among the ten most diverse in the flora of Brazil and the Atlantic Forest Biome (BFG 2015). Fabaceae, Rubiaceae, Euphorbiaceae and Bignoniaceae are also among the ten richest families in the Neotropics (Gentry 1982). In addition, Fabaceae and Myrtaceae stand out in terms of species richness for dense rainforests, semi-deciduous seasonal forests and lowland tropical forests (Gentry 1982, 1988, 1995). However, of the ten families with the greatest species richness in the present work (Fabaceae, Euphorbiaceae, Asteraceae, Sapindaceae, Malvaceae, Cyperaceae, Malpighiaceae, Myrtaceae, Bromeliaceae and Rubiaceae, in descending order), with the exception

Figure 21 – a-e. Endemic species of the state of Rio de Janeiro occurring in the Brisas Environmental Protection Area, Rio de Janeiro, Brazil – a. *Vriesea neoglutinosa*; b. *Piptadenia trisperma*; c. *Anthurium harrisii*; d. *Ditaxis simoniana*; e. *Doliocarpus sessiliflorus.* (Photos: G. S. Guimarães).

Table 3 – Species richness by phytophysiognomy and habit in the Brisas Environmental Protection Area, Rio de Janeiro. R = Restinga; LDOF = Lowland Dense Ombrophylous Forest; M = Mangrove.

Features		**Phytophysiognomy**		
		R	**LDOF**	**M**
Richness	Species	201	68	7
	Exclusive by phytophysiognomy	165	35	3
Habit	Herbaceous	64	8	1
	Shrubs	25	7	0
	Trees	53	26	3
	Climbing plants	57	27	1
	Epiphytes	13	2	2

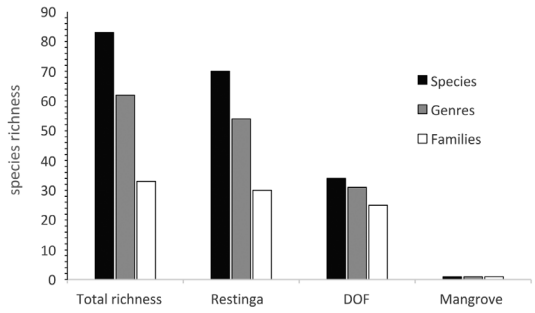


Figure 22 – Species richness by phytophysiognomy in the Brisas EPA, Rio de Janeiro (DOF = Dense Ombrophylous Forest).

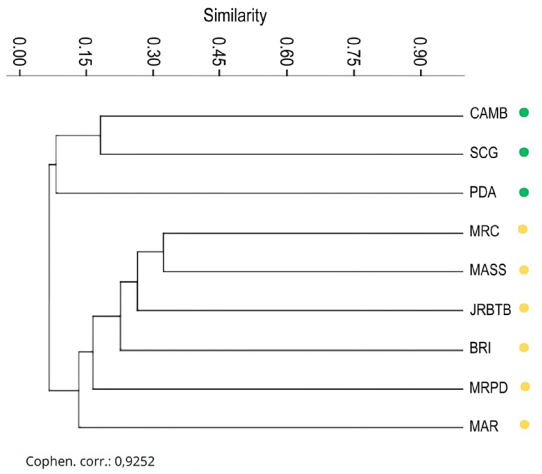


Figure 23 – Dendrogram of similarity between the Brisas Environmental Protection Area and eight other areas in the state of Rio de Janeiro. CAMB = Camboatá forest; SCG = Municipal Natural Park of Serra da Capoeira Grande; PDA = Poço das Antas Biological Reserve; MRC = Maricá Restinga; MASS = Massambaba Restinga; JRBTB = Jurubatiba National Park Restinga; BRI = Brisas Environmental Protection Area; MRPD = Marapendi Municipal Natural Park and Environmental Protection Area; MAR = Marambaia Restinga. Red dot = Study area; Yellow dot = Restinga area; Green dot = Dense Ombrophylous Forest Area.

of Malvaceae, the study by Araujo (2000) demonstrates that the others are among the richest in species in the *Restinga* forests of Rio de Janeiro. Contrary to expectations, Myrtaceae ranked eighth, with only nine species registered. Fabaceae being the family with the highest number of species, as already observed in other works covering *Restinga* areas (Silva & Oliveira 1989; Magnago *et al*. 2011). Regarding pteridophytes, Polypodiaceae is the second richest family in terms of species for the flora of Rio de Janeiro (Prado *et al*. 2015), constituting the family with the highest species richness (4 spp.) in the Brisas EPA. A survey of pteridophytes, when compared with other studies on the same phytophysiognomy (*i.e.*, Santos *et al*. 2004), denotes low species richness and/or little sampling effort for the group.

Herbs stood out in richness for the types of habit, followed by vines and trees, shrubs and epiphytes, which is contrary to what has been observed in Rio de Janeiro sandbanks about the non-predominance of life forms (Araujo 2000). Epiphytism proved to be rare in the vegetation sampled, as was also observed by Pereira *et al*. (1998) and Pereira & Assis (2000) for forests close to the sea in the state of Espírito Santo when compared to vegetation located further inland. According to Fontoura *et al*. (1997), the low richness of epiphyte species would be expected for areas that have suffered anthropic interference in secondary forests. Perhaps, this could also be a justification for the low representativeness of epiphytes in the Brisas EPA, but more detailed studies on this characteristic should be carried out for a more accurate statement.

Among the 311 species inventoried, 21 (6.45%) are considered exotic. Despite the low number for an area inserted in an urban context, Alvey (2006) highlights the risk that Conservation Units face with the homogenization of biodiversity as a result of urban expansion, which can lead to the replacement of native species by invasive exotic species. Almost all species occur in the *Restinga*, with the exception of *Salicornia fruticosa* L. which occurs only in the Mangrove. *Terminalia catappa* L. exhibits an aggressive invasive behavior, especially in mangrove vegetation, suppressing native vegetation. *Syzygium cumini* (L.) Skeels and *Triplaris americana* L. also show invasive behavior in *restinga*. Therefore, it is recommended, on an emergency basis, the removal of these species to safeguard the native vegetation.

The floristic survey carried out in the Brisas EPA identified five endemic species in the state, four of which are endemic to the *Restinga* forests of Rio de Janeiro. In addition to 97 endemic species from Brazil and 51 endemic species from the Atlantic Forest. Mori *et al*. (1981) highlighted the state of Rio de Janeiro as an important center of endemism in Brazil, while Werneck *et al*. (2011) demonstrated

Table 4 – Comparative data between the study area and eight other Atlantic Forest areas in the state of Rio de Janeiro. CAMB = Camboatá Forest; SCG = Municipal Natural Park of Serra da Capoeira Grande; PDA = Poço das Antas Biological Reserve; MRC = Restinga Maricá; MASS = Massambaba Restinga; JRBTB = Jurubatiba National Park Restinga; MRPD = Marapendi Municipal Natural Park; MAR = Marambaia Restinga; BRI = Brisas Environmental Protection Area.

Location (code)	Phytophysiognomy	Area (ha)	Reference
Camboatá Forest (CAMB)	Lowland Dense Ombrophylous Forest	200	Gribel *et al.* 2013; Terra Nova 2019
Municipal Natural Park of Serra da Capoeira Grande (SCG)	Submontane Dense Ombrophylous Forest	80	Peixoto 2002
Poço das Antas Biological Reserve (PDA)	Lowland Dense Ombrophylous Forest	5.000	Lima *et al.* 2006; Specieslink 2023
Restinga Maricá (MRC)	Restinga	10	Silva & Oliveira, 1989; Specieslink 2023
Massambaba Restinga (MASS)	Restinga	496	Araujo *et al.* 2009. Specieslink 2023
Jurubatiba National Park Restinga (JRBTB)	Restinga	14.922	Montezuma & Araujo 2007; Santos *et al.* 2004
Marapendi Municipal Natural Park (MRPD)	Mangrove and Restinga	153	Specieslink, 2023; JABOT (Silva *et al.* 2017)
Marambaia Restinga (MAR)	Mangrove and Restinga	4.960	Specieslink 2023; JABOT (Silva *et al*. 2017)
Brisas Environmental Protection Area (BRI)	Mangrove, Restinga and Lowland Dense Ombrophylous Forest	101	Present study

that the highest number of endemic species in this state in a single sampling unit occurs in the region of the city of Rio de Janeiro. The presence of these species in the study area denotes the importance of the permanence of urban remnants, even if small, for the conservation of species with a high level of endemism. Therefore, the absence of the Brisas EPA would possibly compromise the occurrence of these species in the region.

Despite forming a cluster between *Restinga* areas, these areas (Fig. 23; Tab. 4) showed low floristic similarity. This result corroborates Cerqueira's (2000) and Scarano (2002) statement that each *Restinga* has its floristic peculiarities due to the unique character of its composition, especially related to the geomorphological aspects of the areas.

Despite all the sampling effort and accumulated knowledge about the flora of Rio de Janeiro, the challenge in advancing qualitative and quantitative knowledge is still very great, as there is still an unequal struggle between the vulnerability of the vegetation and the advancement of knowledge about it (Coelho *et al*. 2017). These authors also highlight the need to explore areas which are little or not yet visited in order to expand taxonomic studies on various taxa and to know the floristic richness of different remnants.

The Brisas EPA presents particular floristic characteristics with high richness, represented by 303 species of angiosperms and eight of pteridophytes, distributed in the three main coastal phytophysiognomies of the area: *Restinga* (the predominant one), Lowland Dense Ombrophylous Forest and Mangrove. Herbaceous and climbing species are predominant, followed by tree species, shrubs, and to a lesser degree, epiphytes. The soil type, the presence of typical species and the grouping with areas of the same phytophysiognomy, such as the Marambaia *Restinga* and the Marapendi Municipal Natural Park confirm the predominance and existence of the *Restinga* phytophysiognomy in the Brisas EPA. Part of the regional floristic diversity was probably lost after consecutive years of deforestation, irregular occupations and other forms of altering the original vegetation

conditions, so that the Brisas EPA resists in an urban environment as an important remnant of the continental native vegetation of the coast of Sepetiba Bay. In this context, the loss of swamps (for example), being particular ecosystems in this *Restinga* stretch of the coast of Rio de Janeiro, would cause irreparable damage to biodiversity and to the water table in the study area. Finally, the presence of unique ecosystems, in addition to endemic and endangered species, reinforces the need to undertake strategies and action plans for the conservation of the biodiversity in the remnants of this Conservation Unit.

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Data availability statement

In accordance with Open Science communication practices, the authors inform that all data used in this manuscript is publicly available.

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