



Checklist of sand dune vegetation on the tropical southeastern Brazil coast

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Abstract: Restingas are mosaics of plant communities living on marine sand deposits of the late Quaternary period, located between the sea and the Atlantic Forest. This study presents the diversity of the vegetation of coastal sand dunes in the southeastern coast of Brazil. A floristic survey and bibliographic review of the nine restinga regions of Rio de Janeiro state was carried out, and information is presented about the habit, life form, dispersion syndrome, distribution, and biome occurrence of each species. Ninety-eight species were recorded, distributed among 81 genera and 38 families, of which the most diverse are Asteraceae (12 species), Poaceae (12 species), Fabaceae (11 species), and Rubiaceae (6 species). The majority of species have herbaceous habits and predominantly are camephyte-autochoric species. They present wide geographical distributions or are restricted to just some Brazilian states and are more similar to the Atlantic Forest biome.

Key words: Atlantic Forest; Restinga; Rio de Janeiro; coastal vegetation; species' inventory

INTRODUCTION

Restingas, located between the sea and the Atlantic Forest, are defined as a mosaic of plant communities living on marine sand deposits of the late Quaternary period (SCARANO 2002). They present different physiognomies, diversified geomorphological and climatic characteristics, and a great floristic diversity (ARAUJO 2000). They also are one of the ecosystems associated with the Brazilian Atlantic Forest. The plant species characteristic of restingas are expected to have originated from the adjacent ecosystems of Caatinga, Cerrado, Amazon Rainforest, and the Atlantic Forest because of the recent geomorphological formations of Brazilian coastal plains (FREIRE 1990; RIZZINI 1997; ARAUJO et al. 1998; CERQUEIRA 2000; SCARANO 2002; ROCHA et al. 2004; ARAUJO & PEREIRA 2009).

Sand dune vegetation is one of the vegetation formations of restingas. These are located along the backshore. They are composed by the halophyte formation established

on higher parts of the beach and by the psammophyte formation established on the foredune, dune, or areas of mobile sand (PEREIRA 1990; MENEZES & ARAUJO 1999). This vegetation occurs in the majority of Brazilian restingas but with differing floristic composition (PEREIRA et al. 1992). Sand dune vegetation also occurs along the coastline of Rio de Janeiro state, where the restingas are drastically fragmented by accelerated urban growth and use for agriculture. The restingas are currently reduced to areas of variable size, usually small fragments, forming a total of 60,516.20 ha (ROCHA et al. 2007). The environment of dunes is characterized by the presence of saline spray, sand substrate, elevated temperature, and solar radiation, and by strong and constant wind (HESP 1991; COSTA et al. 1996; BEDUSCHI & CASTELLANI 2008).

Previous studies on sand dune vegetation show low species richness, predominance of herbaceous species, and variability of floristic diversity along the coast. However, despite this coastal flora being one of the best studied throughout the coast of Brazil, there are still significant gaps (ARAUJO 2000). Therefore, the objective of this study is to provide an updated list of plant species of coastal sand dunes of Rio de Janeiro state. Additionally, information is given about habit, life form, dispersion syndrome, distribution and the occurrence in Brazilian biomes of each of the species listed.

MATERIAL AND METHODS

Study site

The coastline of Rio de Janeiro state extends 636 km from the broad coastal plains of Paraíba do Sul River in the north, to the narrow plains that are bordered by the steep cliffs of the Serra do Mar in the south. The climate, according to the Köppen classification, is tropical (Aw), which is characterized by a rainy season in the summer, with a high pluviometric index, and a dry season in the winter.

Based on natural barriers, such as orographic features and water courses, ARAUJO & MACIEL (1998) divided the

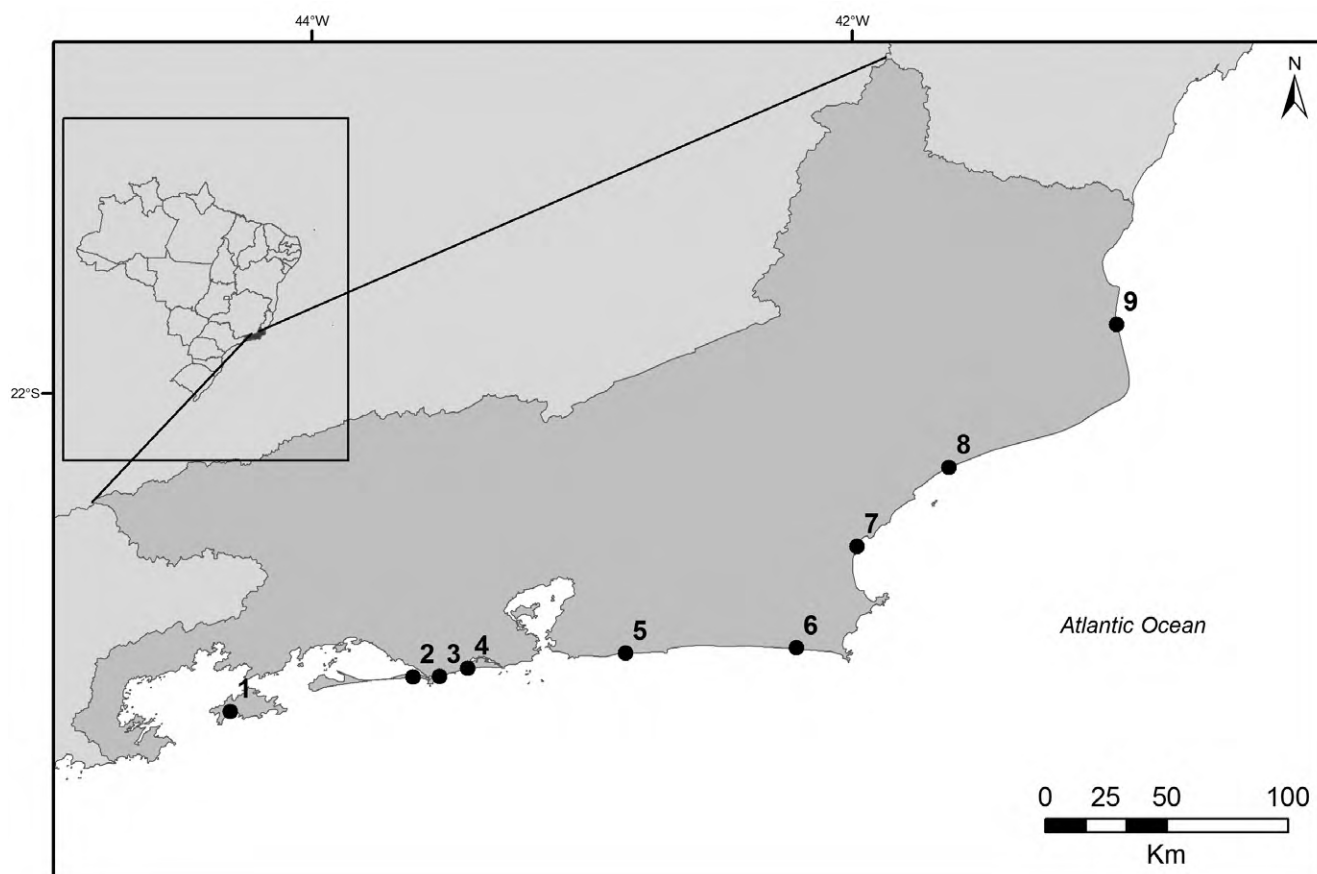


Figure 1. Map with locations of the nine regions of Restinga of Rio de Janeiro state. Restinga da Praia do Sul (1), Restinga da Marambaia (2), Restinga de Grumari (3), Restinga de Jacarepaguá (4), Restinga de Maricá (5), Restinga de Massambaba (6), Restinga de Barra de São João (7), Restinga de Jurubatiba (8), Restinga do Açú (9).

coastline into nine restinga regions. The remnants surveyed (Figure 1) were Restinga da Praia do Sul, inserted in the Praia do Sul State Biological Reserve, Angra dos Reis municipality (23°10' S, 044°17' W); Restinga da Marambaia, located at Sepetiba Bay, Rio de Janeiro, Itaguaí, and Mangaratiba municipalities (23°02' S, 043°37' W); Restinga de Grumari, within two overlapped conservation units, the Grumari Natural Municipal Park and the Grumari Environmental Protection Area, Rio de Janeiro municipality (23°02' S, 043°31' W); Restinga de Jacarepaguá, a small restinga in Marapendi Natural Municipal Park and Marapendi Environmental Protection Area, Rio de Janeiro municipality (23°01' S, 043°25' W); Restinga de Maricá, partially within the Maricá Environmental Protection Area, Maricá municipality (22°57' S, 042°50' W); Restinga de Massambaba, located in Costa do Sol State Park, Saquarema, Araruama, Arraial do Cabo, Cabo Frio, Armação dos Búzios, and São Pedro da Aldeia municipalities (22°56' S, 042°12' W); Restinga de Barra de São João, Casimiro de Abreu, and Rio das Ostras municipalities (22°34' S, 041°58' W); Restinga de Jurubatiba, partially within the Restinga de Jurubatiba National Park, Macaé, Quissamã, and Carapebus municipalities (22°16' S, 041°38' W); and Restinga do Açú, partially in the Caruara Private Natural Heritage Reserve, São João da Barra municipality (21°44' S, 041°01' W) and the Lagoa do Açú State Park, Campos dos Goytacazes, and São João da Barra municipalities (21°58' S, 040°58' W).

Data collection

Botanical sampling was carried out in 2012. For each restinga, one 1 km long stretch (parallel to the sea) of dune vegetation was selected with the aid of satellite imagery. The exception was Restinga de Grumari for which the central portion of the area was selected, thus avoiding the extremities because the extent of this restinga is only about 2 km. The field data were compared to literature and herbarium records. Voucher samples are deposited in the herbarium of the Rio de Janeiro Botanical Garden (RB). The datum used for geographic coordinates was the South American Datum (SAD69).

This list presents the botanical families and species in alphabetical order. The classification system used is based on APG IV (2016). Current species names were confirmed by consulting THE BRAZIL FLORA GROUP (2015), and THE PLANT LIST (2013). Species were classified using literature, field observations, and/or collected samples: in relation to the habit in herb, shrub, subshrub, vine, and parasite; in relation to life form according to the system of RAUNKIER (1934), based on the protection level of the vegetative buds in six classes: phanerophytes, camephytes, hemicyptophytes, geophytes, therophytes, and liana; in relation to the dispersion syndrome through morphological criteria of the fruit (VAN DER PIJL 1982), classified in three groups: anemochoric (dispersion by wind), autochoric (dispersion through gravity or explosive), and zoochoric (dispersion by

animals); and in relation to geographical distribution and occurrence in Brazilian biomes, according to THE BRAZIL FLORA GROUP (2015).

RESULTS

Floristic diversity

Ninety-eight species were inventoried, distributed in 81 genera and 38 families (Table 1). The most representative families were Asteraceae (12 species), Poaceae (12 species), Fabaceae (11 species), and Rubiaceae (6 species), corresponding to 41.83% of all the species. Twenty-two families (57.89% of all families) were represented by only one species. The most diverse genera were *Ipomoea* (3 species), *Mikania* (3 species), and *Portulaca* (3 species). Other genera counted two registered species: *Alternanthera*, *Borreria*, *Centrosema*, *Commelina*, *Diodella*, *Emilia*, *Euphorbia*, *Mitracarpus*, *Opuntia*, *Paspalum*, and *Sida* (Table 1). Comparing the present study with previous restinga studies, a higher species richness was obtained in almost all the inventoried restingas, and the same richness for Restinga da Marambaia (Table 2).

Habit, life form and dispersion syndrome

Of the recorded species 70 (71.42%) were herbs, 10 (10.20%) shrubs, 10 (10.20%) vines, seven (7.14%) subshrubs, and one (1.02%) parasite. The majority of the species were herbaceous plants (Figure 2A).

In life form, 37 (37.75%) species are camephyte, 18 (18.36%) geophyte, 17 (17.34%) phanerophyte, 13 (13.26%) therophyte, 11 (11.22%) hemicryptophyte, and two (2.04%) lianas. Therefore, the dune vegetation presents a mostly camephytic phytoclimate (Figure 2B).

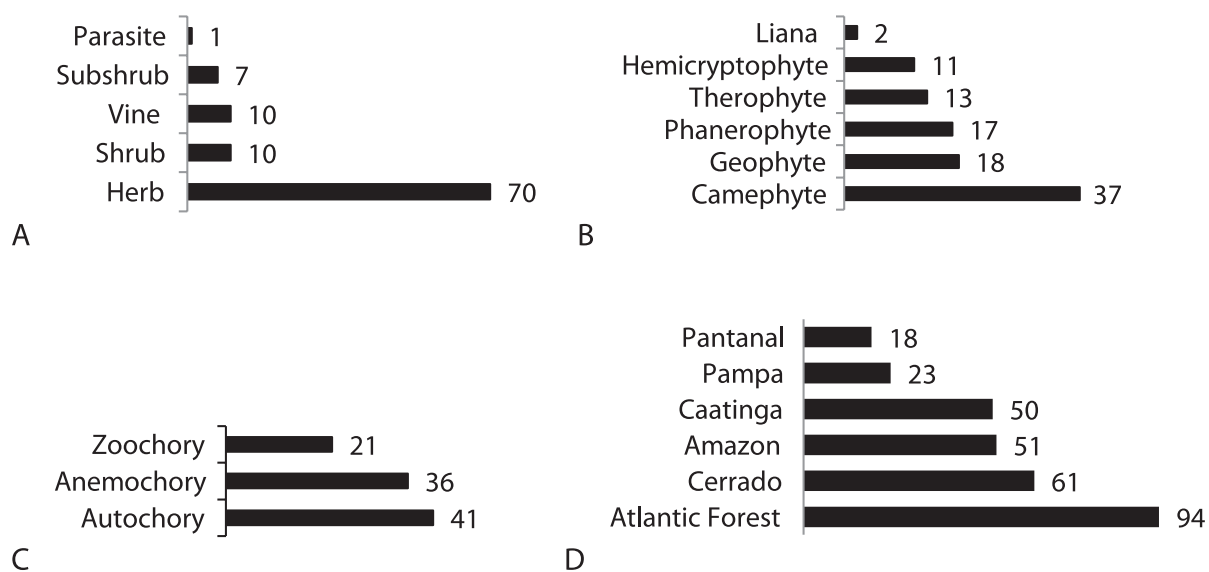
The dispersion spectrum was represented by 41 (41.83%) autochoric species, 36 (36.73%) anemochoric, and 21

(21.42%) zoochoric. The majority of the species disperses seeds through the action of gravity or by an explosive opening of the capsules (autochory), while more than a third of the species disperse by wind (anemochory) and the remainder through the action of animals (zoochory) (Figure 2C).

Geographical distribution and biome occurrence

Some species occur in all of the Brazilian states: *Chamaecrista flexuosa*, *Commelina benghalensis*, *Croton glandulosus*, *Emilia fosbergii*, *Euphorbia hyssopifolia*, *Microstachys corniculata*, and *Waltheria indica*. Other species present a more restricted geographical distribution, occurring in three states: *Matelea maritima*, *Peplonia asteria*, *Pilosocereus arrabidaei*, *Stigmaphyllon arenicola*, two states: *Mikania stipulacea*, *Stachytarpheta restingensis*, and one state: *Lepidaploa obtusifolia* (Table 1). Most species are native to Brazil, but eight species are exotic, according to THE BRAZIL FLORA GROUP (2015): *Agave vivipara*, *Barleria repens*, *Cocos nucifera*, *Euphorbia tirucalli*, *Furcraea foetida*, *Sansevieria trifasciata*, *Terminalia catappa*, and *Yucca gigantea*.

The species listed occur in all Brazilian biomes; 94 (95.91%) species have been recorded in the Atlantic Forest, 61 (62.24%) in the Cerrado, 51 (52.04%) in the Amazon Rainforest, 50 (51.02%) in the Caatinga, 23 (23.46%) in the Pampa, and 18 (18.36%) in the Pantanal (Figure 2D). However, 19 (19.38%) species were recorded only in the Atlantic Forest: *Acicarpa bonariensis*, *Allagoptera arenaria*, *Alternanthera littoralis*, *Cenchrus tribuloides*, *Heteropterys chrysophylla*, *Hippeastrum reticulatum*, *Jacquinia armillaris*, *Justicia cydoniifolia*, *Lepidaploa obtusifolia*, *Mikania hoehnei*, *Mikania stipulacea*, *Mitracarpus eichleri*, *Neoregelia cruenta*, *Peplonia asteria*, *Pilosocereus arrabidaei*, *Remirea maritima*, *Scaevola plumieri*, *Stachytarpheta restingensis*, and *Stigmaphyllon arenicola* (Table 1).



Figures 2. Distribution of the number of species listed in the Restingas of Rio de Janeiro state, Brazil. **A:** In relation to the habit. **B:** In relation to the life form. **C:** In relation to the dispersion syndrome. **D:** In relation to the occurrence of Brazilian biomes.

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Table 1. Continued.

Families / Species	Habit	LF	DS	Occurrence State (Brazil)	Biome	Voucher
<i>Opuntia dillenii</i> (Ker Gawl.) Haw.	Subshrub	Pha	Zoo	AL, BA, CE, PB, PE, RN, SE, RJ	Caa, Atl	Castelo, 125 RB 568508
<i>Opuntia monacantha</i> Haw.	Subshrub	Pha	Zoo	BA, SE, ES, MG, RJ, SP, PR, RS, SC	Cer, Atl	Castelo, 54 RB 568437
<i>Pilosocereus arrabidaei</i> (Lem.) Byles & Rowley	Subshrub	Pha	Zoo	BA, ES, RJ	Atl	Castelo, 232 RB 568615
Calyceaceae						
<i>Acicarpha bonariensis</i> (Pers.) Herter	Herb	Cam	Zoo	BA, MA, ES, MG, RJ, SP, PR, RS, SC	Atl	Castelo, 253 RB 568636
Chrysobalanaceae						
<i>Chrysobalanus icaco</i> L.	Shrub	Pha	Zoo	AM, AP, PA, AL, BA, CE, MA, PI, RN, SE, ES, RJ, SP	Ama, Atl	Castelo, 250 RB 568633
Commelinaceae						
<i>Commelina benghalensis</i> L.	Herb	The	Aut	All Brazil	Ama, Caa, Cer, Atl	Castelo, 39 RB 568422
<i>Commelina erecta</i> L.	Herb	The	Aut	AM, PA, RO, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl, Pan	Castelo, 173 RB 568556
Convolvulaceae						
<i>Ipomoea cairica</i> (L.) Sweet	Herb	The	Ane	RO, AL, BA, CE, PB, PE, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC	Ama, Cer, Atl	Castelo, 142 RB 568525
<i>Ipomoea imperati</i> (Vahl) Griseb.	Herb	Geo	Aut	AP, PA, AL, BA, CE, MA, PB, PE, RN, SE, ES, RJ, SP, PR, RS, SC	Ama, Atl	Castelo, 236 RB 568619
<i>Ipomoea pes-caprae</i> (L.) R.Br.	Herb	Cam	Aut	PA, AL, BA, CE, MA, PB, PE, PI, RN, SE, ES, RJ, SP, PR, RS, SC	Ama, Atl	Castelo, 249 RB 568632
Cyperaceae						
<i>Fimbristylis cymosa</i> R.Br.	Herb	Hem	Ane	AP, PA, AL, BA, CE, MA, PB, PE, PI, RN, SE, ES, MG, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl	Castelo, 189 RB 568572
<i>Remirea maritima</i> Aubl.	Herb	Geo	Aut	AL, BA, CE, MA, PB, PE, PI, RN, SE, ES, RJ, SP, PR, RS	Atl	Castelo, 224 RB 568607
Euphorbiaceae						
<i>Croton glandulosus</i> L.	Herb	The	Zoo	All Brazil	Ama, Caa, Cer, Atl, Pam, Pan	Melo, 13 RB 580106
<i>Euphorbia hyssopifolia</i> L.	Herb	The	Aut	All Brazil	Ama, Caa, Cer, Atl, Pam	Castelo, 149 RB 568532
<i>Euphorbia thymifolia</i> L.	Herb	Cam	Aut	AM, AP, PA, AL, BA, CE, MA, PB, PE, RN, DF, GO, MS, MT, ES, RJ, SP, SC	Ama, Caa, Cer, Atl, Pam, Pan	Fernandes, 25 RB 583088
<i>Microstachys corniculata</i> (Vahl) Griseb.	Herb	Cam	Aut	All Brazil	Ama, Caa, Cer, Atl	Castelo, 52 RB 568435
Fabaceae						
<i>Abrus precatorius</i> L.	Vine	Cam	Zoo	AM, PA, RO, RR, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, MS, MT, ES, MG, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl, Pam, Pan	Oliveira, 118 RB 389858
<i>Alysicarpus vaginalis</i> (L.) DC.	Herb	Cam	Aut	TO, BA, PI, GO, MS, MT, ES, RJ, SP, PR	Cer, Atl, Pan	Castelo, 157-
<i>Canavalia rosea</i> (Sw.) DC.	Herb	Cam	Aut	PA, AL, BA, CE, MA, PB, PE, RN, SE, ES, RJ, SP, PR, RS, SC	Ama, Atl	Castelo, 131 RB 568514
<i>Centrosema brasilianum</i> (L.) Benth.	Herb	Cam	Aut	AM, AP, PA, RR, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl, Pan	Castelo, 220 RB 568603
<i>Centrosema virginianum</i> (L.) Benth.	Herb	Geo	Aut	AC, AM, AP, PA, RO, AL, BA, CE, PB, PE, PI, RN, SE, ES, MG, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl, Pam, Pan	Castelo, 217 RB 568600
<i>Chamaecrista flexuosa</i> (L.) Greene	Herb	Cam	Aut	All Brazil	Ama, Caa, Cer, Atl, Pan	Castelo, 114 RB 568497
<i>Clitoria laurifolia</i> Poir.	Herb	Cam	Aut	AM, PA, RR, AL, BA, CE, PB, PE, PI, RN, SE, ES, MG, RJ, SP, PR	Ama, Caa, Cer, Atl	Occhioni, 468RB 268090
<i>Dalbergia ecastaphyllum</i> (L.) Taub.	Shrub	Pha	Ane	AP, PA, AL, BA, CE, MA, PB, PE, RN, SE, ES, RJ, SP, PR, RS, SC	Ama, Atl	Oliveira, 308 RB 446411
<i>Sophora tomentosa</i> L.	Subshrub	Pha	Aut	AP, PA, AL, BA, CE, MA, PB, PE, RN, SE, ES, RJ, SP, PR, RS, SC	Ama, Atl	Castelo, 69 RB 568452
<i>Stylosanthes viscosa</i> (L.) Sw.	Herb	Cam	Ane	AM, AP, PA, RO, RR, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl	Castelo, 112 RB 568495
<i>Zornia latifolia</i> Sm.	Herb	Hem	Zoo	AC, AM, AP, PA, RO, TO, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS	Ama, Caa, Cer, Atl, Pam, Pan	Castelo, 119 RB 568502
Goodeniaceae						
<i>Scaevola plumieri</i> (L.) Vahl	Shrub	Cam	Zoo	AL, BA, CE, PB, PE, RN, SE, ES, RJ, SP, PR, SC	Atl	Castelo, 90 RB 568473
Lauraceae						
<i>Cassytha filiformis</i> L.	Parasite	Lia	Aut	AM, PA, RO, RR, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR	Ama, Caa, Cer, Atl	Castelo, 247 RB 568630
Malpighiaceae						
<i>Byrsonima sericea</i> DC.	Shrub	Pha	Zoo	PA, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, GO, MT, ES, MG, RJ, SP	Ama, Caa, Cer, Atl	Silva, 01 RB 480782

Continued

Table 1. Continued.

Families / Species	Habit	LF	DS	Occurrence State (Brazil)	Biome	Voucher
<i>Heteropteris chrysophylla</i> (Lam.) DC.	Vine	Geo	Ane	BA, ES, RJ, SP	Atl	Dias, 44 RB 414333
<i>Stigmaphyllon arenicola</i> C.E.Anderson	Herb	Cam	Ane	RJ, SP, PR	Atl	Castelo, 234 RB 568617
Malvaceae						
<i>Sida ciliaris</i> L.	Herb	Cam	Aut	-	-	Castelo, 159-
<i>Sida cordifolia</i> L.	Herb	Hem	Aut	AM, PA, RO, RR, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR	Ama, Caa, Cer, Atl	Castelo, 209 RB 568592
<i>Waltheria indica</i> L.	Herb	Pha	Aut	All Brazil	Ama, Caa, Cer, Atl, Pan	Castelo, 196 RB 568579
Molluginaceae						
<i>Mollugo verticillata</i> L.	Herb	The	Zoo	AM, PA, AL, BA, CE, MA, PB, PE, RN, SE, DF, MS, MT, MG, RJ, SP, RS, SC	Ama, Caa, Cer, Atl, Pam	Castelo, 109 RB 568492
Myrtaceae						
<i>Eugenia uniflora</i> L.	Shrub	Pha	Zoo	BA, MS, ES, MG, RJ, SP, PR, RS, SC	Cer, Atl, Pam	Castelo, 130 RB 568513
Orchidaceae						
<i>Cyrtopodium flavum</i> Link & Otto ex Rchb.f.	Herb	Geo	Ane	AL, BA, PB, PE, SE, ES, MG, RJ, SP, PR, RS, SC	Cer, Atl	Liene, 3668 RB 110016
<i>Epidendrum denticulatum</i> Barb.Rodr.	Herb	Hem	Ane	TO, BA, GO, ES, MG, RJ, SP, PR, RS, SC	Cer, Atl	Bovini, 705 RB 530077
<i>Vanilla chamissonis</i> Klotzsch	Herb	Geo	Ane	AM, BA, PE, DF, GO, MT, ES, MG, RJ, SP, PR, SC	Ama, Caa, Cer, Atl	Fontella, 1407 RB 324914
Passifloraceae						
<i>Passiflora mucronata</i> Lam.	Vine	Lia	Zoo	BA, PB, PE, RN, SE, ES, RJ, SP	Caa, Cer, Atl	Castelo, 19 RB 568402
Plantaginaceae						
<i>Bacopa monnieri</i> (L.) Pennell	Herb	Cam	Aut	BA, CE, PE, ES, RJ, SP, PR, RS, SC	Caa, Atl	Sucre, 1047 RB 133488
Poaceae						
<i>Cenchrus tribuloides</i> L.	Herb	The	Zoo	RJ, SP, RS, SC	Atl	Castelo, 206 RB 568589
<i>Chloris pycnothrix</i> Trin.	Herb	The	Ane	BA, CE, MA, PE, PI, RN, DF, GO, MS, ES, MG, RJ, SP, PR, RS, SC	Caa, Cer, Atl, Pam	Castelo, 201 RB 568584
<i>Cynodon dactylon</i> (L.) Pers.	Herb	Hem	Aut	AM, PA, RO, BA, PB, PE, RN, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl, Pam, Pan	Sampaio, 8933 RB 82917
<i>Dactyloctenium aegyptium</i> (L.) Willd.	Herb	Hem	Ane	AP, PA, RR, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, GO, MS, MT, ES, MG, RJ, SP, RS, SC	Ama, Caa, Cer, Atl, Pam, Pan	Castelo, 187 RB 568570
<i>Dichanthelium surrectum</i> (Chase ex Zuloaga & Morrone) Zuloaga	Herb	Hem	Ane	DF, MS, MG, RJ, SP, PR, RS, SC	Cer, Atl	Castelo, 200 RB 568583
<i>Panicum racemosum</i> (P. Beauv.) Spreng.	Herb	Geo	Ane	BA, CE, MA, PE, RN, ES, RJ, SP, RS, SC	Atl, Pam	Castelo, 121 RB 568504
<i>Paspalum maritimum</i> Trin.	Herb	Geo	Ane	AM, AP, PA, RR, TO, AL, BA, CE, MA, PB, PE, RN, GO, ES, MG, RJ, SP, RS, SC	Ama, Caa, Cer, Atl	Castelo, 50 RB 568433
<i>Paspalum vaginatum</i> Sw.	Herb	Geo	Ane	PA, AL, BA, CE, PB, PE, RN, SE, MS, ES, RJ, SP, PR, RS, SC	Ama, Caa, Atl, Pam, Pan	Lobão, 175 RB 332626
<i>Setaria setosa</i> (Sw.) P.Beauv.	Herb	Geo	Ane	AL, BA, CE, PB, PE, SE, ES, MG, RJ, PR, RS	Caa, Cer, Atl	Fonseca, 26 RB 303413
<i>Spartina ciliata</i> Brongn.	Herb	Hem	Ane	RJ, SP, PR, RS, SC	Atl, Pam	-RB 146723
<i>Sporobolus virginicus</i> (L.) Kunth	Herb	Geo	Ane	PA, AL, BA, MA, PB, PE, PI, RN, ES, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl, Pam	Castelo, 51 RB 568434
<i>Stenotaphrum secundatum</i> (Walter) Kuntze	Herb	Cam	Ane	AL, BA, CE, PB, RJ, SP, PR	Caa, Atl	Castelo, 143 RB 568526
Polygalaceae						
<i>Polygala cyparissias</i> A.St.-Hil. & Moq.	Herb	Cam	Aut	AL, BA, CE, PB, PE, SE, ES, RJ, SP, PR, RS, SC	Atl, Pam	Castelo, 87 RB 568470
Portulacaceae						
<i>Portulaca grandiflora</i> Hook.	Herb	The	Aut	BA, GO, MS, MT, MG, RJ, SP, PR	Caa, Cer, Atl	-
<i>Portulaca halimoides</i> L.	Herb	Hem	Aut	AP, PA, RR, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, ES, MG, RJ	Ama, Caa, Cer, Atl	Castelo, 199 RB 568582
<i>Portulaca mucronata</i> Link	Herb	Cam	Aut	PA, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl	Castelo, 188 RB 568571
Primulaceae						
<i>Jacquinia armillaris</i> Jacq.	Shrub	Pha	Zoo	AL, BA, CE, PB, PE, PI, RN, ES, RJ	Atl	Castelo, 28 RB 568411
Rubiaceae						
<i>Borreria capitata</i> (Ruiz & Pav.) DC.	Herb	Cam	Aut	AM, AP, PA, RO, RR, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MT, ES, MG, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl	Castelo, 05 RB 568388

Continued

Table 1. Continued.

Families / Species	Habit	LF	DS	Occurrence State (Brazil)	Biome	Voucher
<i>Borreria verticillata</i> (L.) G.Mey.	Herb	Cam	Aut	AC, AM, AP, PA, RO, RR, TO, AL, BA, CE, MA, PB, PE, PI, RN, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl	Castelo, 161 RB 568544
<i>Diodelia apiculata</i> (Willd. ex Roem. & Schult.) Delprete	Herb	Cam	Aut	AP, PA, RR, TO, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC	Ama, Caa, Cer, Atl, Pam	Castelo, 113 RB 568496
<i>Diodelia radula</i> (Willd. ex Roem. & Schult.) Delprete	Herb	Cam	Aut	BA, CE, PB, PE, PI, RN, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC	Caa, Cer, Atl	Carvalho, 38 RB 456181
<i>Mitracarpus eichleri</i> K.Schum.	Herb	Cam	Aut	BA, RN, ES, RJ	Atl	Castelo, 134 RB 568517
<i>Mitracarpus frigidus</i> (Willd. ex Roem. & Schult.) K.Schum.	Herb	Cam	Aut	AM, RO, BA, PB, PE, PI, ES, MG, RJ, SC	Ama, Caa, Cer, Atl	Castelo, 117 RB 568500
Smilacaceae						
<i>Smilax rufescens</i> Griseb.	Vine	Geo	Zoo	AM, RO, AL, BA, MA, ES, RJ, SP, PR, SC	Ama, Cer, Atl	Menezes, 166 RB 547460
Turneraceae						
<i>Turnera subulata</i> Sm.	Subshrub	Cam	Ane	AM, AP, PA, RO, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR	Ama, Caa, Cer, Atl	Castelo, 208 RB 568591
Verbenaceae						
<i>Stachytarpheta restingensis</i> Moldenke	Herb	Pha	Aut	ES, RJ	Atl	Castelo, 122 RB 568505
Violaceae						
<i>Pombalia calceolaria</i> (L.) Paula-Souza	Herb	Cam	Ane	AM, AP, PA, RR, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, MS, MT, ES, MG, RJ, SP	Ama, Caa, Cer, Atl, Pam	Castelo, 20 RB 568403

DISCUSSION

All of the restinga regions, except Barra de São João, have had their dune vegetation previously surveyed, with the highest richness found in Restinga da Marambaia (26 species). The present study found greater diversity, with Jurubatiba the restinga with the most species (48). The families most represented in dune vegetation are included in the 10 most important families in number of species for the restingas of Rio de Janeiro state (ARAUJO 2000).

Nevertheless, there are species registered in those previous studies that were not observed in some areas of the present survey, as follows: in Restinga da Marambaia, MENEZES & ARAUJO (2005) registered six different species (*Byrsonima sericea*, *Epidendrum denticulatum*, *Heteropterys chrysophylla*, *Neoregelia cruenta*, *Paspalum vaginatum*, and *Setaria setosa*); in Restinga da Praia do Sul, ARAUJO & OLIVEIRA (1988) recorded two (*Paspalum vaginatum*, and *Vigna* sp); Restinga de Grumari, NUNES-FREITAS et al. (2004) registered five (*Abrus precatorius*, *Croton glandulosus*, *Herreria salsaparrilha*, *Hippeastrum reticulatum*, and *Justicia cydoniifolia*); Restinga de Maricá, SILVA & OLIVEIRA (1989) registered six (*Centella asiatica*, *Croton glandulosus*, *Hydrocotyle bonariensis*, *Paspalum vaginatum*, *Richardia* sp, and *Spartina ciliata*); Restinga do Açú, ASSUMPÇÃO & NASCIMENTO (2000) registered four (*Bacopa monnieri*, *Borreria verticillata*, *Cynodon dactylon*, and *Euphorbia thymifolia*); and in the Restinga de Massambaba, ARAUJO et al. (2009) registered five species not seen in this study (*Achyrocline satureioides*, *Acicarpha bonariensis*, *Euphorbia thymifolia*, *Paspalum vaginatum*, and *Polygala cyparissias*). The species registered in the literature have been included in the species list, although they are not regularly found, and can occasionally occur in transition areas between the dune vegetation and neighbouring vegetation formations.

Among the registered species, *Chloris pycnothrix* and *Matelea maritima* were the first records for dune vegetation in Rio de Janeiro state (BFG 2015), and there is no record of endemic species. Despite the number of studies carried out in the restingas of Rio de Janeiro, these findings make evident the importance of the conservation of restinga remnants and the intensification of floristic surveys along Brazilian coastline.

The dune vegetation is represented mainly by herbaceous species, prostrate or semi-prostrate (Figures 3A–I), usually with shrub species (e.g. *Chrysobalanus icaco*, *Dalbergia ecastaphyllum*, *Eugenia uniflora*, *Jacquinia armillaris*, *Schinus terebinthifolius*, *Sophora tomentosa*, *Varronia curassavica*). However, development in shrub species is often limited by environmental conditions such as saline sprays and winds, resulting in a different morphology.

Each life form demonstrates an adaptation to the environmental conditions (Figures 4A–Z), in which the species are dependent on soil and climate characteristics. In this manner, the percentages of different life forms are variable for dune vegetation (see SEABRA 1949; ALMEIDA & ARAUJO 1997; GANDULLO et al. 1998; MENEZES & ARAUJO 1999; BOEGER & GLUZEZAK 2006; ALMEIDA JUNIOR & ZICKEL

Table 2. Species richness of this study and previous studies in the nine restingas.

Restingas	Size (ha)	Species richness	References	Species richness this study
Praia do Sul	397.48	20	ARAÚJO & OLIVEIRA (1988)	29
Marambaia	4,961.31	26	MENEZES & ARAÚJO (2005)	26
Grumari	143.1	14	NUNES-FREITAS ET AL. (2004)	26
Jacarepaguá	620.8	22	TEIXEIRA-FILHO ET AL. (1994)	32
Maricá	272.15	17	SILVA AND OLIVEIRA (1989)	34
Massambaba	7,630	17	ARAÚJO ET AL. (2009)	29
Barra de São João	–	–	–	25
Jurubatiba	14,860	16	ARAÚJO ET AL. (1998)	48
Açu	3,844.73	12	ASSUMPÇÃO & NASCIMENTO (2000)	31



Figure 3. Habitats of the sand dunes vegetation of Rio de Janeiro state, Brazil. **A:** Restinga da Praia do Sul. **B:** Restinga da Marambaia. **C:** Restinga de Grumari. **D:** Restinga de Jacarepaguá. **E:** Restinga de Maricá. **F:** Restinga de Massambaba. **G:** Restinga de Barra de São João. **H:** Restinga de Jurubatiba. **I:** Restinga do Açu.

2009), which exhibits a predominance of camephytes, geophytes and phanerophytes.

The capacity of a species to colonize a new area is directly related to the form of dispersion, whereas the anemochoric species have a great dispersion capacity over long distances (WILLSON & TRAVESET 2000) and the autochoric have less dispersion capacity. The dispersion of low mass seeds, easily dispersed by wind, has been found to be advantageous in open plant communities (LAKE & LEISHMAN 2004) and

in coastal dunes (MAUN 2009). The open vegetation and constancy of winds help the dispersion, and the investment in a self-dispersion mechanism, with no dependence on vectors, is the most viable (MARQUES & OLIVEIRA 2005).

In general, the composition of species observed along the coastline of Rio de Janeiro state is most similar to the Atlantic Forest, since this biome predominates in the state, and the restinga is an associated ecosystem of this biome. A total of 19 species (19.38%) that occur exclusively in the



Figures 4. Species from sand dune vegetation of Rio de Janeiro state, Brazil. **A:** *Achyrocline satureioides*. **B:** *Borreria capitata*. **C:** *Borreria verticillata*. **D:** *Canavalia rosea*. **E:** *Centrosema brasilianum*. **F:** *Centrosema virginianum*. **G:** *Chamaecrista flexuosa*. **H:** *Chloris pycnothrix*. **I:** *Commelina benghalensis*. **J:** *Commelina erecta*. **K:** *Cyrtocymura scorpioides*. **L:** *Emilia fosbergii*. **M:** *Emilia sonchifolia*. **N:** *Fimbristylis cymosa*. **O:** *Hydrocotyle bonariensis*. **P:** *Matelea maritima*. **Q:** *Panicum racemosum*. **R:** *Paspalum vaginatum*. **S:** *Peplonia asteria*. **T:** *Porophyllum ruderale*. **U:** *Portulaca halimoides*. **V:** *Portulaca mucronata*. **W:** *Remirea maritima*. **X:** *Scaevola plumieri*. **Y:** *Sida cordifolia*. **Z:** *Stylosanthes viscosa*.

Atlantic Forest were observed. However, several species are represented in other biomes, mainly the Cerrado, Amazon Rainforest, and Caatinga. ARAUJO (2000) compared the 20 richest families in the restingas with other biomes, and observed a relatively high level of similarity with the Atlantic Forest, Cerrado, and Amazon Rainforest biomes. This study also demonstrated that approximately 60% of species listed for the restingas in Rio de Janeiro are from the Atlantic Forest, and the remaining ones are associated with other types of vegetation (coastal inselbergs and dry deciduous forests) and other regions of Brazil (Cerrado, Caatinga, and Amazon Rainforest). According to SCARANO (2002), restinga species have had not enough time to develop speciation mechanisms, since the coastal plains are recent geological environments, and the species that colonized this area have barely adapted themselves to extreme environmental conditions.

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