Acta Botanica Brasilica - 30(3): 455-461. July-September 2016.
doi: 10.1590/0102-33062016abb0130

Bryophyte communities of *restingas* in Northeastern Brazil and their similarity to those of other *restingas* in the country

Mércia Patrícia Pereira Silva[1*], Carmen Sílvia Zickel[2] and Kátia Cavalcanti Pôrto[3]

Received: April 15, 2016
Accepted: July 28, 2016

ABSTRACT

Restingas are a coastal component of the Atlantic Forest. They experience high temperatures and possess soils with a low capacity to retain water, low nutrient content and high salt concentrations. Studies on bryophytes of *restingas* have been mostly conducted in Southeastern Brazil, and so we aimed to characterize the bryophyte flora of seven areas of *restinga* in the Northeastern Region and to establish their floristic affinities with other *restingas* in Brazil. Fifty-five species were found in the studied *restingas*, the vast majority of which are generalist species with life forms of intermediate tolerance to desiccation and of corticicolous and terrestrial habitat. The number of species per area is low compared to the species richness of other *restingas* in Brazil. A cluster analysis, although based on low similarity, showed that the bryoflora from the surveyed areas is distinct from those of *restingas* from Bahia, Espírito Santo and Rio de Janeiro, which all form a group, and those of the coast of São Paulo, which also comprised a cluster. The heterogeneous climate, soils and vegetation structure of the studied *restingas*, in comparison those of the Southeast, act as selective filters for the species, thereby contributing to the distinction observed in those communities.

Keywords: distribution, diversity, flora, liverworts, mosses

Introduction

Brazilian *restingas* (a type of tropical coastal vegetation) comprise a diverse set of plant communities that extend discontinuously along approximately 80% (7,110 km) of the Atlantic Coast, from 4°N to 34°S (Suguio & Tessler 1984). *Restingas* are recent formations that originated in the Quaternary as result of regressions and transgressions of the sea, with climatic and, mainly, edaphic factors acting as conditioners (Magnago *et al.* 2013).

The vegetation of Brazilian coastal *restingas* exhibit a wide variety of phytophysiognomies, from open fields closer to the sea to forest with canopies of up to 20 meters in height. In these forested areas, organic matter tends to accumulate in the soil and light intensity is lower due to shading by the forest canopy (Scarano 2002; Sampaio *et al.* 2005). The woody flora is closely associated with the Atlantic Forest (Pereira 2003).

In general, *restinga* vegetation withstands limiting conditions because the soils are oligotrophic, salty and have low water retention, plus they experience high temperatures, intense sunlight and strong winds (Rizzini 1997).

Floristic, phytosociological, taxonomical, ecological and/or conservation studies have been conducted in areas

[1] Departamento de Botânica, Instituto de Biologia, Universidade Federal da Bahia, Campus de Ondina, 40170-280, Salvador, BA, Brazil
[2] Departamento de Biologia, Área de Botânica, Universidade Federal Rural de Pernambuco, Av. Dom Manuel de Medeiros, Dois Irmãos, 52171-900, Recife, PE, Brazil
[3] Departamento de Botânica, Centro de Ciências Biológicas, Universidade Federal de Pernambuco, Av. Prof. Moraes Rêgo, 1235, Cidade Universitária, 50670-901, Recife, PE, Brazil
* Corresponding author: merciapps@ufba.br

of *restinga* in Brazil for both phanerogams (Assumpção & Nascimento 2000; Almeida Jr. *et al.* 2009; Pires *et al.* 2012; Monteiro *et al.* 2014; Fernandes & Queiroz 2015; Santos-Filho *et al.* 2015) and ferns and lycophytes (Behar & Viégas 1992; 1993; Santos *et al.* 2004; Athayde Filho & Windish 2006).

Present knowledge regarding the bryophytes of *restingas* basically comes from areas concentrated in Southeastern Brazil, thanks to the contributions of Behar *et al.* (1992), Visnadi & Vital (1995) and Silva & Piassi (2010) in the state of Espírito Santo; Costa & Yano (1998), Costa *et al.* (2006) and Imbassahy *et al.* (2009) in Rio de Janeiro; and Vital & Visnadi (1994), Yano & Peralta (2004), Visnadi (2010) and Santos *et al.* (2011) in São Paulo. In contrast, there has been only one study on the bryophytes of *restingas* of Northeastern Brazil, an inventory by Bastos & Yano (2006) for the metropolitan area of Salvador and the north coast of Bahia.

Thus, the present study represents the first investigation into the bryophytes of the *restingas* of the coastline between the states of Rio Grande do Norte and Sergipe in Northeastern Brazil. The goal was to determine the floristic composition and characterize the bryophyte communities of these *restingas*, and to assess their floristic affinities with *restingas* of Southeastern Brazil.

Material and methods

Study area

Seven areas of *restinga* were selected for study, most of them being littoral, classified as protected areas and located in the states between Rio Grande do Norte and Sergipe: A1 - Parque Estadual Dunas de Natal/RN (05º48'45"S; 35º11'35"W), A2 - RPPN Mata Estrela/RN (06º22'27"S; 35º00'48"W), A3 - APA de Mamanguape/PB (06º47'06"S; 35º04'48"W), A4 - Praia do Sossego/PE (07º45'04"S; 34º51'27"W), A5 - RPPN Nossa Senhora do Outeiro/PE (08º31'48"S; 35º01'05"W), A6 - Taperaguá/AL (09º44'47"S; 35º49'29"W) and A7 - Reserva Ecológica de Santa Isabel/SE (10º44'37"S; 36º51'41"W).

A standardized sampling effort of five-hours was established in order to explore, by foot, each area as much as possible and to record all vegetation types of each area. Samples were collected from preferred substrates such as live tree trunks (ground level to nearly 2m height), rotting logs and soil. The procedure of collection and herborization of material followed the methodology described by Yano (1989). All voucher material was deposited in the Herbarium UFP Geraldo Mariz of the Federal University of Pernambuco.

Samples were identified with the aid of literature such as Frahm (1991), Reese (1993), Sharp *et al.* (1994), Buck (1998), Lemos-Michel (2001), Gradstein & Costa (2003) and Bordin & Yano (2013). Worldwide geographic distribution patterns were determined according to this literature and according to the Brazilian phytogeographic domains in http://floradobrasil.jbrj.gov.br/. The classification systems adopted were based on Crandall-Stotler *et al.* (2009) for Marchantiophyta and Goffinet *et al.* (2009) for Bryophyta.

Species were classified according to light tolerance (shade tolerant, sun tolerant and generalist species) according Gradstein (1992), Pócs & Tóthmérész (1997), Gradstein *et al.* (2001), Reiner-Drehwald (2000), Alvarenga *et al.* (2010) and Oliveira *et al.* (2011): for life-form in relation to desiccation tolerance (exigent, intermediate and tolerant) according to Gimingham & Birse (1957) and Glime (2013); and for habitat type (corticolous, epixylic and terrestrial).

Data analysis

Bryophyte floristic composition, species richness (number of species), Shannon diversity index (H') and evenness (J') (Ricklefs 2001) were determined for each area of *restinga*.

Bryophyte floristic composition was compared among areas by calculating similarities using the Sörensen coefficient and UPGMA (Krebs 1989). Cluster analyses were performed using the software Primer 6.0 (Clarke & Warwick 2001) and adopting values of cophenetic relation of clusters above 0.7 as an indication of satisfactory correspondence (Visnadi & Vital 2001).

In order to assess affinities between the bryofloras of the study areas with those reported for *restingas* of Bahia and Southeastern Brazil, a matrix of binary data was built by compiling data from the following: Bahia (Bastos & Yano 2006); Espirito Santo (Behar *et al.* 1992; Visnadi & Vital 1995; Silva & Piassi 2010); Rio de Janeiro (Costa *et al.* 2006; Imbassahy *et al.* 2009); and São Paulo (Vital & Visnadi 1994; Yano & Peralta 2004; Visnadi 2010; Santos *et al.* 2011). This matrix was subjected to the same methodology described for the calculation of floristic similarity.

Results and discussion

The present work provides the first report of bryophyte species composition, richness and similarity for areas of *restinga* of the coast of Northeastern Brazil. Fifty-five species of bryophytes were recorded (Tab. S1 in supplementary material), among which 27 were mosses and 28 liverworts.

The most-represented families were Lejeuneaceae (24 spp.), Fissidentaceae (eight spp.) and Calymperaceae (six spp.). The high-representation of Lejeuneaceae is common to nearly all floristic surveys of tropical forests, but especially in lowlands up to moderate altitudes (Gradstein *et al.* 2001), including areas of *restinga* (Bastos & Yano 2006; Peralta & Yano & 2008; Imbassahy *et al.* 2009; among others). The genera *Lejeunea* and *Fissidens* had the greatest species richness with 10 and eight species, respectively.

Five geographical patterns of distribution were recognized among the bryophytes sampled. Species with a Neotropical distribution (52.7%) predominated, followed by species with Pantropical (31%), Wide (6%) and African-American (5.3%) distributions. One species (5%), *Fissidens flabellatus* Hornsch, is endemic to Brazil (Bordin & Yano 2013). The sampled species are widely distributed in Brazil, and most have been reported from more than one phytogeographical domain, especially the Atlantic Forest, and none are under threat of extinction (MMA 2008; Martinelli & Moraes 2013).

Generalist species were quantitatively (number of species) and qualitatively (number of samples) more represented, followed by sun tolerant and, finally, shade tolerant species (Tab. 1). Most species have a wide range of ecological tolerance, growing in several forest phytophysiognomies as well as open, semi-arid, plantation and urban areas, such as: *Acrolejeunea* spp., *Bryum coronatum*, *Calymperes afzelii*, *C. palisotti*, *Cheilolejeunea rigidula*, *Lejeunea flava*, *L. laetevirens*, *Octoblepharum albidum*, *Schiffneriolejeunea polycarpa* and *Sematophyllum* spp. (Visnadi & Monteiro 1990; Bastos & Yano 1993; Lisboa & Ilkiu-Borges 1995; Câmara *et al.* 2003; Yano & Câmara 2004; Bordin & Yano 2009). The pronounced representation of these species is consistent with the environmental characteristics of *restingas*, wherein intense sunshine, high temperatures and strong winds, among other factors, limit the growth and development of many plant species and dictate the occurrence of those more tolerant.

In turn, life-forms with high (tuft and cushion) or intermediate (mat and carpet) tolerance to desiccation were dominant; the former were found colonizing soil or live trunks, and the latter colonizing live trunks and/or, more rarely, decaying trunks. With respect to sun tolerance, there was greater representation for species with life forms of intermediate desiccation tolerance colonizing live trunks or decayed logs. Shade tolerant species were numerically less abundant and were represented by *Fissidens* spp., which are tufts and have terrestrial habitat, and by the pendant and corticicolous *Squamidium nigricans*. Extensive colonization of live trunks and soil undoubtedly reflects the large availability of these types of substrates in the studied environments. Epiphylls were absent, which is not surprising considering the high exposure to solar radiation (Bastos & Yano 2006) and low water retention capacity of leaf surfaces making them an inhospitable substrate for colonization by bryophytes in these environments.

Richness ranged from 12 to 23 species per area, whereas floristic affinity among the seven areas varied between 23 and 66% (Tab. 2). Five out of the seven areas inventoried in this study were protected areas, which seems to be a providential action since these areas are close to major urban centers and are highly susceptible to a wide variety of human impacts. It is noteworthy that the *restinga* with the highest richness of bryophytes in this study (RPPN Nossa Senhora do Outeiro), is located next to an area of intensive tourism, yet is still considered to be of good conservation status (Almeida Jr. *et al*. 2009). The bryophyte floras of the studied *restingas* had low species richness in comparison to other Brazilian *restingas*, and were among the lowest values reported for this type of vegetation (Tab. 3). *Restingas* from Bahia and Southeastern Brazil that were selected for comparative analysis in this study ranged in bryophyte species richness from eight to 175 species.

Table 1. Bryophyte communities of *restingas* of Northeastern Brazil according to light tolerance, life-form and habitat. Absolute frequencies are provided in parentheses.

Light tolerance	Life-form/ desiccation tolerance	Habitat type
Generalist	Turf/ tolerant	**Terrestrial**: *Archidium ohioense* (3), *Bryum coronatum* (8), *B. leptocladon* (4), *Calymperes lonchophyllum* (1), *Fissidens hornschuchii* (8), *F. submarginatus* (1), *Hyophiladelphus agrarius* (5), *Rosulabryum billarderii* (1) **Corticicolous**: *Calymperes afzelii* (4), *C. erosum* (2), *C. palisotii* (87), *Fissidens radicans* (1), *Octoblepharum albidum* (44), *Pilosium chlorophyllum* (7)
	Mat/ intermediate	**Corticicolous and/or epixylic**: *Archilejeunea fuscescens* (1), *Cheilolejeunea adnata* (1), *C. discoidea* (4), *C. rigidula* (25), *Entodontopsis leucostega* (19), *Frullanoides corticalis* (2), *Lejeunea caespitosa* (3), *Lejeunea caulicalyx* (3), *L. controversa* (1), *L. flava* (1), *L. lepida* (7), *L. phyllobola* (3), *L. trinitensis* (1), *Metalejeunea cucullata* (1), *Microlejeunea bullata* (19), *M. epiphylla* (12), *Sematophyllum subpinnatum* (1), *S. subsimplex* (19), *Taxithelium planum* (14)
Sun tolerant	Turf/ intolerant	**Terrestrial**: *Campylopus gardneri* (1), *C. savannarum* (3)
	Mat/ intermediate	**Corticicolous and/or epixylic**: *Acrolejeunea emergens* (17), *A. torulosa* (1), *Caudalejeunea lehmanniana* (1), *Frullania dusenii* (6), *F. gibbosa* (7), *F. kunzei* (1), *F. nodulosa* (1), *L. laetevirens* (50), *Lejeunea magnoliae* (1), *Pycnolejeunea contigua* (2), *Schiffneriolejeunea polycarpa* (4)
Shade tolerant	Turf/ tolerant	**Terrestrial**: *Fissidens angustifolius* (5), *F. flabellatus* (2), *F. flaccidus* (1), *F. goyazensis* (2), *F. pellucidus* (2) **Corticicolous and/or epixylic**: *Syrrhopodon ligulatus* (1)
	Mat/ intermediate	**Corticicolous and/or epixylic**: *Cololejeunea diaphana* (1), *Lejeunea boryanna* (1)
	Pendant/intolerant	**Corticicolous**: *Squamidium nigricans* (1)

Table 2. Comparison of bryophyte species richness, similarity and diversity of *restingas* from Northeastern Brazil. Bold = number of species per area; normal font = number of species shared between areas; italics = Sørensen similarity index; underlined = Diversity (H'); and gray stripe = Equitability (J'). A1 - Parque Estadual Dunas de Natal/RN; A2 -RPPN Mata Estrela/RN; A3 - APA de Mamanguape/PB; A4 - Praia do Sossego/PE; A5 -RPPN Nossa Senhora do Outeiro/PE; A6 - Taperaguá/AL; A7 - Reserva Ecológica de Santa Isabel/SE.

	A1	A2	A3	A4	A5	A6	A7
A1	**23**	*0.40*	*0.29*	*0.38*	*0.57*	*0.40*	*0.33*
A2	8	**14**	*0.42*	*0.29*	*0.33*	*0.38*	*0.23*
A3	7	5	**20**	*0.29*	*0.32*	*0.26*	*0.24*
A4	6	4	7	**13**	*0.43*	*0.50*	*0.66*
A5	10	5	5	5	**12**	*0.53*	*0.33*
A6	11	8	5	6	6	**18**	*0.51*
A7	6	9	4	3	4	8	**13**
H'	3.9	3.2	3.7	3.3	3.1	3.3	3.2
J'	0.86	0.86	0.87	0.89	0.86	0.81	0.88

Table 3. Bryophyte species richness for areas of Brazilian restinga used for comparative analysis in this study.

Brazilian State	Restinga localities	Number of species	Reference
Rio Grande do Norte	Parque Estadual Dunas de Natal	12	This study
	RPPN Mata Estrela	20	This study
Paraíba	APA de Mamanguape	13	This study
Pernambuco	Praia do Sossego	14	This study
	RPPN Nossa Senhora do Outeiro	23	This study
Alagoas	Taperaguá	18	This study
Sergipe	Reserva Ecológica de Santa Isabel	13	This study
Bahia	Salvador e litoral Norte	29	Bastos & Yano (2006)
Espírito Santo	Setiba, Guarapari	38	Behar *et al.* (1992); Visnadi & Vital (1995); Silva & Piassi (2010)
Rio Janeiro	Jurubatiba, Carapebus	41	Imbassahy *et al.* 2009
	Macaé	36	Costa & Yano (1998); Costa *et al.* (2006)
	Massambaba	19	Costa *et al.* (2006)
	Rio das Ostras	11	Costa *et al.* (2006)
	Maricá	8	Costa *et al.* (2006)
São Paulo	Floresta de Restinga de Juréia, Peruíbe	59	Vital & Visnadi (1994)
	Floresta de Restinga da Serra do Mar, Ubatuba	175	Santos *et al.* (2011)
	Cananéia	43	Visnadi (2010)
	Itanhaé	40	Visnadi (2010)
	Bertioga	26	Visnadi (2010)
	Praia Grande	11	Visnadi (2010)
	Barra do Ribeira, Iguapé	69	Yano & Peralta (2004)

Extensive heterogeneity in bryophyte species richness among *restingas* has been noted previously, such as for the Parque Nacional da *restinga* de Jurubatiba, Rio de Janeiro (Imbassahy *et al.* 2009) and the Parque Estadual Paulo César Vinha in Espírito Santo (Silva & Piassi 2010). The authors of these studies considered ecotonal factors and dissimilarities of vascular communities to be determinants in the differentiation of the non-vascular flora. With regard to the phanerogamic flora, Zickel *et al.* (2004) also found striking differences in species composition and representativeness between *restingas* of Southeastern and Northeastern Brazil due to their geomorphological differences. However, more recent work on the vascular flora of *restingas* of Northeastern Brazil (CS Zickel unpubl. res.) found that geomorphology and abiotic factors were not significant.

Although based on a relatively low degree of similarity (between 22-30%), cluster analysis (cophenetic correlation 0.85) revealed the existence of three groups of *restingas* based on bryophyte flora: the first is comprised of the *restingas* of the present study in Northeastern Brazil; the second clusters the *restingas* from Bahia, Espírito Santo and Rio de Janeiro; and the third group contains exclusively the *restingas* from São Paulo (Fig. 1). Some species stand out as being reported, to date, only from the Northeastern *restingas*, although they are common in other vegetation formations, such as *Calymperes lonchophyllum, Campylopus gardneri, Fissidens goyazensis, Lejeunea trinitensis* and *Metalejeunea cucullata*. On the other hand, the absence of representatives of Metzgeriaceae, Plagiochilaceae and Radulaceae is remarkable, since they are common in the

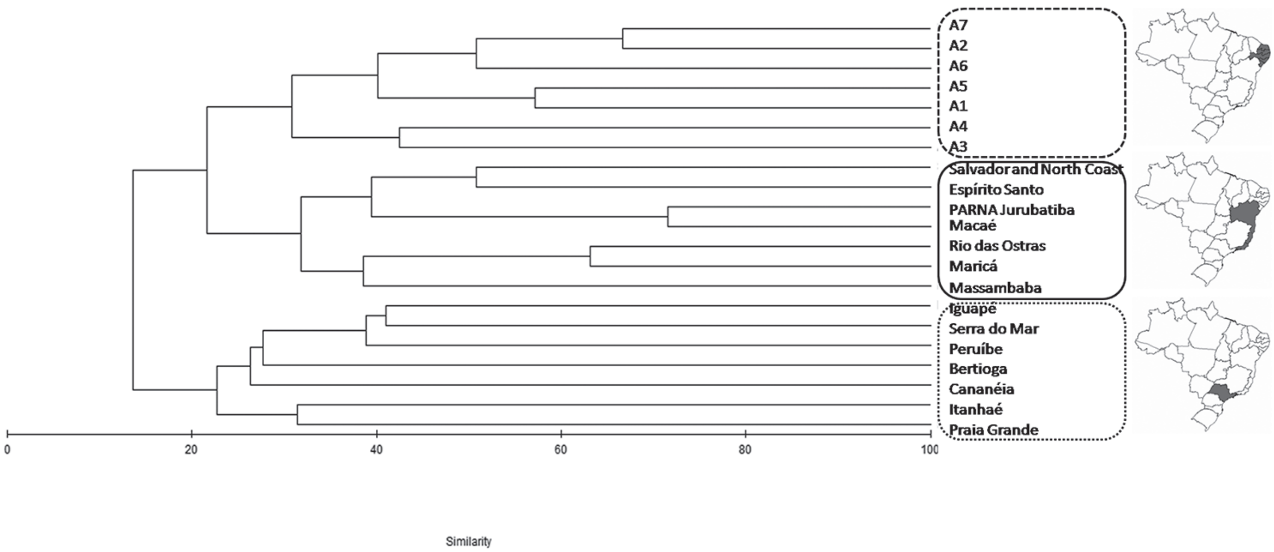

Figure 1. Dendrogram showing similarities (Sörensen index) among *restinga* bryofloras from Northeastern, Bahia and Southeastern Brazil. Captions: A1 - Parque Estadual Dunas de Natal/RN; A2 - RPPN Mata Estrela/RN; A3 - APA de Mamanguape/PB; A4 - Praia do Sossego/PE; A5 - RPPN Nossa Senhora do Outeiro/PE; A6 - Taperaguá/AL(09°44'47"S; 35°49'29"W); A7 - Reserva Ecológica de Santa Isabel/SE; SSA – Salvador and North Coast/BA; Setiba + Guarapari/ES; Macaé/RJ; Rio das Ostras/RJ; Maricá/RJ; Massambaba/RJ; Iguape/SP; Ubatuba/SP; Peruíbe/SP; Bertioga/SP; Cananéia/SP; Itanhaé/SP; Praia Grande/SP.

Southeastern *restingas* (e.g., Costa *et al.* 2006; Imbassahy *et al.* 2009; Visnadi 2010) and relatively widely distributed in remnants of Atlantic Forest in the Northeast. One of factors that may be responsible for limiting the species of these families from occupying the studied *restingas* may be their more severe limitation of moisture. *Restingas* of the Southern and Southeastern regions of Brazil have longer periods of soil flooding, which in turn favors increased water content of the soils of these environments due to, mainly, the topography, the depth of the water table, and the proximity of water bodies (Silva 1999). These factors, based on recent studies, influence the distribution of the phanerogamic flora in the *restingas* of the Southern and Southeastern regions (Assis 2011; Marques *et al.* 2011).

On the other hand, studies that seek to empirically determine what environmental factors affect the spatial distribution of bryophyte species in *restingas* are absent. Due to their structural and physiological characteristics, bryophytes respond more significantly to microenvironmental than to macroenvironmental variables (e.g. Alvarenga *et al.* 2010), and so it is reasonable to consider the importance of microenvironmental variables in the distribution of these plants in *restingas*.

The heterogeneous environmental conditions, geomorphology, soil and vegetation structure and composition of the areas of *restinga* studied in Northeastern Brazil, compared to those of the Southeast, represent selective filters for the species, and contribute to the observed differences in communities. Moreover, stochastic events, such as dispersion, human interference or other biotic or abiotic variables that were out of the scope of the present study, may be acting on bryophyte composition and must be taken into account in future studies.

Acknowledgments

We thank Milena Rodrigues dos Santos for sampling bryophytes in some areas of *restinga* and the Fundação Grupo Boticário de Proteção à Natureza for financial support.

References

Almeida Jr EB, Olivo MA, Araújo EL, Zickel CS. 2009. Caracterização da vegetação de restinga da RPPN de Maracaípe, Pernambuco, com base na fisionomia, flora, nutrientes do solo e lençol freático. Acta Botanica Brasilica 23: 36-48.

Alvarenga LDP, Pôrto KC, Oliveira JRPM. 2010. Habitat loss effects on spatial distribution of epiphytic bryophytes in a Brazilian Atlantic forest. Biodiversity and Conservation 19: 619-635.

Assis AM, 2011. Florestas de restinga e de terras baixas na planície costeira do sudeste do Brasil: vegetação e heterogeneidade ambiental. Biota Neotropica 11: 103-121.

Assumpção J, Nascimento MT. 2000. Estrutura e composição florística de quatro formações vegetais de Restinga no complexo lagunar Grussaí/Iquipari, São João da Barra, RJ, Brasil. Acta Botanica Brasilica 14: 301-315.

Athayde Filho FP, Windisch PG. 2006. Florística e aspectos ecológicos das pteridófitas em uma floresta de restinga no estado do Rio Grande do Sul, Brasil. Iheringia, Série Botânica 61: 63-71.

Bastos CJP, Yano O. 1993. Musgos da zona urbana de Salvador, Bahia, Brasil. Hoehnea 20: 23-33.

Bastos CJP, Yano O. 2006. Briófitas de restinga das regiões Metropolitana de Salvador e Litoral Norte do Estado da Bahia, Brasil. Boletim do Instituto de Botânica 18: 197-205.

Behar L, Viégas GMF. 1992. Pteridophyta da restinga do Parque Estadual de Setiba, Espírito Santo. Boletim do Museu de Biologia Mello Leitão, Nova Série 1: 39-59.

Behar L, Viégas GMF. 1993. Pteridophyta da restinga de Comboios, Aracruz/Linhares-ES. In: ACIESP-SP (orgs.) Anais do III Simpósio de Ecossistemas da Costa Brasileira: subsídios a um gerenciamento ambiental, Serra Negra, SP. São Paulo, ACIESP. p. 134-143.

Behar L, Yano O, Vallandro GC. 1992. Briófitas da restinga de Setiba, Guarapari, Espírito Santo. Boletim do Museu de Biologia Mello Leitão, Nova Série 1: 25-38.

Bordin J, Yano O. 2009. Briófitas do centro urbano de Caxias do Sul, Rio Grande do Sul, Brasil. Hoehnea 36: 7-71.

Bordin J, Yano O. 2013. Fissidentaceae (Bryophyta) do Brasil. Boletim do Instituto de Botanica 22: 1-168.

Buck WR. 1998. Pleurocarpous mosses of the West Indies. Memoirs of The New York Botanical Garden 82: 1-400.

Câmara PEAS, Teixeira R, Lima J, Lima J. 2003. Musgos urbanos do Recanto das Emas, Distrito Federal, Brasil. Acta Botanica Brasilica 17: 507-513.

Clarke KR, Warwick RM. 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2nd. edn. Plymouth, PRIMER-E.

Costa DP, Yano O. 1998. Briófitas da restinga de Macaé, Rio de Janeiro, Brasil. Hoehnea 25: 99-119.

Costa DP, Imbassahy CAA, Almeida JSS, Santos ND, Imbassahy TFV. 2006. Diversidade das briófitas nas restingas do estado do Rio de Janeiro, Brasil. Boletim do Instituto de Botânica 18: 131-139.

Crandall-Stotler B, Stotler RE, Long DG. 2009. Morphology and classification of the Marchantiophyta. In: Goffinet B, Shaw AJ. (eds.) Bryophyte biology. 2nd. ed. Cambridge, Cambridge University Press. p. 1-54.

Fernandes MF, Queiroz LP. 2015. Floristic surveys of Restinga Forests in southern Bahia, Brazil, reveal the effects of geography on community composition. Rodriguésia 66: 51-73.

Frahm J-P. 1991. Dicranaceae: Campylopodioideae, Paraleucobryoideae. Flora Neotropica, Monograph 54: 1-238.

Gimingham CH, Birse EM. 1957. Ecological studies on growth-form in bryophytes: 1. Correlations between growth-form and habitat. Journal of Ecology 45: 533-545.

Glime JM. 2013. Adaptive strategies: growth and life forms. Chapt. 4-5. In: Glime JM. (ed.) Bryophyte ecology. Volume 1. Physiological ecology. Houghton, Ebook sponsored by Michigan Technological University. p. 1-21.

Goffinet B, Buck WR, Shaw AJ. 2009. Morphology, anatomy, and classification of the Bryophyta. In: Goffinet B, Shaw AJ. (eds.) Bryophyte biology. Cambridge, Cambridge University Press. p. 55-138.

Gradstein SR. 1992. The vanishing tropical rain forest as an environment for bryophytes and lichens. In: Bates JW, Farmes AM. (eds.) Bryophytes and lichens in a changing enviroment. Oxford, Clarendon Press. p. 234-258.

Gradstein SR, Churchill ST, Salazar-Allen N. 2001. Guide to the bryophytes of Tropical America. Memoirs of The New York Botanical Garden 86: 1-577.

Gradstein SR, Costa DP. 2003. The Hepaticae and Anthocerotae of Brazil. Memoirs of The New York Botanical Garden 87: 1-318.

Imbassahy CAAI, Costa DP, Araújo DSD. 2009. Briófitas do Parque Nacional da Restinga de Jurubatiba, RJ, Brasil. Acta Botanica Brasilica 23: 558-570.

Krebs CJ. 1989. Ecological methodology. 2nd. edn. New York, Harper and Row Publishers.

Lemos-Michel E. 2001. Hepáticas epifíticas sobre o pinheiro brasileiro no Rio Grande do Sul. Porto Alegre, Ed. da Universidade Federal do Rio Grande do Sul.

Lisboa RCL, Ilkiu-Borges AL. 1995. Diversidade das briófitas do Belém (PA) e seu potencial como indicadoras de poluição. Boletim do Museu Paraense Emílio Goeldi, série Botânica 11: 131-293.

Magnago LFS, Martins SV, Schaefer CEGR, Neri AV. 2013. Structure and diversity of restingas along a flood gradient in southeastern Brazil. Acta Botanica Brasilica 27: 801-809.

Marques MCM, Swaine MD, Liebsch D. 2011. Diversity distribution and floristic differentiation of the coastal lowland vegetation: implications for the conservation of the Brazilian Atlantic Forest. Biodiversity and Conservation 20: 153-168.

Martinelli G, Moraes MA. 2013. Livro vermelho da flora do Brasil. Rio de Janeiro, Instituto de Pesquisas Jardim Botânico do Rio de Janeiro.

MMA – Ministério do Meio Ambiente. 2008. Espécies da flora brasileira ameaçadas de extinção. Instrução normativa n.6, de 23 de setembro de 2008. Brasília, MMA.

Monteiro MM, Giaretta A, Pereira OJ, Menezes LFT. 2014. Composição e estrutura de uma restinga arbustiva aberta no norte do Espírito Santo e relações florísticas com formações similares no Sudeste do Brasil. Rodriguésia 65: 61-72.

Oliveira JRPM, Pôrto KC, Silva MPP. 2011. Richness preservation in a fragmented landscape: a study of epiphytic bryophytes in an Atlantic forest remnant in Northeast Brazil. Journal of Bryology 33: 279-290.

Peralta DF, Yano O. 2008. Briófitas do Parque Estadual da Ilha Anchieta, Ubatuba, estado de São Paulo. Iheringia, Série Botanica 63: 101-127.

Pereira OJ. 2003. Restinga: origem, estrutura e diversidade. In: Jardim MAG, Bastos NNC, Santos JUM. (orgs.) Desafios da botânica brasileira no novo milênio: inventário, sistematização e conservação da diversidade vegetal. Belém, Sociedade Brasileira de Botânica. p. 177-179.

Pires LA, Cardoso VJM, Rodrigues RR, Joly, CA. 2012. Survival and initial growth of *Ocotea pulchella* (Lauraceae) in a restinga forest at Ilha do Cardoso, SP. Rodriguésia 63: 763-774.

Pócs T, Tóthmérész B. 1997. Foliicolous bryophyte diversity in tropical rainforests. In: Farkas E, Pócs T. (eds.) Cryptogams in the phyllosphaere: systematics, distribution, ecology and use. Abstracta Botanica 21: 135-144.

Reese WD. 1993. Calymperaceae. Flora Neotropica, Monograph 58: 1-102.

Reiner-Drehwald ME. 2000. Las Lejeuneaceae (Hepaticae) de Misiones, Argentina. VI. *Lejeunea* y *Taxilejeunea*. Tropical Bryology 19: 81-131.

Ricklefs RE. 2001. The economy of nature. 5th. edn. New York, WH Freeman.

Rizzini CT. 1997. Tratado de fitogeografia do Brasil. Aspectos ecológicos, sociológicos e florísticos. 2nd. edn. Rio de Janeiro, Âmbito Cultural Edições Ltda.

Sampaio D, Oliveira AA, Rodrigues RR, Souza JP. 2005. Árvores da Restinga. 1st. edn. São Paulo, Neotrópica.

Santos MG, Sylvestre LS, Araujo DSD. 2004. Análise florística das pteridófitas do Parque Nacional da Restinga de Jurubatiba, Rio de Janeiro, Brasil. Acta Botanica Brasilica 18: 271-280.

Santos ND, Costa DP, Kinoshita LS, Shepherd GJ. 2011. Aspectos brioflorísticos e fitogeográficos de duas formações costeiras de Floresta Atlântica da Serra do Mar, Ubatuba/SP, Brasil. Biota Neotropica 11: 425-438.

Santos-Filho FS, Almeida Jr EB, Lima, PB, Soares, CJRS. 2015. Checklist of the flora of the restingas of Piauí state, Northeast Brazil. Check List 11: 1-10. http://dx.doi.org/10.15560/11.2.1598.

Scarano FR. 2002. Structure, function and floristic relationships of plant communities in stressful habitats marginal to the brazilian Atlantic Rainforest. Annals of Botany 90: 517-524.

Sharp AJ, Crum H, Eckel PM. 1994. The moss flora of Mexico. Memoirs of The New York Botanical Garden 69: 1-1113.

Silva LTP, Piassi M. 2010. Briófitas da formação herbácea inundada do Parque Estadual Paulo César Vinha, Setiba, Guarapari, Espírito Santo, sudeste do Brasil. Natureza (online): 8: 32-39. http://www.naturezaonline.com.br/

Silva SM. 1999. Diagnóstico das restingas do Brasil. In: Workshop de avaliação e ações prioritárias para conservação da biodiversidade da zona costeira e marinha. Porto Seguro, Fundação BIO RIO. Anais eletrônicos. http://www.brasil-rounds.gov.br/round7/arquivos_r7/SISMICA_R7/refere/Restingas.pdf

Suguio K, Tessler MG. 1984. Planícies de cordões litorâneos do Brasil: origem e nomenclatura. In: Lacerda, LD, Araujo DSD, Cerqueira R, Turcq RB. (eds.) Restingas: origem estruturas e processos. Niterói, CEUFF. p. 15-26.

Visnadi SR. 2010. Briófitas das formações florestais não inundáveis das restingas do estado de São Paulo, Brasil. Tropical Bryology 32: 74-86.

Visnadi SR, Monteiro R. 1990. Briófitas da cidade de Rio Claro, estado de São Paulo, Brasil. Hoehnea 17: 71-84.

Visnadi SR, Vital DM. 1995. Bryophytes from restinga in Setiba State Park, Espírito Santo State, Brazil. Tropical Bryology 10: 69-74.

Visnadi SR, Vital DM. 2001. Briófitas das Ilhas de Alcatrazes, do Bom Abrigo, da Casca e do Castilho, estado de São Paulo, Brasil. Acta Botanica Brasilica 15: 255-270.

Vital DM, Visnadi SR. 1994. Briófitas de um trecho de restinga da Estação Ecológica da Jureia, Peruíbe, Estado de São Paulo, Brasil. Anais do III Simpósio de Ecossistemas da Costa Brasileira 3: 153-157.

Yano O. 1989. Briófitas. In: Fidalgo O, Bononi VLR. (eds.) Técnicas de coleta, preservação e herborização de material botânico. São Paulo, Série Documentos/Instituto de Botânica. p. 27-30.
Yano O, Câmara PEAS. 2004. Briófitas de Manaus, Amazonas, Brasil. Acta Amazonica 34: 445-457.
Yano O, Peralta DF. 2004. Briófitas da restinga de Barra do Ribeira, São Paulo, Brasil. Anais do VI Simpósio de Ecossistemas Brasileiros. São Paulo, ACIESP. p. 573-587.
Zickel CS, Vicente A, Almeida Jr EB, Cantarelli JRR, Sacramento AC 2004. Flora e vegetação das restingas no Nordeste Brasileiro. In: Eskinazi-Leça E, Neumann-Leitão S, Costa MF. (orgs.) Oceanografia: um cenário tropical. Recife, Bargaço. p. 689-701.