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Diversity of bryophytes in priority areas for conservation in the Atlantic forest of northeast Brazil

Mércia Patrícia Pereira Silva[1,3] and Kátia Cavalcanti Pôrto[2]

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ABSTRACT

The northeastern Brazilian Atlantic forest is the region with the greatest diversity of bryophytes in the country. However, knowledge about bryophytes is irregularly distributed among Brazilian regions. Therefore, we aimed to contribute to knowledge about bryophytes on a regional scale in the northeastern Atlantic forest, to identify the centers of bryophyte diversity in that region, and to reiterate the importance and identify locations for which new protected areas should be created. We built a database of bryophytes in 23 locations of the region, based on a literature review and new floristic inventories. To identify the locations of greatest relevance to bryophyte conservation, we considered 1) total and endemic species richness, 2) phylogenetic diversity (PD), and 3) functional diversity (proportion of shade specialists). The northeastern Atlantic rainforest contains 396 spp., representing 26% of the taxa occurring in the country, 13 of which are endemic. Generalist species predominated (164 spp.), followed by shade (133 spp.) and sun (92 spp.) specialists. The Murici Ecological Station had the highest richness, number of endemic species, and phylogenetic diversity.

Keywords: conservation units, liverwort, moss, richness, tropical forest

Introduction

The Atlantic forest is the phytogeographic domain that shelters the greatest diversity of bryophytes in Brazil (Gradstein *et al.* 2001). The same authors also state that in the Neotropics, the diversity of bryophytes in the Atlantic Forest is surpassed only by those of the forests of the northern Andes and Central America. In addition, the Atlantic Forest is remarkable for its relevance and urgency of conservation, sheltering 16 of the 17 threatened Brazilian bryophyte species (Fundação Biodiversitas 2005; MMA 2008).

Currently, 378 (94% of all Brazilian) genera and 1,351 (88% of Brazilian) species of bryophytes are recorded for the Atlantic forest (Costa *et al.* 2014). According to Gradstein & Costa (2003) and Santos *et al.* (2011), Montane Atlantic Forest areas, particularly in the southeast, have many records of endemic bryophytes, many liverwort species, and interesting affinities with the bryoflora of the Andes. These authors also state that the number of endemic species occurring in the Atlantic coast region is twice that in the Amazon region, including 12 endemic families. With respect to mosses in particular, the endemism level for that domain is even greater with 190 species (20%), whereas only 10 endemic species (1%) are recorded in the Amazon Rainforest (Costa *et al.* 2011).

Despite its great biodiversity, the Atlantic Forest is one of the main targets of environmental degradation by exploitative human activities, such as the expansion of agriculture and urban areas and logging (Conservação Internacional do Brasil *et al.* 2000; Angelo 2013). According to Campanili & Prochnow (2006), this is the second most threatened vegetation domain on the planet, the first being the nearly extinct forests of the island of Madagascar off the coast of Africa. In the Brazilian Northeast Atlantic Forest, where the exploitation of forest resources is secular (Tabarelli *et al.* 2005), large gaps in the knowledge of the distribution of bryophytes in different states are notable.

Several important floristic surveys of the bryophytes of northeast Brazil have been published in the last two decades, particularly focusing on the state of Pernambuco (Pôrto 1990; Germano & Pôrto 1996; 1997; 1998; Sá & Pôrto 1996), and allowed Pôrto & Germano (2002) to compile 315 species of bryophytes for the state. Most records (84%) are derived from refuges of lowland Atlantic forest (Pôrto 1990; Pôrto *et al.* 1993; Germano &

[1] Universidade Federal da Bahia, Instituto de Biologia, Departamento de Botânica, Laboratório Taxonomia de Briófitas, Campus de Ondina, Ondina, Salvador, BA, Brazil
[2] Universidade Federal de Pernambuco, Centro de Ciências Biológicas, Departamento de Botânica, Laboratório Biologia de Briófitas, Av. Prof. Moraes Rego, 1235, Cidade Universitária, Recife, PE, Brazil
[3] Author for correspondence: merciapps@yahoo.com.br

Pôrto 1996; 1998; Sá & Pôrto 1996), or tropical altitudinal wet forests, "Brejos de altitude" (Yano & Andrade-Lima 1987; Pôrto 1990; Pôrto *et al.* 1999; 2000; Valdevino *et al.* 2002). Efforts have been recently made to increase the knowledge of bryophytes in other states, for example in Alagoas and Bahia with respect to bryoflora (Bastos & Yano 2004; Valente & Pôrto 2006; Valente *et al.* 2009; 2011) as well as conservation of populations and communities (Alvarenga *et al.* 2009; 2010; Oliveira *et al.* 2011; Silva & Pôrto 2009; 2010).

To the best of our knowledge, this work is the first effort to contribute to the information about bryophytes in the northeastern Atlantic forest on a regional scale and to identify the centers of floristic (total number of species and endemics), phylogenetic (proportions of species and topological differences between them) and functional (proportions of functional groups) diversity for bryophytes. Furthermore, we aimed to test whether these parameters are influenced by a latitude gradient through the northeastern Atlantic forest and to highlight locations where stronger conservation measures, viareinforcement of existing protected areas or creation of new ones, are urgently required.

Material and methods

Study area

The study was conducted in the northern part of the Atlantic Forest, *sensu lato*, covering the states of Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, and Sergipe (34°51'41"-37°20'32"W, 5°51'00"-10°45'16"S) (Table 1, Fig. 1) (hereafter, northeastern Atlantic forest), covering a linear distance of 595 km from north to south through 6° of latitude. This forest is mainly distributed up to 1,000 m altitude (Tabarelli *et al.* 2006), including tropical altitudinal wet forests, "Brejo de altitude," enclaves of moist forest surrounded by a near-desert vegetation (*sensu* Andrade-Lima 1982). The average temperature in the region is 25 °C and

Table 1. Locations, number of species, and references of the northeastern Atlantic forest sites surveyed in the present study.

Site	Site name	Location (W;S)	Altitude (m)	Reference
A1	Dunas do Natal State Park (PDU)	-35.1833;-5.8500	29	This study
A2	Mata Bela Private Reserve of Natural Heritage (MBL)	-35.0659;-6.4092	30	This study
A3	Mata Estrela Private Reserve of Natural Heritage (MET)	-35.0235;-6.3744	30	This study
A4	Guaribas Biological Reserve (GBA)	-35.1419;-6.7420	157	This study
A5	Barra do Rio Mamanguape Environmental Protection Area (APA)	-34.9091;-6.8536	40	This study
A6	Mata do Pau-Ferro Ecological Reserve (PFE)	-35.7445;-6.9836	600	This study
A7	Gargaú Reserve of Natural Heritage (GGA)	-34.9563;-6.9913	51	This study
A8	Pacatuba Reserve of Natural Heritage (PAC)	-35.1566;-7.0425	114	This study
A9	Benjamim Maranhão Botanical Garden (JBB)	-34.8614;-7.1366	35	This study
A10	Engenho Água Azul (AZU)	-35.3333;-7.5833	380	Germano & Pôrto (1996, 1997, 1998)
A11	Mata do Estado/ Serra dos Mascarenhas (MDE)	-35.5094;-7.6162	600	This study
A12	Dois Irmãos Ecological Reserve (DIR)	-35.0000;-7.9167	30	Pôrto & Oliveira (1998)
A13	Fazenda Bituri Reserve of Natural Heritage (BIT)	-36.3711;-8.1458	800	Valdevino et al. (2002); Pôrto *et al.* (2004)
A14	Gurjaú Ecological Reserve (GJA)	-35.6750;-8.3589	100	Germano & Pôrto (2005); Pôrto *et al.* (2006); Alvarenga & Pôrto (2007)
A15	João Vasconcelos Sobrinho Municipal Ecological Park (VSO)	-35.6167;-8.3692	850	Pôrto (1990); Pôrto *et al.* (2004)
A16	Bonito Municipal Reserve (BOT)	-35.7156;-8.5039	700	Pôrto & Germano (2002)
A17	Frei Caneca Reserve of Natural Heritage (FCA)	-35.8333;-8.7000	630	Pôrto *et al.* (2006); Alvarenga & Pôrto (2007); Campelo & Pôrto (2007)
A18	Saltinho Biological Reserve (SAL)	-35.1833;-8.7333	20	Pôrto (1990)
A19	Usina Serra Grande (SGR)	-36.1128;-9.0003	500	Pôrto *et al.* (2006); Alvarenga *et al.* (2008)
A20	Pedra Talhada Biological Reserve (PTA)	-36.4304;-9.2591	775	This study
A21	Murici Ecological Station (MUR)	-35.9167;-9.2667	500	Alvarenga *et al.* (2009, 2010); Silva & Pôrto (2009, 2010); Oliveira *et al.* (2011)
A22	Mata do Junco Wildlife Refuge (MJU)	-37.0588;-10.5382	142	This study
A23	Itabaiana National Park (ITA)	-37.3423;-10.7545	530	This study

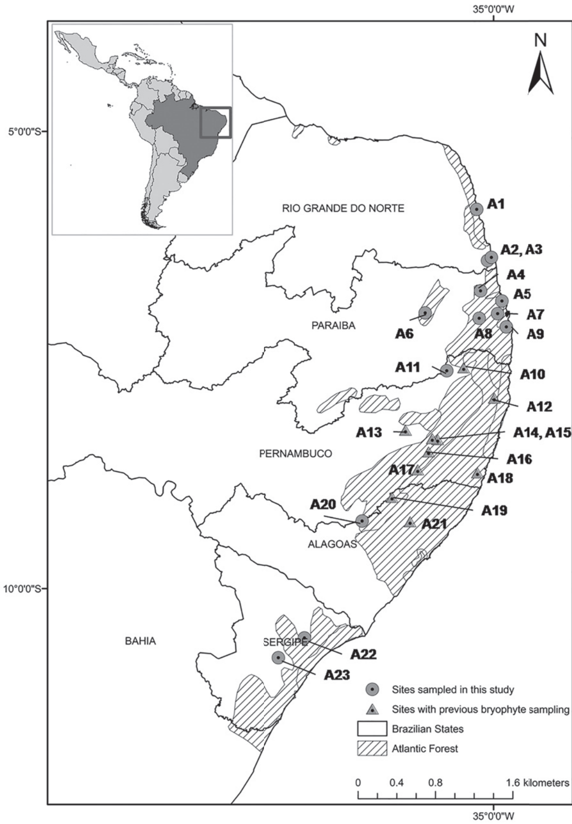

Figure 1. Location of the Atlantic Forest remnants surveyed in the present study. See Table 1 for site names.

annual precipitation varies between 1,300 and 2,400 mm, with a rainy season from March to September (Veloso *et al*. 1991).

Database

We built a comprehensive database of the bryophytes of the northeastern Atlantic forest. To this end, we reviewed literature of all bryophyte records in the area to identify sites with systematic bryophyte sampling, resulting in 10 locations that were integrated into the study (Table 1).

After the initial diagnosis of gaps in bryophyte sampling in the Northeast Atlantic Forest, 13 sites were selected to conduct further bryophyte surveys. To identify the highest possible bryoflora diversity, these locations were sampled for three days, during which exploratory walks were taken to collect plant material. Information from this sampling was incorporated into the literature review, so that the total database was composed of 23 sites in the Atlantic rainforest.

Study Material

The samples were identified to species level based on the literature (Ochi 1980; 1981; 1982; Sharp *et al.* 1994; Buck 1998; Reiner-Drehwald 1998; 2000; Gradstein & Costa 2003; Pursell 2007; Costa 2008) and submitted to the UFP herbarium, Department of Botany, Federal University of Pernambuco.

If necessary, the taxonomic nomenclature was updated using taxonomic revisions and checklists (Buck 1998; Crosby *et al.* 1999; Gradstein & Costa 2003; Bastos & Yano 2004; Pócs & Bernecker 2009), and the query database of the Missouri Botanical Garden (http://mobot.mobot.org/Pick/Search/most.html). The classification system of Crandall-Stotler *et al*. (2009) was adopted for liverwort and Goffinet *et al.* (2009) for mosses.

Data Analysis

For the determination of endemic taxa of the Atlantic Forest, Gradstein & Costa (2003) and Costa *et al.* (2011; 2014) were consulted.

To establish the distributions of functional groups, species were classified into functional groups according to their microhabitat preference, in the form of tolerance to light exposure (sun specialist, shade specialist or generalist) based on specialized work (Ochi 1980; 1981; 1982; Gradstein 1992; Sharp *et al.* 1994; Buck 1998; Heinrichs *et al.* 1998; Reiner-Drehwald 1998; 2000; Reiner-Drehwald & Goda 2000; Gradstein *et al.* 2001; Gradstein & Costa 2003; Bastos 2004; Bischler-Causse *et al.* 2005; Visnadi 2006; Pursell 2007; Reiner-Drehwald & Pôrto 2007; Costa 2008; Ilkiu-Borges & Alvarenga 2008; Alvarenga *et al.* 2009; 2010; Silva & Pôrto 2009; 2010; 2013; Oliveira *et al.* 2011; Glime 2012), expert consultation, and field experience of the authors. These functional groups have shown effective responses to loss and fragmentation of habitat in the Atlantic rainforest in previous studies (Alvarenga *et al.* 2009; 2010; Silva & Pôrto 2009; 2010; 2013; Oliveira *et al.* 2011). Owing to insufficient or duplicated information, four species were excluded from this analysis (Supplemental material 1).

Phylogenetic diversity (PD) was calculated using an adaptation of the method proposed by Faith (1992). However, for bryophytes, particularly for tropical species, there is no single classification system based on molecular analysis. Thus, the "phylogenetic tree" used was based on the taxonomic hierarchy of species, as indicated by Warwick & Clarke (1995; 1998). The calculation was performed with R 2.15.1 using the "vegan" package.

To identify the locations of greatest relevance to the conservation of bryophytes, three criteria were considered: 1) total richness and endemic species of the Atlantic Forest, 2) phylogenetic diversity (PD), and 3) proportion of indicator species for forest conservation (shade specialists).

Simple linear regression was used to identify dependences among these criteria and latitude using Statistica 8.0. Variables were logarithmically transformed (Zar 1999).

Results and discussion

Based on the literature survey, 371 specific taxa were compiled, distributed in 147 genera and 52 families, three hornworts (one family and two genera), 193 liverworts (18 families and 58 genera), and 178 mosses (34 families and 89 genera). Bryophyte sampling contributed 200 species, distributed in 95 genera and 40 families, with 103 liverworts (42 genera and 13 families), and 97 mosses (53 genera and 27 families). These inventories added 27 new species to the list based on the literature.

The combination of literature and sampling information thus led to a total of 396 spp. (3 hornworts, 203 liverworts, and 190 mosses), distributed in 52 families (Fig. 2). Of the 396, 13 species (3%) are endemic to the Atlantic Forest (9 liverworts and mosses 4) and 145 (37%) occur in only one location. Among the ten most frequent species, nine are generalist and one is a sun specialist: *Octoblepharum albidum* (22), *Cheilolejeunea rigidula* (21), *Sematophyllum subsimplex* (21), *Lejeunea laetevirens* (20), *Calymperes palisotii*, *Isopterygium tenerum*, *Leptolejeunea elliptica*, *Symbiezidium barbiflorum*, and *Taxithelium planum* (18 each) and *Sematophyllum subpinnatum* (17) (Supplemental material 1).

Together, the 396 bryophyte species of the northeastern Atlantic forest comprised an appreciable fraction of the total in the country, accounting for 26% of the total diversity of bryophytes in Brazil (1,527 spp. *sensu* Costa *et al.* 2014), 10% of the neotropics (4,000 spp.; Gradstein *et al*. 2001) and 2% of the world (18,000 spp.; Goffinet & Shaw 2009). Furthermore, 101 species were recorded for the first time for at least one of the five Brazilian states sampled. This result shows the importance of broad-scale studies to increase knowledge of Brazilian bryophytes. On the other hand, it also demonstrates sampling gaps in some Brazilian states. For example, *Chryso-hypnum diminutivum* is a widely distributed species in Brazil, being reported in 20 (77%) Brazilian states (Costa *et al.* 2014; Silva & Pôrto 2010; 2013; Oliveira *et al.* 2011). However, the present study includes the first record for Paraíba and Sergipe, probably owing to a lack of previous sampling in those areas. This situation can be observed for several other species, such as *Fissidens zollingeri* and *Pilosium chlorophyllum*, recorded in 23 (88%) and 24 (92%) of the states of Brazil, respectively (Costa *et al.* 2014), and here reported for the first time in the state of Rio Grande do Norte.

Certainly owing to the large size of Brazil, studies of bryophyte diversity on a regional scale are rare. The studies of Santos *et al*. (2011) for the Atlantic Forest and Mota de Oliveira *et al*. (2009) and Mota de Oliveira (2010) for the Amazon rainforest can be cited. Santos *et al.* (2011) recorded 192 species of bryophytes in Restinga Forest and Lowland Forest areas in the Southeast and found that, when evaluated in terms of landscape, the two forest formations formed distinct floristic groups. However, at the regional level the bryophytes had more affinities with one another than with those of other phyto-physionomically similar areas of the Atlantic Forest.

For the Amazon Rainforest, Mota de Oliveira *et al.* (2009) and Mota de Oliveira (2010) presented a systematic approach to identify community structures of epiphytic bryophytes in a transect from east to west across the Amazon Basin that resulted in the identification of 225 species and 38 morphospecies. For the Atlantic Forest, the present study is the first contribution to the knowledge of communities of bryophytes at the regional level. It was observed that, even considering differences in methodologies, overall bryofloristic richness was higher in the northeastern Atlantic forest than in the Amazon, an observation that is recurrent in the literature (Gradstein *et al.* 2001; Gradstein & Costa 2003; Costa *et al.* 2011).

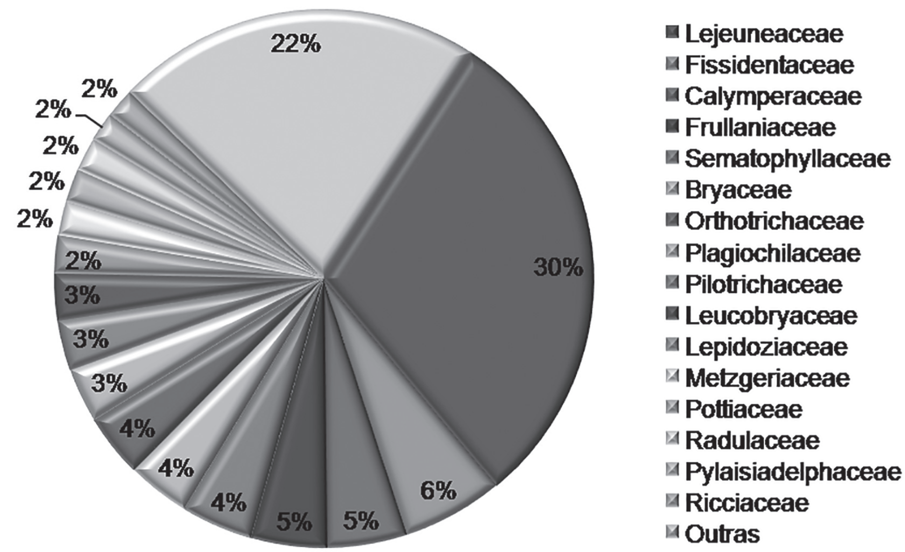

Figure 2. Representatives of the main families of bryophytes, compiled by literature review and inventory performed in the present study.

In total, 300 species of liverworts (Gradstein & Costa 2003) and 350 species of mosses (Costa *et al.* 2011) have been registered for the Amazon rainforest, whereas in the Atlantic forest these figures are larger (500 spp. of liverworts and 700 spp. of mosses). However, these authors argue that the great richness of the Atlantic Forest is due to the presence of areas with high elevation (>1000 m), especially in the southeast, which are unusual in the Amazon Rainforest. For the northeast, areas with an altitude between 30 and 990 m were analyzed, and even then, the higher floristic variety of the Atlantic Forest was confirmed.

It is noteworthy that generalist species predominated (164 spp., 41%), followed by specialists in shade (133 spp., 34%) and sun (92 spp., 23%) (for 7 spp., 2%, there was no information on specialism). This result is recurrent in the literature for the Northeast Atlantic Forest (Alvarenga & Pôrto 2007; Silva & Pôrto 2009; 2010) and other tropical forests (Acebey *et al.* 2003). These studies showed that shade specialists are more sensitive to deforestation, and sometimes are completely absent from degraded sites, followed by sun specialists, whereas generalists are indifferent. Thus, degradation and loss of habitat recurring in the region (*sensu* Tabarelli *et al.* 2006) are indicated as causes of the predominance of generalists (Naaf & Wulf 2010).

Species richness ranged from 12 (PDU and APA) to 199 spp. (MUR) (Table 2). An increase in richness ($R^2 = 0.35$, $p < 0.01$), phylogenetic diversity ($R^2 = 0.41$, $p < 0.001$) and the proportion of shade specialists ($R^2 = 0.26$, $p = 0.01$) in a north-to-south direction (that is, with increasing latitude), was observed. However, the number of endemic species did not vary significantly with latitude ($R^2 = 0.08$, $p = 0.17$).

The Murici Ecological Station (MUR) also had the highest number of endemic species (5 spp.), followed by VSO (3 spp.). These two sites, together with FCA (119 spp.), harbor high diversity, a result in agreement with several reports on ecological groups including birds (Roda & Pereira 2006), reptiles (Guedes *et al.* 2011), mammals (Asfora Mendes & Pontes 2009), bryophytes (Pôrto 1990; Pôrto *et al.* 2006), and angiosperms (Grillo *et al.* 2006).

Table 2. Phylogenetic diversity (PD), percentage of shade specialist species, and numbers of endemic (Brazilian) species of bryophytes of the northeastern Atlantic forest sites surveyed in the present study. For site abbreviations see Table 1.

Site	Number of species	Number of endemic species	Phylogenetic diversity (PD)	% shade specialists
PDU	12	0	269,4	0
MBL	24	0	407,1	0
MET	20	1	392,2	15
GBA	40	0	700,1	13
APA	12	0	277,3	0
PFE	50	1	869,8	18
GGA	35	0	620,7	9
PAC	46	0	954,6	24
JBB	21	0	440,7	10
AZU	70	0	1090,4	30
MDE	99	1	1628,2	34
DIR	59	1	809,6	12
BIT	90	2	1218,9	26
GJA	105	2	1427,9	24
VSO	157	3	1855,8	31
BOT	80	0	1215,8	31
FCA	119	1	1619,1	34
SAL	86	1	1180,8	19
SGR	75	0	1141,2	29
PTA	103	0	1651,7	25
MUR	199	5	2313,7	30
MJU	62	0	1074,4	15
ITA	70	1	1082,2	19

Among the studied Conservation Units, the Murici Ecological Station stood out. It is an Integral Protection Conservation Unit and was created to protect one of the largest remnants of Atlantic Forest in the northeast of Brazil (ca. 6,100 ha) and to promote the development of scientific research and environmental education programs. It is the site with the highest concentration of threatened taxa in northeast Brazil: 27 taxa endemic to Centro Pernambuco (*sensu* Olmos 2005) and 5 more widely distributed taxa (Olmos 2005). The area has been the subject of several studies (Ferrarezzi & Freire 2001; Olmos 2005; Moura 2006; Roda & Pereira 2006; Guadanucci *et al*. 2007; Rodrigues & Buckup 2007; Ilkiu-Borges & Alvarenga 2008; Alvarenga *et al*. 2009; 2010; Guedes *et al*. 2011; Nascimento & Campos 2011; Oliveira *et al*. 2011; Silva & Pôrto 2009; 2010; Pôrto *et al*. 2012).

On the other hand, even though the reserve is still widely covered, most forest fragments do not reach 1,000 ha and all are immersed in a very inhospitable matrix, consisting of pasture for cattle and sugar cane (Silva & Pôrto 2009; Pôrto *et al*. 2012). Selective logging, firewood, hunting, and animal poaching, particularly of birds for captive breeding and wildlife trafficking (Pôrto *et al*. 2012), are additional problems. Thus, we emphasize the vital significance of the Conservation Unit for regional bryophytes and suggest the implementation of effective public policies in APA Murici, a buffer zone in areas surrounding the Murici Ecological Station, especially in the areas of remaining private forest belonging to the sugar mills in the region.

It is noteworthy that *Fissidens flabellatus* and *Syrrhopodon brasiliensis*, endemic mosses endemic of Brazil, have been reported here for the first time in the Brazilian Northeast, recorded in MET and ITA, respectively.

Despite the high richness and presence of endemic species relevant to conservation in the Northeast Atlantic Forest, logging, cultivation of sugar cane, and hunting are common practices. Thus, we emphasize the vital importance of the Northeast Atlantic Forest to the national bryophytes and suggest the implementation of effective conservation activities in the region, especially in the Murici Ecological Station and FCA as well as in private forest remnants.

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References

Acebey A, Gradstein SR, Krömer T. 2003. Species diversity and habitat diversification of epiphytic bryophytes in submontane forest and fallows in Bolivia. Journal of Tropical Ecology 19: 9-18.

Alvarenga LDP, Pôrto KC. 2007. Patch size and isolation effects on epiphytic and epiphyllous bryophytes in the fragmented Brazilian Atlantic Forest. Biological Conservation 134: 415-427.

Alvarenga LDP, Oliveira JRPM, Silva MPP, Costa SO, Pôrto KC. 2008. Liverworts of Alagoas State, Brazil. Acta Botanica Brasilica 22: 878-890.

Alvarenga LDP, Pôrto KC, Silva MPP. 2009. Relations between regional–local habitat loss and metapopulation properties of epiphyllous bryophytes in the Brazilian Atlantic Forest. Biotropica 41: 682-691.

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.

Andrade-Lima D. 1982. Present day forest refuges in Northeastern Brazil. In: Prance GT. (ed.) Biological diversification in the Tropics. New York, Columbia University. p. 245-254.

Angelo C. 2013. Florestas mais iguais - Proliferação de espécies nativas resistentes a perturbações no ambiente reduz a biodiversidade da Mata Atlântica. Pesquisa FAPESP 203: 58-61.

Asfora PH, Mendes Pontes AR. 2009. The small mammals of the highly impacted North-eastern Atlantic Forest of Brazil, Pernambuco Endemism Center. Biota Neotropica 9: 31-35.

Bastos CJP. 2004. Lejeuneaceae (Marchantiophyta) no estado da Bahia, Brasil. PhD Thesis. Universidade de São Paulo, Brazil.

Bastos CJP, Yano O. 2004. O gênero *Lejeunea* Libert (Lejeuneaceae) no Estado da Bahia, Brasil. Hoehnea 36: 303-320.

Bischler-Causse H, Gradstein SR., Jovet-Ast S, Long DG, Allen NS. 2005. Marchantiidae. Flora Neotropica. New York, New York Botanical Garden.

Buck WR. 1998. Pleurocarpous Mosses of the West Indies. Memoirs of the New York Botanical Garden 1: 1-401.

Campanili M, Prochnow M. 2006. Mata Atlântica, uma rede pela floresta. Brasília, RMA.

Campelo MJA, Pôrto KC. 2007. Brioflora epífita e epífila da RPPN Frei Caneca, Jaqueira, PE, Brasil. Acta Botanica Brasilica 21: 185-192.

Conservação Internacional do Brasil; Fundação SOS Mata Atlântica; Fundação Biodiversitas; Instituto de Pesquisas Ecológicas & Secretaria do Meio Ambiente do Estado de São Paulo. 2000. Avaliação e Ações Prioritárias para Conservação da Biodiversidade da Mata Atlântica e Campos Sulinos. Brasília, Ministério do Meio Ambiente.

Costa DP. 2008. Metzgeriaceae. Flora Neotropica Monograph 102. New York, New York Botanical Garden.

Costa DP, Pôrto KC, Luizi-Ponzo AP, *et al*. 2011. Synopsis of the Brazilian moss flora: checklist, distribution and conservation. Nova Hedwigia 93: 277-334.

Costa DP, Câmara PEAS, Pôrto KC, Luizi-Ponzo AP, Ilkiu-Borges AL. 2014. Briófitas. Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/2010/FB096039 01 Sep. 2013.

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

Crosby MR, Magill RE, Allen B, He S. 1999. A Checklist of the Mosses. St. Louis, USA, Missouri Botanical Garden.

Faith DP. 1992. Conservation evaluation and phylogenetic diversity. Biological Conservation 61: 1-10.

Ferrarezzi H, Freire EMX. 2001. New species of *Bothrops* Wagler, 1824 from the Atlantic forest of northeastern Brazil (Serpentes, Viperidae, Crotalinae). Boletim do Museu Nacional Nova Série, Zoologia 440: 1-10.

Fundação Biodiversitas 2005. Espécies Ameaçadas online. http://www.biodiversitas.org.br/boletim/EAO/ 05 Feb. 2013.

Germano SR, Pôrto KC. 1996. Floristic survey of epixylic bryophytes of an Area Remnant of the Atlantic Forest (Timbaúba – PE, Brazil). 1. Hepaticopsida (except Lejeuneaceae) and Bryopsida. Tropical Bryology 12: 21-28.

Germano SR, Pôrto KC. 1997. Ecological analysis of epixylic bryophytes in relation to the decomposition of the substrate (Municipality of Timbaúba – Pernambuco, Brazil). Cryptogamie, Bryologie, Lichenologie 18: 143-150.

Germano SR, Pôrto KC. 1998. Briófitas epíxilas de uma área remanescente de Floresta Atlântica (Timbaúba, PE, Brasil). 2. Lejeuneaceae. Acta Botanica Brasilica 12: 53-66.

Germano, SR, Pôrto KC. 2005. A bryophyte checklist of the Ecological Reserve of Gurjaú, Pernambuco, Brazil. Tropical Bryolog 26: 1-12.

Glime J. 2012. Bryophyte Ecology. http://www.bryoecol.mtu.edu. 03 Mar. 2013.

Goffinet B, Buck WR, Shaw AJ. 2009. Morphology, anatomy, and classification of the Bryophyta. In: Goffinet B, Shaw AJ. (eds.) Bryophyte Biology, 2nd edition. Cambridge, Cambridge University Press. p. 56-138.

Goffinet B, Shaw AJ. 2009. Bryophyte Biology, 2nd edn. Cambridge, Cambridge University Press.

Gradstein SR. 1992. Threatened bryophytes of the neotropical rain forest: a status report. Tropical Bryology 6: 83-93.

Gradstein SR, Costa DP. 2003. The Hepaticae and Anthocerotae of Brazil. Memoirs of the New York Botanical Garden 88: 1-673.

Gradstein SR, Churchill SP, Salazar AN. 2001. Guide to the Bryophytes of Tropical America. Memoirs of the New York Botanical Garden 86: 1-577.

Grillo A, Oliveira MA, Tabarelli M. 2006. Árvores. In: Pôrto KC, Almeida-Cortez JS, Tabarelli M. (eds.) Diversidade biológica e conservação da Foresta Atlântica ao norte do Rio São Francisco. Brasília, Ministério do Meio Ambiente. p. 191-216.

Guadanucci JPL, Lucas SM, Indicatti RP, Yamamoto FU. 2007. Description of *Guyruita* gen. nov. and two new species (Ischnocolinae, Theraphosidae). Revista Brasileira de Zoologia 24: 991-996.

Guedes TB, Nunes GSS, Prudente ALC, Marques OAV. 2011. New records and geographical distribution of the Tropical Banded Treesnake *Siphlophis compressus* (Dipsadidae) in Brazil. Herpetology Notes 4: 341-346.

Heinrichs J, Gradstein SR, Grolle R. 1998. A revision of the Neotropical species of *Plagiochila* (Dumort.) Dumort. (Hepaticae) described by Olof Swartz. Journal of the Hattori Botanical Laboratory 85: 1-32.

Ilkiu-Borges AL, Alvarenga LDP. 2008. On *Ceratolejeunea atlantica*, a new species of Lejeuneaceae (Jungermanniopsida) from Brazil. Nova Hedwigia 86: 237-241.

MMA - Ministério do Meio Ambiente. 2008. Instrução Normativa nº 6, 23 de setembro de 2008.

Mota de Oliveira S. 2010. Diversity of epiphytic bryophytes across the Amazon. PhD Thesis. Universiteit Utrecht, Holanda.

Mota de Oliveira S, ter Steege H, Cornelissen JHC, Gradstein SR. 2009. Niche assembly of epiphytic bryophyte communities in the Guianas: a regional approach. Journal of Biogeography 36: 2076-2084.

Moura FBP. 2006. A Mata Atlântica em Alagoas. Maceió, EDUFAL.

Naaf T, Wulf M. 2010. Habitat specialists and generalists drive homogenization and differentiation of temperate forest plant communities at the regional scale. Biological Conservation 143: 848-855.

Nascimento JL, Campos IB. 2011. Atlas da fauna brasileira ameaçada de extinção em Unidades de Conservação federais. Brasília, Instituto Chico Mendes.

Ochi H. 1980. A revision of the Neotropical Bryoideae, Musci (First part). Journal of the Faculty of Education, Tottori University, Natural Science 29: 45-154.

Ochi H. 1981. A revision of the Neotropical Bryoideae, Musci (Second part). Journal of the Faculty of Education, Tottori University, Natural Science 30: 21-55.

Ochi H. 1982. A revision of Bryoideae (Musci) in Southern South America. Journal of the Faculty of Education, Tottori University, Natural Science 31: 11-47.

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.

Olmos F. 2005. Aves ameaçadas, prioridades e políticas de conservação no Brasil. Natureza & Conservação 3: 21-42.

Pócs T, Bernecker A. 2009. Overview of *Aphanolejeunea* (Jungermanniopsida) after 25 years. Polish Botanical Journal 54: 1-11.

Pôrto KC. 1990. Bryoflores d'une forêt de plaine et d'une forêt d'altitude moyenne dans l'État de Pernambuco (Brésil), Analyse floristique. Cryptogamie, Bryologie, Lichenologie 11: 109-161.

Pôrto KC, Oliveira SM. 1998. Biodiversidade e Biologia reprodutiva de briófitas da Reserva Ecológica de Dois Irmãos. In: Machado IC, Lopes AV, Pôrto KC. (eds.) Reserva Ecológica de Dois Irmãos: estudos em um remanescente de Mata Atlântica em Área Urbana (Recife – Pernambuco – Brasil). Recife, SECTMA. p. 115-135.

Pôrto KC, Germano SR. 2002. Biodiversidade e importância das briófitas na conservação dos ecossistemas naturais de Pernambuco. In: Tabarelli M, Silva JMC. (eds.) Diagnóstico da biodiversidade de Pernambuco. Recife, Editora Massangana. p. 125-152.

Pôrto KC, Belo MML, Fonseca ER, Silva EC. 1993. Brioflora da Reserva do Gurjaú (Cabo - PE). Biologica Brasilica 5: 27-42.

Pôrto KC, Gradstein SR, Yano O, Germano SR, Costa DP. 1999. New and interesting records of Brazilian bryophytes. Tropical Bryology 17: 19-45.

Pôrto KC, Germano SR, Oliveira SM. 2000. New records of bryophytes Pernambuco State, Brazil. Tropical Bryology 18: 107-114.

Pôrto KC, Cabral JJP, Tabarelli M. 2004. Brejos de altitude em Pernambuco e Paraíba. História Natural, Ecologia e Conservação. Brasília, MMA.

Pôrto KC, Alvarenga LDP, Santos GHF. 2006. Briófitas. In: Pôrto KC, Almeida-Cortez JS, Tabarelli M. (eds.) Diversidade Biológica e Conservação da Floresta Atlântica ao Norte do Rio São Francisco. Brasília, MMA. p. 25-37.

Pôrto KC, Barbosa MCA, Cavalcanti e Silva IC, Silva MPP. 2012. Estação Ecológica de Murici, Alagoas, Brasil: espécies ameaçadas, nativas e raras. Recife, Fundação Grupo O Boticário de Proteção À Natureza.

Pursell RA. 2007. Fissidentaceae. Flora Neotropica Monograph 101. New York, New York Botanical Garden.

Reiner-Drehwald ME. 1998. Las Lejeuneaceae (Hepaticae) de Misiones, Argentina V. *Cheilolejeunea* y *Lepidolejeunea*. Tropical Bryology 14: 53-68.

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

Reiner-Drehwald ME, Goda A. 2000. Revision of the genus Crossotolejeunea (Lejeuneaceae, Hepaticae). Journal of the Hattori Botanical Laboratory 89: 1-54.

Reiner-Drehwald ME, Pôrto KC. 2007. *Lejeunea perpapillosa* (Lejeuneaceae), a new species from north-eastern Brazil. Nova Hedwigia 85: 541-546.

Roda SA, Pereira GA. 2006. Distribuição recente e conservação das aves de rapina florestais do Centro Pernambuco. Revista Brasileira de Ornitologia 14: 331-344.

Rodrigues ENL, Buckup EH. 2007. O gênero *Nesticella* Lehtinen & Saaristo (Araneae, Nesticidae) no Brasil. Revista Brasileira de Zoologia 24: 673-676.

Sá PSA, Pôrto KC. 1996. Novos registros de Hepaticopsida para Pernambuco. Revista Nordestina de Biologia 11: 37-43.

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). Biota Neotropica (Edição em português. Impresso) 11: 1-14.

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

Silva MPP, Pôrto KC. 2009. Effect of fragmentation on the community structure of epixylic bryophytes in Atlantic Forest remnants in the Northeast of Brazil. Biodiversity and Conservation 18: 317-337.

Silva MPP, Pôrto KC. 2010. Spatial structure of bryophyte communities along an edge-interior gradient in an Atlantic Forest remnant in Northeast Brazil. Journal of Bryology 32: 101-112.

Silva MPP, Pôrto KC. 2013. Bryophyte communities along horizontal and vertical gradients in a human-modified Atlantic Forest remnant. Botany 91: 155-166.

Tabarelli M, Pinto LP, Silva JMC, Hirota M, Bedê L. 2005. Challenges and opportunities for biodiversity conservation in the Brazilian Atlantic Forest. Conservation Biology 19: 695-700.

Tabarelli M, Siqueira Filho JA, Santos AMM. 2006. A Floresta Atlântica ao norte do rio São Francisco. In: Pôrto KC, Almeida-Cortez JS, Tabarelli M. (eds.) Diversidade Biológica e Conservação da Floresta Atlântica ao Norte do Rio São Francisco. Brasília, MMA. p. 25-40.

Valdevino JA, Sá PS, Pôrto KC. 2002. Musgos pleurocárpicos de mata serrana em Pernambuco, Brasil. Acta Botanica Brasilica 16: 161-174.

Valente EB, Pôrto KC. 2006. Hepáticas (Marchantiophyta) de um fragmento de Mata Atlântica na Serra da Jibóia, município de Santa Teresinha, Bahia, Brasil. Acta Botanica Brasilica 20: 433-441.

Valente EB, Pôrto KC, Bôas-Bastos SBV, Bastos CJP. 2009. Musgos (Bryophyta) de um fragmento de Mata Atlântica na Serra da Jibóia município de Santa Terezinha, Bahia, Brasil. Acta Botanica Brasilica 23: 369-375.

Valente EB, Pôrto KC, Bastos CJP. 2011. Checklist of Bryophytes of Chapada Diamantina, Bahia, Brazil. Boletim do Instituto de Botânica (São Paulo) 21: 111-124.

Veloso HP, Rangel Filho ALR, Alves-Lima JC. 1991. Classificação da vegetação brasileira, adaptada a um sistema universal. Rio de Janeiro, Fundação IBGE.

Visnadi SR. 2006. Sematophyllaceae da Mata Atlântica do nordeste do Estado de São Paulo. Hoehnea 33: 455-484.

Warwick RM, Clarke KR. 1995. New "biodiversity" measures reveal a decrease in taxonomic distinctness with increasing stress. Marine Ecology, Progress Series 129: 301-305.

Warwick RM, Clarke KR. 1998. Taxonomic distinctness and environmental assessment. Journal of Applied Ecology 35: 532-543.

Yano O, Andrade-Lima D. 1987. Briófitas no Nordeste brasileiro: Estado de Pernambuco. Revista Brasileira de Botânica 10: 171-181.

Zar JH. 1999. Biostatistical analysis. 4th edn. Upper Saddle River, Prentice Hall.