Biodiversity survey, ecology and new distribution records of *Marchantiophyta* in a remnant of Brazilian Atlantic Forest

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ABSTRACT – We present the results of a survey of the liverwort species occurring in a fragment of dense montane ombrophilous forest in Parque Nacional de Boa Nova, located in a transition zone between Caatinga and Atlantic Forest in southwestern Bahia State, Brazil. A total of 126 species distributed among 41 genera and 14 families were found. Sixteen species are reported for the first time from the state of Bahia, while ten species represent new records for the Northeast Region of Brazil. The family *Acroblaceae* E.A. Hodgs and the genus *Dicranolejeunea* (Spruce) Schiffn. are also reported for the first time from Bahia. *Cololejeunea winkleri* (Morales & Benecker) Bernecker & Pócs, is cited for the first time from the Brazilian Atlantic Forest. The results obtained in this study demonstrate the importance of Parque Nacional de Boa Nova for the conservation of bryophyte biodiversity in Brazil.

Keywords: Bahia, bryophytes, phytogeography, liverworts


Palavras-chave: Bahia, briófitas, fitogeografia, hepáticas

INTRODUCTION

The Atlantic Forest is considered a global conservation priority, and is an important center of bryophyte diversity (Gradstein et al. 2001, Mittermeier et al. 2006, Silva & Pôrto 2014). Despite high endemism and biodiversity, this biome has been subjected to extensive destruction that has dramatically reduced its coverage to approximately 11% to 16% of its original extent (Ribeiro et al. 2009).

The few remnants of Atlantic Forest that remain in the Northeast Region of Brazil are estimated to cover only 2% of its original area in the region (Tabarelli et al. 2002). These remnants occupy a thin coastal strip from the state of Rio Grande do Norte to extreme southern Bahia, where it extends inland (Silva & Pôrto 2014). Several studies have emphasized the importance of the Atlantic Forest in southern Bahia as one of the main sites of plant endemism in the World (Gentry 1992, Martini et al. 2007).

Studies on bryophyte diversity in the Brazilian Atlantic Forest have historically been concentrated in the South and Southeast regions of the country (e.g. Bordin & Yano 2009, Costa 1995, Costa & Yano 1995, 1998, Costa et al. 2015, Santos & Costa 2008, Schäfer-Verwimp 1991, Visnadi & Vital 1989, 2000, Yano & Colletes 2000, Visnadi 2002, 2005, 2006, 2015, Yano & Peralta 2008, 2009, 2011). However, the Northeast Region has recently received increasing attention, which has resulted in a better comprehension of the bryophyte flora of the Atlantic Forest (Silva & Pôrto 2014). It is estimated that approximately 1,524 bryophyte species occur in this biome (Costa & Peralta 2016), with 788 in the Atlantic Forest of the Northeast Region (Silva & Pôrto 2014). Research in the state of Bahia has contributed significantly to this increased knowledge, accounting for more than 50% of the scientific production in the region (Silva & Pôrto 2014).

Several studies on liverwort flora have been carried out in Bahia over the last two decades, most of which have provided new species records from a variety of localities in the state (Bastos et al. 1998a, Bastos & Vilas Bôas-Bastos 2000a; b, Bastos 2011, 2012, Bastos & Yano 2002, 2004, 2005, Bastos & Gradstein 2006, Valente & Pôrto 2006a). Data on the bryophyte flora of rupestrian...
grasslands ( campos rupestres) of Chapada Diamantina were provided by Bastos et al. (2000), for various areas of Chapada Diamantina by Valente et al. (2011) and for the Caatinga by Bastos et al. (1998b). Specific floristic data on liverworts were provided by Bastos & Valente (2009) for the Michelin Ecological Reserve, by Valente & Pôrto (2006b) for Serra da Jibóia. Valente et al. (2011, 2013a; b) and Oliveira & Bastos (2014) reported on ecological studies undertaken in Chapada Diamantina and the Michelin Ecological Reserve, respectively.

The aim of the present study was to present the results of a survey of liverwort species in a fragment of dense montane ombrophilous forest located in Parque Nacional de Boa Nova. Floristic and ecological information, specifically with regard to Brazilian and global phytogeographical patterns, and the distribution of species on different substrates in the study area, was also gathered. The data obtained contribute to a better understanding of the bryophyte flora of ecotonal vegetation within the state of Bahia.

**MATERIAL AND METHODS**

**Study site**

Parque Nacional de Boa Nova is located in the municipality of Boa Nova, northeast of the Plateau of Vitória da Conquista and south of the Rio de Contas (Bencke et al. 2006) (Fig. 1). The park encompasses approximately 120 km², and was established as a Protected Area in 2010 by Decree No. 12642, of June 11, 2010. The park is located in a transition zone between Atlantic Forest and Caatinga (Brasil 2010) and includes a variety of phytosociomomies, such as dense montane ombrophilous forest, deciduous and semi-deciduous seasonal forests, and open and arboreal caatinga. This region is considered a priority area for conservation of flora, and bird and invertebrate fauna in Brazil (Gonzaga et al. 1995, MMA 2000, Bencke et al. 2006, Develey & Goerck 2009).

The fragment studied is located in the eastern portion of the park (14°24'53"S, 40°07'55.6"W) in an area classified as dense montane ombrophilous forest at 764–1043 m a.s.l., where forest remnants are confined to hilltops and hillsides (Bencke et al. 2006, Develey & Goerck 2009). Dense ombrophilous forests typically occur in tropical climates with high temperatures (above 25°C), heavy rainfall and few dry days, and contain high densities of epiphytes (IBGE 2012).

**Data sampling and analysis**

Botanical material was collected during four expeditions, totaling 10 sampling days, in 2013 and 2014. Plants were collected along trails and in the forest interior, with the substrates on which they were growing being recorded for later assessment of their ecological spectrum (i.e., the diversity of substrates colonized by the communities Fudali 2000). The substrates considered were based on Richards (1984) and Fudali (2001), and included: five trunks (corticicolous), decomposing trunks (epixilous), soil (terricolous), leaves (epiphyllous) and rocks (saxicolous). Collected samples were placed in paper bags and herborized according to the methodology proposed by Frahm (2003). Vouchers were deposited in the herbarium of the Universidade Estadual de Feira de Santana, Bahia (HUEFS).


The geographical distributions in Brazil of the species collected were analyzed in consultation with Brazilian Flora 2020 (FBO 2016), published reports from floristic surveys and new records reported for species in different states of Brazil. Nationwide distribution patterns of species were classified according to frequency of occurrence across Brazilian states as: narrow (1–4 Brazilian states), moderate (5–9 Brazilian states), and wide (more than 10 Brazilian states). Phytogeographical patterns were based on Gradstein & Costa (2003), Valente & Pôrto (2006b), Campelo & Pôrto (2007), Alvarenga et al. (2008), Santos & Costa (2008), Bastos & Valente (2009), Oliveira & Bastos (2009), Valente et al. (2013a, b) and Oliveira & Bastos (2014).

Floristic surveys from other areas of the Atlantic Forest of Brazil where consulted for comparisons with the data from the present survey (Tab. 1). For this, a presence/absence spreadsheet was created with rare species (i.e., present in only one area) being excluded.

The Jaccard index was used to determine the floristic similarity between different areas. This index is based on the correlation between the species that are present in two areas and the number of species unique to each area (Muller-Dombois & Ellenberg 1974). The results of this analysis were used to construct a dendrogram using the unweighted pair group method with arithmetic mean (UPGMA) in FITOPAC 2.0. (Shepherd 2007).

**RESULTS AND DISCUSSION**

**Species richness and new records**

A total of 918 specimens were analyzed and 126 species were identified, belonging to 41 genera and 14 families (Tab. 2). Of the total number of species, 16 were reported for the first time from Bahia, 10 of which were also new records for the Northeast Region of Brazil.

The family Acrobolbaceae E.A. Hodgs.is reported for the first time in the Northeast Region. According to Costa (2015), three genera of Acrobolbaceae have been reported from Brazil, namely Lethocolea Mitt., Marsupidium Mitt. and Tylimanthus Mitt. The genus Tylimanthus has been recorded in the Brazilian states of Mato Grosso, Mato Grosso do Sul, Paraná, São Paulo, Rio de Janeiro and Espírito Santo, in areas of Cerrado, Pantanal and Atlantic...
The genus *Tylimanthus* is recognized by its glossy whitish-green to bluish gametophytes, which form dense tufts. The leaves are oblique and succous, with a truncated to emarginated apex, cells with trigons and numerous oil bodies, and a papillose cuticle (Gradstein & Costa 2003). In Brazil this genus is represented by the species *Tylimanthus laxus* (Lehm. & Lindenb.) Spruce (Gradstein & Costa 2003, Costa 2015), and, in the present study was found growing on live trunks. This species is rare in Brazil and has been found in rainforests, riparian forests, high altitude fields (campos de altitude) and cerrado (Costa 2015).

The genus *Dicranolejeunea* (Spruce) Schiffn. (Fig. 2) is also reported for the first time from the Northeast Region. This genus is widely distributed throughout tropical America where it is represented by a single species, *Dicranolejeunea axilaris* (Nees & Mont.) Schiffn.. In Brazil this species, which has been found in the states of Paraná, Rio de Janeiro and Espírito Santo (Costa et al. 2015), occurs in dense and mixed ombrophilous forest. Its diagnostic characteristics are a glossy brownish-green gametophyte with a predominantly *Frullania*-type branching pattern, stems with protruding cortical cells and medullar cells with thickened walls, oblique and dentate leaves that are convoluted when dehydrated and have small lobes, dentate female bracteoles and a flat ciliate-laciniate perianth that lacks a peduncle (Kruijfit 1988; Gradstein 1994; Gradstein & Costa 2003).

*Cololejeunea winkleri* (Morales & Benecker) Bernecker & Pócs, is a new record for the Northeast Region of Brazil, formerly known only from the Amazon in the states of
Amazonas and Pará (Gradstein & Costa 2003, Ilkiu-Borges & Lisboa 2004; Costa et al. 2015). The species is easily recognized by the rounded opening in the apex lobe formed by the apical tooth and a protuberance of approximately two cells long on the margin of the ventral lobe (Ilkiu-Borges & Lisboa 2004).

Riccardia schwanekei (Steph.) Pagán, Calypogea uncinulatula Herzog, Drepanolejeunea biocellata A. Evans, Lejeunea raddiana Lindencb., Plagiochila macrostachya Lindencb., Plagiochila stricta Lindencb. and Radula nudicaulis Steph. are also new records for the Northeast Region of Brazil. Anaira pinguis (L.) Dumort., Kymatocalyx dominicensis (Spruce) Vána, Frullania serrata Gottsche, Frullanoides liebmanniana (Lindencb. & Gottsche) van Slageren, Leptolejeunea obfuscata (Spruce) Steph. and Metzgeria conjugata Lindencb. are all new records for the state of Bahia. All these species occur in Atlantic Forest, and especially in dense and mixed ombrophilous forest, but also gallery forests. Some species are known to also occur in cerrado (T. laxus, C. uncinulatula, F. liebmanniana and L. obfuscata), the Amazon (P. macrostachya, C. winkleri, F. liebmanniana, L. obfuscata), the Pantanal (T. laxus, A. pinguis) and the Pampas (R. schwanekei). The remaining species occur only in Atlantic Forest.

Marchesinia bongdariae (Lehm. and Lindencb.) Trevis., is not considered a new record for Brazil in this work. This species was long treated as a synonym of Marchesinia brachiata (Sw.) Schiffn. However, molecular studies performed by Heinrichs et al. (2009) demonstrated that these are indeed two distinct species. The authors indicate that this species differs from M. brachiata by having loosely-arranged amphigastria on the caulidium and not moderately recurrent, as in M. brachiata. Marchesinia brachiata is widely distributed in Brazil, and additional research on these two species is needed.

Lejeuneaceae had the highest generic and specific richness, accounting for 53% of the total number of species in the area, followed by Plagiochiaceae and Frullaniaceae, with 17 and 7 species, respectively. Plagiochila (Dumort) Dumort was the most represented genus with 17 species, followed by Lejeunea Lib. with 13 species. Gradstein & Pócs (1989) point out that 90% of the entire diversity of bryophytes in tropical rainforests belongs to 15 families, among them Lejeuneaceae, Frullaniaceae, Lepidoziaceae, Plagiochiaceae, and Radulaceae. The results obtained here corroborate previously studies, which found high prevalences of Lejeuneaceae in tropical forests, which, according to Gradstein (1995), represents about 70% of the diversity of bryophytes in lowland ombrophilous forests. Lejeuneaceae also stood out as the most abundant family in the present study, with almost 420 samples being collected. Ceratolejeunea cornuta (Lindencb.) Schiffn. was the most abundant species in the area, being found in 53 samples, followed by Lejeunea flava (Sw.) Nees and Omphalanthus filiformis (Sw.) Nees, found in 51 and 31 samples, respectively.

Ecological spectrum

Regarding the ecological spectrum of substrates, corticicolous species (82 species) were most prevalent, followed by epixilous (69), terricolous (39), saxicolous (30), and epiphyllous (28) species (Fig. 3). Approximately 45% (58) of the species exhibited substrate specialization, most of which were corticicolous (24), epiphyllous (11) or epixilous (10). Sixty-six species colonized two to four substrates. Among the species that were found on multiple types of substrates, Cheirolejeunea oncophylla (Aongström) Grolle & E. Reiner, Lejeunea flava (Sw.) Nees, and Plagiochila patentissima Lindencb. stood out because they colonized all substrate types considered. The predominance of corticicolous bryophyte communities is expected in tropical forests, where there is great availability of live-trunks, which are the preferred substrates of liverwort species. The high number of epixilous species in the present study can be attributed to large tree-falls in the forest, which destroys smaller trees and leads to an increase in the availability of this substrate (personal observation).

Epiphyllous communities develop under specific conditions of humidity and shade, which are typically present only in rainforests (Richards 1954, 1984). In the studied area, 28 species were found in the phyllophore, with 11 of them being specific to this substrate type. More than 80% of the 28 species belong to the family Lejeuneaceae were epiphyllous, which is, according to Gradstein (1994; 1997), one of the families with the greatest evolutionary success in colonizing this substrate. As epiphyllous are extremely sensitive to microclimatic conditions (Gradstein et al. 2001), they can be indicative of environment quality. Although the studied forest area has been anthrropized and used for eco-tourism, a significant number of epiphyllous species was still found, probably due to the high humidity of the site throughout the entire year (personal observations of the first author). Leptolejeunea exocellata (Spruce) A. Evans, Cololejeunea papilliloba (Steph.) Steph. and Diplasiolejeunea brunnea Steph. were all well represented in the epiphyllous community; they were found in seven, six, and five samples, respectively.

Geographic distribution

Regarding the distribution of the species in Brazil, 43.3% were widely distributed, occurring in more than nine Brazilian states, 19.9% were narrowly distributed, found in less than five states, and 36.2% were moderately distributed. As for global distribution, the following patterns were observed: Neotropical (68.3%); Pantropical (13.5%); American (North, Central and South American: 5.5%); Disjunct (American and African, Neotropical and African, Neotropical and Asian, Neotropical and Madagascar and West Indian and Brazilian: 6.4%); Cosmopolitan and Subcosmopolitan (3.9%); and Brazilian endemic (2.4%). The high number of Neotropical species was expected, because, in general, they are more abundant than Pantropical
species (Tan & Pócs 2000). These data corroborate other studies in the state of Bahia, such as Valente et al. (2009), Bastos & Valente (2009), Valente et al. (2013b) and Oliveira & Bastos (2014).

Floristic similarity

As for floristic similarity (Fig. 4), the dendrogram showed that the areas of Serra Negra (MG), Reserva do Poço (BA), Ubajara Montane Forest (CE) and Serra da Jibóia (BA) formed branches isolated from other areas reflecting low floristic similarity (> 25%). According to Muller-Dombois & Ellenberg (1974), two areas can be considered similar if they share about 25% of their floral components. In general, higher floristic similarities are found between neighboring areas and between those belonging to the same river basin. The formation of two groups was also observed; the first group consisted of the areas of PRNP El Nagual (RJ), Brejos de Altitude (PE/PB), Reserva Ecológica da Michelin (BA) and Parque Estadual Ilha da Anchieta (SP); and the second group consisted of Parque Estadual Intervales (SP), Parque Estadual Pedra Azul (ES), Chapada Diamantina Montane Forests (BA), Parque Nacional de Boa Nova (BA), Parque Estadual Serra do Mar (SP) Parque Nacional Itatiaia (RJ).

Parque Estadual Boa Nova was clustered with Parque Estadual Serra do Mar and Parque Nacional Itatiaia, with 38% of floristic similarity; the similarity was greater between the last two areas, with 47% floristic similarity. These two areas are geographically distant from Parque Nacional de Boa Nova, but they are close to each other. In this case, the observed similarity may be associated with environmental factors such as climate, rainfall, and edaphic characteristics (Oliveira-Filho et al. 2001). The three areas consist of dense montane and dense high montane ombrophilous forests with a humid tropical climate. It is important to emphasize that these areas have a high number of species of liverworts (Parque Nacional de Boa Nova – 126 spp.; Parque Nacional Itatiaia – 230 spp.; Parque Estadual Serra do Mar – 196 spp.), which demonstrates the importance of Protected Areas for the conservation of bryophyte diversity in Brazil.

In this study, high floristic richness was observed in the forest fragment inventoried in Parque Nacional de Boa Nova. The species recorded correspond to nearly 54% of the total number of liverworts reported for Bahia and 20% of those occurring in Brazil. Eighteen taxa of Marchantiophyta are reported for the first time from Bahia. Despite the intense ongoing research on bryophytes in

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Fig. 3. Graphical representation of substrates colonized by liverwort species in the fragment of dense montane ombrophilous forest studied in the National Park of Boa Nova, Bahia, Brazil.
Biodiversity surveys in other regions of the state are still likely to recover additional species, and thus are necessary. The results of the present study emphasize the importance of Parque Nacional de Boa Nova for the conservation of bryophyte biodiversity in Brazil.

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REFERENCES


Fig. 4. Dendrogram based on UPGMA of the species composition of liverworts in the study fragment of dense montane ombrophilous forest in Parque Nacional de Boa Nova and other areas of Atlantic Forest in Brazil.


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


