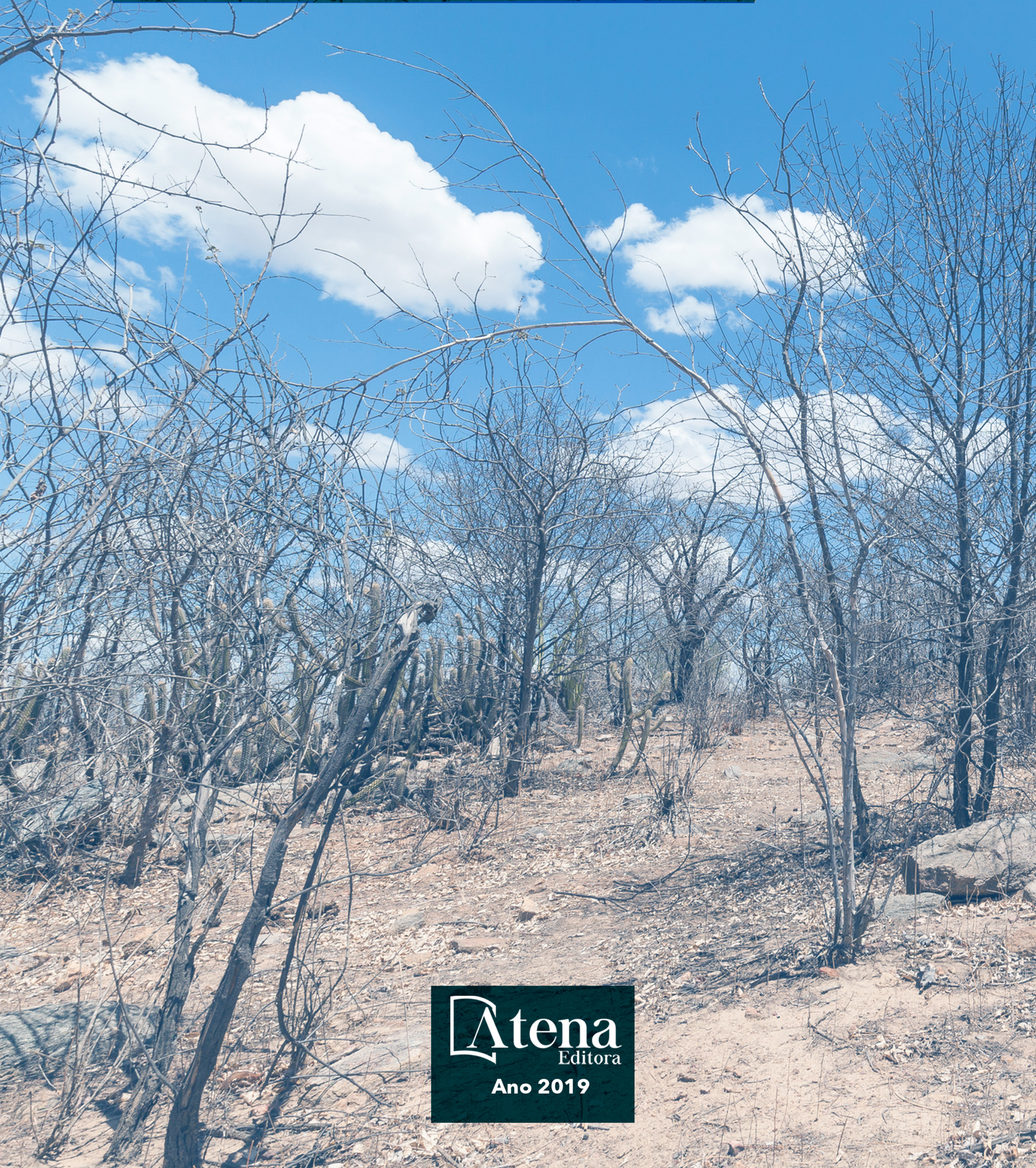
As Regiões Semiáridas e suas Especificidades 3

Alan Mario Zuffo
(Organizador)



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APRESENTAÇÃO

A obra "*As Regiões Semiáridas e suas Especificidades*" aborda uma série de livros de publicação da Atena Editora, em seu III volume, apresenta, em seus 23 capítulos, com conhecimentos tecnológicos das regiões semiáridas e suas especificidades.

As Ciências estão globalizadas, englobam, atualmente, diversos campos em termos de pesquisas tecnológicas. O semiárido brasileiro tem característica peculiares, alimentares, culturais, edafoclimáticas, étnicos, entre outros. Tais, diversidades culminam no avanço tecnológico, nas áreas de Agronomia, Engenharia Florestal, Engenharia de Pesca, Medicina Veterinária, Zootecnia, Engenharia Agropecuária e Ciências de Alimentos que visam o aumento produtivo e melhorias no manejo e preservação dos recursos naturais, bem como conhecimentos nas áreas de políticas públicas, pedagógicas, entre outros. Esses campos de conhecimento são importantes no âmbito das pesquisas científicas atuais, gerando uma crescente demanda por profissionais atuantes no semiárido brasileiro e, também nas demais regiões brasileiras.

Este volume dedicado à diversas áreas de conhecimento trazem artigos alinhados com a região semiárida brasileira e suas especificidades. As transformações tecnológicas dessa região são possíveis devido o aprimoramento constante, com base em novos conhecimentos científicos.

Aos autores dos diversos capítulos, pela dedicação e esforços sem limites, que viabilizaram esta obra que retrata os recentes avanços científicos e tecnológicos, os agradecimentos do Organizador e da Atena Editora.

Por fim, esperamos que este livro possa colaborar e instigar mais estudantes e pesquisadores na constante busca de novas tecnologias para o semiárido brasileiro, assim, garantir perspectivas de solução para o desenvolvimento local e regional para as futuras gerações de forma sustentável.

Alan Mario Zuffo

SUMÁRIO

CAPÍTULO 18

RICHNESS AND DISTRIBUTION OF MOSSES IN A BRAZILIAN DRY FOREST

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RESUMO: A Caatinga encontra-se sob forte pressão de desertificação e apesar disso, pouco mais de 1% da sua área no estado da Paraíba está protegida por lei. Esse estudo buscou catalogar e descrever a comunidade de musgos presentes na Área de Proteção Ambiental das Onças (São João do Tigre, PB) sob o ponto de vista conservacionista, pois esta unidade apresenta informações insuficientes sobre sua vegetação. Nós utilizamos estatística multivariada e curva de rarefação com base no estimador de riqueza Chao 2 para descrição da flora. Em 92 amostras identificamos 16 espécies de musgos, distribuídas em seis famílias. Solo e rocha foram os substratos mais colonizados. A APA das Onças apresenta uma flora com composição e riqueza típicos de áreas secas, sendo duas espécies pleurocárpicas e com maiores exigências ambientais, indicando um potencial para área bem conservada.

PALAVRAS-CHAVE: Área de Proteção Ambiental. Conservação. Florística. Semiárido.

ABSTRACT: The Caatinga is under heavy pressure from desertification, yet just a little more than 1% of its area in the state of Paraíba is protected by law. This study sought to catalog and describe the community of mosses present in the Área de Proteção Ambiental das Onças (São João do Tigre, PB) from a conservation point of view since there is insufficient information regarding its vegetation. We used multivariate statistics and rarefaction based on the Chao 2 richness estimator to describe the flora. In 92 samples we identified 16 species of mosses distributed among six families. Soil and rock were the most colonized substrates. The APA das Onças possesses a flora with species composition and richness typical of dry areas, with two pleurocarpous species with greater environmental requirements, suggesting that it is a well-conserved area.

KEY WORDS: Área de Proteção Ambiental, Conservation, Floristic, Semi-arid.

1 I INTRODUCTION

Dry forests cover large areas throughout the world (SORENSEN et al., 2009) and are one of the most endangered ecosystems on the planet (LEAL et al., 2003). Nonetheless, there have been few studies performed in these environments (WERNECK et al., 2011), which worsens the situation. In addition to the severe natural conditions of these environments, in Brazil the Caatinga is experiencing a scenario of susceptibility to desertification (VIEIRA et al., 2015), which is exacerbated by intensive unorganized exploitation of its natural resources (LEAL et al., 2003; ARAÚJO; SOUZA, 2011). This is particularly true for the state of Paraíba, where most of its territory has Caatinga vegetation – and is scarcely studied byrofloristically – yet only 1% of the area of she state is protected by a conservation unit (THE NATURE CONSERVANCE DO BRASIL AND ASSOCIAÇÃO CAATINGA, 2004). This protected area corresponds to 16 federal and seven state conservation units that protect Caatinga formations or transitional environments between Caatinga and other biomes (LEAL et al., 2005). Among these conservation units, the Área de Proteção Ambiental (APA; environmental protection area) das Onças, stands out as one of the largest, although studies related to its flora are especially scarce and recent (e.g. MELO et al., 2014; XAVIER et al., 2015; TORRES 2015 – unpublished data).

In dry forests, such as the Caatinga, insolation and water scarcity modulate the composition of plant communities (MORO et al., 2016), which is especially true for bryophytes, a group of avascular plants that regulate their water content according to the moisture saturation of the environment (i.e., poikilohydry –PÉREZ et al., 2011). In spite of this, bryophytes have been found as representatively composing assemblages in dry forests (e.g., PÔRTO; SILVEIRA; SÁ, 1994; FRAHM, 1996; SILVA; GERMANO, 2013; VALENTE et al., 2013; SMITH; STARK 2014). This is especially true to mosses, the structurally more complex plants among phyla of bryophytes plants (GLIME, 2017a).

Floristic knowledge regarding bryophytes is of great ecological importance because floristic inventories, in general, allow the assessment of conservation *status*, predictions of temporal and spatial changes of plant communities, evaluation of species richness along gradients of distance form the ocean (e.g. SUNDBERG; HANSSON; RYDIN, 2006; SILVA; SANTOS; PÔRTO, 2014) and geographic distribution patterns of species that can be used to infer the effects of niches in the composition of plant assemblages. Thus, our objective was to document and characterize the taxonomic and functional structure of the moss community of an area of Caatinga in an Área de Proteção Ambiental (APA das Onças, São João do Tigre, PB).

2 I METHODS

2.1 Study area

The Área de Proteção Ambiental das Onças (APA das Onças) was created in 2002 and is located in the extreme south of the state of Paraíba, in the municipality of São João do Tigre (08°4'53"S, 36°50'41"W), and protects a portion of the Caatinga, exclusively (Figure 1). With a total area of 360 Km², the APA is the largest conservation unit in the state. This APA is inserted within the complex of the Serras dos Cariris Velhos (Cariris Velhos Mountain Range), at an elevation of approximately 1192 m.

The municipality in which the APA is located possesses a typical landscape of the semi-arid region of Northeast Brazil, with vegetation composed of hyperxerophilic Caatinga with stretches of deciduous forests. The climate is of the semi-arid type of BShw, according to the classification of Köppen (1948), with summer rains beginning in November and ending in April, and an average annual precipitation of 431.8 mm (NASCIMENTO; ALVES, 2008). Its relief is predominantly softly undulating and cut by narrow valleys with dissected slopes. Part of its southern area is part of the Planalto da Borborema (Borborema Plateau) geo-environmental unit (MME, 2005).

2.2 Sampling design

The sampling points were selected according to the criteria of (a) ease of access and, mainly, (b) presence of dense vegetation. The importance of collecting in areas of dense vegetation is that they are locations with less human disturbance, less insolation, more humidity and potentially greater diversity.

Standard samples of 10 cm² were collected from floristic habitats considering all available substrates: live trunks, dead trunks, soil and rock (FRAHM et al., 2003). Herborization techniques followed Frahm (2003), the standard literature for the herborizaiton of bryophytes.

Identification of taxa was based on bryological literature (e.g. SHARP; CRUM; ECKEL, 1994). The system of classification used was that proposed by Goffinet, Buck and Shaw (2009) and the nomenclature updated according to Bordin and Yano (2013) – for *Fissidens* Hedw. – and the site W³ TROPICOS (W3MOST –www.mobot.org/W3T/search/most.Hltm.osfato). Geographic distributions were based on Gradstein and Costa (2003) and, when necessary, specific literature, while growth forms followed Richards (1984). Voucher material is being accessioned by the herbarium Manuel de Arruda Câmara (ACAM), of the Universidade Estadual da Paraíba.

2.3 Data analysis

2.3.1 Floristic similarity

We evaluated floristic similarity between the APA das Onças and other areas of the Caatinga of Paraíba using the Dice-Sørensen Similarity Index – here considering a cut-off point of 70%. This index was used to represent species common among communities, and allows an evaluation of similarity among samples because decreases the effect rare species incidence (VALENTIN, 2012). We then performed a cluster analysis with weighted means (Weighted Pair-Group Method Using Aritmethic Averages -WPGMA). This method minimizes the effects of varying sampling efforts (VALENTIN, 2012). To evaluate local richness we used the Chao 2 richness estimator, which takes into account rare species and the total number of species observed in the sample from the incidence (absence or presence) of a species in the samples. The results of the estimator were used to generate a rarefaction curve to analyze sample adequacy (CHAO, 1987).

2.3.2 Spatial distribution of species

We identified the main functional attributes responsible for the spatial distribution of species through Principal Component Analysis (PCA). This analysis summarizes the set of variables with a smaller one from the original set, identifying those variables that can best explain groupings. The “broken stick” method was used to arrive at the stopping point of the analysis (JACKSON, 1993). For this analysis we evaluated all the attributes for the corresponding species described in the literature (POREMBSKI; SEINE; BARTHLOTT, 1997; PROCTOR, 2000; GIGNAC, 2001; KÜRSCHNER, 2004; CRANDALL-STOTLER, BARTHOLOMEW-BEGAN, 2007; PROCTOR, 2008). Life forms were excluded from the analysis because in addition to being mutually exclusive, they present degrees of ecological importance according to each environment (GLIME, 2017b) and are not attributable to incidence.

3 I RESULTS

A total of 92 samples were collected in which 16 species were identified distributed among six families and eight genera (Table 1). Fissidentaceae (seven species) was the most species rich family of the APA, followed by Bryaceae, Stereophyllaceae, Bartramiaceae and Pottiaceae (two species each) and Calymperaceae (one species) (Table 1). *Tortella humilis* was the most frequent species, followed by *Bryum argenteum*.

With regard to the life forms of the species found, tuft was the most representative, with a predominance of acrocarpous over pleurocarpous species; only two species were pleurocarpous (*Entodontopsis leucostega* and *Eulacophyllum cultelliforme*) (Table 1).

3.1 Similarity

The similarity analysis revealed no groupings among the areas of the state of Paraíba, considering a cut-off of 70% (Figure 2). Regarding the present study area, APA das Onças is in a group that possesses about 20% similarity and includes three areas of rocky outcrops an one area of campo rupestre (rupestrian field) present in Bahia. The species richness of APA das Onças was estimated by Chao 2 to have a mean of 13.21 species, while the rarefaction curve showed stabilization indicating that sampling was sufficient at representing the species of the APA (Figure 3).

3.2 Potential functional attributes of mosses

Regarding functional attributes, the first two axes of the PCA explained 79.27% of the groupings formed, with 45.52% being explained by the first axis and 33.75% by the second (Figure 4). Table 2 shows that axis 1 was most correlated with the attributes of whitish coloring of the leaf, and the presence of papillae and revolute margins. The formation of groups could also be observed according to the most important attributes for the establishment of this group in the APA. The presence of papillae was strongly correlated with the presence of the family Fissidentaceae; revolute margins and enrolled leaves were correlated with the families Bartramiaceae and Pottiaceae; and the presence of hyaline cells and whitish coloring were correlated with Bryaceae, Stereophyllaceae and Calymperaceae.

4 I DISCUSSION

4.1 Community composition and functional attributes

In comparison to wet forest areas, few species of moss were recorded for the studied area, but for a xerophytic environment the species richness found was consistent with that found in other areas of Caatinga (see PÔRTO; SILVEIRA; SÁ, 1994; BASTOS et al., 1998). The rarefaction curve based on the Chao 2 index revealed a tendency towards stabilization, indicating that the observed richness is consistent with the estimator and that species considered rare contributed to the value of the index.

In general, the species found are predominant in tropical and subtropical regions where they occupy several different habitats (COSTA; LUIZE-PONZO, 2010), and are well represented in the Caatinga (e.g. PÔRTO; SILVEIRA; SÁ, 1994; PÔRTO; BEZERRA 1996; BASTOS; BÔAS – BASTOS, 1998). The most frequent species in the APA was *T. humilis*, of the family Pottiaceae, which has been recorded in several environments of differing characteristics, and can therefore persist under a variety of different pressures such a desiccation, disturbance or extreme conditions (ZANDER, 1996). In addition, all the mosses recorded here for the APA have adaptive attributes either for drought avoidance or drought tolerance.

The APA constitutes a unique local delimitation when compared to other areas of Caatinga already studied in the state of Paraíba. Germano et al, (2016) explains the low number of species found in this region in the extreme south of the state as due to the effects caused by the gradient of distance from the coast along with collecting in the interior being only incipient. Another issue that should be considered is the inadequate amount of bryophyte specialists in Brazil (FORZZA et al., 2010), especially those who study bryophytes in dry forests such as the Caatinga (SILVA, 2016).

4.2 Spatial distribution and adaptations of mosses

All of the mosses studied here possessed some type of adaptation to capture and store water (e.g. concave leaf, developed costa, presence of papilla) and/or to resist dehydration (e.g. changes in the orientation of the leaf, bordered margins, structures such as pseudoparaphyllia, and dead and hyaline cells – PROCTOR, 2000; KÜRSCHNER, 2004). Some of these characteristics were of greater importance for the establishment and maintenance of mosses in APA das Onças: papilla, hyaline cells, whitish coloring, enrolled leaf and revolute margins. These attributes are very important to these species for desiccation avoidance and tolerance (Table 2). The papillae provide increased surface area for absorption, and also form capillary spaces, which retain excess water (VANDERPOORTEN; GOFFINET, 2009) and act as a system of water circulation by rapid capillarity (PROCTOR, 2000). Hyaline cells can store water while whitish cells are important for reflecting solar radiation, thus reducing the stress it can cause. The enrolled leaf and revolute margins can protect the leaf from solar radiation and reduce water loss (KÜRSCHNER, 2004).

Among other adaptations found, some species possessed bordered margins, which is a characteristic with a significant role in mosses: assisting in the twisting of the leaves when they are dry. This trait provides protection to the caulidium, reduces desiccation and protects against solar radiation and dehydration (KÜRSCHNER, 2004). Leaves with a concave shape, which is well represented in the species *Entodontopsis leucostega*, *Eulacophyllum cultelliforme* and *B. argenteum*, favors water storage (PROCTOR, 2008).

Costae were present in all the species found in the APA. In *T. humilis* and *W. breutelii*, a layer of large, bulky, longitudinally arranged tabular cells was observed forming part of the conduction parenchyma. These cells are arranged between two layers of stereids and provide central support and facilitate water transport (VANDERPOORTEN; GOFFINET; BUCK; SHAW, 2009; CRANDALL-STOTLER; BARTHOLOMEW-BEGAN, 2007). The widening of this central vein provides the plant with greater resistance to drought, and can compensate photosynthesis (PROCTOR, 2000). Moreover, when leaves contort and curl around the steam when in a dry environment, the abaxial surface of the plant exposes the bright costa, which reflects radiation. This behavior can be observed in the family Pottiaceae (KÜRSCHNER, 2004).

In the species *Entodontopsis leucostega*, pseudoparaphyllia were observed, which are structures found only in pleurocarpous species. Their probable function is to protect the beginning branches of the plant, and to increase external surface area, consequently increasing the absorption surface (CRANDALL-STOTLER; BARTHOLOMEW-BEGAN, 2007).

The predominance of acrocarpous over pleurocarpous species can be explained, according to Kürschner (2004), by the fact that in xeric environments, and when exposed to the sun, there is a tendency for more acrocarpy. Pleurocarpous mosses are more easily found in shaded, moist places or locations with water availability (KÜRSCHNER, 2004). According to Song et al. (2014), increased temperature and decreased water availability have a negative impact on the growth of epiphytic bryophytes. This explains the finding of just two pleurocarpous species in APA das Onças, both of which were found in shaded areas: *Entodontopsis leucostega* and *Eulacophyllum cultelliforme*.

The species composition and richness of the flora of APA das Onças is typical of dry areas, with the majority of plants being generalists or photophilious species. This area can be considered a potential refuge for bryophytes, since despite the adverse conditions, mosses with greater environmental requirements (*Entodontopsis leucostega* **and** *Eulacophyllum cultelliforme*) were recorded. Such species were located in places considered more conserved and with greater angiosperm densities, which promote more suitable environments for the establishment of these mosses at frequencies similar to that of most other mosses that are less demanding, thus indicating that the area is well conserved.

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FIGURAS E LEGENDAS

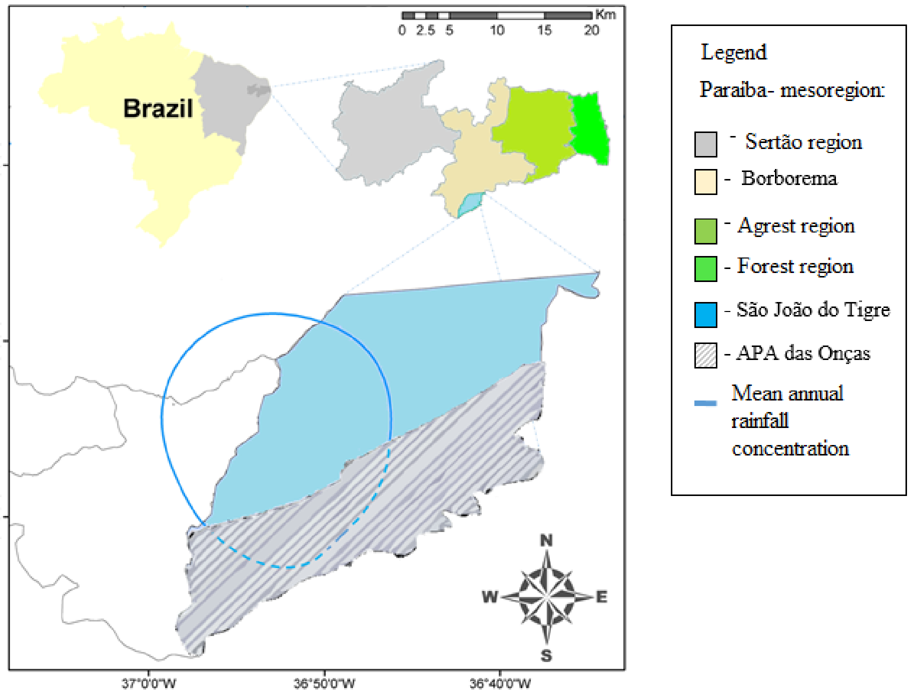


Figure 1. Map of APA das Onças, municipality of São João do Tigre - PB, Northeast Brazil.

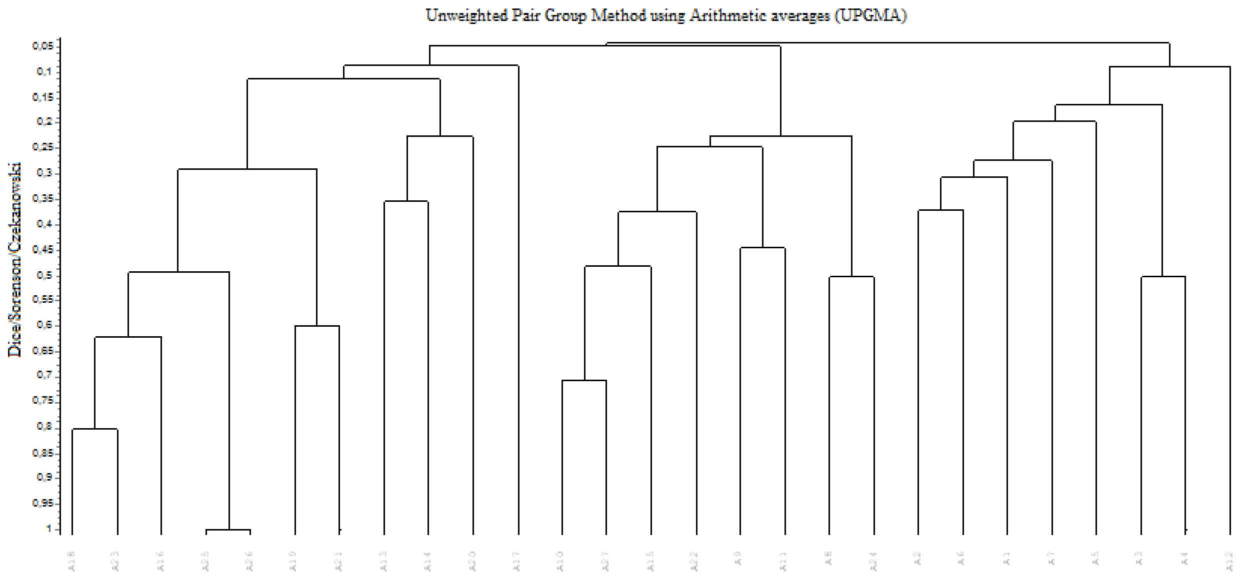


Figure 2. Dendrogram of floristic similarity (WPGMA) based on the similarity index of Sørensen. Legend: A1- APA das Onças; A2- Bahia; A3- Pernambuco; A4- Agrestina- PE; A5- Afloramento rochoso, Serra da Jibóia- BA; A6- Afloramento rochoso, Puxinanã- PB; A7- Afloramento rochoso- PE; A8- Areial- PB; A9- Afloramento rochoso 4- PB; A10- Afloramento rochoso 6- PB; A11- afloramento rochoso 5- PB; A12- Bananeiras- PB; A13- Remígio-PB; A14- Alagoa Grande-PB; A15- afloramento rochoso 7-PB; A16- Pombal- PB; A17- Campina Grande- PB; A18- Boqueirão- PB; A19- Junco do Seridó- PB; A20- Esperança- PB; A21-Juarez Távora- PB; A22- afloramento rochoso 3- PB; A23- Soledade- PB; A24- afloramento rochoso 2- PB; A25- São Mamede- PB; A26- Condado- PB; A27- afloramento rochoso 1- PB.

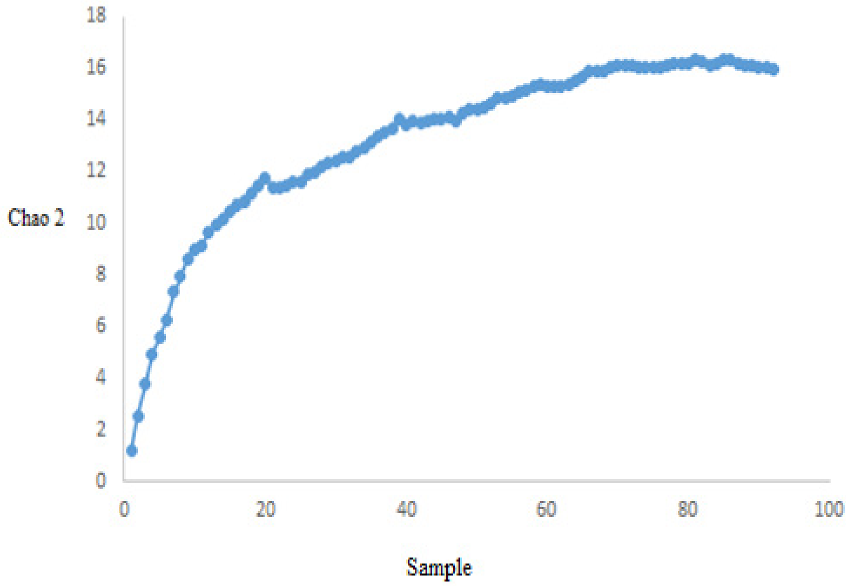


Figure 3. Rarefaction curve showing the amount of samples collected in the APA das Onças (São João do Tigre - PB), based on the Chao 2 wealth estimator.

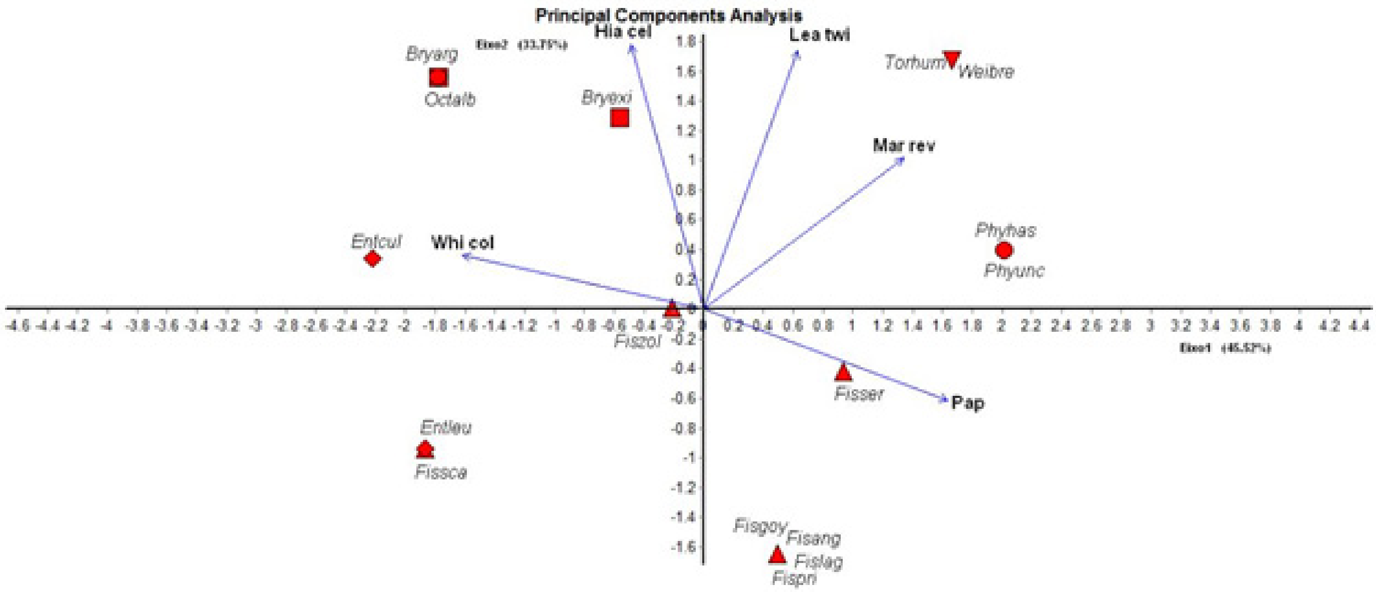
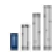
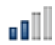
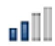
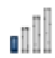
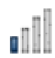
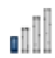
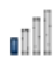
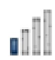


Figure 4. Ordering by Principal Component Analysis (PCA) showing species distribution. Arrows represent adaptive attributes. Legend: Lea twi = Leaf twisted, Mar. rev.= revolute margin, Pap = papila, Hia. cel. = célula hialina, Whi col = coloração esbranquiçada. Square- Bryaceae Family (Bryarg- *Bryum argenteum*; Bryexi- *Bryum exile*); Triangle- Família Fissidentaceae (*Fiszol- Fissidens zollingeri; Fisser- Fissidens serratus; Fissca- Fissidens scariosus*); Circle-Bartramiaceae Family (*Phyhas- Philonotis hastata; Phyunc- Philonotis uncinata*); Losangelo-Stereophylaceae Famiy (*Entcul- Eulacophyllum cultelliforme; Entleu- Entodontopsis leucostega*; Inverted Triangle- Pottiacea Family (*Torhum-Tortella humilis; Weibr- Weissia breutelii*).

Family / Species	Distribution		Life forms	Substrate				Relative frequency
	World	Brazil		Rock	Soil	Life trunk	Dead trunk	
Bartramiaceae								
Philonotis hastata (Duby) Wijk & Margad	Widely distributed	AM, PR, RO, BA, CE, MA, PI, GO, MS, MT, MG, RJ, SP, PA, RS.	Tuff	•	•			
Philonotis uncinata (Schwägr.) Brid	Pantropical	AC, AM, AP, PA, RO, TO, BA, CE, PB, PE, PI, DF, GO, MS, MT, ES, MG, RJ, SP, PA, RS, SC.	Tuff				•	
Bryaceae								
Bryum argenteum Broth.	Widely distributed	AM, RR, AL, BA, CE, MA, PB, PE, RN, DF, GO, MS, MO, ES, MG, RJ, SP, PR, RS, SC.	Tuff		•		•	
Bryum exile (Dozy & Molk) J.R. Spence & H.P. Ramsay	Pantropical	AC, AL, AM, AP, BA, CE, DF, ES, FN, GO, MA, MG, MS, MT, PA, PB, PE, PI, PR, RJ, RN, RO, RR, RS, SC, SE, SP, TO.	Tuff		•			
Calymperaceae								
Octoblepharum albidum Hedw	Pantropical	AC, AL, AM, AP, BA, CE, DF, ES, FN, GO, MA, MG, MS, MT, PA, PB, PE, PI, PR, RJ, RN, RO, RR, RS, SC, SE, SP, TO.	Tuff		•			
Fissidentaceae								
Fissidens angustifolius Sull	Pantropical	AC, AM, BA, CE, GO, MA, PB, PE, PI, PR, RJ, RO, RS, SP.	Tuff		•			
Fissidens goyazensis Broth	Neotropical	AM, BA, CE, DF, GO, MG, PB, PE, PI, RJ, SP.	Tuff		•			
Fissidens lagenarius Mitt. var. lagenarius	Neotropical	AM, CE, DF, ES, GO, MA, MG, MS, MT, PA, PB, PE, PI, PR, RJ, RO, RS, SC, SP.	Fan		•			
Fissidens prionodes Mont	Neotropical	AC, AM, MT, PA, PB, RO, RR.	Fan		•			

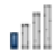
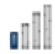
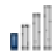
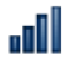
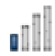
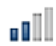
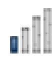
**Fissidens serratus* Müll. Hal.	Pantropical	AM, BA, ES, MA, MG, PA, PB, PE, PR, RJ, RO, RR, RS, SC, SP.	Fan		•			
Fissidens scariosus Mitt.	Neotropical	AM, BA, ES, MA, MG, PA, PB, PE, PR, RJ, RO, RR, RS, SC, SP.	Mat		•			
Fissidens zollingeri Mont.	Pantropical	AC, AL, AM, BA, CE, DF, ES, GO, MA, MG, MS, MT, PA, PB, PE, PR, RJ, RO, RS, SC, SE, SP, TO.	Tuff		•			
Pottiaceae								
**Tortella humilis* (Hedw.) Jenn.	Widely distributed	BA, DF, ES, GO, MA, MG, MS, PR, RJ, RS, SC, SP.	Tuff	•	•			
**Weissia breutelii* Müll. Hal.	Neotropical	ES, PE, PB, RS, SC.	Tuff		•			
Stereophylaceae								
Entodontopsis leucostega (Brid.) W.R. Buck & Ireland	Pantropical	AC, AM, BA, CE, DF, GO, MA, MG, MS, MT, PA, PB, PE, PI, RJ, RN, RO, SP, TO.	Trama	•		•	•	
Eulacophyllum cultelliforme (Sull.) W.R. Buck & Ireland	Neotropical	AM, BA, CE, ES, MG, MS, MT, PB, PE, PR, RJ, RS, SE, SP, TO.	Trama	•				

Table 1. Table 1. List of species, worldwide distribution and in Brazil, life forms, substrata colonized by species and relative frequency of moss species. * Cited for the second time to the State of Paraíba. Frequency between 1-9%( ), 10-19% ( ), 20-29% ( ) e >30% ( ).

	Axis 1	Axis 2
Lea. twi.	----	0.8138
Rev. mar.	0.7279	----
Pap.	0.8868	----
Hya. Cel.	----	0.8302
Whit. Col.	-0.8781	----

Table 2. Correlation between axes and potentially adaptive attributes of mosses in xeric environments (PCA). Legend: Lea. twi. = Twisted leaf, Rev. mar. = revolute margin, Pap. = papila, Hya. cel.= hyaline cell, Whit. col = whitish coloring.

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