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Diversity and structure of the woody component of a restinga in Alcântara, Maranhão State, Brazil

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Abstract

Although Maranhão State has the second longest coastline of Brazil, phytosociological studies are necessary to expand the knowledge of the restinga vegetation therein. Thus, the present study characterizes structural parameters of the woody component of a restinga in Alcântara city, west coast of Maranhão State. The phytosociological sampling included thirteen 100 m parallel transects, totaling 50 points. The inclusion criterion established for the species was perimeter at ground level ≥ 10 cm. We sampled 34 species, 26 genera, and 17 families, totaling 200 individuals. The species with the highest importance value (IV) were *Guettarda angelica* Mart. ex Müll.Arg., *Anacardium occidentale* L., *Myrcia splendens* (Sw.) DC., *Cenostigma bracteosum* (Tul.) E. Gagnon & G.P. Lewis, *Fridericia* sp., *Eugenia stictopetala* Mart. ex DC., and *Mouriri guianensis* Aubl. The average height of the specimens was 4.44 m, and the average diameter was 12.6 cm. The Shannon diversity index found in the restinga was 2.92 nat. ind^{-1}, and Pielou's evenness was 0.83. It is worth mentioning the presence of *Sapium glandulosum* (L.) Morong and *Manilkara bidentata* (A.DC.) A.Chev, which are common species of the Cerrado and the Amazonian forest, respectively. Our findings contribute to the knowledge of diversity, generating data for the development of conservation studies, besides reinforcing the influence of the flora of neighboring ecosystems in the colonization of the restingas of Maranhão State.

Keywords: Importance value, northeast coast, species richness, woody component.

Diversidade e estrutura da comunidade lenhosa de uma restinga no litoral de Alcântara, Maranhão, Brasil

Resumo

Apesar do Maranhão ser considerado o segundo maior litoral do país, estudos fitossociológicos são necessários para ampliar o conhecimento da vegetação das restingas do Estado. Assim, o presente estudo teve como objetivo caracterizar os parâmetros estruturais do componente lenhoso de uma restinga no município de Alcântara, Maranhão. Para a amostragem fitossociológica foram instalados 13 transectos de 100 m paralelos, totalizando 50 pontos com critério de inclusão de espécies foi o Perímetro à Altura do Solo ≥ 10 cm. Foram amostradas 34 espécies, 26 gêneros e 17 famílias, em um total de 200 indivíduos. As espécies de maior valor de importância foram *Guettarda angelica* Mart. ex Müll.Arg., *Anacardium occidentale* L., *Myrcia splendens* (Sw.) DC., *Cenostigma bracteosum* (Tul.) E. Gagnon & G.P. Lewis, *Fridericia* Mart. sp., *Eugenia stictopetala* Mart. ex DC. e *Mouriri guianensis* Aubl. A altura média dos espécimes foi de 4,44 m e o diâmetro médio foi de 12,6 cm. O índice de diversidade de Shannon foi de 2,92 nat. ind^{-1} e a equabilidade de 0,83. Cabe ressaltar a presença de *Sapium glandulosum* (L.) Morong e *Manilkara bidentata* (A.DC.) A.Chev., que são espécies comuns de áreas de Cerrado e de Floresta Amazônica, respectivamente. Os dados apresentados contribuem para o conhecimento da diversidade, gerando dados para o desenvolvimento de estudos direcionados a conservação, além de reforçar a influência da flora dos ecossistemas vizinhos na colonização das áreas de restinga do Maranhão.

Palavras-chave: Valor de importância, litoral do nordeste, riqueza de espécies, componente lenhoso.

Introduction

Considered an extremely fragile ecosystem, the restingas in Brazil have had their vegetation suppressed by anthropogenic actions such as real estate speculation, planting of monocultures, and exploitation of resources (Machado & Almeida Jr., 2019). The northeast region has the longest coastline in the country, with 3,306 km (Pinheiro, Coriolano, Costa & Dias, 2008). However, considering its extension and

plant heterogeneity (Machado & Almeida Jr., 2019), there is still a need for further studies in this region (Santos-Filho, Almeida Jr. & Zickel, 2013).

Located in northeastern Brazil, Maranhão State has the second longest coastline in the country, with 640 km (El-Robrini *et al*., 2006), and is inserted in a transition area between the northeast and the Amazon region. This region can be characterized as ecotonal due to the influence of the flora of the Amazon, Cerrado, and Caatinga ecosystems, providing a unique diversity for the state.

Some phytosociological studies have already been developed in this region, the majority addressing the herbaceous component. Among these, the following stand out: Amorim, Santos-Filho & Almeida Jr. (2016), who carried out a phytosociological study in the dunes of Araçagi beach; Araújo *et al*. (2016), and Santos, Amorim & Almeida Jr. (2019), in the dunes of São Marcos beach. Regarding the phytosociology of the woody component, the only published study to date was conducted by Machado and Almeida Jr. (2019), who described the structural arrangement of the Curupu restinga and analyzed the species similarity between different restinga areas.

In view of the environmental heterogeneity in Maranhão state, phytosociological approaches in restingas contribute with important data to preserve these areas (Dias & Araujo, 2017). Accelerated suppression of vegetation and anthropogenic processes have contributed to the entry of ruderal/exotic species, becoming a threat to the native flora of coastal areas. This justifies the development of more targeted research to understand the structural organization of the woody component, contributing with data on the arrangement, distribution, recruitment, and regeneration of the coastal vegetation of Maranhão State. Thus, this study characterizes the structure of the woody component and describes the phytophysiognomy of the restinga vegetation on the coast of Alcântara, Maranhão State, Brazil.

Materials and Methods

Study area

The study was conducted in the restinga of Itatinga beach, Alcântara city, west coast of Maranhão State. The area is approximately 2 km long (Figure 1). According to the Köppen classification (1948), the climate of the region is Aw, with two defined seasons: a rainy season, from January to June; and a dry season, from July to December. The region has an average temperature of 26 °C to 28 °C, and annual rainfall of 2,000 mm (INMET, 2018).

According to the classification proposed by Santos-Filho, Almeida Jr., Soares & Zickel (2010), the restinga of Itatinga beach has three physiognomies: nonflooded fields, open nonflooded shrublands, and closed nonflooded shrublands. Phytosociological analysis was performed only on the closed nonflooded shrublands physiognomy, characterized by shrub-tree vegetation, comprising the woody component of the area.

Figure 1. Restinga of Itatinga beach, Alcântara city, Maranhão State, Brazil. (Source: GoogleEarth – 2015; Prepared by: L. B. S. Costa).

Sampling and data analysis

The phytosociological study was conducted in July 2013, in the closed nonflooded shrublands physiognomy (02°24'46.6" S, 44°24'01.7" W). For this, we used the point-centered quarter method (Cottam & Curtis, 1956). Due to plant formation, 13 transects were drawn in parallel, 10 m apart, all perpendicular to the beach line. In view of the cut of the restinga vegetation, 3 to 6 quadrant points were allocated in each transect, 10 m apart, being organized as follows: five transects with three points, six transects with four points, a transect with five points, and a transect with six points, totaling 50 sampling points. The present study followed the methodology that sampling 50 points in restingas already allow to achieve stability in the species curve. This methodology was used in different studies for the northeast coast (Medeiros *et al*., 2014; Zickel *et al*., 2015), enabling sampling standardization.

For the structural analysis of vegetation, woody individuals with perimeter at ground level (PGL) ≥ 10 cm were considered. In individuals branched at ground level, all branches were measured, the values being summed and transformed into a single value to represent the final diameter. The basal area of the plant was then calculated (Shepherd, 2010). The height of the sampled plants was

measured by visual estimate. The botanical material was collected, herborized, and identified following the usual methodology (Mori *et al*., 1989; Peixoto & Maia, 2013).

The list of families was organized following the proposal of APG IV (2016). Species were taxonomically identified by consulting the specialized literature (Pessoa & Barbosa, 2012; Zappi *et al*., 2017; Mattos *et al*., 2018; Trindade, Rosário & Santos, 2018; among others). Subsequently, we compared the identifications with the Herbarium collection and sent the material to specialists. Notwithstanding, some species were collected in the vegetative stage, rendering identification impossible. The nomenclature was checked on the Flora do Brasil 2020 website (http://floradobrasil.jbrj.gov.br) (http://floradobrasil.jbrj.gov.br/). The material was then incorporated into the collection of Herbarium of Maranhão (MAR), Department of Biology, Federal University of Maranhão (UFMA).

After sampling, the following phytosociological parameters were calculated: relative density (RD), relative frequency (RF), relative dominance (RDo), importance value (IV), and coverage value (CV), all determined according to Mueller-Dombois & Ellenberg (1974), besides the Shannon index (H'), Pielou's evenness (J'), and total richness (S). All phytosociological parameters were calculated using the Fitopac 2.1 software (Shepherd, 2010). Tables with the number of individuals were also organized by intervals of height (amplitude of 1 meter) and diameter (amplitude of 10 cm).

Results and Discussion

A total of 34 species, 26 genera, and 17 families were identified (Table 1), with 200 individuals sampled. Of the total species, six remained as morphospecies (two species identified only as family, and four species maintained as indeterminate). The families with the highest species richness were Rubiaceae (six species), Fabaceae (four species), and Anacardiaceae, Erythroxylaceae, Myrtaceae, and Sapotaceae (two species each). The sum of the species of these families correspond to 52.9% of the total richness.

When studying different restingas in Pernambuco, some authors also highlighted the families Rubiaceae, Myrtaceae, and Fabaceae as more representative due to the wide distribution and phenotypic plasticity of the species (Almeida Jr., Olivo, Araújo & Zickel, 2009; among others).

The species richness values of the present study were similar to those found by Machado and Almeida Jr. (2019), who listed 32 species when studying the woody vegetation of the shrub-tree physiognomy on Curupu Island, Maranhão State. On the other hand, our study showed a higher value when compared to the restingas of Piauí State, in which Santos-Filho *et al*. (2013) reported low values for the woody component in Ilha Grande (12 species), Parnaíba (18 species), and Luiz Correia (23 species). Moreover, the values were lower when compared to those observed in the coast of Pará State, where 41 species were listed (Santos *et al*., 2003).

The average height of the individuals was 4.44 m (standard deviation of ± 2 m), with a maximum height of 15.7 m and a minimum of 1.45 m. Of the total number of individuals sampled in the study area, 67% had a height between 2 and 5 m (Table 2), with higher prevalence of individuals 4 to 5 m high (Table 2). Species *Agonandra brasiliensis* (10 m), *Anacardium occidentale* (11.5 m), and *Sapium glandulosum* (15.7 m) were the tallest in the woody component of the studied physiognomy. The tallest individuals have spaced, branched crowns, and emerging species do not stand out due to the approximate height of many arboreal individuals and the similarity between the crown and stem of these plants.

The average diameter of the individuals was 12.76 cm (standard deviation of 15.6 cm), with a maximum value of 167.4 cm and a minimum of 3.18 cm. Most individuals were recorded in the first diameter class, with values from 3 to 13 cm; and in the second diameter class, with values from 13 to 23 cm (Table 2). The diameter distributions of the present study were similar to the pattern of forests areas, with most individuals concentrated in the first diameter classes and a gradual decrease in larger diameter classes (Machado & Almeida Jr., 2019). This distribution was also demonstrated in the study of Machado and Almeida Jr. (2019) in a restinga in Maranhão State. The authors highlighted a woody component with thinner, branched, and medium stems, which characterize the physiognomic formation of closed shrublands.

The sampling resulted in an average distance of 1.95 m between individuals, corresponding to a total density of 2,644.46 ind.ha^{-1}, and dominance of 69.64.

The following community arrangements stand out with the highest number of individuals per family: Rubiaceae (68 individuals), with most records of *Guettarda angelica* (43); Myrtaceae (25), with most records of *Myrcia splendens* (14); Fabaceae (24), mostly represented by *Cenostigma bracteosum* (17); and Bignoniaceae, with 20 individuals of *Fridericia* sp. The species mentioned above have a wide distribution, occurring in the Amazonian vegetation, Cerrado, and Caatinga (BFG, continuously edited). This can reinforce differences in the woody component due to the transition between the vegetation formations of the Amazon forest and Cerrado.

Families Fabaceae, Myrtaceae, and Rubiaceae are also representative in restingas. Their species have a high dispersion capacity and develop in environments with limiting conditions due to water scarcity and low soil fertility. These species are thus more likely to establish in these environments, mainly those of the family Myrtaceae.

The species with the highest IV were *Guettarda angelica*, *Anacardium occidentale*, *Myrcia splendens*, *Cenostigma bracteosum*, and *Fridericia* sp., accounting for 54.88% of the species in the community.

Regarding coverage values (CV), the same species stood out, although in a different order: *Anacardium occidentale*, *Guettarda angelica*, *Myrcia splendens*, *Cenostigma bracteosum*, and *Fridericia* sp., highlighting the ecological importance of these species regarding their plant size and tree canopy branches, which allow shading for the development of other species and contribute to the spatial organization of individuals in the area.

Table 1. Phytosociological parameters of the species sampled in the restinga of Itatinga, Alcântara city, Maranhão State, Brazil. n = number of individuals per species, RD = relative density, AF = absolute frequency, RF = relative frequency, RDo = relative dominance, IV = importance value, CV = coverage value. Species ordered from the value of n.

Specie	Family	n	AF	RF	RD	RDo	IV	CV
Guettarda angelica Mart. ex Müll.Arg.	Rubiaceae	43	50	16.34	21.50	12.02	49.86	33.52
Fridericia sp.	Bignoniaceae	20	26	8.50	10.00	1.73	20.23	11.73
Cenostigma bracteosum (Tul.) Gagnon & G. P. Lewis	Fabaceae	17	24	7.84	8.50	8.86	25.21	17.36
Myrcia splendens (Sw.) DC.	Myrtaceae	14	22	7.19	7.00	11.25	25.44	18.25
Eugenia stictopetala Mart. ex DC.	Myrtaceae	11	20	6.54	5.50	2.33	14.36	7.83
Mouriri guianensis Aubl.	Melastomatacae	10	20	6.54	5.00	1.87	13.41	6.87
Manilkara bidentata (A.DC.) A.Chev.	Sapotaceae	9	14	4.58	4.50	1.24	10.31	5.74
Agonandra brasiliensis Miers ex Benth. & Hook.f.	Opiliaceae	9	14	4.58	4.50	0.69	9.76	5.19
Tocoyena sellowiana (Cham. & Schltdl.) K.Schum.	Rubiaceae	7	10	3.27	3.50	0.79	7.55	4.29
Cordiera myrciifolia (K.Schum.) C.H.Perss. & Delprete	Rubiaceae	7	8	2.61	3.50	0.16	6.27	3.66
Faramea nitida Benth.	Rubiaceae	6	10	3.27	3.00	0.27	6.53	3.27
Anacardium occidentale L.	Anacardiaceae	5	10	3.27	2.50	38.14	43.91	40.64
Guettarda spruceana Müll.Arg.	Rubiaceae	4	8	2.61	2.00	1.55	6.16	3.55
Conocarpus erectus L.	Combretaceae	4	6	1.96	2.00	1.76	5.72	3.76
Centrolobium sp.	Fabaceae	3	4	1.31	1.50	5.14	7.95	6.64
Maytenus erythroxyla Reissek	Celastraceae	3	4	1.31	1.50	2.59	5.40	4.09
Byrsonima crassifolia (L.) Kunth	Malpighiaceae	3	6	1.96	1.50	0.91	4.37	2.41
Manilkara triflora (Allemão) Monach.	Sapotaceae	3	6	1.96	1.50	0.52	3.99	2.02
Sapium glandulosum (L.) Morong	Euphorbiaceae	2	4	1.31	1.00	5.01	7.32	6.01
Erythroxylum barbatum O.E.Schulz	Erythroxylaceae	2	4	1.31	1.00	0.32	2.63	1.32
Manihot tristis Müll.Arg.	Euphorbiaceae	2	4	1.31	1.00	0.26	2.57	1.26
Pseudima frutescens (Aubl.) Radlk.	Sapindaceae	2	4	1.31	1.00	0.26	2.57	1.26
Dalbergia ecastaphyllum (L.) Taub.	Fabaceae	2	4	1.31	1.00	0.24	2.55	1.24
Cynophalla flexuosa (L.) J.Presl	Capparaceae	2	4	1.31	1.00	0.22	2.52	1.22
Indeterminate 25	-	1	2	0.65	0.50	0.49	1.65	0.99
Indeterminate 6	-	1	2	0.65	0.50	0.48	1.63	0.98
Chloroleucon acacioides (Ducke) Barneby & J.W.Grimes	Fabaceae	1	2	0.65	0.50	0.38	1.53	0.88
Alibertia edulis (Rich.) A.Rich.	Rubiaceae	1	2	0.65	0.50	0.15	1.31	0.65
Fabaceae 2	Fabaceae	1	2	0.65	0.50	0.15	1.31	0.65
Coccoloba latifolia Lam.	Polygonaceae	1	2	0.65	0.50	0.07	1.23	0.57
Erythroxylum pungens O.E.Schulz	Erythroxylaceae	1	2	0.65	0.50	0.06	1.21	0.56
Indeterminate 7	-	1	2	0.65	0.50	0.05	1.21	0.55
Indeterminate 13	-	1	2	0.65	0.50	0.02	1.17	0.52
Anacardiaceae 1	Anacardiaceae	1	2	0.65	0.50	0.01	1.17	0.51

Table 2. Frequency (absolute and relative) of individuals of restinga species per height and diameter classes; Itatinga beach, Alcântara city, Maranhão State, Brazil.

Plant height (m)			
1.0 – 2.0	12(6.0%)	8.1 – 9.0	6(3.0%)
2.1 – 3.0	41(20.5%)	9.1 – 10.0	1(0.5%)
3.1 – 4.0	28(14%)	10.1 – 11.0	0(0.0%)
4.1 – 5.0	65(32.5%)	11.1 – 12.0	1(0.5%)
5.1 – 6.0	23(11.5%)	12.1 – 13.0	1(0.5%)
6.1 – 7.0	13(6.5%)	> 13.0	1(0.5%)
7.1 – 8.0	8(4.0%)		
Diameter (cm)			
3 - 13	139(69.5%)	44- 54	1(0.5%)
14 - 23	37(18.5%)	55 - 63	4(2.0%)
24 - 33	10(5.0%)	64 or more	1(0.5%)
34- 43	8(4.0%)		

Species *Anacardium occidentale* also stood out among the species of greatest importance value (IV) in the restinga of Curupu, Maranhão State (Machado & Almeida Jr., 2019). This species is common in different areas of the northeast coast, as recorded for Rio Grande do Norte (Medeiros *et al*., 2014), Pernambuco (Cantarelli *et al*., 2012), and Piauí (Santos-Filho *et al*., 2013). Its predominance in restingas occurs because it is a pioneer species, occupying edges of forest fragments, clearings, and open canopy areas (Zickel *et al*., 2015). Species *Cenostigma bracteosum*, common in the Caatinga and Cerrado domains, stood out among the species of highest IV in the restinga. This highlight is possibly linked to growth strategies in the succession process, with high resistance to drought and the ability to compete for light, which makes it a dominant species (Sampaio, Araújo, Salcedo & Tiessen, 1998). Species *Guettarda angelica*, typical of the Caatinga biome, also stood out, establishing and developing in the coastal areas of Maranhão State.

Species *Guettarda angelica*, *Myrcia splendens*, *Cenostigma bracteosum*, *Fridericia* sp., *Eugenia stictopetala*, and *Mouriri guianensis* were the most frequent. In turn, species *Alibertia edulis*, *Chloroleucon acacioides*, *Coccoloba latifolia*, and *Erythroxylum pungens* were considered rare (Martins, 1991) due to the lower representativeness in the area, with only one individual.

The Shannon diversity index (H') was 2.92 nat. ind^{-1}, and the Pielou's evenness index (J') was 0.83. Despite restinga being considered a low diversity ecosystem, the value recorded for the study area was close to the values found by Machado and Almeida Jr. (2019), who recorded H' of 2.9 $nat.ind^{-1}$ in the restinga of Curupu, Maranhão State; and Santos-Filho, Almeida Jr. & Zickel (2013), who recorded H' of 2.44 $nat.ind^{-1}$ in Parnaíba, 2.18 $nat.ind^{-1}$ in Luiz Correia, and 2.22 $nat.ind^{-1}$ in Ilha Grande, all representing the coast of Piauí State. According to Corsini *et al*. (2014), the equivalent values can indicate more uniform communities and a balance in the plant structure, even if in a more attenuated way, with few groups dominating. It is worth noting, therefore, that the values found in restingas should be interpreted with caution in view of the limitations imposed by environmental stresses for plant growth.

Among the species mentioned above, it is worth mentioning *Sapium glandulosum*, a common species in Cerrado areas that was collected in a restinga. Furthermore, species *Manilkara bidentata*, common in the Amazon forest, was also collected in a restinga, which reinforces the influence of neighboring ecosystems on the colonization of coastal vegetation in Maranhão State (Almeida Jr. *et al*., 2011; Serra *et al*., 2016). Considering the species distribution along the northeast coast, the presence of these species in restingas supports the hypothesis that coastal vegetation may provide species to compose corridors in ecotonal environments (Castro, Moro & Menezes, 2012).

Conclusion

The studied area presented species richness and diversity values close to those of other restingas in the northeast. The closed shrublands physiognomy in the Itatinga restinga is characterized by medium vegetation; taller trees showing spaced canopy; lack of emerging species; thinner stems; and branched shrubs. This makes the spatial arrangement of individuals looks closer and denser.

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