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PHYTOSOCIOLOGICAL ANALYSIS OF THE THICKET'S VEGETATION IN TWO 'RESTINGA' SITES ON THE NORTH COAST OF BAHIA STATE, BRAZIL

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Abstract – This study aimed to define the floristic and structure composition of the thickets' vegetation in two sites of 'restingas' (coastal sand vegetation) in the beaches of Santo Antônio and Massarandupió, both located on the north coast of Bahia. In the thickets evaluated, we collected 44 species from 28 genera, and 23 botanic families. Fabaceae, Myrtaceae, and Nyctaginaceae presented the highests specific richness. In the first site, *Manilkara decrescent* T. D. Penn (32.52%), followed by *Tabebuia elliptica* (DC.) Sandwith (28.18%) and *Myrcia ramuliflora* (O.Berg) N. Silveira (28.14%), were the species with the highest importance value (IV), and in the second site, *Emmotum nitens* (Benth.) Miers (91.73%) and *Doliocarpus sellowianus* Eichler. (31.88%) were the species with the highest IV. For Santo Antônio beach, the thickets sampled showed Shannon diversity indices H'=3.024 nats/m^2, and in the Massarandupió beach, the diversity index found was H'=2.423 nats/m^2.
Keywords: Bahia state, floristic, restinga, thickets.

ANÁLISE FITOSSOCIOLÓGICA DA VEGETAÇÃO DE MOITA EM DUAS ÁREAS DE RESTINGA NO NORTE DO ESTADO DA BAHIA, BRASIL

Resumo – Este estudo visou definir a composição florística e estrutural da vegetação de moitas em dois locais de restingas (vegetação de área arenosa costeira), nas praias de Santo Antônio e Massarandupió, no litoral norte da Bahia. Nas moitas avaliadas, foram coletadas 44 espécies de 28 gêneros e 23 famílias botânicas. Fabaceae, Myrtaceae e Nyctaginaceae apresentaram a maior riqueza específica. No primeiro

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local, *Manilkara decrescent* T. D. Penn (32,52%), seguida por *Tabebuia elliptica* (DC.) Sandwith (28,18%) e *Myrcia ramuliflora* (O.Berg) N. Silveira (28,14%), foram as espécies com maior valor de importância (IV), e no segundo local, *Emmotum nitens* (Benth.) Miers (91,73%) e *Doliocarpus sellowianus* Eichler. (31,88%) foram as espécies com o maior IV. Para a praia de Santo Antônio, as moitas amostradas apresentaram índices de diversidade de Shannon H' = 3,024 nats/m^2, e na praia de Massarandupió, o índice de diversidade encontrado foi H' = 2,423 nats/m^2.
Palavras-chave: Bahia, florística, restinga, moitas.

INTRODUCTION

'Restingas' are littoral ecosystems composed of vegetation from adjacent ecosystems, such as the Atlantic Forest, Central Brazilian Savanna ('Cerrado'), and Caatinga (Freire, 1990). This vegetation reflects on the influence of soil conditions, exposure level to sea breezes, and abundant sunlight (Sampaio et al., 2005). In Brazil, this type of vegetation represents a mosaic of forest, shrubland and herbaceous along the coast (Medeiros et al., 2010; Almeida Jr. et al., 2011; Almeida Jr. & Zickel, 2012; Cantarelli et al., 2012, Vicente et al., 2014; Medeiros et al., 2014; Santos et al., 2015).

In 'restinga', the shrub formations can be composed of dense tangles of shrub, or thickets, intercalated by spaces with exposed sand (Zickel et al., 2004). The thickets are fragments of vegetation separated by the bare soil, where their succession occurs through the colonization of pioneer species, such as herbs and/or woody plants (Sampaio et al., 2005). In forming thickets, there are positive and negative interactions between plants, and the greater the level of abiotic stress in the environment, the greater the possibility of new positive interactions (Bertness & Hacker, 1994).

In the 'restingas', the thickets occur due to the discontinuity in the cover of the landscape and to the physiognomy and/or floristic composition, forming a mosaic configuration in open shrub formations (Rocha et al., 2015). According to Matos et al. (2017), the open shrub formation in thickets from the North Coast of Bahia corresponds to the non-flooded open scrub physiognomy, according to the classification of Silva & Britez (2005). This formation features, and presents shrubs and small atrophied trees, with common species including *Manilkara salzmannii* (A. DC.) H.J. Lam and *Tabebuia elliptica* (A. DC.) Sandwith.

The coast of Bahia is the largest in northeastern Brazil, covering 1,120 km in length and ca. 20 km wide (Santos et al., 2021). According to Queiroz (2007), the coast of Bahia is under an accelerated process of human occupation due to real estate speculation. Some studies were carried out on the composition of the vegetation on the coast of Bahia (Menezes et al., 2009; Menezes et al., 2012; Queiroz

et al., 2012; Fernandes & Queiroz, 2015; Santos et al., 2015; Silva et al., 2019; Santos et al., 2021), however there is not enough information about the vegetation structure of the entire coast of the state, mainly for the north coast.

In this context, the present study aimed to analyze the structure of the vegetation in two areas of open shrub 'restinga', specifically within the thickets, on the north coast of Bahia. We tested the following hypothesis: the thicket's vegetation of 'restinga' on the north coast of Bahia state has high richness and diversity. In addition, we aimed to answer the following questions: (1) What is the structural composition of the thicket's vegetation regarding the north coast of Bahia state? (2) Are the species that presented the highest importance value in the thicket vegetation on the north coast of Bahia also found in other 'restingas' along the northeastern coast of Brazil? We also propose expanding studies on the north coast of the Bahia state and contributing information about the vegetation to support future actions that intend to mitigate the impacts caused by human occupation.

MATERIAL AND METHODS

Area of study

The study was carried out in two 'restinga' sites in the north coast of Bahia, Santo Antônio Beach (Site 1 - 12°26'28"S, 37°56'02"W), in the municipality of Mata de São João, and Massarandupió Beach (Site 2 - 12º18'54"S; 37º49'53"W), in the municipality of Entre Rios. Both areas are located in the North Coast of Bahia Environmental Protection Area (EPA) (Figure 1), created by State Decree nº 1.046 of March 17, 92, as a conservation strategy of the National Environmental Policy. This EPA is the second largest in the Bahia state and covers five municipalities with 142 hectares (Menezes et al., 2012).

The climate type (according to Köppen climate classification) along the narrow strip of marine lowland and coastal upland in Bahia is the Af' (Tropical without dry season), a transition between the climate Aw' (Topical with monsoon) in the south and As' (Tropical with dry summer) in the north (Alvares et al., 2014). Annual rainfall varies spatially from south to north, reaching values between 2.000 mm and 1.200 mm, respectively. The Spodosols and Quartzarenic Neosols, typical of Quaternary deposits, are the major soil classes, characterized by being dystrophic and formed from deposits of fluvial-marine sediments from the Quaternary period (Martin et al., 1980).

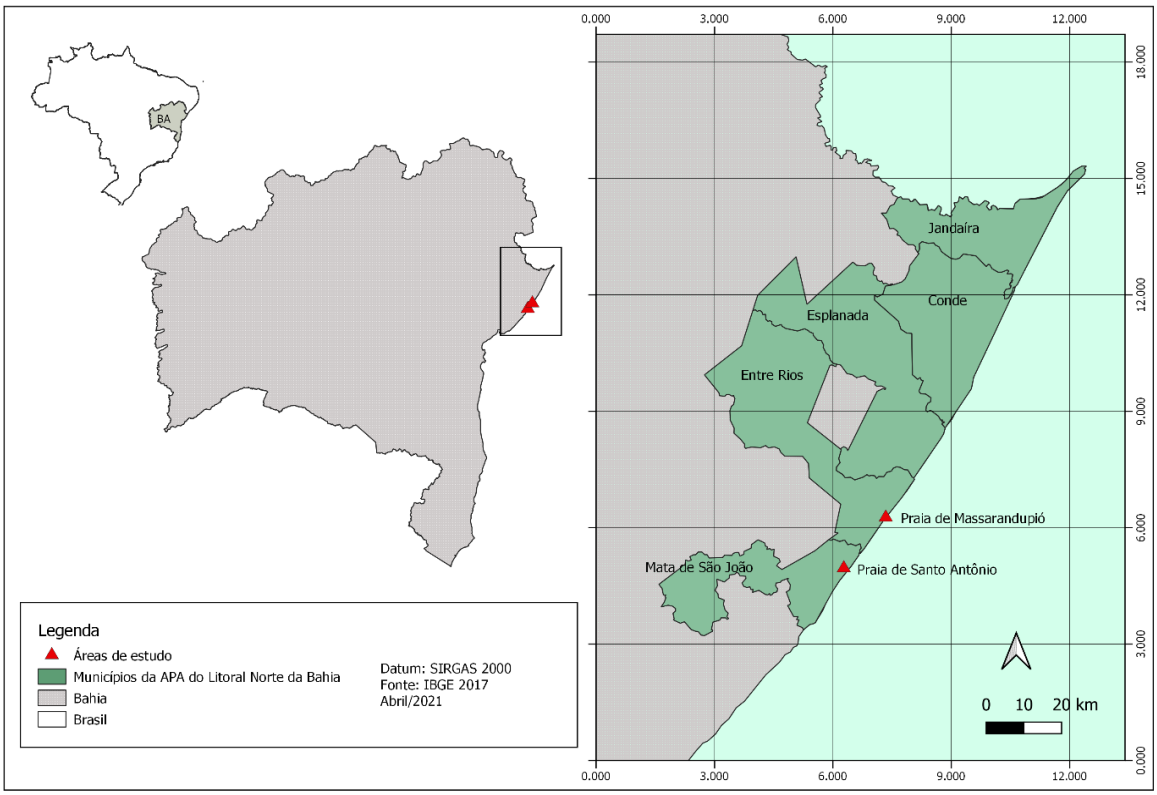

Figure 1. Location of the study areas in the North Coast of Bahia Environmental Protection Area.

Site 1 is composed of thickets of continuous herbaceous-shrub vegetation and extensive areas without vegetation (Figure 2). This beach is accessible and visited by locals and tourists. Site 2 is characterized by a continuous strip of thickets along its extension, with shrub-arboreal and herbaceous-shrub vegetation reaching the tide (Figure 2). The dunes form a barrier to the wind, which arises from the ocean. Tourist exploitation is frequent, with trails for access by "off-road" vehicles used for sports practice; in addition, there is a flow of people in some stretches that are intended for naturism.

Sampling and data analysis

For the phytosociological survey, 10 thickets were randomly selected in each of the studied areas, with every thicket having a perimeter of 250 m² or less, totaling 20 samples. Each thicket is equivalent to a parcel. For the phytosociological analysis, the dimensions of the thicket (width and length) were measured, and to understand their development, only woody plants were analyzed. The diameter and the height of all woody individuals within the thicket were collected. The diameter was measured 1.5 m above the ground. The plant samples were collected, prepared and identified according to the usual

methods in botanical studies (Mori et al., 1989), in the Laboratório de Botânica do Departamento de Educação da Universidade do Estado da Bahia (UNEB) - Campus VII.

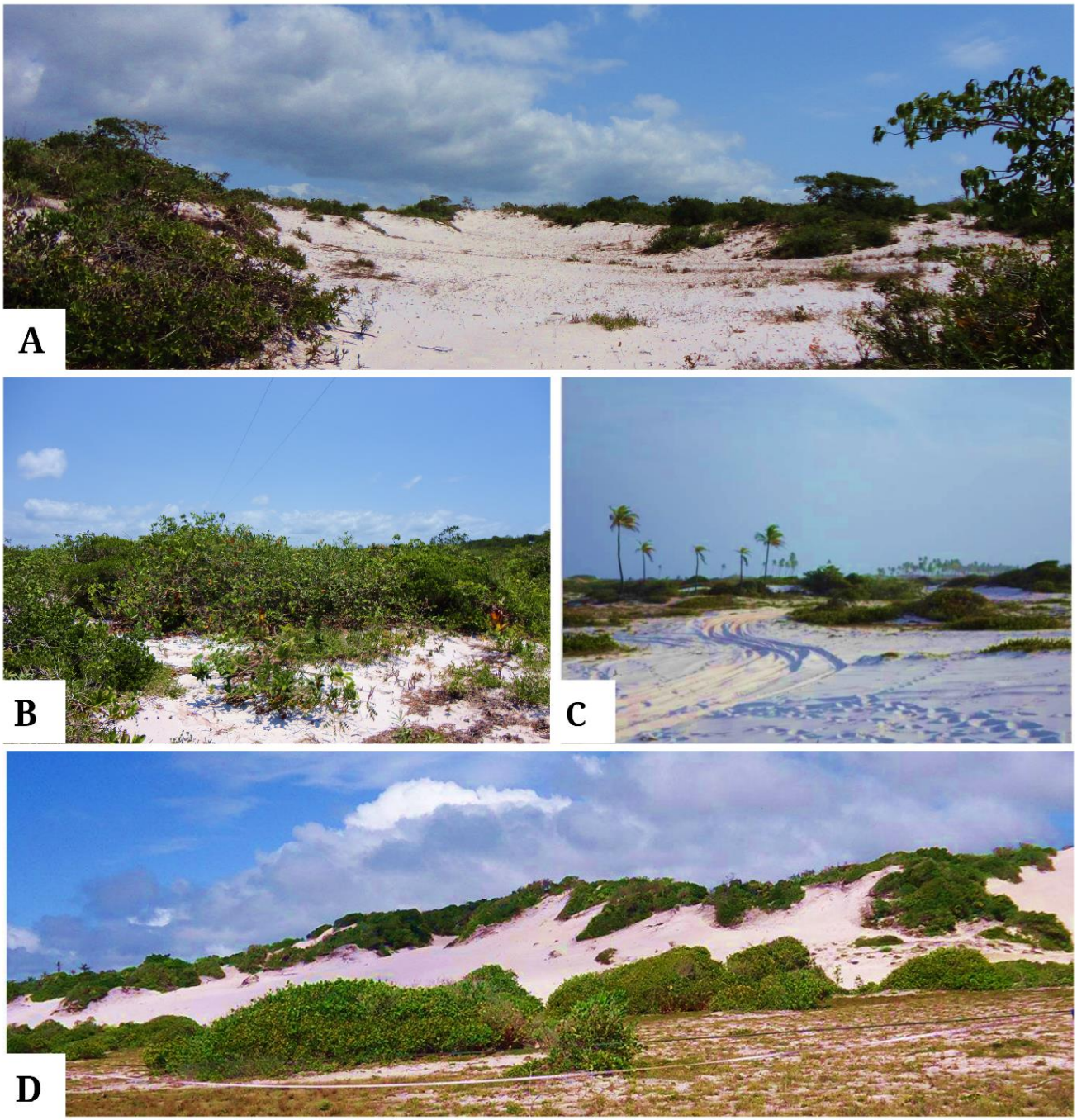

Figure 2. Open shrub formations of thickets in the North Coast of Bahia Environmental Protection Area. A-B. Santo Antonio Beach (Site 1). C-D. Massarandupió Beach (Site 2) (Author: Elizania P. Rios).

The material was identified with the support of specific literature and comparison with specimens from the collections of the Herbarium of the Universidade do Estado da Bahia (HUNEB) and Alexandre Leal Costa Herbarium (ALCB). The organization of families followed the classification system proposed by APG IV (2016).

The following phytosociological parameters were calculated using the Fitopac package (Shepherd, 2005): basal area (BA), relative density (RD), relative frequency (RF), relative dominance (RDo), and importance value (IV). The Shannon (H') and total richness (S). It should be noted that the Fitopac package is a program for phytosociological analysis that allows calculating parameters and analyzing data from vegetation surveys.

RESULTS

In the 20 thickets, there were sampled a total of 1,528 individuals distributed in 44 species from 28 genera, and 23 families (Table 1). For Site 1, the richest families in species were Fabaceae (five species), Myrtaceae and Nyctaginaceae (three species each) representing 31% of the total species. In Site 2, the richest families in species were Myrtaceae e Nyctaginaceae (three species each) and Dilleniaceae (two species each), representing 20% of the total species (Figure 3).

At Site 1, sample of 36 species were found. *Manilkara decrescens* (32.52%), *Tabebuia elliptica* (28.18%), *Myrcia ramuliflora* (28.14%) and *Croton campestris* (20.70%), represent 13% of the total species for this site, with highest importance value, due to their frequency and density (Table 1). Additionally, both *Manilkara decrescens* and *Myrcia ramuliflora* also presented the highest number of individuals.

In Site 2, sample of 20 species were included. *Emmotum nitens* (91.73%), *Doliocarpus sellowianus* (31.88%), *Myrsine guianensis* (29.30%), *Protium bahianum* (25.8%), *Clusia nemorosa* (23.4%) and *Coccoloba laevis* (20.1%) presented the highest importance value. The first two of them presented the highest number of individuals, while *Emmotum nitens* was the most frequency and dominance species (Table 1).

The Shannon diversity index for Site 1 was H' = 3.024 nts/m², and for Site 2 it was H' = 2.42 nts/m². The similarity analysis demonstrated low rates of similarity between the areas.

Table 1. Phytosociological parameters for the species sampled in the thickets in Santo Antônio beach – Site 1 = S 1, and Massarandupió beach – Site 2 = S 2. NI = number of individuals; RD = relative density; RF = relative frequency; RDo = Relative dominance; IV = Importance value. Species are sorted in ascending order according to IV.

Site 1 - 'Restinga' of Santo Antônio - Mata de São João

Species	Family	Area	NI	RF%	RD%	RDo%	IV %
Manilkara decrescens T.D.Penn	Sapotaceae	S1	125	7.46	12.25	12.80	32.52
Tabebuia elliptica (DC.) Sandwith	Bignoniaceae	S1	75	5.97	7.25	14.85	28.18
Myrcia ramuliflora (O.Berg) N. Silveira	Myrtaceae	S1	100	6.72	9.80	11.62	28.14
Croton campestris A.St.-Hil.	Euphorbiaceae	S1	84	4.48	8.24	7.98	20.70
Ouratea suaveolens (A.St.-Hil.) Engl.	Ochnaceae	S1	86	5.97	8.43	3.72	18.12
Alchornea sp.	Euphorbiaceae	S1	63	3.73	618	3.97	13.87
Erythroxylum passerinum Mart.	Erythroxylaceae	S1	45	5.22	4.41	4.04	13.67
Protium bahianum Daly.	Burseraceae	S1	31	5.97	3.04	4.64	13.65
Byrsonima microphylla A.Juss	Malpighiaceae	S1	64	4.48	6.27	2.75	13.50
Fabaceae 2	Fabaceae	S1	36	2.24	3.53	3.80	9.57
Indet 2	-	S1	22	2.99	2.16	4.25	9.39
Mimosa somnians Humb. & Bonpl. ex Willd.	Fabaceae	S1	27	2.99	2.65	3.33	8.96
Calycolpus legrandii Mattos	Myrtaceae	S1	27	2.99	2.65	2.60	8.23
Davilla flexuosa A.St.-Hil.	Dilleniaceae	S1	29	3.73	2.84	1.42	8.00
Trichilia hirta L.	Meliaceae	S1	29	3.73	2.84	1.18	7.75
Guettarda platypoda DC.	Rubiaceae	S1	23	3.73	2.25	1.43	7.41
Coccoloba ramosissima Wedd.	Polygonaceae	S1	35	2.24	3.43	1.62	7.29
Guapira opposita (Vell.) Reitz	Nyctaginaceae	S1	27	2.99	2.65	1.09	7.25
Indet 3	-	S1	10	2.99	0,98	1.22	5.05
Fabaceae 1	Fabaceae	S1	7	2.99	0,69	1.44	4.89
Eriope blanchetii (Benth.) Harley	Lamiaceae	S1	10	2.24	0.98	1.44	4.66
Doliocarpus sellowianus Eichler.	Dilleniaceae	S1	16	1.49	1.57	0.90	3.96
Coccoloba laevis Casar.	Polygonaceae	S1	7	1.49	0.69	1.61	3.78
Schefflera sp.	Araliaceae	S1	6	1.49	0.59	1.57	3.65
Myrcia splendens (Sw.) DC.	Myrtaceae	S1	7	1.49	0.69	0.74	2.92
Melastomataceae	Melastomataceae	S1	6	0.75	0.59	0.90	2.23
Erythroxylaceae	Erythroxylaceae	S1	5	0.75	0.49	0.99	2.23
Guapira pernambucensis (Casar.) Lundell	Nyctaginaceae	S1	6	0.75	0.59	0.35	1.69

Ocotea sp.	Lauraceae	S1	3	0.75	0.29	0.50	1.54
Pouteria grandiflora (A.DC.) Baehni	Sapotaceae	S1	2	0.75	0.20	0.29	1.23
Macrolobium latifolium Vogel.	Fabaceae	S1	2	0.75	0.20	0.18	1.12
Clusia nemorosa G.Mey.	Clusiaceae	S1	1	0.75	0.10	0.20	1.04
Nyctaginaceae	Nyctaginaceae	S1	1	0.75	0.10	0.18	1.03
Indet 1	-	S1	1	0.75	0.10	0.17	0.01
Xylopia laevigata (Mart.) R.E.Fr.	Annonaceae	S1	1	0.75	0.10	0.03	0.88
Bauhinia sp.	Fabaceae	S1	1	0.75	0.10	0.02	0.87

Site 2 - 'Restinga' of Massarandupió - Entre Rios

Species	**Family**	**Area**	**NI**	**FR%**	**DR%**	**DoR%**	**VI %**
Emmotum nitens (Benth.) Miers	Metteniusaceae	S2	87	14.29	17.09	94.17	91.7
Doliocarpus sellowianus Eichler.	Dilleniaceae	S2	114	4.29	22.40	8.11	31.8
Myrsine guianensis (Aubl.) Kuntze	Primulaceae	S2	58	11.43	11.39	10.14	29.3
Protium bahianum Daly.	Burseraceae	S2	45	12.86	8.84	6.53	25.8
Clusia nemorosa G.Mey.	Clusiaceae	S2	22	10.00	4.32	14.30	23.4
Coccoloba laevis Casar.	Polygonaceae	S2	44	5.71	8.64	9.03	20.1
Manilkara decrescens T.D.Penn	Sapotaceae	S2	34	10.00	6.68	2.23	18.1
Ouratea suaveolens (A.St.-Hil.) Engl.	Ochnaceae	S2	21	7.14	4.13	1.22	12.0
Chrysobalanus icaco L.	Chrysobalanaceae	S2	16	4.29	3.14	2.24	8.87
Davilla flexuosa A.St.-Hil.	Dilleniaceae	S2	19	2.86	3.73	0.58	6.96
Guapira sp.	Nyctaginaceae	S2	15	1.43	2.95	0.64	4.78
Guettarda platypoda DC.	Rubiaceae	S2	7	2.86	1.38	0.36	4.46
Myrcia ramuliflora (O.Berg) N. Silveira	Myrtaceae	S2	5	2.86	0.98	0.94	4.44
Indet 2	-	S2	1	1.43	0.20	3.28	3.73
Byrsonima macrophylla (Pers.) W.R.Anderson	Malpighiaceae	S2	8	1.43	1.57	0.78	3.50
Nyctaginaceae 1	Nyctaginaceae 1	S2	3	1.43	0.59	0.75	2.50
Myrcia acuminatissima O.Berg	Myrtaceae	S2	3	1.43	0.59	0.43	2.29
Myrtaceae 1	Myrtaceae	S2	3	1.43	0.59	0.22	2.16
Guapira opposita (Vell.) Reitz	Nyctaginaceae	S2	2	1.43	0.39	0.02	1.83
Indet 1	-	S2	1	1.43	0.20	0.07	1.67

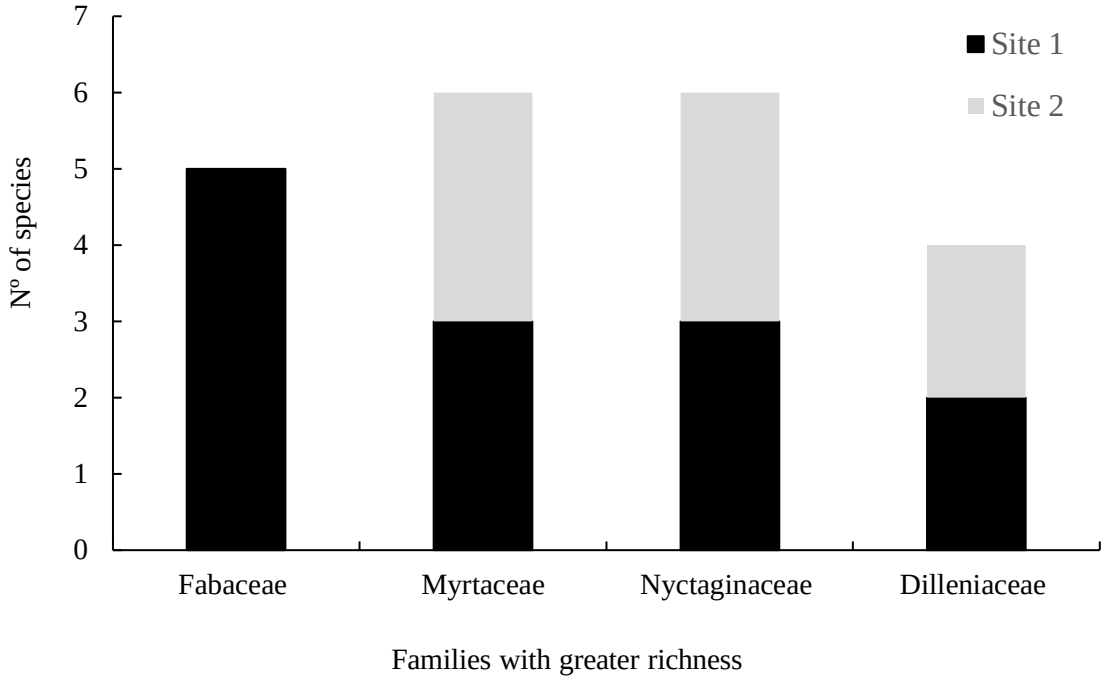

Figure 3. Comparison between families with greater species richness in the North Coast of Bahia Environmental Protection Area. Santo Antonio Beach (Site 1), and Massarandupió Beach (Site 2) (Author: Elizania P. Rios).

DISCUSSION

The families that stood out in the present study are the most common in restinga areas, which aid to understand the distribution pattern of these groups in the coastal areas of the Northeast. The richness for the Site 1 and 2 was low when compared with other restingas along the northeastern coast of Brazil, such as Baia Formosa-Bahia (Menezes et al., 2014), Maracaipe-Pernambuco (Almeida Jr. et al., 2011), Cabedelo-Paraíba (Vicente et al., 2013), and Refúgio da Vida Silvestre do Rio dos Frades-Bahia (Santos et al., 2015). According to Menezes et al. (2014) one of the factors behind the variation in richness between northeastern restingas of Brazil may be levels of anthropogenic impact and different forms of interferences. The anthropization of these areas could potentially facilitate the establishment of ruderal species (Guterres et al., 2019).

The family Fabaceae is well represented on the littoral of Bahia state (Menezes et al., 2009; Menezes et al., 2012; Queiroz et al., 2012; Fernandes & Queiroz, 2015; Santos et al., 2015, Silva et al., 2019; Santos et al., 2021). Myrtaceae has floristic importance in littoral areas, where it is one of the richest families, mainly in woody species (Peixoto & Gentry, 1990; Almeida Jr. et al., 2011; Almeida Jr. & Zickel, 2012; Medeiros et al., 2014; Fernandes & Queiroz, 2015).

Myrcia ramuliflora and *Manilkara decrescens* also were reported with highest importance value for Diego's 'restinga' (Santos et al., 2021), located in the North Coast of Bahia Environmental Protection Area. *Protium bahianum* also had the highest importance value for "Refúgio da Vida Silvestre do Rio dos Frades" (Santos et al., 2015), in the South Coast of Bahia. *Tabebuia elliptica*, that had a high IV in Site 1, often appears in the central area of the thicket, in a prominent position, and may play a facilitating role for other species, as suggested by Menezes et al. (2009).

In terms of diversity, Site 1 (H' = 3.024) presented values close to those reported by Menezes et al. (2012) (H' = 3.835), who studied a shrubby site at Praia do Forte Beach on the north coast of Bahia, as well as by Santos et al. (2015) (H' = 3.553), who analyzed shrub-tree stratum of a restinga in southern Bahia. The diversity index for Site 2 was notably lower compared to Site 1 and the other studies conducted on shrub-tree vegetation along the Bahia coast (Menezes et al., 2012; Santos et al., 2015; Santos et al., 2021).

Although they are geographically close areas, they present significant differences in flora and vegetation structure, which may be related to the intense human pressure on the 'restinga' (Santos et al., 2021). This situation results in microhabitats decrease, leading to environmental homogeneity, the establishment of pioneer species and predominance of species to economic interest (Zickel et al., 2015; Santos et al., 2021). This poses a risk to native species that thrive in coastal environments.

Massarandupió Beach has more tourist exploitation and more frequency of people; different from Santo Antônio Beach, which has low flow of people. Therefore, in addition to ecological studies on thicket vegetation, more analyzes are needed to evaluate the levels of anthropization, with a view to actions for conservation and preservation of restingas, and the management and recovery of degraded areas.

CONCLUSION

The thickets on the restingas on the Santo Antônio and Massarandupió Beach are structurally and floristically distinct; and the thickets of Santo Antônio Beach have greater diversity. The areas also present differences in terms of species composition, total density and IV. These differences may be associated with different conditions of anthropic influence.

Furthermore, the floristic richness allows us to suggest that these areas should be considered as a "vegetation complex", given the unique characteristics and anthropic factors affecting each area. However, it is necessary for new floristic surveys to be carried out to associate soil and ecological factors.

Finally, we conclude that the restingas of northern Bahia have a rich floristic composition, which highlights the importance of conserving this vegetation.

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