Rodriguésia 73: e01252021. 2022
http://rodriguesia.jbrj.gov.br
DOI: http://dx.doi.org/10.1590/2175-7860202273109

Original Paper

Flora and physiognomy of *Caatinga* vegetation over crystalline bedrock in the northern *Caatinga* domain, Brazil

Elnatan Bezerra de Souza[1,6], *Francisco Álvaro Almeida Nepomuceno*[2,7], *Francisco Diego Sousa Santos*[1,8], *Francisco Fernandes de Araújo*[1,9], *Izaíra Vasconcelos Nepomuceno*[3,10], *Alexandre Souza de Paula*[3,11], *Vivian Oliveira Amorim*[3,12], *Mário Sérgio Duarte Branco*[4,13], *Samuel Trajano Rabelo*[5,14], *David Mendes Macelli Pinto*[1,15], *João Batista Silva do Nascimento*[1,16] & *Marcelo Freire Moro*[3,4,5,17,18]

Abstract

The Seasonally Dry Tropical Forests and Woodlands biome (SDTFW) has its largest nucleus in the *Caatinga* domain. We characterized the flora and physiognomy of the vegetation in the Pedra da Andorinha Wildlife Refuge (RPA), in Ceará, Brazil. Plant collections were made between March/2015 and May/2021, applying usual botanical methods. All material was deposited in HUVA herbarium. The phytosociological studies covered five 50 m x 50 m plots established (1.25 ha) in which all individuals with diameters at soil level ≥ 3 cm were inventoried. We identified 266 vascular plants species distributed among 185 genera and 67 families, including one fern (*Marsilea deflexa* - Marsileaceae). Fabaceae had the greatest species richness (38 spp.), while *Ipomoea* was the richest genus (9 spp.). 43.6% of all plant species were herbaceous, with a predominance of therophytes (57.5% of all herbaceous plants). The phytosociological study sampled 1,988 individuals distributed among 24 species of 13 families. The species with the greatest important value were *Cordia oncocalyx* (Boraginaceae) and *Croton blanchetianus* (Euphorbiaceae). We classify the local physiognomy as typical *caatinga sensu stricto* vegetation and rocky vegetation on inselbergs and outcrops. We highlight the richness of herbaceous plants in the local community, which surpass the richness of the woody component.
Key words: floristics, life forms, phytosociology, SDTFW, semiarid.

Resumo

O bioma das Florestas e Arbustais Tropicais Sazonalmente Secos tem na Caatinga sua mais extensa área, possuindo elevada diversidade florística e ambiental. Caracterizamos a composição florística e a fisionomia da vegetação no Refúgio da Vida Silvestre Pedra da Andorinha (RPA), área de conservação no noroeste do estado do Ceará, Brasil. Realizamos coletas botânicas entre março de 2015 e maio de 2021, aplicando os métodos tradicionais de coleta e herborização. Todo o material foi depositado no herbário HUVA. A fitossociologia foi feita em cinco parcelas de 50 x 50 m (1,25 ha), onde os indivíduos lenhosos com diâmetro ao nível do solo ≥ a 3 cm foram inventariados. Avaliamos os parâmetros fitossociológicos de estrutura da vegetação e sua diversidade florística. Identificamos 266 plantas vasculares, distribuídas em 185 gêneros e 67 famílias,

[1] Universidade Estadual Vale do Acaraú, Betânia, Sobral, CE, Brazil.
[2] Universidade Estadual de Feira de Santana - UEFS, Prog. Pós-graduação em Botânica - PPGBot, Feira de Santana, BA, Brasil.
[3] Universidade Federal do Ceará, Prog. Pós-graduação em Sistemática, Uso e Conservação da Biodiversidade, Centro de Ciências, Pici, Fortaleza, CE, Brazil.
[4] Universidade Federal do Ceará, Instituto de Ciências do Mar, Meireles, Fortaleza, CE, Brazil.
[5] Universidade Federal do Ceará, Prog. Pós-graduação em Ciências Marinhas Tropicais, Meireles, Fortaleza, CE, Brazil.
[6] ORCID: <https://orcid.org/0000-0002-5222-4378>. [7] ORCID: <https://orcid.org/0000-0002-4643-8177>. [8] ORCID: <https://orcid.org/0000-0002-0053-1333>.
[9] ORCID: <https://orcid.org/0000-0002-8520-789X>. [10] ORCID: <https://orcid.org/0000-0003-2735-8435>. [11] ORCID: <https://orcid.org/0000-0003-4832-6993>.
[12] ORCID: <https://orcid.org/0000-0002-5068-0206>. [13] ORCID: <https://orcid.org/0000-0002-8428-4252>. [14] ORCID: <https://orcid.org/0000-0001-6985-9428>.
[15] ORCID: <https://orcid.org/0000-0001-6240-3882>. [16] ORCID: <https://orcid.org/0000-0003-2170-9986>. [17] ORCID: <https://orcid.org/0000-0003-4527-346X>.
[18] Author for correspondence: bio_moro@yahoo.com.br

incluindo uma pteridófita (*Marsilea deflexa* - Marsileaceae). A família Fabaceae teve a maior riqueza (38 spp.), enquanto *Ipomoea* foi o gênero mais rico (9 spp.). O componente herbáceo foi o componente mais rico (43,6%), com uma predominância de herbáceas terófitas (57,5% de todas as plantas herbáceas). O estudo fitossociológico amostrou 1.988 indivíduos, distribuídos em 24 espécies de 13 famílias. As espécies com maior valor de importância foram *Cordia oncocalyx* e *Croton blanchetianus*, responsáveis por 63% dos indivíduos amostrados. Classificamos a área como Caatinga *sensu stricto* e em vegetação rupícola de inselbergues e afloramentos rochosos, chamando a atenção para a elevada riqueza de espécies no componente herbáceo, que, como em outras áreas de Caatinga *sensu stricto*, supera a riqueza de espécies lenhosas.
Palavras-chave: fitossociologia, florestas tropicais sazonalmente secas, florística, formas de vida, semiárido.

Introduction

The *Caatinga* domain is currently considered the largest and most diverse nucleus of the Seasonally Dry Tropical Forests and Woodlands biome (SDTFW), in which 3,347 different species, 962 genera, and 153 families of angiosperms have been identified, with 526 species and 29 genera being considered endemic (Fernandes *et al.* 2020).

One hundred and thirty-five geo-environments, composing at least eight ecoregions, exist in that extensive ecological region, demonstrating a significant heterogeneity of *Caatinga* environments (Velloso *et al.* 2002). A number of different proposals of biogeographic subdivisions for the *Caatinga* have been suggested over the years. Silva *et al.* (2017) recently proposed modifying the delimitation of what is normally considered the *Caatinga* phytogeographic domain to include the dry forests along the midcourse of the São Francisco River and to exclude the Campo Maior ecoregion in Piauí state (whose phytophysiognomy and flora are more closely related to the *Cerrado*).

The floristic heterogeneity observed among the diverse *caatinga* phytophysiognomies has been examined based on the hypothesis of the influence of geological strata on the floristic composition of those different areas. Current research indicates that there are at least two large floristic subgroups within the flora of the *Caatinga* domain: sedimentary *caatinga*, on the sandy terrains of the sedimentary basins, and *caatinga* over crystalline bedrock (crystalline *caatinga*). Each subgroup occupies approximately 30% and 70% of the inland semiarid surface respectively (Cardoso & Queiroz 2007; Costa *et al.* 2015; Moro *et al.* 2016; Silva *et al.* 2017). The crystalline *caatinga*, established over shallow soils with moderate to high fertility, constitutes a typical vegetation type of the semiarid region, with the predominance of herbaceous therophytic elements that represent approximately 60% of all species. Sedimentary *caatinga* (also called Sandy *Caatinga* or *Carrasco*) vegetation, on the other hand, is established on sedimentary basins associated with deep sandy soils of low fertility, with its vegetation predominantly composed of low, shrubby plants (Moro *et al.* 2016; Fernandes & Queiroz 2018).

The diversification of botanical components as a function of geological strata, landscape, and soils under the influence of a semiarid climate has resulted, over time, in a high environmental diversity within the *Caatinga* phytogeographic domain (Silva *et al.* 2004, 2017) and, consequently, a high diversity of phytophysiognomies, as the *Caatinga* can be classified into at least 13 different typologies (Andrade-Lima 1981; Prado 2003).

In contrast to the wide phytophysiognomic and floristic diversity encountered in the *Caatinga*, there are insufficient numbers of established conservation areas there, with only 7.96% of the *Caatinga* domain being included within preservation areas, and only 1.3% of those areas are full protection sites (Silva *et al.* 2017; Teixeira *et al.* 2021).

Ceará state, in northeastern Brazil, is included within the *Caatinga* domain, with 70% of its territory over crystalline peneplains. The landscape is largely flat, and is known as the *Sertaneja* depression or the *interplanalto* depression (Moro *et al.* 2015). The extensive planar surface of that region, with elevations generally less than 400 meters above sea level, is notably deficient in water resources and is associated with thin soils covering ancient crystalline bedrock (Moro *et al.* 2015).

The crystalline *caatinga* therefore represents the principal phytoecological region in Ceará state, although it has been largely ignored in terms of floristic studies (which have largely focused on more exceptional phytoecological areas such cerrado enclaves and humid altitudinal forests known as *brejos*). Many questions are therefore still

open concerning the floristic relationships between the crystalline *caatinga* and crystalline dry forests (Moro *et al.* 2015).

Considering the wide extension of crystalline *caatinga* and the diverse mesoregions of Ceará state with probable floristic variations, previous surveys have not filled in the gaps in our current knowledge concerning floristic variations within that vegetation type (Costa *et al.* 2007; Araújo *et al.* 2011; Costa & Araújo 2012; Duarte *et al.* 2013; Pereira *et al.* 2018). Additionally, SDTFW generally have locally abundant but geographically restricted species, with low similarities between areas and high beta diversity - even over relatively short distances (Apgaua *et al.* 2014).

Considering the need for more data concerning the crystalline *caatinga*, especially in Ceará state, the present study sought to characterize the flora and the phytosociology of the *Caatinga* vegetation in the Pedra da Andorinha Wildlife Refuge (RPA), a conservation area located in the northwestern region of that state.

Materials and Methods

Study area

The Pedra da Andorinha Wildlife Refuge (or "Refúgio de Vida Silvestre Pedra da Andorinha", designated here as RPA), covers approximately 600 ha within the Taperuaba District (04°03'51''S, 39°59'51''W), in the municipality of Sobral, in northwestern Ceará state, Brazil (Fig. 1). The RPA was created in 2010 to protect the natural environment of the resident and migratory fauna and flora of the region. The refuge has, as its principal objective, the conservation of biological diversity through research and scientific studies. In addition to protecting *caatinga* vegetation, the RPA serves as a natural refuge for millions of swallows that nest in natural cavities (*tafonis*) in the inselberg that gives the refuge its name (Fig. 1a,b,c).

The borders of the RPA enclose the Pedra da Andorinha inselberg, on the northern slope of the Correntes range (Rodrigues 2018), as well as the lowlands around it. From a geological point of view, the study area is included within the geologic shields and ancient massifs domain (Claudino-Sales & Peulvast 2007), which is composed of predominantly crystalline bedrock of the Tamboril-Santa Quitéria Group (principally granites and migmatites of neoproterozoic origin [630–600 my]) (FUNCEME 2015). The regional landscape is dominated by the Pedra da Andorinha inselberg, which is surrounded by planar erosive surfaces (Claudino-Sales 2016). Elevations within the RPA vary from 200 to 500 masl, with most of the area below 300 m.

The predominant climate in the region of the RPA is characterized as tropical hot and semiarid, with rainfall between January and June and a mean annual precipitation of 539.7 mm (1999–2008), with high mean temperatures, varying between 25 and 27° C (type Bsw'h' by the Köppen climatic classification). Accentuated droughts occur periodically, lasting between seven to eight months, with elevated hydric deficiencies (Rodrigues 2018; Rodrigues *et al.* 2020).

The drainage system within the RPA consists of two small creeks: the Bilheira and the Tamanduá. The former runs from east to northwest, and the latter south to north. The drainage basins are of the dendritic type, and belong to the Aracatiaçu River basin.

The predominant soil types in the RPA are Chromic Luvisols, which occupy approximately 90% of its area. Poorly developed Fluvic Neosols can be found along streams and small fluvial canals, with a superficial covering having a sandy to clayey texture.

Floristic survey

The floristic survey involved 21 sporadic collecting expeditions between March/2015 and May/2021, using random walks through the study area during both the dry and rainy seasons. Collecting efforts were mainly concentrated in flat lowland areas near the Pedra da Andorinha inselberg (up to an elevation of 430 m). That search area comprised most of the RPA, where three environments were identified in terms of collecting sites: (i) rock outcrops and associated habitats, (ii) the margins of temporary watercourses, and (iii) level interfluvial surfaces (Fig. 2).

The collections were made using traditional botanical procedures (Mori *et al.* 1989), taking into consideration the diverse vegetation layers and different substrates within the three environments indicated above. The collected material was deposited in the Prof. Francisco José de Abreu Matos herbarium (HUVA) at the Vale do Acaraú State University; duplicates were sent to other herbaria (EAC, HUEFS, and HDELTA - acronyms according to Thiers, continuously updated).

All of the specimens were photographed, geo-referenced, and subsequently identified based on the technical literature (Lorenzi 2008a,b, 2009a,b;

Souza & Lorenzi 2008), specialized databases (CRIA 2021, Flora do Brasil 2020, REFLORA 2021), comparisons with herbarium material, and consultations with specialists.

The species list was organized alphabetically by family, based on the APG IV (2016), with the exception of Turneraceae, which is considered a different family from Passifloraceae. The spelling of the scientific names and synonyms follow the Flora do Brasil 2020 (constinously updated). Exotic invasive species were recorded, following the recommendations of Moro *et al.* (2012).

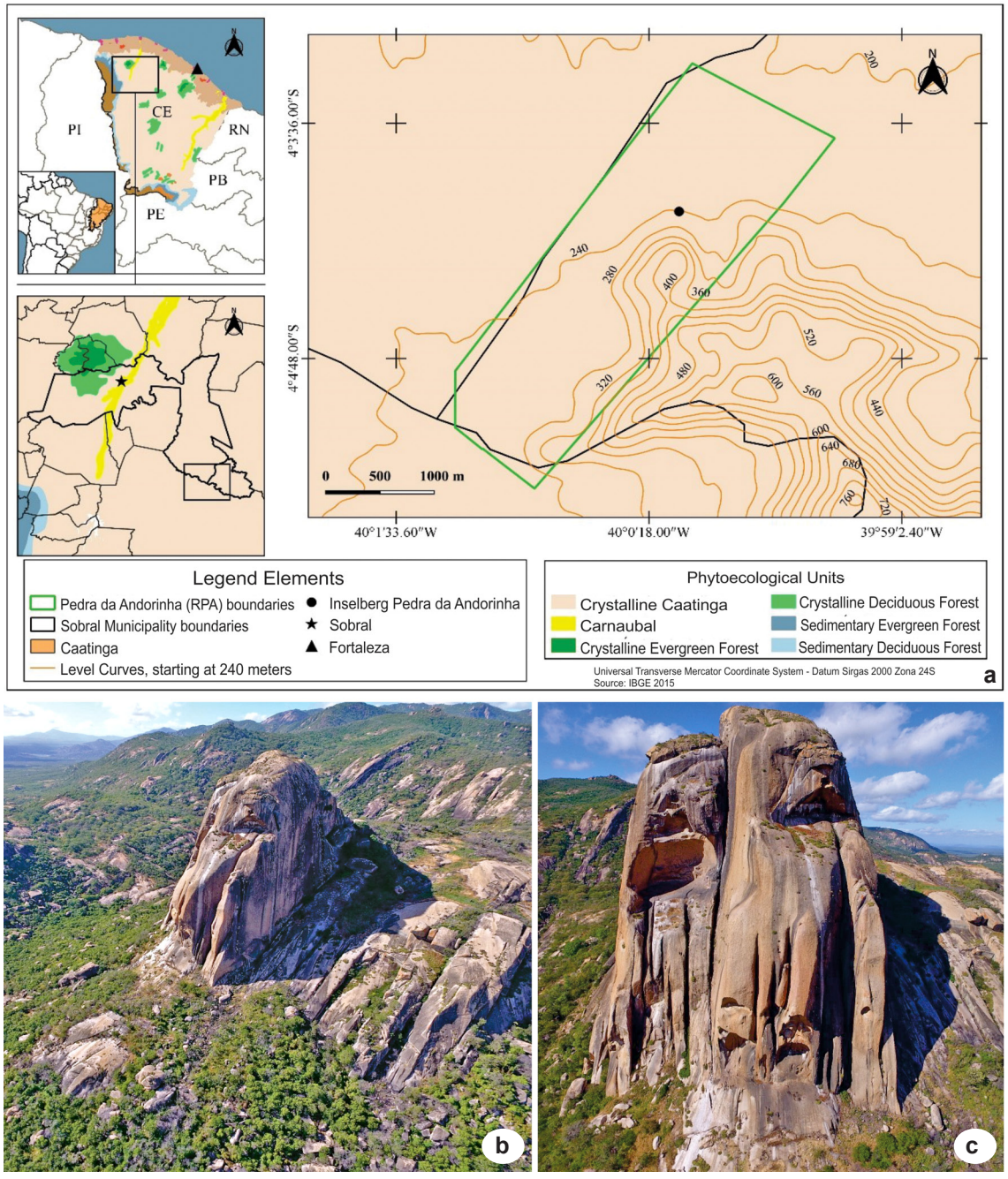

Figure 1 – a. Map locating the Pedra da Andorinha Wildlife Refuge (Refúgio de Vida Silvestre Pedra da Andorinha), in Taperuaba, Sobral municipality, Ceará state, Brazil, within the context of phytoecological areas of Ceará state; b. side view of the Andorinha Inselberg; c. frontal view of the Andorinha Inselberg. (b-c. D. Gomes).

Each species was classified in terms of its habit, following Gonçalves & Lorenzi (2011), and their life forms noted following the system of Raunkiaer (1934) (Braun-Blanquet 1979; Martins & Batalha 2011), classifying them into five categories: phanerophytes, chamaephytes, hemicryptophytes, cryptophytes/geophytes and therophytes. Woody climbers (lianas) and shrub and arboreal cacti were considered phanerophytes, while vines or herbaceous climbing plants were classified according to the degree of reduction of their aerial portions during the dry period, and if they had (or not) underground storage organs (França *et al.* 2005; Araújo *et al.* 2008, 2011; IBGE 2012; Queiroz *et al.* 2015).

Geographic distributions of the species

The distributions of the species among the four major tropical Brazilian phytogeographic domains contiguous to *Caatinga* (*Caatinga*, *Cerrado*, Amazon and Atlantic rainforests) were verified using the Flora do Brasil 2020 (continously updated), and compared in a Venn diagram, using Venny 2.1 software (Oliveros 2007-2015).

Comparing the biological spectra of *Caatinga* areas

A matrix was elaborated with the different spectra of life forms in the different environments encountered in the Pedra da Andorinha Wildlife Refuge (based on data available in the literature) to compare them with other areas within the *Caatinga* phytogeographic domain (Tab. 1). We included within that matrix studies undertaken in areas of crystalline *caatinga*, sedimentary *caatinga*, and on inselbergs. The relationships among the biological spectra were inferred based on non-metric multidimensional scaling (NMDS) analyses, using Euclidean distances (Faith *et al.* 1987; Gotelli & Ellison 2011) and implemented in the R environment with the Vegan package (Oksanen *et al*. 2018).

Phytosociological survey

The sampling technique used was based on five 50 × 50 m (2,500 m^2) plots, each subdivided into twenty-five 10 × 10 m subplots, yielding a total sampling area of 12,500 m² (1.25 ha). Data collection followed the protocol of plots in areas of seasonally dry vegetation as proposed by Moonlight *et al.* (2020), with adaptations. All living woody individuals within the sampling areas with diameters at ground level greater than or equal to 3 cm (DGL ≥ 3 cm) were measured and identified following the standard protocol used in *Caatinga*, as proposed by Rodal *et al.* (1992). The variables measured were: Diameter at Ground Level (DGL, in centimeters), and total height of each individual (HT, in meters). Raw

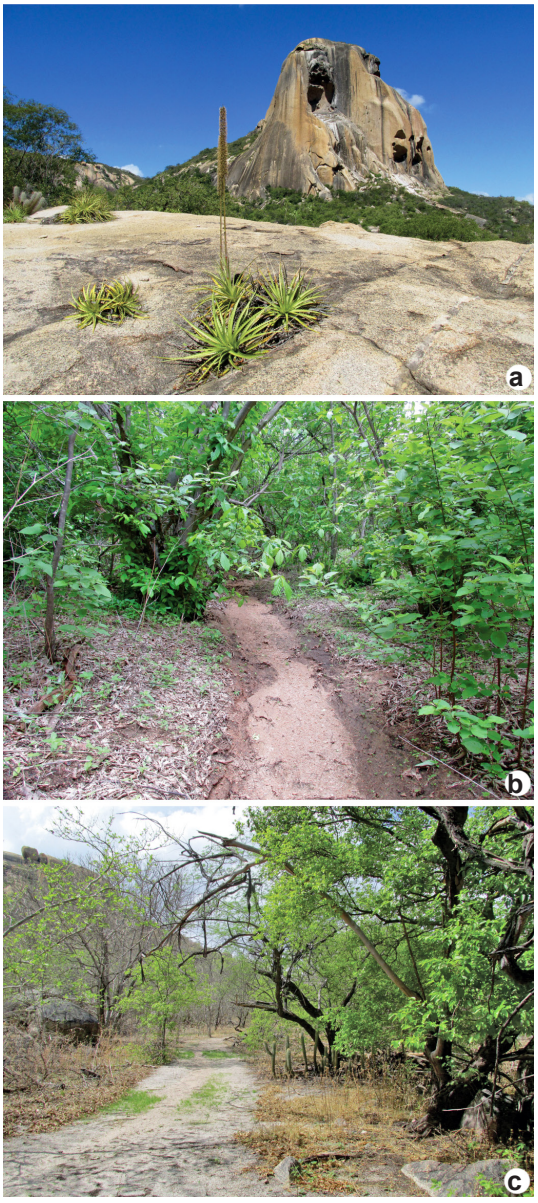

Figure 2 – a-c. Natural environments in the Pedra da Andorinha Wildlife Refuge where the floristic survey was undertaken – a. rock outcrops and associated habitats; b. margins of intermittent watercourses; c. planar and interfluvial surfaces. (a-c. E.B. Souza).

Table 1 – Areas considered in the matrix of biological spectra for NMDS analysis. The = Therophyte; Cry = Cryptophyte; Hem = Hemicryptophyte; Pha = Phanerophyte.

Site	Life forms (%)					Reference
	The	Cry	Hem	Cha	Pha	
Crystalline Caatinga						
Revis Pedra da Andorinha, Sobral, CE	57.52	2.63	1.50	5.26	33.08	This study
Estação ecológica do Seridó, Serra Negra do Norte, RN	79.25	2.72	1.36	3.40	13.27	Queiroz *et al.* (2015)
Reserva Natural Serra das Almas, Crateús, CE	45.26	1.46	6.57	18.98	27.74	Araújo *et al.* (2011)
Reserva Particular do Patrimônio Natural Maurício Dantas, Betânia e Floresta, PE	40.45	1.12	14.61	17.98	25.84	Costa *et al.* (2009)
Reserva Particular do Patrimônio Natural Maurício Dantas, Betânia e Floresta, PE	38.14	1.69	16.10	17.80	26.27	Rodal *et al.* (2005)
Serrote dos Picos, Santa Quitéria, CE	40	0	12	28	20	Pereira *et al.* (2018)
Serrote dos Picos, Santa Quitéria, CE	30	0	13.33	30	26.67	Pereira *et al.* (2018)
Sítio Galinha de Angola, Santa Quitéria, CE	35.5	0	8.82	32.35	23.53	Pereira *et al.* (2018)
Lagoa do Peixe, Groaíras, CE	41.67	0	22.22	19.44	16.67	Pereira *et al.* (2018)
Sedimentary Caatinga						
Reserva Natural Serra das Almas, Crateús, CE	16.91	2.94	3.68	19.12	57.35	Araújo *et al.* (2011)
Reserva Natural Serra das Almas, Crateús, CE	13.20	3.20	2.40	23.20	58	Araújo *et al.* (2011)
São José do Piauí, PI	4.4	3.7	8.1	12.5	71.3	Mendes & Castro (2010)
Inselbergs						
Sítio Santa Luiza, Quixadá, CE	44.74	2.63	13.16	14.47	25	Araújo *et al.* (2008)
Distrito de Lagoa de Pedra, Esperança, PB	42.5	0.78	4.72	12.59	39.37	Porto *et al.* (2008)
Pedra da Guariba, Platô da Borborema, PE	28	8	4.5	6.5	31	Gomes & Alves (2010)
Pedra Cabeça de Velho, Platô da Borberma, PE	38	11	3	5	49	Gomes & Alves (2010)
Pedra do trevo, Catende, PE	33	10	18	16	23	Gomes & Sobral-leite, (2013)
Lajedo do Uruçi, Maraial, PE	27	8	15	19	31	Gomes & Sobral-leite (2013)
Monumento Nacional Monólitos de Quixada, Quixadá, CE	23.36	4.67	5.61	6.54	59.81	Paulino *et al.* (2018)

data available on supplementary material <https://figshare.com/s/9e7be11ce771eb9740a1>

The characterization of the horizontal structures of the sampled species were determined using FITOPAC 2.1 software (Shepherd 2010): Numbers of Individuals (NI), Absolute Density (AD), Relative Density (RD), Absolute Frequency (AF), Relative Frequency (RF), Absolute Dominance (ADo), Relative Dominance (RDo), Importance Value Index (IVI), Coverage Value Index (CVI), and Shannon-Wiener Diversity Index (H').

Rarefaction, extrapolation, and estimates of total richness

The methods of rarefaction (interpolation), extrapolation, and estimates of total richness (asymptotic) were used to evaluate the sampled richness in the phytosociological survey. To that end, we calculated species rarefaction per plot to evaluate the accumulation curves of the species using 1,000 randomizations. As any sampling of biodiversity is typically an underestimation of the total richness of an area, we used a set of non-parametric statistical estimators based on the numbers of rare species and the distributions of species in the sampling plots to estimate the total number of species in the study area. The estimators used were: ICE (an estimator of cover based on incidence), Chao 2, and Jackknife 1 (Gotelli & Colwell 2011). Those algorithms estimate the total numbers of species in a given area based on data from sampling plots (Gotelli & Colwell 2011). After that step, the sampling was extrapolated to a larger area than the true sampling space to evaluate if a considerable increase in the richness recorded in the study areas would be an expected if greater sampling efforts were made. We prepared collection curves for the numbers of species observed in the present study and for the numbers of extrapolated species (Colwell *et al.* 2012). Those analyses were performed using EstimateS 9.1.0 software (Colwell & Elsensohn 2014)

Results

Floristics and geographic distribution

We cataloged 266 vascular plant species in the RPA (Tab. 2; Fig. 3), distributed among 185 genera and 67 families of angiosperms, as well as one fern species (*Marsilea deflexa* - Marsileaceae). The families with the greatest species richness were Fabaceae (38 spp.), Convolvulaceae (19 spp.), Malvaceae (17 spp.), Poaceae and Euphorbiaceae (16 spp. each), Asteraceae (11 spp.), Boraginaceae (9 spp.), Apocynaceae and Solanaceae (7 spp. each), corresponding to 52.6% of all of the species inventoried; 24 families were represented by a single species, and 17 families by two species.

The families with the largest numbers of genera were Fabaceae (22 genera), Poaceae (13), Asteraceae and Malvaceae (11 each), Euphorbiaceae (9), Apocynaceae (7), Commelinaceae (6), Boraginaceae and Rubiaceae (5 each), Bignoniaceae, Cactaceae, and Solanaceae (4 each), and Acanthaceae, Convolvulaceae, Cyperaceae, Lamiaceae, Plantaginaceae, and Verbenaceae (3 each); 34 families (50.7%) were represented by only a single genus. The genera with the largest numbers of species were *Ipomoea* (9), *Croton* (7), *Chamaechrista*, *Jacquemontia*, *Mimosa*, *Senna*, and *Sida* (5 spp. each), *Combretum*, *Portulaca*, and *Solanum* (4 each), *Alternanthera*, *Evolvulus*, *Stachytarpheta*, *Turnera*, and *Varronia* (3 each). Together, those 16 genera comprised 26.7% of the species of the flora of the RPA.

Of the total number (266) of species, 249 (93.6%) were classified as native and 17 (6.4%) as exotic. Among the exotic species, two (*Calotropis procera* and *Cryptostegia madagascariensis*) stood out as being large and vigorous shrubs. Most of the exotic species, however, were part of the herbaceous component, with Poaceae being the family with the greatest number of exotic species (8) (Tab. 2).

The herbaceous component had the largest species richness in the sampling areas, with 116 species of herbs (43.6%), followed by 41 species of shrubs (15.4%), 40 species of vines (15%), 38 species of subshrubs (14.3%), and 28 species of trees (10.5%); there was one holoparasite species (*Cuscuta racemosa*) and one hemiparasite (*Passovia pedunculata*) (0.4% each), and one palm (0.3%) (*Copernicia prunifera*).

As noted above, climbing plants demonstrated significant diversity, and could be classified as herbaceous (9.8%) or woody (5.3%). Four families comprised 70% of the climbing species richness: Convolvulaceae (12 spp.), Fabaceae (6 spp.), Apocynaceae and Bignoniaceae (4 spp. each). Among climbing mechanisms, 28 species (70%) were twiners, followed by 11 species with tendrils (27.5%), and one species with adhesive roots (2.5%) (*Philodendron acutatum*).

Comparisons with the known geographic distributions of the taxa surveyed indicated that most of the species are not endemic to Brazil

Table 2 – List of species identified in the RPA. Environments: I = rock outcrops and associated habitats; II = riverine vegetation on the margins of intermittent watercourses; III = Caatinga *sensu stricto* in planar and interfluvial surfaces. OR: origin (Nat = native; Exn = exotic naturalized; Exi = exotic aggressive invader). GF: growth form (Shr = shrub; Tre = tree; Her = herbaceous; Pal = palm; Par = parasite; Sub = subshrub; Var = vines with adhesive roots; Vtw = twiner vines; Vte = vines with tendrils; Lte = liana with tendrils; Ltw = twiner lianas). LF: life form (The = therophyte; Cha = chamaephyte; Cry = cryptophyte; Pha = phanerophyte; Hem = hemicryptophyte). DB: distribution (*Ad = ample distribution; Ca = Caatinga; Ce = Cerrado; AF = Atlantic Forest; Am = Amazonian; Pa = Pampa; Pt = Pantanal). VC: voucher (EBS = *E.B. Souza et al.*; FFA = *Francisco Fernandes de Araújo*; ASFC = *Antônio Sérgio Farias de Castro*; EAC = acronym according to Thiers, continuously updated). * > three phytogeographic domains. Ob = Observed, but not collected.

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
1. Marsileaceae+									
Marsilea deflexa A. Braun	Trevo-d'água	X			Nat	Her	Cry	Am | Ce	EBS 4656
2. Acanthaceae									
Dicliptera ciliaris Juss.	Melosa-de-boi			X	Nat	Her	The	Ad	EBS 4057
Elytraria imbricata (Vahl.) Pers.	-	X		X	Nat	Her	The	Am | Ca | Ce	EBS 4058
Ruellia asperula (Mart. *ex* Nees) Lindau	Melosa-vermelha		X	X	Nat	Sub	Cha	Ca	EBS 4750
Ruellia paniculata L.	Melosa		X	X	Nat	Sub	Cha	Ca | Ce | AF	EBS 5716
3. Alismataceae									
Echinodorus subalatus (Mart.) Griseb.	Língua-de-vaca		X		Nat	Her	Cry	Am | Ca | Ce	EBS 4627
4. Amaranthaceae									
Alternanthera brasiliana (L.) Kuntze	Cabeça-branca			X	Nat	Her	The	Ad	EBS 3849
Alternanthera martii (Moq.) R.E.Fr.	-	X			Nat	Her	The	Am | Ce	EBS 4506
Alternanthera tenella Colla	Quebra-panela			X	Nat	Her	The	Ad	EBS 3829
Amaranthus viridis L.	Bredo			X	Exn	Her	The	Ad	EBS 5370
Froelichia humboldtiana (Roem. & Schult.) Seub.	ervanço			X	Nat	Her	The	Ca | Ce	EBS 4413
5. Anacardiaceae									
Astronium urundeuva (M. Allemão) Engl.	Aroeira			X	Nat	Tre	Pha	Ad	EBS 5348
6. Apocynaceae									
Aspidosperma pyrifolium Mart. & Zucc.	Pereiro			X	Nat	Tre	Pha	Ca | Ce	EBS 5294

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
Calotropis procera (Aiton) W.T.Aiton	Ciúme			X	Exi	Shr	Pha	Ad	EBS 5371
Cryptostegia madagascariensis Bojer	Unha-de-bruxa		X		Exi	Shr	Pha	Am | Ca	EBS 5272
Ditassa hastata Decne	-			X	Nat	Ltw	Pha	Am | Ca | Ce	EBS 4627
Forsteronia pubescens A.DC.	-			X	Nat	Ltw	Pha	Ca | Ce | AF	FFA 98
Ibatia nigra (Decne.) Morillo	-			X	Nat	Vtw	Pha	Ca	EBS 3856
Petalostelma martianum (Decne.) E. Fourn.	-			X	Nat	Vtw	Pha	Ad	EBS 4955
7. Araceae									
Philodendron acutatum Schott	Imbé	X			Nat	Var	Cha	Ad	EBS 4845
Taccarum ulei Eng. & K. Krause	Milho-de-cobra	X			Nat	Her	Cry	Ca | Ce | AF	EBS 4971
8. Arecaceae									
Copernicia prunifera (Mill.) H.E. Moore	Carnaúba		X		Nat	Pal	Pha	Ca | Ce	Ob
9. Asteraceae									
Baltimora geminata (Brandegee) Stuessy	-	X			Nat	Her	The	Ca | Ce | AF	EBS 4653
Bidens bipinnata L.	Picão			X	Exn	Sub	The	Ca | AF | Pa	EBS 5284
Blainvillea acmella (L.) Philipson	Erva-palha			X	Nat	Her	The	Ca | Ce | AF	EBS 4098
Centratherum punctatum Cass.	Perpétua-do-mato			X	Nat	Her	The	Ad	EBS 5219
Chresta pacourinoides (Mart. *ex* DC.) Siniscalchi & Loeuille	-	X			Nat	Her	The	Ca	EBS 5278
Delilia biflora (L.) Kuntze	Espoleta			X	Nat	Her	The	Ca | Ce | AF	EBS 5281
Lagascea mollis Cav.	-			X	Nat	Her	The	Ca | AF | Pt	EBS 5282
Lepidaploa chalybaea (Mart. *ex* DC.) H.Rob. (Mart. *ex* DC.) H.Rob.	-	X			Nat	Sub	The	Ca | Ce	EBS 3853
Melanthera latifolia (Gardner) Cabrera	-			X	Nat	Her	The	Ad	EBS 3819
Stilpnopappus trichospiroides Mart. *ex* DC.	-			X	Nat	Her	The	Ca | Ce	EBS 4078
Tridax procumbens L.	Dente-de-leão			X	Nat	Her	The	Ad	EBS 3824

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
10. Bignoniaceae									
Cuspidaria argentea (Wawra) Sandwith	-	X			Nat	Lte	Pha	Ca	EBS 5020
Dolichandra quadrivalvis (Jacq.) L.G.Lohmann	Unha-de-gato		X		Nat	Lte	Pha	Ad	EBS 4835
Handroanthus impetiginosus (Mart. *ex* DC.) Mattos	Ipê-roxo			X	Nat	Tre	Pha	Ad	EBS 4969
Tanaecium dichotomum (Jacq.) Kaehler & L.G.Lohmann	-		X		Nat	Lte	Pha	Ad	EBS 5474
Tanaecium parviflorum (Mart. *ex* DC.) Kaehler & L.G.Lohmann	-		X		Nat	Lte	Pha	Ca | Ce	F 96
11. Bixaceae									
Cochlospermum vitifolium (Willd.) Spreng.	Pacotê			X	Nat	Tre	Pha	Ad	EBS 5387
12. Boraginaceae									
Cordia glabrata (Mart.) A. DC.	Pau-branco-louro	X		X	Nat	Tre	Pha	Ca | Ce	EBS 4084
Cordia oncocalyx Allemão	Pau-branco			X	Nat	Tre	Pha	Ca	EBS 4426
Euploca lagoensis (Warm.) Diane & Hilger	-		X		Nat	Her	The	Am | Ca | Ce	EBS 4822
Euploca procumbens (Mill.) Diane & Hilger	-		X		Nat	Her	The	Ad	EBS 4825
Heliotropium indicum L.	Fedegoso			X	Nat	Her	The	Ad	EBS 4824
Myriopus rubicundus (Salzm. *ex* DC.) Lueber	-		X		Nat	Shr	Pha	Ca | Ce | AF	EBS 3844
Varronia dardani (Taroda) J.S.Mill.	-		X		Nat	Shr	Pha	Ca	EBS 4430
Varronia globosa Jacq.	Maria-preta		X		Nat	Shr	Pha	Ca | AF	EBS 4423
Varronia multispicata (Cham.) Borhidi	-	X			Nat	Shr	Pha	Ad	EBS 3855
13. Bromeliaceae									
Encholirium spectabile Mart. *ex* Schult. & Schult.f.	Macambira-de-flecha	X			Nat	Her	Hem	Ca | AF	EBS 4850
14. Burseraceae									
Commiphora leptophloeos (Mart.) J.B.Gillett	Amburana-de-espinho	X		X	Nat	Tre	Pha	Am | Ca | Ce	FFA 92
15. Cactaceae									
Cereus jamacaru DC.	Mandacaru	X		X	Nat	Tre	Pha	Ca | Ce	EBS 4848

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
Pilosocereus chrysostele (Vaupel) Byles & G.D.Rowley	Facheiro, Chico-grilo	X		X	Nat	Tre	Pha	Ca	EBS 4846
Xiquexique gounellei (F.A.C.Weber) Lavor & Calvente	Xique-Xique	X			Nat	Shr	Pha	Ca | Ce	EBS 4847
Tacinga palmadora (Britton & Rose) N.P.Taylor & Stuppy	Palma	X			Nat	Shr	Cha	Ca	EBS 4755
16. Capparaceae									
Cynophalla flexuosa (L.) J. Presl.	Feijão-bravo		X		Nat	Shr	Pha	Ad	EBS 4840
Crateva tapia L.	Trapiá		X		Nat	Tre	Pha	Ad	EBS 4445
17. Cleomaceae									
Physostemon guianense (Aubl.) Malme	-			X	Nat	Her	The	Am | Ca | Ce	EBS 4411
Physostemon lanceolatum Mart. & Zucc.	-			X	Nat	Her	The	Ca | AF	EBS 5204
Tarenaya diffusa (Banks *ex* DC.) Ilts	-	X			Nat	Her	The	Ca | AF	EBS 4450
Tarenaya longicarpa Soares Neto & Roalson	Mussambê			X	Nat	Sub	Cha	Ad	EBS 4826
18. Combretaceae									
Combretum duarteanum Cambess.	Mofumbo		X		Nat	Shr	Pha	Ad	EBS 5386
Combretum glaucocarpum Mart.	Cipaúba		X		Nat	Shr	Pha	Ad	EBS 5221
Combretum leprosum Mart.	Mofumbo		X	X	Nat	Shr	Pha	Ad	EBS 4754
Combretum sp.1	Mofumbo		X		Nat	Shr	Pha	-	EBS 4067
19. Commelinaceae									
Aneilema brasiliense C.B.Clarke	-	X			Nat	Her	The	Ca | Ce | AF	EBS 5291
Callisia filiformis (M.Martens & Galeotti) D.R.Hunt	-			X	Nat	Her	The	Ca | Ce	EBS 5191
Commelina obliqua Vahl.	Marianinha			X	Nat	Her	The	Ad	EBS 4403
Dichorisandra perforans C.B.Clarke	-	X		X	Nat	Her	Hem	Ca | Ce	EBS 3822
Tinantia sprucei C.B.Clarke	-		X		Nat	Her	The	Am | Ca | Ce	EBS 5198
Tradescantia ambigua Mart. *ex* Schult. & Schult.f.	-	X			Nat	Her	The	Ca | Ce	EBS 5019

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
20. Convolvulaceae									
Cuscuta racemosa Mart.	Cipó-dourado			X	Nat	Par	The	Ce | AF | Pa	EBS 5287
Distimake aegyptius (L.) A.R.Simões & Staples	Jitirana cabeluda			X	Nat	Vtw	The	Ca | Ce | AF	EBS 4093
Evolvulus alsinoides L.	-			X	Nat	Her	The	Am | Ce	EBS 5189
Evolvulus filipes Mart.	-			X	Nat	Her	The	Ad	EBS 4081
Evolvulus ovatus Fernald	-			X	Nat	Her	The	Am | Ca | Ce	EBS 4082
Ipomoea acanthocarpa (Choisy) Aschers. & Schweinf.	-			X	Nat	Vtw	The	Am | Ca | AF	EBS 4628
Ipomoea asarifolia (Desr.) Roem. & Schult.	Salsa		X		Nat	Vtw	The	Am | Ca | AF	EBS 5271
Ipomoea bahiensis Willd. *ex* Roem. & Schult.	Jitirana			X	Nat	Vtw	The	Ad	EBS 4094
Ipomoea carnea Jacq.	Mata-cabra		X		Nat	Shr	Pha	Ad	EBS 4629
Ipomoea hederifolia L.	Corda-de-viola			X	Nat	Vtw	The	Ad	EBS 4074
Ipomoea longeramosa Choisy	-			X	Nat	Vtw	The	Ca | Ce	EBS 4095
Ipomoea nil (L.) Roth (L.) Roth	Jitirana			X	Exn	Vtw	The	Ad	EBS 4092
Ipomoea parasitica (Kunth) G.Don	-			X	Exn	Vtw	The	Ca | Ce | AF	EBS 5249
Ipomoea rosea Choisy	-			X	Nat	Vtw	Hem	Ca | Ce | AF	EBS 4631
Jacquemontia corymbulosa Benth.	-			X	Nat	Vtw	The	Ca | Ce	EBS 4963
Jacquemontia evolvuloides (Moric.) Meisn.	-			X	Nat	Vtw	The	Ad	EBS 4406
Jacquemontia ferruginea Choisy	-			X	Nat	Sub	The	AF	EBS 4066
Jacquemontia gracillima (Choisy) Hallier	-			X	Nat	Her	The	Ca | Ce | AF	EBS 4090
Jacquemontia pentanthos (Jacq.) G. Don	-			X	Nat	Vtw	The	Am | Ca | Ce	EBS 5210
21. Cucurbitaceae									
Momordica charantia L.	Melão-de-São-Caetano			X	Exn	Vte	The	Ad	EBS 4830
Sicyos martii Cogn.	-				Nat	Vte	The	Ca | Ce | AF	EBS 5268

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
22. Cyperaceae									
Bulbostylis capillaris C.B.Clarke	-			X	Nat	Her	The	Ad	EBS 5216
Cyperus cuspidatus Kunth.	Barba-de-bode			X	Nat	Her	The	Am | Ca	EBS 4953
Scleria reticularis Michx. *ex* Willd.	-			X	Nat	Her	The	Ad	EBS 5220
23. Dioscoriaceae									
Dioscorea campestris Griseb.	Cará-casco-cavalo			X	Nat	Vtw	Cry	Ad	EBS 4956
Dioscorea ovata Vell.	Inhame-bravo			X	Nat	Vtw	Cry	Ca | Ce | AF	EBS 4421
24. Eriocaulaceae									
Paepalanthus tortilis (Bong.) Mart.	-		X		Nat	Her	The	Ad	EBS 4657
25. Erythroxylaceae									
Erythroxylum revolutum Mart.	Oitizinho			X	Nat	Shr	Pha	Ca | AF	EBS 4429
Erythroxylum subrotundum A. St.-Hil.	-			X	Nat	Shr	Pha	Ca | Ce | AF	EBS 5029
26. Euphorbiaceae									
Acalypha communis Müll. Arg.	Algodãozinho			X	Nat	Sub	Cha	Ad	EBS 4443
Astraea lobata (L.) Klotzsch	Café-bravo			X	Nat	Sub	The	Ce | Pa | Pt	EBS 4439
Cnidoscolus urens (L.) Arthur.	Cansanção			X	Nat	Sub	The	Ad	EBS 5273
Croton adenocalyx Baill.	Marmeleiro-cravim			X	Nat	Shr	Pha	Ca	EBS 4947
Croton anisodontus Müll. Arg.	Marmeleiro			X	Nat	Shr	Pha	AF	EBS 4436
Croton blanchetianus Baill.	Marmeleiro			X	Nat	Shr	Pha	Ca	EBS 4412
Croton hirtus L'Hér.	-			X	Nat	Sub	The	Ad	EBS 5184
Croton japirensis Müll.Arg.	Velame			X	Nat	Shr	Pha	Ca	EBS 4954
Croton rudolphianus Müll. Arg.	-			X	Nat	Shr	Pha	Ca	EBS 4437
Croton triangularis Müll. Arg.	-			X	Nat	Shr	Pha	Ca | Ce	EBS 5025
Dalechampia scandens L.	Cipó-urtiga			X	Nat	Vtw	Cha	Ad	EBS 4949

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
Euphorbia heterophylla L.	Amendoim-bravo	X		X	Nat	Her	The	Am | Ca	EBS 5277
Euphorbia hyssopifolia L.	Burra-leitera	X		X	Nat	Her	The	Ad	EBS 4972
Jatropha mollissima (Pohl.) Baill.	Pinhão-bravo	X		X	Nat	Shr	Pha	Am | Ca | Ce	EBS 3841
Manihot carthagenensis (Jacq.) Müll. Arg.	-	X			Nat	Tre	Pha	Am | Ca | Ce	EBS 4427
Tragia cearensis Pax & K. Hoffm.	-			X	Nat	Her	The	Ca	EBS 5286
27. Fabaceae									
Aeschynomene evenia C.Wrigth & Sauvalle	-		X		Nat	Sub	The	Ad	EBS 4643
Ancistrotropis peduncularis (Kunth) A. Delgado	-			X	Nat	Vtw	The	Ad	EBS 4088
Anadenanthera colubrina (Vell.) Brenan	Angico			X	Nat	Tre	Pha	Ca | Ce | AF	EBS 4839
Arachis dardani Krapov. & W.C.Greg.	Amendoim-de-carcará			X	Nat	Her	The	Ca | Ce | AF	EBS 4422
Bauhinia cheilantha (Bong.) Steud.	Mororó			X	Nat	Shr	Pha	Ca | Ce	EBS 4424
Bauhinia pentandra (Bong.) D. Dietr.	Pata-de-vaca			X	Nat	Shr	Pha	Ca | Ce	EBS 4428
Canavalia brasiliensis Mart. *ex* Benth.	Feijão-de-porco		X	X	Nat	Ltw	Pha	Ad	EBS 5217
Centrosema brasilianum (L.) Benth.	-			X	Nat	Vtw	The	Ad	EBS 5218
Centrosema pascuorum Mart. *ex* Benth.	-			X	Nat	Vtw	The	Ad	EBS 5251
Cenostigma nordestinum Gagnon & G.P. Lewis	Catingueira			X	Nat	Tre	Pha	Ca	EBS 4448
Chamaecrista calycioides (DC. *ex* Collad.) Greene	-			X	Nat	Sub	The	Ad	EBS 5258
Chamaecrista pilosa (L.) Greene	-			X	Nat	Her	The	Ca | Ce | AF	EBS 3827
Chamaecrista repens (Vogel) H.S. Irwin & Barneby	-			X	Nat	Sub	The	Ad	EBS 5193
Chamaecrista rotundifolia (Pers.) Greene	Erva-coração			X	Nat	Her	The	Ad	EBS 5196
Chamaecrista zygophylloides (Taub.) H.S.Irwin & Barneby	-	X		X	Nat	Her	Pha	Ca | Ce | AF	EBS 5016
Crotalaria incana L.	Guiso-de-cascavel			X	Nat	Sub	The	Ad	EBS 5280
Ctenodon paniculatus (Willd. *ex* Vogel) D.B.O.S.Cardoso, P.L.R.Moraes & H.C.Lima	Vassoura-de-pasto			X	Nat	Sub	The	Ad	EBS 5185
Desmodium glabrum (Mill.) DC.	Rapadura-de-cavalo			X	Nat	Sub	The	Ca | Ce | AF	EBS 4073

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
Galactia jussiaeana Kunth	-			X	Nat	Sub	Cha	Ad	EBS 5255
Hymenaea courbaril L.	Jatobá		X		Nat	Tre	Pha	Ad	EBS 5382
Indigofera suffruticosa Mill.	Anil			X	Nat	Shr	Pha	Ad	EBS 4976
Libidibia ferrea (Mart. *ex* Tul.) L.P.Queiroz	Pau-ferro, Jucá			X	Nat	Tre	Pha	Ca | Ce | AF	EBS 4063
Macroptilium gracile (Poepp. *ex* Benth.) Urb.	-			X	Nat	Vtw	The	Ad	EBS 5263
Macroptilium lathyroides (L.) Urb.	Feijão-de-rolinha			X	Nat	Sub	The	Ad	EAC 2239
Macropsychanthus grandiflorus (Mart. *ex* Benth.) L.P.Queiroz & Snak	Mucunã	X			Nat	Ltw	Pha	Ca	EBS 4503
Mimosa caesalpiniifolia Benth.	Sabiá			X	Nat	Tre	Pha	Ca	EBS 4501
Mimosa niomarlei Afr. Fern.	-			X	Nat	Her	The	Ca	EAC 17591
Mimosa paraibana Barneby	Cerrador			X	Nat	Shr	Pha	Ca | AF	EBS 4641
Mimosa somnians Humb. & Bonpl. *ex* Willd.	-				Nat	Sub	The	Ad	EBS 5250
Mimosa tenuiflora (Willd.) Poir.	Jurema-preta			X	Nat	Tre	Pha	Ca | Ce	EBS 4753
Piptadenia retusa P.G.Ribeiro, Seigler & Ebinger	Jurema-branca			X	Nat	Shr	Pha	Ca	EBS 4752
Senna macranthera (DC. *ex* Collad.) H.S. Irwin & Barneby	Aleluia			X	Nat	Shr	Pha	Ca | Ce | AF	EBS 4633
Senna obtusifolia (L.) H.S. Irwin & Barneby	Mata-pasto-liso			X	Nat	Sub	The	Ad	EBS 4823
Senna occidentalis (L.) Link	Manjerioba			X	Nat	Sub	The	Ad	EBS 5276
Senna trachypus (Benth.) H.S. Irwin & Barneby	Pau-de-besouro			X	Nat	Shr	Pha	Ca | Ce	EBS 4642
Senna uniflora (Mill.) H.S.Irwin & Barneby	Mata-pasto-peludo			X	Nat	Her	The	Am | Ca | Ce	EBS 5264
Stylosanthes humilis Kunth	-			X	Nat	Her	The	Ad	EBS 5252
Zornia brasiliensis Vogel	-	X		X	Nat	Her	The	Ca | Ce	EBS 3843
28. Hydroleaceae									
Hydrolea spinosa L.	Carqueja-do-pântano		X		Nat	Her	The	Ad	EBS 4827
29. Iridaceae									
Cipura paludosa Aubl.	-			X	Nat	Her	Cry	Ad	EBS 4493
Trimezia martinicensis (Jacq.) Herb.	-			X	Nat	Her	Cry	Ad	EBS 4494

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
30. Lamiaceae									
Marsypianthes chamaedrys (Vahl) Kuntze	-			X	Nat	Her	The	Ad	EBS 4502
Mesosphaerum suaveolens (L.) Kuntze	Bamburral			X	Nat	Sub	The	Ad	EBS 4635
Vitex gardneriana Schauer	Jaramataia		X		Nat	Tre	Pha	Ca	EBS 4446
31. Loasaceae									
Mentzelia aspera L.	Prega-prega			X	Nat	Her	The	Ad	EBS 4056
32. Loganiaceae									
Spigelia anthelmia L.	Lombrigueira			X	Nat	Her	The	Ad	EBS 5195
33. Loranthaceae									
Passovia pedunculata (Jacq.) Kuijt	Erva-de-passarinho			X	Nat	Par	Pha	Ad	EBS 4435
34. Lythraceae									
Cuphea campestris Koehne	-			X	Nat	Her	The	Ca	EBS 5208
35. Malpighiaceae									
Diplopterys lutea (Griseb.) W.R.Anderson & C.C.Davis	-		X		Nat	Ltw	Pha	Ad	EBS 4833
Heteropterys sp.1	-		X		Nat	Ltw	Pha	-	EBS 4849
Heteropterys sp.2	-		X		Nat	Ltw	Pha	-	EBS 4832
36. Malvaceae									
Briquetiastrum spicatum (Kunth *in* H.B.K.) Bovini	Paco-paco			X	Nat	Sub	The	Ad	EBS 4640
Ceiba glaziovii (Kuntze) K. Schum.	Barriguda	X			Nat	Tre	Pha	Ca	Ob
Corchorus hirtus L.	-			X	Nat	Her	The	Ad	EBS 5192
Helicteres velutina K. Schum.	Saca-rolha			X	Nat	Shr	Pha	Ca | Ce	EBS 4965
Herissantia tiubae (K. Schum.) Brizicky	Mela-bode			X	Nat	Sub	Pha	Ca | Ce	EBS 4650
Melochia pyramidata L.	Guaxuma			X	Nat	Sub	The	Ad	EBS 3823
Melochia tomentosa L.	-			X	Nat	Sub	Cha	Ca | Ce | AF	EBS 4420
Pavonia cancellata (L.) Cav.	Malva-rasteira			X	Nat	Her	The	Ad	EBS 4097

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
Pseudobombax marginatum (A.St.-Hil., Juss. & Cambess.) A. Robyns	Embiratanha			X	Nat	Tre	Pha	Ca | Ce | Pt	ASFC 1205
Sida ciliaris L.	-			X	Nat	Her	The	Ca | AF	EBS 4410
Sida cordifolia L.	Malva-branca			X	Nat	Sub	The	Ad	EBS 4059
Sida galheirensis Ulb.	Canela-de-siriema			X	Nat	Sub	The	Ca | Ce | AF	EBS 3830
Sida linifolia Cav.	Malva-fina			X	Nat	Her	The	Ad	EBS 4649
Sida spinosa L.	Guaxuma-de-spinho			X	Nat	Sub	The	Ca | Ce | AF	EBS 3848
Sidastrum micranthum (A.St.-Hil.) Fryxell	Malva-preta			X	Nat	Sub	The	Ad	EBS 3821
Waltheria operculata Rose	-	X			Nat	Her	The	Ca | Ce | Pt	EBS 4080
Wissadula contracta (Link) R.E.Fr.	-			X	Nat	Sub	Cha	Ad	EBS 5266
37. Microteaceae									
Microtea celosioides Moq. *ex* Sennikov & Sukhor.	Capim-névoa		X	X	Nat	Her	The	Ad	EBS 3851
38. Molluginaceae									
Mollugo verticillata L.	Molugo, vassourinha			X	Nat	Her	The	Ad	EBS 3840
39. Moraceae									
Brosimum gaudichaudii Trécul	Conduru, Inharé		X		Nat	Tre	Pha	Ad	EBS 4838
Ficus gomelleira Kunth	Gameleria		X		Nat	Tre	Pha	Ad	EBS 4843
40. Myrtaceae									
Eugenia stictopetala Mart. *ex* DC.	Pitanga-do-mato	X	X		Nat	Tre	Pha	Ad	EBS 4087
41. Nyctaginaceae									
Boerhavia diffusa L.	Pega-pinto			X	Exn	Her	Hem	Ad	EBS 3850
Guapira laxa (Netto) Furlan	João-mole		X		Nat	Shr	Pha	Ca	EBS 4854
42. Onagraceae									
Ludwigia erecta (L.) H.Hara.	Cruz-de-malta		X		Nat	Her	The	Ad	EBS 4061
Ludwigia octovalvis (Jacq.) P.H. Raven	Cruz-de-malta		X		Nat	Sub	The	Ad	EBS 4648

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
43. Oxalidaceae									
Oxalis divaricata Mart.*ex* Zucc.	Azedinha			X	Nat	Her	The	Ad	EBS 4075
Oxalis frutescens L.	-			X	Nat	Her	The	Ad	EBS 4405
44. Passifloraceae *sensu stricto*									
Passiflora foetida L.	Maracujá-do-mato			X	Nat	Vte	Cha	Ad	EBS 4968
Passiflora cincinnata Mast.	-			X	Nat	Lte	Pha	Ad	Ob
45. Phyllanthaceae									
Phyllanthus niruri L.	Quebra-pedra			X	Nat	Her	The	Ad	EBS 3820
Phyllanthus orbiculatus Rich.	-			X	Nat	Her	The	Ad	EBS 5018
46. Phytollacaceae									
Petiveria alliacea L.	Tipí		X		Exn	Sub	Cha	Ad	EBS 4634
47. Piperaceae									
Peperomia pellucida (L.) Kunth	Erva-de-jaboti	X			Nat	Her	The	Ad	EBS 5295
48. Plantaginaceae									
Angelonia pubescens Benth.	-			X	Nat	Her	The	Ca | Ce	EBS 5283
Scoparia dulcis L.	Vassourinha			X	Nat	Sub	The	Ad	EBS 4831
Stemodia durantifolia (L.) Sw.	-		X		Nat	Her	The	Ad	EBS 4821
49. Plumbaginaceae									
Plumbago scandens L.	-		X		Nat	Sub	Cha	Am | Ca | AF	EBS 5376
50. Poaceae									
Aristida adscensionis L.	-			X	Exn	Her	The	Ad	EBS 5201
Aristida setifolia Kunth.	-			X	Nat	Her	The	Ca | Ce | AF	EBS 4089
Cenchrus ciliaris L.	Capim-búfalo			X	Exn	Her	The	Am | Ca | Ce	EBS 4064
Cenchrus echinatus L.	Capim-carrapicho			X	Nat	Her	The	Ad	EBS 3836
*Chloris barbata (*L.) Sw.	-			X	Nat	Her	The	Ca | Ce | AF	EBS 3838

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
Cynodon dactylon (L.) Pers.	-			X	Exn	Her	The	Ad	EBS 5190
Dactyloctenium aegyptium (L.) Willd.	Pé-de-galinha			X	Exn	Her	The	Ad	EBS 3834
Digitaria horizontalis Willd.	Capim-de-roça			X	Exn	Her	The	Ad	EBS 5205
Eleusine indica (L.) Gaertn	Pé-de-galinha			X	Exn	Her	The	Ad	EBS 5265
Eragrostis ciliaris (L.) R. Br.	Capim-mimoso	X		X	Exn	Her	The	Ad	EBS 4654
Hyparrhenia bracteata (Hum. & Bonpl. *ex* Willd.) Stapf	-	X		X	Nat	Her	The	Ce | AF | Pt	EBS 4655
Melinis repens (Willd.) Zizka	-	X		X	Exn	Her	The	Ad	EBS 4065
Panicum trichoides Sw.	-			X	Nat	Her	The	Ad	EBS 4060
Paspalum arenarium Schrad.	-			X	Nat	Her	The	Ad	EBS 5256
Paspalum scutatum Nees *ex* Trin.	-			X	Nat	Her	The	Ca	EBS 5203
Setaria parviflora (Poir.) Kerguélen	Capim-rabo-de-gato			X	Nat	Her	The	Ad	EBS 5595
51. Polygalaceae									
Asemeia violacea (Aubl.) J.F.B.Pastore & J.R.Abbott	Roxinha			X	Nat	Her	The	Ad	EBS 5211
Polygala boliviensis A.W. Benn.	-			X	Nat	Her	The	Ca | AF	EBS 5213
Polygala trichosperma Jacq.	-			X	Nat	Her	The	Ad	EBS 5253
52. Polygonaceae									
Triplaris gardneriana Wedd.	Pajeú		X		Nat	Tre	Pha	Ad	EBS 4837
53. Portulacaceae									
Portulaca elatior Mart.	-	X		X	Nat	Her	The	Ca | Ce | AF	EBS 4418
Portulaca halimoides L.	-	X		X	Nat	Her	The	Ad	EBS 3825
Portulaca mucronata Link	-	X		X	Nat	Her	The	Ad	EBS 4076
Portulaca umbraticola Kunth	-	X		X	Nat	Her	The	Ad	EBS 4400
54. Rhamnaceae									
Crumenaria decumbens Mart.	-			X	Nat	Her	The	Ca	EBS 5197
Sarcomphalus joazeiro (Mart.) Hauenshild	Juazeiro		X	X	Nat	Tre	Pha	Ca	EBS 4844

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
55. Rubiaceae									
Borreria scabiosoides Cham. & Schltdl.	Cabeça-branca		X		Nat	Her	The	Ad	EBS 4499
Hexasepalum apiculatum (Willd.) Delprete & J.H. Kirkbr.	-			X	Nat	Sub	The	Ad	EBS 3837
Mitracarpus baturitensis Sucre	Ervância-do-mato	X			Nat	Her	The	Ca | Ce	EBS 4086
Mitracarpus strigosus (Thunb.) P.L.R. Moraes, De Smedt & Hjertson	-			X	Nat	Her	The	Ad	EBS 4079
Staelia virgata (Link *ex* Roem. & Schult.) K. Schum.	-	X		X	Nat	Her	The	Ad	EBS 4651
Tocoyena sellowiana (Cham. & Schltdl.) K.Schum.	Jeniparana		X		Nat	Shr	Pha	Am | Ca | AF	EBS 4842
56. Salicaceae									
Prockia crucis P.Browne *ex* L.	-	X			Nat	Shr	Pha	Ad	EBS 4442
57. Sapindaceae									
Cardiospermum corindum L.	Balãozinho			X	Nat	Vte	The	Ca | Ce | AF	EBS 4630
58. Simaroubaceae									
Simarouba versicolor A.St.-Hil.	Paraíba	X		X	Nat	Tre	Pha	Am | Ca | Ce	EBS 4447
59. Solanaceae									
Capsicum parvifolium Sendtn.	-			X	Nat	Shr	Pha	Ca | AF	EBS 5030
Physalis pubescens L.	Juá-de-capote			X	Nat	Her	The	Ad	EBS 3828
Schwenckia americana L.	-	X			Nat	Her	The	Ad	EBS 3857
Solanum agrarium Sendtn.	-			X	Nat	Her	The	Ca | Ce | AF	EBS 5270
Solanum americanum Mill.	Pimenta-de-galinha			X	Nat	Her	The	Ad	EBS 4828
Solanum graniticola V.S. Sampaio & Gouvêa	-	X			Nat	Shr	Pha	Ca	EBS 4070
Solanum paludosum Moric.	-			X	Nat	Shr	Pha	Am | Ca | AF	EBS 5027
60. Talinaceae									
Talinum fruticosum (L.) Juss.	Bredo			X	Nat	Her	The	Ad	EBS 5477
61. Turneraceae (Passifloraceae *sensu lato*)									
Piriqueta guianensis N.E.Br.	-			X	Nat	Her	The	Ad	EBS 5219

Family / species	Common name	Environment			OR	GF	LF	DB	VC
		I	II	III					
Piriqueta viscosa Griseb.	-			X	Nat	Her	The	Ad	EBS 4407
Turnera chamaedrifolia Cambess.	Chanana			X	Nat	Sub	The	Ca | Ce | AF	EBS 3854
Turnera pumilea L.	Arranca-estrepe			X	Nat	Her	The	Ca | Ce | AF	EBS 4401
Turnera subulata Sm.	Chanana			X	Nat	Her	Cha	Ad	EBS 3831
62. Urticaceae									
Laportea aestuans (L.) Chew	Urtiga-vermelha			X	Nat	Her	The	Ad	EBS 5279
63. Verbenaceae									
Lantana camara L.	Cambara-chumbinho			X	Exn	Shr	Pha	Ad	EBS 5207
Lantana fucata Lindl.	Cambará			X	Nat	Shr	Pha	Ad	EBS 4957
Lippia origanoides Kunth	-			X	Nat	Shr	Pha	Ad	EBS 5293
Stachytarpheta angustifolia (Mill.) Vahl	Gervão-do-alagadiço			X	Nat	Her	The	Ad	EBS 5187
Stachytarpheta macedoi Moldenke	-			X	Nat	Her	The	Ca | Ce	EBS 5259
Stachytarpheta sessilis Moldenke	Rabo-de-tatu			X	Nat	Her	The	Ca	EBS 4083
64. Vitaceae									
Cissus tinctoria Mart.	-	X			Nat	Lte	Pha	Ad	EBS 4085
Cissus verticillata (L.) Nicolson & C.E.Jarvis	Uva-do-mato	X			Nat	Lte	Pha	Ad	EBS 3847
65. Violaceae									
Pombalia calceolaria (L.) Paula-Souza	Ipapeconha			X	Nat	Her	The	Ad	EBS 4507
Pombalia communis (A.St.-Hil.) Paula-Souza	Bandeira-branca			X	Nat	Sub	The	Ad	EBS 4416
66. Vochysiaceae									
Callisthene fasciculata Mart.	Capitão-do-mato	X			Nat	Tre	Pha	Ad	EBS 4434
Callisthene minor Mart.	Pau-de-pilão	X			Nat	Tre	Pha	Ca | Ce | AF	EBS 5269
67. Ximeniaceae									
Ximenia americana L.	Ameixa-de-espinho			X	Nat	Shr	Pha	Ad	EBS 4431

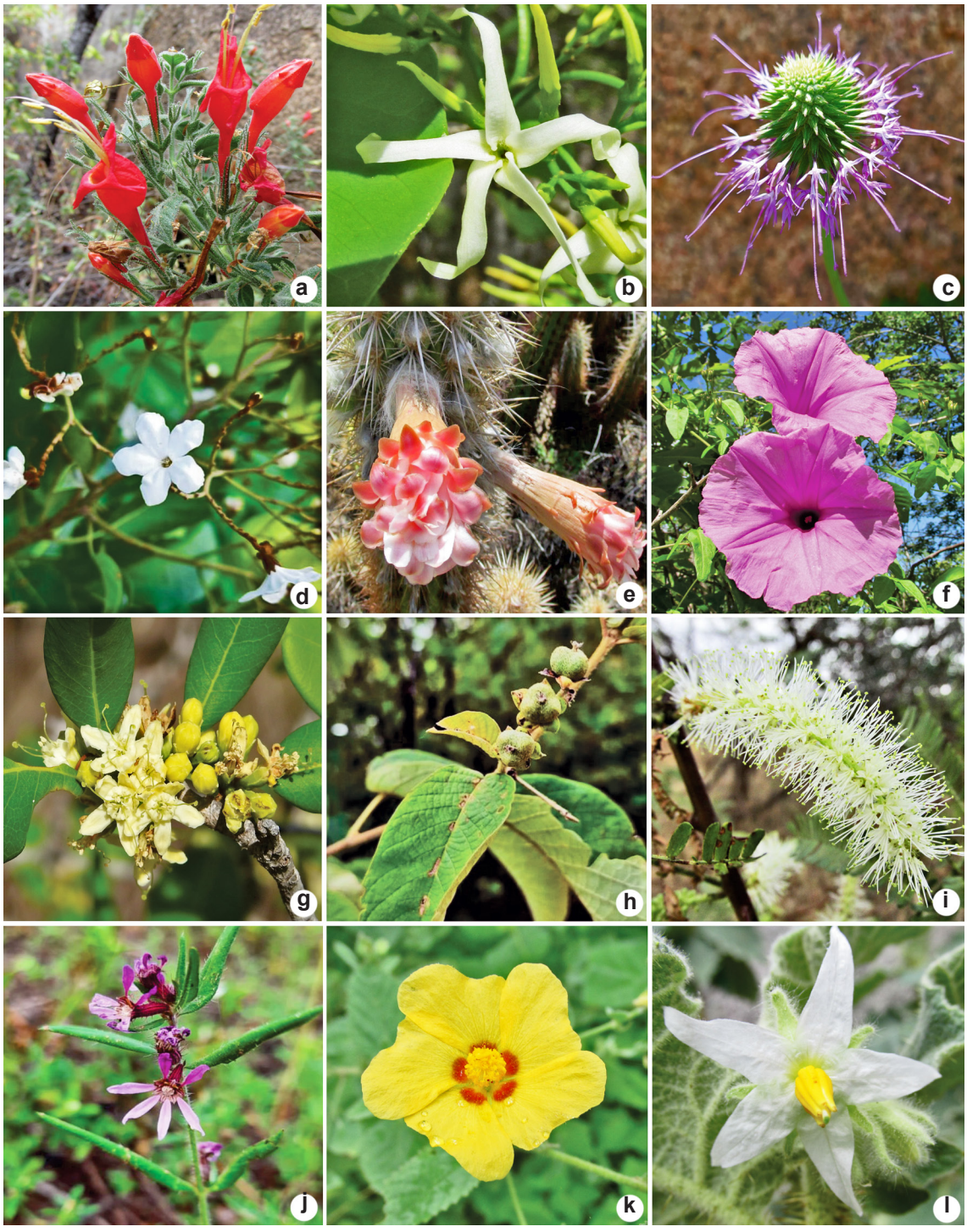

Figure 3 – a-l. Representatives of the flora of the Pedra da Andorinha Wildlife Refuge – a. *Ruellia asperula* (Acanthaceae); b. *Aspidosperma pyrifolium* (Apocynaceae); c. *Chresta pacourinoides* (Asteraceae); d. *Cordia oncocalyx* (Boraginaceae); e. *Xiquexique gounellei* (Cactaceae); f. *Ipomoea rosea* (Convolvulaceae); g. *Erythroxylum revolutum* (Erythroxylaceae); h. *Croton blanchetianus* (Euphorbiaceae); i. *Mimosa tenuiflora* (Fabaceae); j. *Cuphea campestris* (Lythraceae); k. *Sida galheirensis* (Malvaceae); l. *Solanum graniticola* (Solanaceae). (a, b, e, f, g, h, i, k, l. E.B. Souza; c, d, h, j. V.O. Amorim).

(73,3%) (Fig. 4a), especially the family Poaceae, whose species were classified as either exotic or native with ample geographic distribution (Tab. 2). The only exception was *Paspalum scutatum*, a grass species endemic to the *Caatinga* domain.

In relation to the phytogeographic domains of Brazil, 10.2% of the species surveyed are exclusive to the *Caatinga* domain (Fig. 4b), followed by three major distribution patterns: (i) *Caatinga* | *Cerrado* | Atlantic Forest; (ii) *Caatinga* | *Cerrado*; (iii) *Caatinga* | *Cerrado* | Amazonian. Most of the species are widely distributed, occurring in more than three phytogeographic domains (44.4%) (Tab. 2).

Among the 23 species endemic to the *Caatinga* phytogeographic domain, four species belong to the family Euphorbiaceae (*Croton adenocalyx, C. blanchetianus, C. japirensis* and *C. rudolphianus*), three to the family Fabaceae (*Cenostigma nordestinum, Mimosa niomarlei* and *Macropsychanthus grandiflorus*), with two species each belonging to Cactaceae (*Pilosocereus chrysostele* and *Tacinga palmadora*) and Boraginaceae (*Cordia oncocalyx* and *Varronia dardani*).

New occurrences for Ceará state were encountered in the survey area (the species *Marsilea deflexa*, *Cuscuta racemosa*, *Evolvulus alsinoides*, and *Petiveria alliacea*), as well as new occurrences for Northeastern Brazil (*Hyparrhenia bracteata*).

Some species occupied restricted environments in the RPA, such as the fern *Marsilea deflexa*, which has an amphibious habit and produces floating fronds in the shape of four-leaf-clovers that appear in small pools formed during the rainy period on the slopes of the inselberg. Their sporocarps are found buried in the substrate when those pools completely evaporate during the dry period. Species growing on rocky substrates include: the phanerophytes *Callisthene fasciculata*, *C. minor*, *Pilosocereus chrysostele*, *Solanum graniticola*, *Tacinga palmadora*, *Xiquexique gounellei*, and the chamaephyte *Philodendron acutatum*; the hemicryptophyte *Encholirium spectabile*; and the therophytes *Alternathera martii*, *Chresta pacourinoides*, *Dichorisandra perforans*, *Mitracarpus baturitensis*, *Portulaca* spp., *Tradescantia ambigua*, and *Waltheria operculata*. From a phytogeographic point of view, some of the species growing on rock outcrops are listed as endemic to the *Caatinga* (5 spp.), or are species shared by both the *Caatinga* and *Cerrado* (5 spp.).

Species including *Cordia oncocalix*, *Croton blanchetianus*, *Mimosa caesalpiniifolia*, and *Mimosa tenuiflora*, can be found in areas that had been burned but are currently in the process of recuperation. Species including *Amburana cearensis*, *Anadenanthera colubrina*, *Handroanthus impetiginosus*, and *Astronium urundeuva* were encountered immediately at the base of the Pedra da Andorinha inselberg where the vegetation is taller.

Life forms

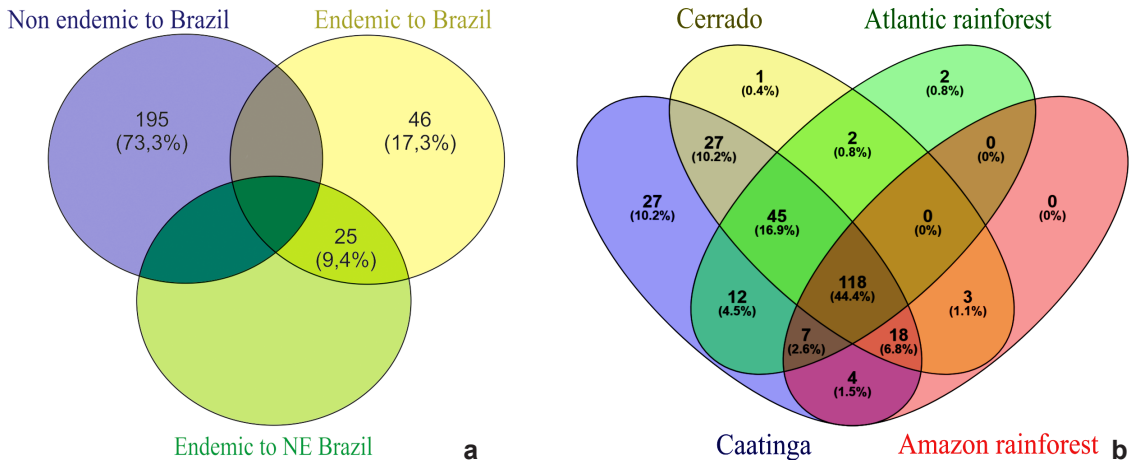

Figure 4 – a-b. Venn diagram demonstrating the overlapping and exclusive taxa of the 266 species surveyed in the RPA – a. Brazil and northeastern Brazil; b. Brazilian phytogeographic domains.

The spectrum of life forms (as defined by Raunkiaer) for the RPA (CE-Cry-And1) include 153 therophytes (57.5% of the flora), 88 phanerophytes (33.1%), 14 chamaephytes (5.3%), seven cryptophytes (2.6%), and four hemicryptophytes (1.5%) (Tab. 2).

We observed the dominance of therophyte species within the general biological spectrum in areas of crystalline *caatinga* (Fig. 5). Therophytes likewise showed elevated proportions in four areas of the inselbergs, while the other three areas had a majority of phanerophytes. Evaluating a *Caatinga* wide analysis of life form spectra, we observe that phanerophytes are predominant in all of the areas of sedimentary *caatinga* with sandy soils. Chamaephytes are well-represented in the two types of *caatinga*, with proportions comparable to the phanerophytes. Hemicryptophytes and cryptophytes have lower levels of occurrence, although they are present in practically all areas.

The NMDS analysis (stress: 0.109) of life forms in each area indicated the formation of three groups (Fig. 6): one was formed by all of the sedimentary *caatinga* areas, which have phanerophytes as the principal life form; another group was formed by areas of crystalline *caatinga* (in close proximity to each other due) with the dominance of therophyte species; the third group was formed by inselberg areas, apparently grouped due to their higher proportions of cryptophytes on sediments accumulating in depressions in the rocks.

Phytosociology survey

We recorded 1988 woody individuals belonging to 24 species distributed among 13 families (Tab. 3; Fig. 7). The species with the largest numbers of individuals were: *Croton blanchetianus* (681), *Cordia oncocalyx* (558), *Combretum leprosum* (164), and *Mimosa caesalpiniifolia* (127). Those woody individuals in the survey area had a total basal area of 45.31 m^2 and a mean height of 4.68 m. The tallest plant measured was a specimen of *Cordia oncocalyx* (12 m tall).

The total density of the survey area was 1,590.4 individuals/ha. Within that total, two species corresponded to 62.33% of the individuals surveyed: *Croton blanchetianus*, the species with the greatest absolute (544.8) and relative (34.26) densities; and *Cordia oncocalyx*. *Cordia oncocalyx* had the second greatest absolute density (446.4), as well as the greatest absolute dominance (22.16), the greatest relative dominance (61.12), the greatest importance value index (111.48), and the greatest cover value index (89.19).

In relation to the structural parameters of frequency, *Cordia oncocalyx* had the greatest absolute (90.40) and relative (22.29) frequencies,

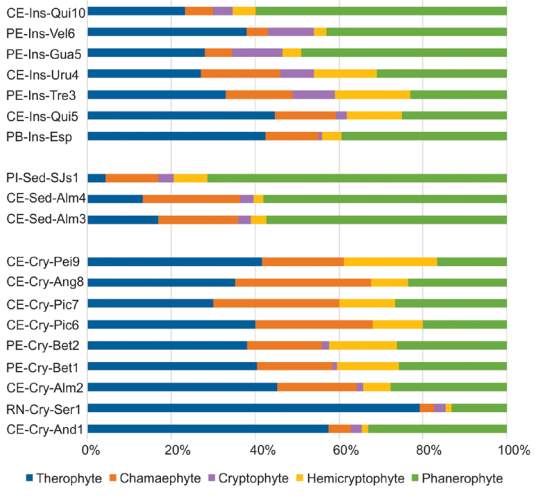

Figure 5 – Life form spectra of areas with different types of bedrock within the Caatinga phytogeographic domain. CE = Ceará state; PB = Paraíba; PE = Pernambuco; PI = Piauí; RN = Rio Grande do Norte; Cry = Crystalline Caatinga; Ins = Inselbergs; Sed = Sedimentary Caatinga.

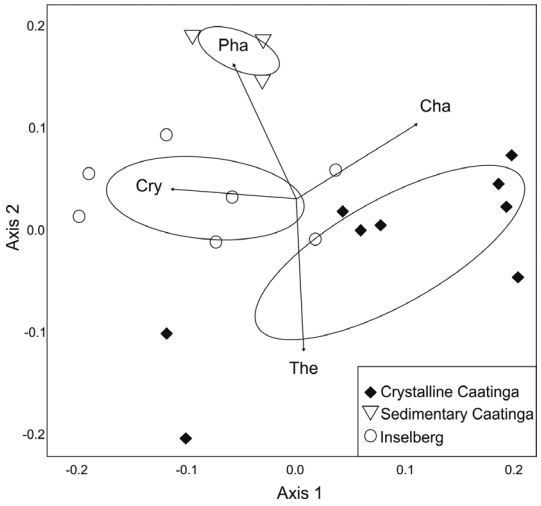

Figure 6 – Non-metric multidimensional scaling (NMDS) analysis of the Raunkiaer life forms for Crystalline Caatinga, Sedimentary Caatinga, and Inselbergs.

Table 3 – Structural parameters of the species, ordered according to their IVI indices (Importance Value Index). NI = number of individuals; AD = absolute density; RD = relative density; AF = absolute frequency; RF = relative frequency; ADo = absolute dominance; RDo = relative dominance; IVI = importance value Index; CVI = cover value index.

Species	NI	AD	RD	AF	RF	ADo	RDo	IVI	IVC
Cordia oncocalyx	558	446,4	28,07	90,4	22,29	22,16	61,12	111,48	89,19
Croton blanchetianus	681	544,8	34,26	35,2	8,68	3,18	8,78	51,71	43,03
Mimosa tenuiflora	104	83,2	5,23	45,6	11,24	3,14	8,66	25,13	13,89
Mimosa caesalpiniifolia	127	101,6	6,39	37,6	9,27	2,83	7,8	23,46	14,19
Combretum leprosum	164	131,2	8,25	47,2	11,64	1,19	3,3	23,18	11,55
Piptadenia retusa	123	98,4	6,19	38,4	9,47	0,65	1,79	17,44	7,97
Cenostigma nordestinum	70	56	3,52	30,4	7,5	1,65	4,56	15,58	8,08
Bauhinia cheilantha	50	40	2,52	14,4	3,55	0,28	0,78	6,85	3,3
Aspidosperma pyrifolium	25	20	1,26	10,4	2,56	0,16	0,44	4,26	1,69
Libidibia ferrea	13	10,4	0,65	8,8	2,17	0,16	0,45	3,27	1,1
Sarcomphalus joazeiro	10	8	0,5	7,2	1,78	0,19	0,52	2,8	1,03
Xiquexique gounellei	13	10,4	0,65	7,2	1,78	0,08	0,22	2,65	0,88
Cardiospermum corindum	7	5,6	0,35	4,8	1,18	0,08	0,23	1,76	0,58
Cereus jamacaru	6	4,8	0,3	4,8	1,18	0,02	0,06	1,55	0,36
Luetzelburgia auriculata	10	8	0,5	2,4	0,59	0,1	0,29	1,38	0,79
Commiphora leptophloeos	5	4	0,25	4	0,99	0,03	0,08	1,32	0,33
Cynophalla flexuosa	5	4	0,25	3,2	0,79	0,05	0,13	1,17	0,38
Varronia globosa	4	3,2	0,2	3,2	0,79	0,02	0,05	1,04	0,25
Cordia glabrata	4	3,2	0,2	3,2	0,79	0,02	0,05	1,04	0,25
Anadenanthera colubrina	2	1,6	0,1	1,6	0,39	0,19	0,54	1,03	0,64
Astronium urundeuva	2	1,6	0,1	1,6	0,39	0,03	0,09	0,59	0,19
Cochlospermum vitifolium	2	1,6	0,1	1,6	0,39	0,01	0,03	0,53	0,13
Jatropha mollissima	2	1,6	0,1	1,6	0,39	0	0,01	0,5	0,11
Pseudobombax marginatum	1	0,8	0,05	0,8	0,2	0,01	0,03	0,28	0,08

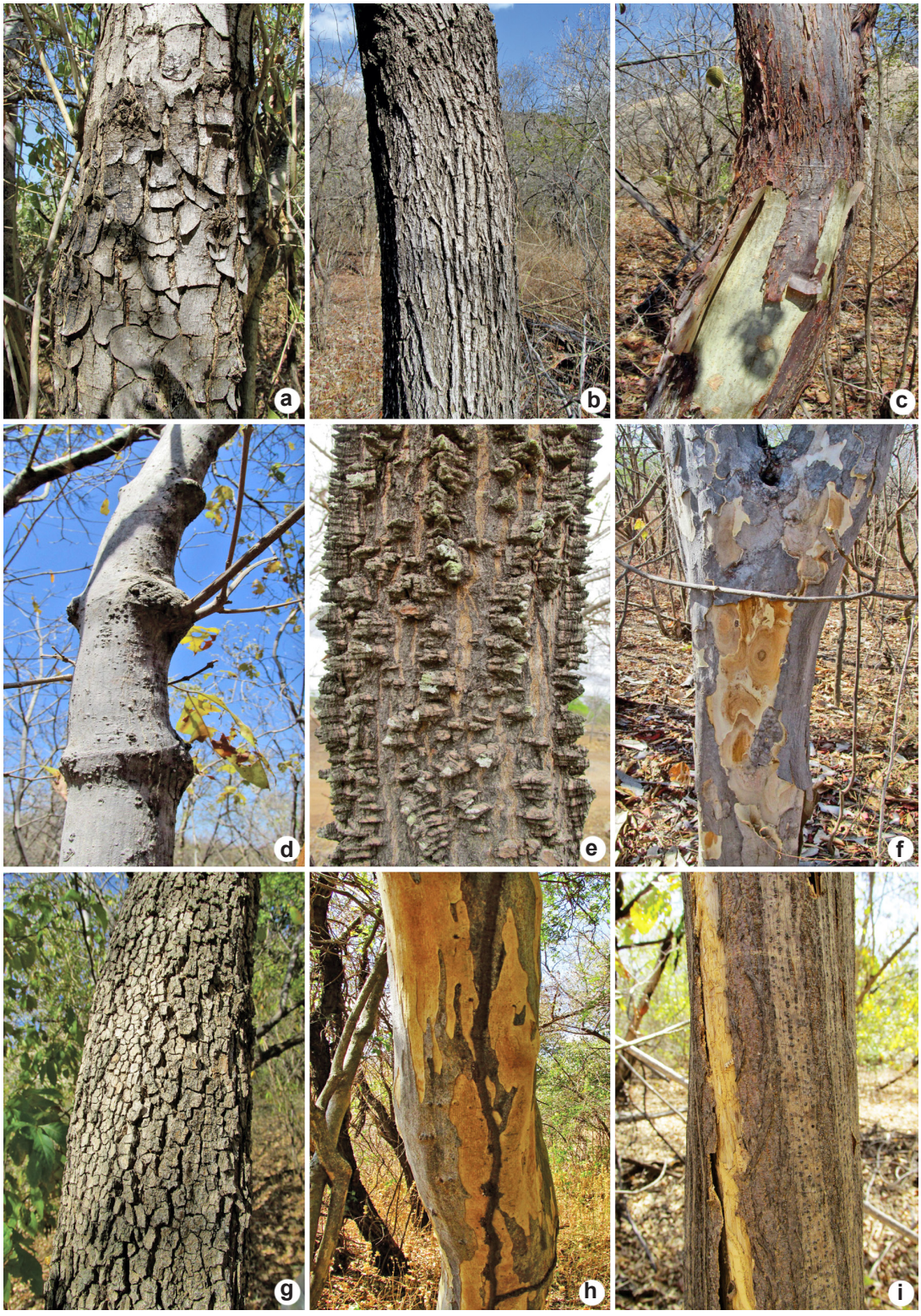

Figure 7 – a-i. Demonstration of the diversity of tree trunks of species catalogued within the Pedra da Andorinha Wildlife Refuge – a. *Astronium urundeuva*; b. *Handroanthus impetiginosus*; c. *Commiphora leptophloeos*; d. *Combretum leprosum*; e. *Anadenanthera colubrina*; f. *Cenostigma nordestinum*; g. *Cynophalla flexuosa*; h. *Libidibia ferrea*; i. *Piptadenia retusa.* (a-i. E.B. Souza).

followed by *Combretum leprosum* (47.20; 11.64), and then *Mimosa tenuiflora* (45.60; 11.24). The floristic diversity analyzed by the Shannon-Wiener diversity index (H') was 1.94.

Rarefaction, extrapolation, and estimation of total richness

All three asymptotic richness estimators used indicated similar richness values for the study area [ICE (24.4 spp.), Chao 2 (24 spp.), and Jack 1 (24.99 spp.)] (Fig. 8) - indicating that the numbers of plots used was satisfactory for sampling local woody species richness. The extrapolation method estimated that even if the number of plots was tripled, the numbers of species encountered would not be altered (Fig. 9). As such, the richness sampled in the present study appears very close to the true richness of the locality.

Discussion

Floristics and distribution

The family Fabaceae had the greatest species richness, appearing as the principal family composing the flora of the RPA, a position that family frequently holds in studies of the *Caatinga* flora. What is interesting, however, is that Convolvulaceae ranks as the second most important family in terms of species diversity (usually occupying approximately a fifth level ranking), although its genus *Ipomoea* is usually among the richest in *Caatinga* areas (a pattern that was repeated in the present study) (Costa *et al.* 2007; Araújo *et al.* 2008; Queiroz 2009; Gomes *et al.* 2011; Duarte *et al.* 2013; Ferreira *et al.* 2013; Moro *et al.* 2014; Queiroz *et al.* 2015; Pereira *et al.* 2018).

The absence and low richness of Orchidaceae and Bromeliaceae families in inselbergs, respectively, may be related to the dry climate of the studied area and its surroundings. The few studies carried out in inselbergs in Ceará also have similar results, suggesting that these families are richer in more humid climates (Araújo *et al*. 2008; Paulino *et al*. 2018; Pereira *et al*. 2018) than in the *Caatinga* domain.

The genera having the greatest species richness in the present study area were the same as the most well-represented genera in a composite list of 131 floristic and phytosociological studies of the *Caatinga* compiled by Moro *et al.* (2014), as for example *Croton*, *Ipomoea* and *Mimosa*. Based on the recent checklist of angiosperms in Ceará state (Loiola *et al.* 2020), six new records can now be added to the Flora of Ceará, totaling 2,590 species.

The proportions of different habits within the RPA were very similar to those reported for other *Caatinga* areas (Costa *et al.* 2009; Araújo *et al.* 2011; Silva *et al.* 2013), with herbaceous plants, especially those with therophytic life forms, being the most species rich. Herbaceous plants, largely therophytes, are the predominant component of the flora in the RPA, as was observed in similar surveys in crystalline *caatinga* (Costa *et al.* 2007; Araújo *et al.* 2008, 2011; Gomes *et al.* 2011; Duarte *et al.* 2013; Ferreira *et al.* 2013; Queiroz *et al.* 2015; Pereira *et al.* 2018). The woody component, represented by phanerophytes,

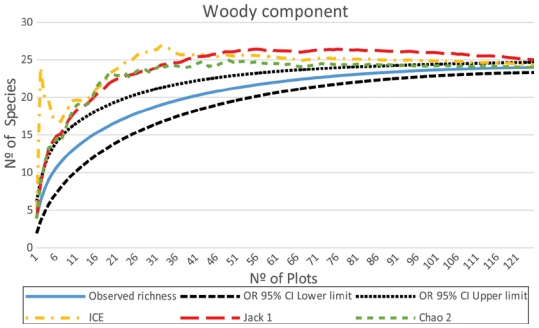

Figure 8 – Interpolated accumulation curve of the species sampled demonstrating the numbers of woody species observed in the study area (solid blue line) and the numbers of species estimated by three different richness estimators. OR = Observed richness; CI = Confidence interval.

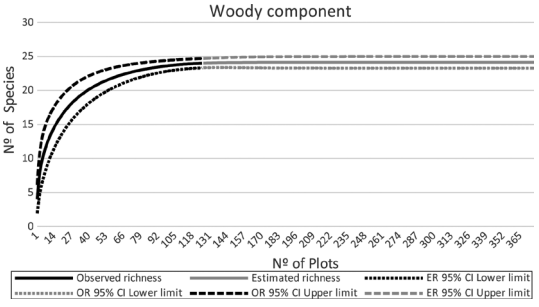

Figure 9 – Interpolated species accumulation curve to determine the richness of woody plants sampled within the study area, and the interpolated curve calculated for three times the sampling effort. ER = estimated richness; OR = observed richness; CI = confidence interval.

constitutes a third of the floristic composition of the RPA, and their presence is fundamental to defining the structure and physiognomy of *caatinga* vegetation.

The present survey area included a higher proportion of herbaceous species than reported for another area of crystalline *caatinga* at Quixadá, also in Ceará (Costa *et al.* 2007), although a smaller proportion than reported in Seridó in Rio Grande do Norte state (Queiroz *et al.* 2015).

The proportion of species found in the RPA having climbing mechanisms as opposed to tendrils was equivalent to the value (67%) reported by Araújo (2014) for the *Caatinga* domain. Other recent studies have corroborated those findings and identified climbing vines as important components in many *Caatinga* areas, presumably representing a successful adaptation related to competition in that environment. Those plants are associated with initial successional phases and occurring principally in clearings and along forest edges (Araújo 2014; Lucena *et al.* 2017, 2020).

In relation to endemism, we found numerous species endemic to the *Caatinga* domain in the RPA, such as *Solanum graniticola* (Sampaio *et al.* 2019), as well as others considered typical of (or frequent in) Cerrado *sensu lato* vegetation, such as *Callisthene minor*, *C. fasciculata*, and *Simarouba versicolor* (Fina & Monteiro 2013) - indicating that northwestern Ceará state shares floristic elements associated with both the *Caatinga* and *Cerrado* phytophysiognomies. Additionally, our survey evidenced high species richness and a significant number of endemic species growing on rock outcrops, in agreement with the observation that Brazil is among three global hot spots of inselberg plant diversity (Porembski 2007).

The single fern collected in the area (*Marsilea deflexa*) is widely distributed, occurring into Mexico, Guatemala, Honduras, Costa Rica, Colombia, Venezuela, Brazil, Peru, and Paraguay (Stefano *et al.* 2005). Although there have been very few records from Brazil (Xavier *et al.* 2012; Windisch 2015).

Life forms

The proportion of therophytes encountered in the RPA study area was in agreement with the proportion projected for crystalline *caatinga* based on Moro *et al.* (2016) and Fernandes & Queiroz (2018). Therophytes generally show high richness in *Caatinga* vegetation established on crystalline bedrock regions (Araújo *et al.* 2005, 2008; Rodal *et al.* 2005; Costa *et al.* 2007, 2015; Mamede & Araújo 2008; Queiroz *et al.* 2015) and generally appear as the dominant life form in arid and semiarid vegetations (Kovács-Lang *et al.* 2000; Costa *et al.* 2015; Queiroz *et al.* 2015; Moro *et al.* 2016). In areas of sandy sedimentary *caatinga*, however, phanerophytes tend to demonstrate the greatest species richness (Moro *et al.* 2016), as was found in the three areas considered in the biological spectrum matrix (Fig. 3) - a pattern observed in other studies in the *Caatinga* domain (Araújo *et al.* 2011; Moro *et al.* 2016).

Therophytes and phanerophytes tend to predominate on inselbergs in *Caatinga*, with little difference between their observed richness. Comparing the biological spectra of inselbergs with that of the crystalline *caatinga*, similarities can be seen in terms of the proportions of each life form, with therophytes and phanerophytes demonstrating the greatest numbers of species, followed by chamaephytes and hemicryptophytes. The areas of both environments shared very similar climatic characteristics - with the exception of the inselbergs designated as PE-Ins-Uru4 and PE-Ins-Tre3, which are located in the *caatinga-agreste* transition zone and receive more rainfall and experience lower temperatures. Those areas are also located over crystalline bedrock formations, where greater richness of therophytes is usually observed (Araújo *et al.* 2005, 2008; Rodal *et al.* 2005; Costa *et al.* 2007, 2015; Mamede & Araújo 2008; Queiroz *et al.* 2015).

Comparing the observed biological spectrum with the results of the NMDS, it was notable to observe that cryptophyte species constitute an important element for grouping inselberg areas. Taking into consideration the environmental conditions of crystalline bedrock areas as having low rainfall rates, high temperatures, and shallow soils (Nimer 1972; Santos *et al.* 2018; IPECE 2020), it would be expected that the plants growing there would have developed survival strategies adequate for inselberg environments. Cryptophytes are characterized as plants having subterranean reserve structures (such as bulbs) that allow their survival through the dry season (Martins & Batalha 2011), and those plants normally occur on inselbergs in crevices or depressions with accumulations of substrate.

Phytosociology

The study area evidenced a density of plant

individuals (1,590.4 ind.ha^{-1}) smaller than has been reported in most phytosociological surveys undertaken in crystalline *caatinga* sites: 2,448 ind. ha^{-1} by Santana & Souto (2006); 2,448 ind.ha^{-1} by Pereira-Júnior *et al.* (2012); and 4,822 ind.ha^{-1} by Lima *et al.* (2019). Similar surveys undertaken by Rodal *et al.* (1992) (1,076 ind.ha^{-1}) and Lacerda & Barbosa (2018) (1,623 ind.ha^{-1}), however, likewise reported low plant densities in that habitat.

The sum of the basal area of the individuals found in the RPA (36.25 m2. ha^{-1}) was similar to what Lima *et al.* (2019) reported (38.85 m2.ha^{-1}) and greater than Pereira-Júnior *et al.* (2012) (28.77 m2.ha^{-1}) described, although those authors reported greater values of absolute abundance. That contrast is probably due to the high frequency and dominance of *Cordia oncocalyx* in the area surveyed here, as that species is relatively tall and develops relatively large diameter stems.

The notable presence of *Cordia oncocalyx* in the study area is crucial for identifying the vegetation type now known as Median *Caatinga* Forest according to the classification system of Prado (2003), Unit VII/Type 13 - a phytophysiognomy marked by the presence of *C. oncocalyx*. A phytosociological study undertaken in RRPN Serra das Almas in Ceará state (Costa & Araújo 2012) likewise reported *Caatinga* vegetation with *C. oncocalyx* as a distinct floristic subtype community within the *Caatinga* domain.

The Pedra da Andorinha Wildlife Refuge was established only 11 years ago, and its vegetation still retains marks of previous degradation, with areas in different successional stages - a heterogeneity that was sampled in the study plots. Additionally, local residents have commented on the occurrence of anthropic fires along the boundaries of the Refuge that have penetrated into its interior, generating severe environmental impacts.

The plots evidencing some type of recent degradation contained elevated numbers of individuals of *Croton blanchetianus*, adding to its overall high absolute density; that same species was also reported as occurring at high densities by Lacerda & Barbosa (2018). A number of different authors have reported *Croton* species as occurring with high abundances in phytosociological surveys undertaken in crystalline *caatinga* sites (Pereira-Júnior 2012; Lemos *et al.* 2019), reflecting its habit and developmental characteristics, including its shrub form and facility for sprouting, which makes it, like many representatives of the Euphorbiaceae family, well adapted to the dry *Caatinga* climate (Oliveira 2013; Barros *et al.* 2021).

The Shannon-Wiener diversity index (H') of 1.94 is comparatively low in relation to reports from other crystalline *caatinga* areas: 3.466 by Lemos *et al.* 2019; 2.35 by Santana & Souto 2006; 2.29 by Pereira-Júnior 2012; and 2.18 by Lacerda & Barbosa 2018. That result reflects, in part, the high abundances of *Cordia oncocalyx* and *Croton blanchetianus* (62.33 % of all individuals) as compared to the total richness of the 24 woody species identified in the area.

Our results indicate that the flora of the RPA is composed of a large proportion of herbaceous plants, with the predominance of therophytes, a pattern frequently encountered in crystalline *caatinga*. The biological spectrum indicated a significant diversity of life and growth forms, especially of vine species, reflecting the heterogeneity of habitats and the different states of conservation of the individual plots. Most of the species encountered in this study have ample geographic distributions within Brazil, although endemic species are also present. The horizontal structure of the vegetation is principally marked by an abundance of *Croton blanchetianus* in areas with histories of recent degradation, and an abundance of *Cordia oncocalyx* in more highly conserved sites. Based on floristic and physiognomic data, the vegetation in the RPA was identified as Median *Caatinga* Forest. The existence of plant species endemic to Brazil, and to the *Caatinga*, within the Refuge boundaries reinforces its important to conservation efforts - not only in terms of the plants themselves and the resident native fauna, but also the migratory birds that depend on it for their reproduction and survival.

Acknowledgments

The authors thank the Fundação Cearense de Apoio ao Desenvolvimento Científico e Tecnológico (FUNCAP) for financing this research and for the Iniciação à Pesquisa (IC) grant through the "Inventários Florísticos no Domínio da Caatinga: riqueza e potencial de uso da biodiversidade cearense" project (Processo BP4-0172-00170.01.00/20); Francisco Ávila Mendes, director of the Conservação Refúgio de Vida Silvestre Pedra da Andorinha and his wife Vilma Mendes, as well as their employee José Barros Mesquita for his invaluable support and collaboration during the fieldwork; the

superintendent of the Agência Municipal do Meio Ambiente de Sobral (AMA), Jorge Vasconcelos Trindade, for his support during the collection activities; the Equipe do Herbário HUVA for their support and collaboration; the Universidade Estadual Vale do Acaraú for the logistic support and infrastructure it provided for our research; the Science and Technology Facility Council, of the United Kingdom, for financing the phytosociological survey within the Pedra da Andorinha Wildlife Refuge and for the post-doctoral grants awarded to MF Fernandes, VO Amorim, and AS Paula through the "Remote sensing for sustainable use of seasonally dry tropical forests - learning to live with the forest" project. We Thank Moabe F. Fernandes for his help in the phytosociological sampling of the plots recorded for this work.

References

Andrade-Lima D (1981) The caatinga dominium. Revista Brasileira de Botânica 1: 49-153.

APG IV - Angiosperm Phylogeny Group (2016) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society 181: 1-20.

Apgaua DMG, Santos RM, Pereira DGS, Menino GCO, Pires GG, Fontes MAL & Tng DYP (2014) Beta-diversity in seasonally dry tropical forests (SDTF) in the Caatinga Biogeographic Domain, Brazil, and its implications for conservation. Biodiversity and Conservation 23: 217-232. DOI: 10.1007/s10531-013-0599-9

Araújo D (2014) Trepadeiras do Bioma Caatinga. *In:* Villagra BLP, Melo MMRF, Romaniuc Neto S & Barbosa LM (eds.) Diversidade e conservação de trepadeiras contribuição para restauração de ecossistemas brasileiros. Instituto de botânica, São Paulo. Pp. 33-58.

Araújo FS, Costa RC, Figueiredo MA & Nunes EP (2005) Vegetação e flora fanerogâmica da área Reserva Serra das Almas, Ceará. *In*: Araújo FS, Rodal MJN & Barbosa MRV (orgs.) Análise das variações da biodiversidade do bioma Caatinga: suporte a estratégias regionais de conservação. Ministério do Meio Ambiente, Brasília. 28p.

Araújo FS, Oliveira RF & Lima-Verde ELW (2008) Composição, espectro biológico e síndromes de dispersão da vegetação de um inselberg no domínio da Caatinga, Ceará. Rodriguésia 59: 659-671.

Araújo FS, Costa RC, Lima, JR, Vasconcelos SF, Girão LC, Sobrinho MS, Bruno MMA, Souza SSG, Nunes EP, Figueiredo MA, Lima-Verde LW & Loiola MIB (2011) Floristics and life-forms along a topographic gradient, central-western Ceará, Brazil. Rodriguésia 62: 341-366.

Barros MF, Ribeiro EMS, Vanderlei RS, Paula AS, Silva AB, Wirth R, Cianciaruso MV & Tabarelli M (2021) Resprouting drives successional pathways and the resilience of Caatinga dry forest in human-modified landscapes. Forest Ecology and Management 482: 118-881.

Braun-Blanquet J (1979) Fitosociologia. Bases para el estudio de las comunidades vegetales. Blume, Madrid. 820p.

Cardoso DBOS & Queiroz LP (2007) Diversidade de Leguminosae nas caatingas de Tucano, Bahia: implicações para a fitogeografia do semiárido do Nordeste do Brasil. Rodriguésia 58: 379-391.

Claudino-Sales V (2016) Megageomorfologia do estado do Ceará: história da paisagem geomorfológica. Novas Edições Acadêmicas, Saarbrücken. 68p.

Claudino-Sales V & Peulvast JP (2007) Evolução morfoestrutural do relevo da margem continental do estado do Ceará, Nordeste do Brasil. Caminhos da Geografia 7: 1-21.

Colwell RK & Elsensohn JE (2014) EstimateS turns 20: statistical estimation of species richness and shared species from samples, with non-parametric extrapolation. Ecography 37: 609-613.

Colwell RK, Chao A & Gotelli NJ (2012) Models and estimators linking individual-based and sample based rarefaction, extrapolation and comparison of assemblages. Journal of Plant Ecology 5: 3-21.

Costa GM, Cardoso DBOS, Queiroz LP & Conceição AA (2015) Variações locais na riqueza florística em duas ecorregiões de caatinga. Rodriguésia 66: 685-709.

Costa KC Lima ALA, Fernandes CHM, Silva MCNA, Silva ACBL & Rodal MJN (2009) Flora vascular e formas de vida em um hectare de caatinga no nordeste brasileiro. Revista Brasileira de Ciências Agrárias 4: 48-54.

Costa RC & Araújo FS (2012) Physiognomy and structure of a caatinga with *Cordia oncocalyx* (Boraginaceae), a new type of community in Andrade-Lima's classification of caatingas. Rodriguésia 63: 269-276.

Costa RC, Araújo FS & Lima-Verde LW (2007) Flora and life-form spectrum in an area of deciduous thorn woodland (caatinga) in northeastern, Brazil. Journal of Arid Environments 68: 237-247.

CRIA - Centro de Referência em Informação Ambiental (2021) *species*Link. Available at <http://www.splink.org.br/index?lang=pt>. Access on 11 June 2020.

Duarte RC, Duarte MCC & Souza EB (2013) Flora de uma área de Caatinga no distrito de Aracatiaçu, Sobral, Ceará, Brasil. Essentia 14: 33-51.

Faith DP, Minchin PR & Belbin L (1987) Compositional dissimilarity as a robust measure of ecological distance. Vegetatio 69: 57-68.

Fernandes MF & Queiroz LP (2018) Vegetação e flora da Caatinga. Ciência & Cultura 70: 51-56.

Fernandes MF, Cardoso DBOS & Queiroz LP (2020) An updated plant checklist of the Brazilian Caatinga seasonally dry forests and woodlands reveals high species richness and endemism. Journal of Arid Environments 174: 104079.

Ferreira EVR, Prata APN & Mello AA (2013) Floristic list from a Caatinga remnant in Poço Verde, Sergipe, Brazil. Check List 9: 1354-1360.

Fina BG & Monteiro R (2013) Análise da estrutura arbustivo-arbórea de uma área de cerrado sensu stricto, município de Aquidauana-Mato Grosso do Sul. Revista Árvore 37: 577-585.

Flora do Brasil 2020 (continuously updated) Jardim Botânico do Rio de Janeiro. Available at <http://floradobrasil.jbrj.gov.br/>. Access on 11 June 2020.

França F, Melo E, Santos AKA, Melo JGAN, Marques M, Silva-Filho MFB, Moraes L & Machado C (2005) Estudos ecológico e florístico em ilhas de vegetação de um inselberg no semiárido da Bahia, Brasil. Hoehnea 32: 93-101.

FUNCEME - Fundação Cearense de Meteorologia e Recursos Hídrico (2015) Zoneamento ecológico-econômico das áreas susceptíveis à desertificação do núcleo I - Irauçuba/Centro-Norte. Fundação Cearense de Meteorologia e Recursos Hídricos/ Departamento Nacional de Obras Contra as Secas. Expressão Gráfica e Editora, Fortaleza. 300p.

Gomes P & Alves M (2010) Floristic diversity of two crystalline rocky outcrops in the Brazilian northeast semi-arid region. Revista Brasileira de Botânica 33: 661-676.

Gomes P, Costa KCC, Rodal MJN & Alves M (2011) Checklist of Angiosperms from the Pedra Furada Municipal Park, northeastern Brazil. Check List 7: 173-181.

Gomes P & Sobral-Leite M (2013) Crystalline rock outcrops in the Atlantic Forest of northeastern Brazil: vascular flora, biological spectrum, and invasive species. Revista Brasileira de Botânica 36: 111-123.

Gonçalves EG & Lorenzi H (2011) Morfologia vegetal: organografia e dicionário ilustrado de morfologia das plantas vasculares. Plantarum, Nova Odessa. 512p.

Gotelli NJ & Ellison AM (2011) Princípios de estatística em ecologia. Artmed, Porto Alegre. 528p.

Gotelli NJ & Colwell RK (2011) Estimating species richness. *In*: Magurran AE & McGill BJ (eds.) Biological diversity frontiers in measurement and assessment. Oxford University Press, Oxford. Pp. 39-54.

IBGE - Instituto Brasileiro de Geografia e Estatística (2012) Manual técnico da vegetação brasileira (Manuais Técnicos de Geociências nº. 1). 2ª ed. IBGE, Rio de Janeiro. 271p.

IPECE (2020) Ceará em mapas: mapa exploratório - reconhecimento de solos do estado do Ceará. Available at <http://www2.ipece.ce.gov.br/atlas/capitulo1/12/124x.htm>. Access on 23 June 2020.

Kovács-Lang E, Kroel-Dulay G, Kertész M, Fekete G, Bartha S, Mika J, Dobiwantuch I, Rédei T, Rajkai K & Hahn I (2000) Changes in composition of sand grasslands along a gradient in Hungary and implications for climate change. Phytocoenologia 30: 385-407.

Lacerda AV & Barbosa FM (2018) Fitossociologia da vegetação arbustivo-arbórea em uma área de mata ciliar no semiárido paraibano, Brasil. Gaia Scientia 12: 34-43.

Lima JR, Silva RG, Tomé MP, Sousa-Neto EP, Queiroz RT, Branco MSD & Moro MF (2019) Fitossociologia dos componentes lenhoso e herbáceo em uma área de caatinga no Cariri Paraibano, PB, Brasil. Hoehnea 46: e792018.

Loiola MIB, Ribeiro RTM, Sampaio VS & Souza EB (2020) Diversidade de angiospermas do Ceará. Herbário Prisco Bezerra: 80 anos de história. Edições UVA, Sobral. 257p.

Lorenzi H (2008a) Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil. Vol. 1. Plantarum, Nova Odessa. 384p.

Lorenzi H (2008b) Plantas daninhas do Brasil: terrestres, aquáticas, parasitas e tóxicas. Plantarum, Nova Odessa. 640p.

Lorenzi H (2009a) Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil Vol. 2. Plantarum, Nova Odessa. 384p.

Lorenzi H (2009b) Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil Vol. 3. Plantarum, Nova Odessa. 384p.

Lucena DS, Lucena MFA & Alves M (2017) Climbers from two rock outcrops in the semi-arid region of Brazil. Check List 13: 417-427.

Lucena DS, Souza BC, Carvalho ECD, Araújo FS & Alves M (2020) Plantas trepadeiras em afloramentos rochosos no nordeste do Brasil: padrões de riqueza, similaridade florística e síndromes de dispersão. Rodriguésia 71: 1-12. <https://doi.org/10.1590/2175-7860202071145>

Mamede MA & Araújo FS (2008) Effects of slash and burn practices on a soil seed bank of caatinga vegetation in Northeastern Brazil. Journal of Arid Environments 72: 458-470.

Martins FR & Batalha MA (2011) Formas de vida, espectro biológico de Raunkiaer e fisionomia da vegetação. *In*: Felfili JM, Eisenlohr PV, Fiuza de Melo MMR, Andrade LA & Meira-Neto JAA (orgs.) Fitossociologia no Brasil: métodos e estudos de caso. Vol. 1. Editora UFV, Viçosa. 41p.

Moonlight PW, Banda-R K, Phillips OL, Dexter KG, Pennington RT, Baker TR, Lima HC, Fajardo L, González RM, Linares-Palomino R, Lloyd J, Nascimento M, Prado D, Quintana C, Riina R, Rodríguez, G, Villela DM, Aquino ACMM, Arroyo L, Bezerra C, Brunello AT, Brienen RJW, Cardoso D, Chao KJ, Coutinho IAC, Cunha J, Domingues

T, Santo MME, Feldspausch TR, Fernandes MF, Goodwin ZA, Jiménez EM, Levesley A, Lopez-Toledo L, Marimom B, Miatto RC, Mizushima M, Monteagudo A, Moura MSB, Murakami A, Neves D, Chequín RN, Oliveira TCS, Oliveira EA, Queiroz LP, Pilon A, Ramos DM, Reynel C, Rodrigues PMS, Santos R, Sarkinen T, Silva VF, Souza RMS, Vasquez R, Veenendaal E (2020) Expanding tropical forest monitoring into Dry Forests: The DRYFLOR protocol for permanent plots. Plants People Planet 3: 295-300. DOI: https://doi.org/10.1002/ppp3.10112.

Mori SA (1989) Manual de manejo do herbário fanerogâmico. Centro de Pesquisa do Cacau, Ilhéus. 103p.

Moro MF, Sousa VC, Oliveira-Filho AT, Queiroz LP, Fraga CN, Rodal MJN, Araujo FS & Martins FR (2012) Alienígenas na sala: o que fazer com espécies exóticas em trabalhos de taxonomia, floristica e fitossociologia? Acta Botanica Brasílica 26: 991-999.

Moro MF, Lughadha EM, Filer DL, Araújo FS & Martins FR (2014) A catalogue of the vascular plants of the Caatinga Phytogeographical Domain: a synthesis of floristic and phytosociological surveys. Phytotaxa 160: 1-118.

Moro MF, Macedo MB, Moura-Fé MM, Castro ASF & Costa RC (2015) Vegetação, unidades fitoecológicas e diversidade paisagística do estado do Ceará. Rodriguésia 66: 717-743.

Moro MF, Nic-Lughadha E, Araújo FS & Martins FR (2016) A phytogeographical metaanalysis of the semiarid Caatinga Domain in Brazil. The Botanical Review 82: 91-148.

Nimer E (1972) Climatologia da Região Nordeste do Brasil: introdução à climatologia dinâmica. Revista Brasileira Geografia 34: 3-51.

Oksanen J, Blanchet FG, Friendly M, Kindt R, Legendre P, McGlinn D, Minchin PR, O'Hara RB, Simpson GL, Solymos P, Henry M, Stevens H, Szoecs E & Wagner H (2018) Vegan: community ecology package. R package version 2.5-2. Available at <https://CRAN.R-project.org/package=vegan>. Access on 10 January 2020.

Oliveira DG (2013) A família Euphorbiaceae Juss. em um fragmento de Caatinga em Sergipe. Scientia Plena 9: 041201.

Oliveros JC (2007-2015) Venny. An interactive tool for comparing lists with Venn's diagrams. Available at <https://bioinfogp.cnb.csic.es/tools/venny/index.html>. Access on 26 March 2021.

Paulino RC, Gomes VS & Silveira AP (2018) Flora de Inselbergues do Monumento Natural Monólitos de Quixadá, no sertão central do Ceará. Iheringia 73: 182-190.

Pereira-Júnior LR, Andrade AP & Araújo KD (2012) Composição florística e fitossociológica de um fragmento de caatinga em Monteiro, PB. Holos 6: 73-87.

Pereira MMD, Braga PET, Guiomar N, Santos FDS & Ribeiro S (2018) A flora e a vegetação dos afloramentos rochosos em três municípios na região norte do Ceará, Brasil: caracterização fitossociológica. Rodriguésia 69: 281-299.

Porembski S (2007) Tropical inselbergs: habitat types, adaptive strategies and diversity patterns. Revista Brasileira de Botânica 30: 579-586.

Prado DE (2003) As caatingas da América do Sul. *In*: Leal RI, Tabarelli M & Silva JMC (eds.) Ecologia e conservação da Caatinga. Ed. Universitária da UFPE, Recife. Pp. 3-74.

Queiroz LP (2009) Leguminosas da Caatinga. Universidade Estadual de Feira de Santana, Feira de Santana. 467p.

Queiroz RT, Moro MF & Loiola MIB (2015) Evaluating the relative importance of woody versus non-woody plants for alpha-diversity in a semiarid ecosystem in Brazil. Plant Ecology and Evolution 148: 361-376.

Raunkiaer C (1934) The life forms of plants and statistical plant geography. Clarendon Press, Oxford. 632p.

REFLORA (2021) Herbário Virtual. Available at <http://reflora.jbrj.gov.br/reflora/herbarioVirtual/>. Access on 11 June 2021.

Rodal MJN, Sampaio EVSB & Figueiredo MA (1992) Manual sobre métodos de estudo florístico e fitossociológico - ecossistema caatinga. Sociedade Botânica do Brasil, São Paulo. 24p.

Rodal MJN, Lins-Silva ACB, Pessoa LM & Cavalcanti ADC (2005)Vegetação e flora fanerogâmica da área de Betânia, Pernambuco. *In*: Araújo FS, Rodal MJN & Barbosa MRV (orgs.) Análise das variações da biodiversidade do bioma Caatinga: suporte a estratégias regionais de conservação. Ministério do Meio Ambiente, Brasília. 26p.

Rodrigues WF (2018) Evolução geomorfológica do inselberg Pedra da Andorinha. Fortaleza, CE. Dissertação de Mestrado. Universidade Federal do Ceará, Fortaleza. 92p.

Rodrigues JMD, Lima EC, Claudino-Sales C & Tatumi S (2020) Classificação e análise das unidades de paisagens no distrito de Taperuaba, Sobral, Ceará. Revista Caminhos de Geografia 21: 283-297.

Sampaio VS, Vieira IMF, Júnior EAL & Loiola MIB (2019) Flora of Ceará, Brazil: Solanum (Solanaceae). Rodriguesia 70. DOI: https://doi.org/10.1590/2175-7860201970029

Santana JAS & Souto JS (2006) Diversidade e Estrutura Fitossociológica da Caatinga na Estação Ecológica do Seridó. Revista de Biologia e Ciências da Terra 6: 232-242.

Santos HG, Jacomine PKT, Dos Anjos LHC, Oliveira VA, Lumbreras JF, Coelho MR, Almeida JA, Araújo Filho JC, Oliveira JB & Cunha TJF (2018) Sistema brasileiro de classificação de solos. 5ª ed. Embrapa Solos, Brasília. 356p.

Shepherd GD (2010) FITOPAC 2.1. Universidade Estadual de Campinas, Campinas. Available at

<https://pedroeisenlohr.webnode.com.br/fitopac/>. Access on 15 January 2020.

Silva ACC, Prata APN & Mello AA (2013) Flowering plants of the Grota do Angico Natural Monument, Caatinga of Sergipe, Brazil. Check List 9: 733-739.

Silva JMC, Tabarelli M, Fonseca MT & Lins LV (2004) Biodiversidade da Caatinga: áreas e ações prioritárias para a conservação. Ministério do Meio Ambiente, Brasília. 382p.

Silva JMC, Barbosa LCF, Leal IR & Tabarelli M (2017) The Caatinga: understanding the challenges. *In*: Silva JMC, Leal IR & Tabarelli M (eds.) Caatinga. The largest tropical dry forest region in South America. Springer International Publishing, Cham. 19p.

Stefano RD, Concha GCF, Muñoz JLT, Morillo IMR & Aguilar SH (2005) Notes on the flora of the Yucatan Peninsula IV: *Marsilea vestita* Hook. et Grev. var. *vestita* (Marsileaceae), a new record and some comments about the genus in the region, Boletín de la Sociedad Botánica de México 76: 37-41.

Teixeira LP, Lughadha EM, Silva MVC & Moro MF (2021) How much of the Caatinga is legally protected? An analysis of temporal and geographical coverage of protected areas in the Brazilian semiarid. Acta Botanica Brasilica 35: 473-485. DOI: <https://doi.org/10.1590/0102-33062020abb0492>

Thiers B (continuously updated) Index Herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. Available at <http://sweetgum.nybg.org/science/ih/>. Access on 6 July 2021.

Velloso AL, Sampaio EVSB & Pareyn FGC (2002) Ecorregiões propostas para o bioma caatinga. The Nature Conservancy do Brasil, Associação Plantas do Nordeste, Recife. 76p.

Windisch PG (2015) Marsileaceae. *In*: Flora do Brasil 2020 (continuously updated) Jardim Botânico do Rio de Janeiro. Available at <http://floradobrasil2015.jbrj.gov.br/FB91500>. Access on 23 February 2021.

Xavier SRS, Barros ICL & Santiago ACP (2012) Ferns and lycophytes in Brazil's semi-arid region. Rodriguésia 63: 483-488.

Area Editor: Dra. Tatiana Carrijo
Received in August 12, 2021. Accepted in March 21, 2022.