ADVANCES IN FORESTRY SCIENCE

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Tree structure and composition of a coastal remnant of the Atlantic Forest in Rio de Janeiro

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ABSTRACT: The Atlantic Forest is one of the richest and most threatened biomes in Brazil. However, the structure and floristic composition of many of its remnants are still unknown. This study assessed the structure and tree composition of the Serra da Tiririca – SET coastal remnant, is the largest remnant in Serra da Tiririca State Park – PESET (Atlantic Forest, RJ). In ten 50 × 20 m plots installed between the edges and the interior of the remnant, we registered 403 trees distributed in 29 families, 59 genera, and 126 species. The richest and most abundant families were Fabaceae, Myrtaceae, and Meliaceae, while the most representative species were *Gallesia integrifolia* towards the interior of the remnant and *Piptadenia gonoacantha* towards the edges. The remnant had an average Shannon-Wiener Diversity of 3.69, a total basal area of 19.3 m^2/ha, and an average diameter and height of 20.42 cm and 11.8 m, respectively. This study shows that the SET remnant is floristically heterogeneous and has distinct structural characteristics and stretches in different successional stages related to edge and interior gradients. Anthropogenic pressures on the remnant are likely to persist and are evidenced mainly by the forest structure.

Composição e estrutura arbórea de um remanescente costeiro de Mata Atlântica no Rio de Janeiro

RESUMO: A Mata Atlântica é um dos biomas mais ricos e ameaçados do Brasil. No entanto, a estrutura e composição florística de muitos de seus remanescentes ainda são desconhecidas. Este estudo avaliou a estrutura e a composição arbórea do remanescente costeiro da Serra da Tiririca - SET, o maior remanescente do Parque Estadual da Serra da Tiririca - PESET (Mata Atlântica, RJ). Em dez parcelas de 50 × 20 m instaladas entre as bordas e o interior do remanescente, registramos 403 árvores distribuídas em 29 famílias, 59 gêneros e 126 espécies. As famílias mais ricas e abundantes foram Fabaceae, Myrtaceae e Meliaceae, enquanto as espécies mais representativas foram *Gallesia integrifolia* para o interior do remanescente e *Piptadenia gonoacantha* para às bordas. O remanescente apresentou uma diversidade média de Shannon-Wiener de 3,69, uma área basal total de 19,3 m^2/ha e diâmetro e altura médios de 20,42 cm e 11,8 m, respectivamente. Este estudo mostra que o remanescente da SET é florísticamente heterogêneo e possui características estruturais distintas e trechos em diferentes estágios sucessionais relacionadas aos gradientes de bordas e interior. De igual forma, este estudo observou que as pressões antrópicas sobre o remanescente tendem a persistir e são evidenciadas principalmente pela estrutura florestal.

Introduction

Tropical forests are immensely rich in biodiversity (Gentry 1992; Sullivan et al. 2017). Of the 65,000 tree species currently known to science (Beech et al. 2017), about 53,000 are in tropical forests (Slik et al. 2015) and approximately 8,700 of these are found in Brazil (Flora do Brasil 2021). Despite the great diversity, most of these species are threatened by human activities that have negative impacts, such as deforestation (Laurance et al. 2018). Therefore, to conserve their habitats, it is vitally important to know the species composition (taxonomic diversity) and structure of these forests (Caiafa and Martins 2007).

Studying forest biodiversity using different approaches allows us to infer numerous ecological processes (Wheeler et al. 2016). For example, determining species composition and defining the spatial distribution of biodiversity allow us to characterize different habitats (e.g. edge and interior) and, at the same time, assess the anthropogenic influence on these habitats and their species (Laurance et al. 2018). On the other hand, determining the forest structure allows us to deduce the adaptation mechanisms of individuals and find interspecific associations (Apagua et al. 2014). Both approaches are particularly needed to define patterns in secondary succession (Chazdon et al. 2010). However, defining these patterns in the Atlantic Forest is still a challenge (Alves et al. 2010).

The Atlantic Forest is a priority hotspot for biodiversity conservation (Myers et al. 2000) and one of the richest rainforest biomes in Brazil (Mittermeier et al. 2011). In this biome, there are more than 15,500 plant species and more than 70% of the tree species are endemic (Flora do Brasil 2021). This floristic diversity is partially due to the interaction of the arboreal component with edaphic, environmental, and anthropogenic interference gradients (Sanchez et al. 2013; Neves et al. 2017; Caglioni et al. 2018). This last factor is one of the main reasons for the fragmentation of the Atlantic Forest (Scarano and Ceotto 2015); it is estimated that less than 12.4% of its original coverage remains (SOS Mata Atlântica and INPE 2019).

Among the forest types in the Atlantic Forest, dense rainforest is one of the most diverse (Scudeller et al. 2001). This forest types has high rates of endemism and is characterized by its extremely heterogenous arboreal component (Veloso et al. 1991). The diversity and endemism levels of this forest types has resulted in an increase in the number of floristic studies in recent decades (e.g. Lemos et al. 2001; Guedes-Bruni et al. 2006; Barros 2008; Sanchez et al. 2013; Lingner et al. 2015; Pinto et al. 2019), mainly in the state of Rio de Janeiro. However, the structure and floristic composition of many of the coastal remnants are still unknown. Therefore, this study had the following objectives: i) analyze the tree composition and diversity of a coastal remnant of the Atlantic Forest; ii) Analyze composition similarity in an edge effect distance gradient (edge x interior); and iii) determine the forest structure of this remnant.

Material and Methods

Study area

Serra da Tiririca (SET) is the main coastal remnant in Serra da Tiririca State Park (PESET) located in the municipalities of Niterói and Maricá (22º48'-23º00'S, 42º57'-43º02'W) in Rio de Janeiro State (Figure 1). This protected area cover 1,975.06 ha and its vegetation is dense submontane rainforest with rocky outcrops (Atlantic Forest) (Barros 2008). The climate is Aw (according to Köppen), which is hot and humid with rainstorms in the summer and a dry season in the winter (Alvares et al. 2013). The average annual temperature is 23.7 °C, the average annual precipitation is 1172 mm, the annual relative humidity is 80%, and the soils are Argissoils, Gleissolos, Neosols, and Cambisols (INEA 2015).

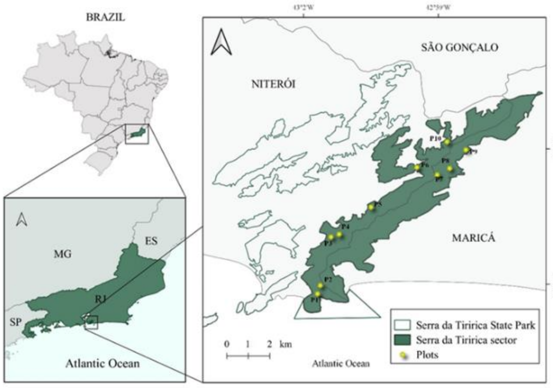

Figure 1. Location map of the study area and plots installed between 2019 and 2020 in SET, Rio de Janeiro.

Data collection

Between November 2019 and December 2020, we randomly established ten plots with 50 × 20 m (1 ha), distributed between two habitat types (edge and interior). The five edge plots were installed no further than 20 m from an anthropogenic edge. All plots were a minimum of 200 m from each other (Figure 1). Within each plot, we measured all living trees with a diameter at breast height (DBH) ≥ 10 cm. We then recorded the diameter and height and made botanical collections of all marked trees. Subsequently, the botanical material were processed, identified, and deposited in the Museu Nacional Herbarium (R). Species were identified by consulting with specialists and comparing exsiccatae with those of online botanical collections, such as Reflora(http://reflora.jbrj.gov.br/reflora/herbarioVirtual/), GBIF (https://www.gbif.org/) and The Plant List (http://www.theplantlist.org). Families were classified according to the APG IV system (APG 2016).

Data analysis

First, we analyzed the tree species composition. Then, the indicator species were analyzed by type of habitat (edge and interior) using an indicator species analysis (ISA) (Dufrêne and Legendre 1997). For this analysis, a Monte Carlo test with 1000 permutations was applied to test the hypothesis that the species would not have an indicator value; the species with a p-value $\leq$ 0.05 and IndVal $\geq$ 0.7 were considered indicators (Dufrêne and Legendre 1997).

To assess the sampling sufficiency, a rarefaction curve was built on the collector curve of the number of species per plot. For this analysis, only trees identified to the specific level were considered. To construct the rarefaction curve, we used the Chao 1 index and a 95% confidence interval (Chao et al. 2014). To verify significant differences between the collector curve (observed species) and the rarefaction curve (estimated species), a Tukey test (Haynes 2013) was applied. Subsequently, to define the similarity between plots based on species composition, a matrix with presence/absence data was constructed with the sampled species, and an unweighted pair group method with arithmetic mean (UPGMA) clustering analysis was conducted, applying the coefficient of Jaccard. Then, an abundance matrix was created with the same species and the species diversity was evaluated using the Shannon-Wiener (H') and Pielou (J') indices (Moreno et al. 2011).

Finally, to describe the forest structure, the total basal area was calculated, and the plots were sorted according to habitat type, number of individuals, and median diameter and height. Additionally, a phytosociological analysis was performed for the entire remnant by calculating the following parameters: absolute (AD) and relative density (RD), relative frequency (RF), absolute (AoD) and relative dominance (RoD), and the importance value (IV) (Mueller-Dombois and Ellenberg 2002). All analyses were conducted in the programs R 4.0.5 (R Core Team 2021), Past 4.07 (Hammer 2001), and Fitopac 2.1 (Shepherd 2010). We constructed the rarefaction curve and conducted the ISA analysis in R; for this analysis, the *indicspecies* 1.7.9 package (De Caceres and Legendre 2009) was used. The grouping and diversity analyses were conducted in Past. All phytosociological analyses were conducted in Fitopac.

Results

In total, we registered 403 trees distributed in 29 families, 59 genera, and 126 species, of which 53.97% were identified to the specific level (68 species), 0.87% to the generic level, and 15.08% to the family level. Only 29.36% of the trees were not identified to any taxonomic level. The families with the highest number of species were Fabaceae (11 spp.), Myrtaceae (6), and Sapindaceae (5) (Table 1). The families with the highest number of individuals were Fabaceae (79 trees), Meliaceae (38), and Anacardiaceae (31). The most abundant species were *Erythroxylum pulchrum* (28 trees), *Astronium graveolens* (25) and *Piptadenia gonoacantha* (21). The indicator species for the habitats were *Gallesia integrifolia* (Spreng.) Harms for the interior (IndVal = 0.973; p = 0.005) and *Piptadenia ganoacantha* for the edges (IndVal = 0.78; p = 0.05). The collector curve showed a slight tendency to stabilize and, according to the Tukey test (p = 0.06), did not show significant differences between the observed and estimated species (Figure 2).

Table 1. Tree composition and phytosociological parameters of species sampled in SET, Rio de Janeiro. AD = absolute density (trees/ha), RD = relative density (%), RF = relative frequency (%), AoD = absolute dominance (m^2/ha), RoD = relative dominance (%), and IV = importance value.

Family/*Species*	**AD**	**RD**	**FR**	**AoD**	**RoD**	**IV**
ANACARDIACEAE						
Astronium fraxinifolium Schott	3	0.74	1.16	0.07	0.38	2.28
Astronium graveolens Jacq.	25	6.2	2.31	0.57	2.89	11.4
Mangifera indica L.	3	0.74	0.58	0.49	2.49	3.82
ANNONACEAE						
Annonaceae sp.	1	0.25	0.58	0.01	0.05	0.88
Guatteria australis A.St.-Hil.	2	0.5	1.16	0.04	0.21	1.87
APOCYNACEAE						
Apocynaceae sp.	1	0.25	0.58	0.04	0.18	1.01
Aspidosperma parvifolium A.DC.	5	1.24	1.16	0.16	0.82	3.21

....continue

... Table 1 Continuation

Family/*Species*	**AD**	**RD**	**FR**	**AoD**	**RoD**	**IV**
ASTERACEAE						
Asteraceae sp.	1	0.25	0.58	0.14	0.70	1.53
Moquiniastrum polymorphum (Less.) G. Sancho	18	4.77	1.73	0.61	3.10	9.29
Piptocarpha macropoda (DC.) Baker	1	0.25	0.58	0.03	0.15	0.98
BIGNONIACEAE						
Handroanthus impetiginosus (Mart. ex DC.) Mattos	1	0.25	0.58	0.03	0.17	0.99
Sparattosperma leucanthum (Vell.) K.Schum.	16	3.94	2.31	0.8	4.07	10.35
BORAGINACEAE						
Cordia ochnaceae A.DC.	1	0.25	0.58	0.01	0.07	0.9
CAPPARACEAE						
Crateva tapia L.	4	0.99	1.16	0.09	0.48	2.62
CELASTRACEAE						
Maytenus communis Reissek	4	0.99	1.16	0.07	0.35	2.50
CHRYSOBALANACEAE						
Licania octandra (Hoffmanns. ex Schult.) Kuntze	5	1.24	0.58	0.19	0.99	2.81
CLUSIACEAE						
Tovomita leucantha (Schltdl.) Planch. & Triana	1	0.25	0.58	0.02	0.11	0.94
ERYTHROXYLACEAE						
Erythroxylum pulchrum A.St.-Hil.	28	6.95	2.89	0.81	4.12	13.96
Erythroxylum sp.	1	0.25	0.58	0.01	0.06	0.89
EUPHORBIACEAE						
Alchornea glandulosa Poepp.	3	0.74	0.58	0.28	1.43	2.75
Sapium glandulosum (L.) Morong	1	0.25	0.58	0.05	0.25	1.08
FABACEAE						
Albizia polycephala (Benth.) Killip	5	1.24	1.16	0.17	0.86	3.26
Anadenanthera colubrina (Vell.) Brenan	4	0.99	1.16	0.27	1.39	3.53
Caesalpinia pluviosa DC.	2	0.5	0.58	0.02	0.11	1.19
Fabaceae sp. 1	2	0.5	0.58	0.05	0.25	1.33
Fabaceae sp. 2	1	0.25	0.58	0.03	0.16	0.98
Fabaceae sp. 3	1	0.25	0.58	0.02	0.11	0.94
Fabaceae sp. 4	1	0.25	0.58	0.02	0.08	0.90
Fabaceae sp. 5	2	0.5	0.58	0.04	0.19	1.27
Fabaceae sp. 6	1	0.25	0.58	0.03	0.17	0.99
Fabaceae sp. 7	1	0.25	0.58	0.08	0.39	1.22
Fabaceae sp. 8	1	0.25	0.58	0.03	0.13	0.96
Fabaceae sp. 9	1	0.25	0.58	0.06	0.31	1.13
Inga congesta T.D.Penn.	1	0.25	0.58	0.04	0.18	1.01
Machaerium hirtum (Vell.) Stellfeld	3	0.74	1.16	0.07	0.33	2.24
Mimosa artemisiana Heringer & Paula	1	0.25	0.58	0.06	0.33	1.15
Ormosia arborea (Vell.) Harms	1	0.25	0.58	0.07	0.34	1.17
Piptadenia gonoacantha (Mart.) J.F.Macbr.	21	5.21	3.47	0.5	2.55	11.23

....continue

... Table 1 Continuation

Family/*Species*	**AD**	**RD**	**FR**	**AoD**	**RoD**	**IV**
Piptadenia paniculata Benth.	10	2.48	1.73	0.24	1.22	5.44
Pseudopiptadenia contorta (DC.) G.P.Lewis & M.P.Lima	19	4.71	1.16	0.68	3.46	9.33
Pterogyne nitens Tul.	1	0.25	0.58	0.07	0.35	1.18
INDETERMINATE						
Indeterminate 1	1	0.25	0.58	0.07	0.37	1.19
Indeterminate 2	1	0.25	0.58	0.2	1.01	1.84
Indeterminate 3	1	0.25	0.58	0.05	0.26	1.09
Indeterminate 4	1	0.25	0.58	0.02	0.08	0.91
Indeterminate 5	1	0.25	0.58	0.07	0.35	1.17
Indeterminate 6	1	0.25	0.58	0.09	0.46	1.29
Indeterminate 7	1	0.25	0.58	0.06	0.31	1.14
Indeterminate 8	1	0.25	0.58	0.07	0.36	1.18
Indeterminate 9	1	0.25	0.58	0.02	0.08	0.90
Indeterminate 10	1	0.25	0.58	0.21	1.08	1.90
Indeterminate 11	1	0.25	0.58	0.02	0.10	0.93
Indeterminate 12	1	0.25	0.58	0.02	0.11	0.94
Indeterminate 13	1	0.25	0.58	0.05	0.23	1.06
Indeterminate 14	1	0.25	0.58	0.04	0.22	1.04
Indeterminate 15	1	0.25	0.58	0.06	0.29	1.12
Indeterminate 16	1	0.25	0.58	0.03	0.16	0.98
Indeterminate 17	3	0.74	0.58	0.17	0.89	2.21
Indeterminate 18	1	0.25	0.58	0.04	0.23	1.05
Indeterminate 19	1	0.25	0.58	0.01	0.05	0.88
Indeterminate 20	1	0.25	0.58	0.07	0.37	1.20
Indeterminate 21	3	0.74	0.58	0.06	0.30	1.62
Indeterminate 22	1	0.25	0.58	0.05	0.27	1.10
Indeterminate 23	1	0.25	0.58	0.02	0.09	0.92
Indeterminate 24	1	0.25	0.58	0.01	0.06	0.88
Indeterminate 25	1	0.25	0.58	0.01	0.07	0.89
Indeterminate 26	1	0.25	0.58	0.02	0.08	0.91
Indeterminate 27	1	0.25	0.58	0.02	0.09	0.91
Indeterminate 28	2	0.5	0.58	0.07	0.35	1.43
Indeterminate 29	1	0.25	0.58	0.03	0.18	1.00
Indeterminate 30	1	0.25	0.58	0.02	0.09	0.92
Indeterminate 31	1	0.25	0.58	0.04	0.23	1.05
Indeterminate 32	4	0.99	0.58	0.13	0.67	2.24
Indeterminate 33	4	0.99	0.58	0.17	0.85	2.42
Indeterminate 34	1	0.25	0.58	0.04	0.20	1.03
Indeterminate 35	2	0.5	0.58	0.05	0.23	1.31
Indeterminate 36	1	0.25	0.58	0.02	0.08	0.9
Indeterminate 37	1	0.25	0.58	0.02	0.10	0.92

....continue

... Table 1 Continuation

Family/*Species*	**AD**	**RD**	**FR**	**AoD**	**RoD**	**IV**
LACISTEMATACEAE						
Lacistema hasslerianum Chodat	1	0.25	0.58	0.01	0.06	0.89
LAMIACEAE						
Aegiphila mediterranea Vell.	1	0.25	0.58	0.01	0.05	0.88
LAURACEAE						
Aniba firmula (Nees & Mart.) Mez	3	0.74	1.16	0.05	0.23	2.13
Cryptocarya moschata Nees & Mart.	1	0.25	0.58	0.01	0.06	0.88
Ocotea aniboides Mez	1	0.25	0.58	0.01	0.04	0.87
Ocotea daphnifolia (Meisn.) Mez	1	0.25	0.58	0.02	0.12	0.94
LECYTHIDACEAE						
Couratari pyramidata (Vell.) R.Knuth	1	0.25	0.58	0.01	0.04	0.87
MALVACEAE						
Ceiba crispiflora (Kunth) Ravenna	3	0.74	0.58	0.25	1.29	2.61
Luehea grandiflora Mart.	2	0.5	0.58	0.06	0.29	1.36
Malvaceae sp. 1	4	0.99	0.58	0.41	2.07	3.82
Pachira glabra Pasq.	2	0.5	0.58	0.02	0.09	1.16
Quararibea turbinata (Sw.) Poir.	1	0.25	0.58	0.01	0.05	0.88
MELIACEAE						
Guarea guidonia (L.) Sleumer	19	4.71	1.73	1.62	8.25	14.7
Guarea kunthiana A.Juss.	17	4.22	1.73	1.21	6.17	12.12
Trichilia casaretti C. DC.	2	0.5	0.58	0.03	0.14	1.21
MORACEAE						
Artocarpus heterophyllus Lam.	1	0.25	0.58	0.02	0.1	0.93
Brosimum guianense (Aubl.) Huber ex Ducke	2	0.5	0.58	0.27	1.35	2.43
Ficus adhatodifolia Schott	1	0.25	0.58	0.01	0.04	0.87
Ficus luschnathiana (Miq.) Miq.	5	1.24	0.58	1.37	7.00	8.82
Ficus sp.	1	0.25	0.58	0.05	0.23	1.06
MYRISTICACEAE						
Virola gardneri (A.DC.) Warb.	1	0.25	0.58	0.13	0.66	1.49
MYRTACEAE						
Calyptranthes grandifolia O.Berg	4	0.99	1.73	0.15	0.78	3.51
Campomanesia laurifolia Gardner	1	0.25	0.58	0.02	0.11	0.94
Eugenia sp.	1	0.25	0.58	0.09	0.47	1.3
Eugenia candolleana DC.	1	0.25	0.58	0.01	0.06	0.89
Eugenia marambaiensis M.C.Souza & M.P.Lima	1	0.25	0.58	0.02	0.09	0.92
Myrcia splendens (Sw.) DC.	6	1.49	0.58	0.09	0.44	2.51
Myrtaceae sp. 1	1	0.25	0.58	0.01	0.07	0.90
Myrtaceae sp. 2	2	0.5	0.58	0.05	0.24	1.31
Myrtaceae sp. 3	1	0.25	0.58	0.02	0.12	0.94
Myrtaceae sp. 4	1	0.25	0.58	0.04	0.19	1.02
Plinia grandifolia (Mattos) Sobral	3	0.74	0.58	0.13	0.68	2.00

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... Table 1 Continuation

Family/*Species*	**AD**	**RD**	**FR**	**AoD**	**RoD**	**IV**
NYCTAGINACEAE						
Guapira opposita (Vell.) Reitz	7	1.74	1.73	0.21	1.09	4.56
OLACACEAE						
Heisteria perianthomega (Vell.) Sleumer	1	0.25	0.58	0.02	0.08	0.91
PHYTOLACCACEAE						
Gallesia integrifólia (Spreng.) Harms	19	4.71	3.47	3.06	15.61	23.79
Seguieria langsdorffii Moq.	2	0.5	0.58	0.04	0.23	1.30
RUBIACEAE						
Bathysa mendoncae K.Schum.	1	0.25	0.58	0.01	0.04	0.87
Chomelia brasiliana A.Rich.	1	0.25	0.58	0.01	0.04	0.87
Simira viridiflora (Allemão & Saldanha) Steyerm.	2	0.5	1.16	0.04	0.18	1.83
RUTACEAE						
Zanthoxylum rhoifolium Lam.	1	0.25	0.58	0.01	0.07	0.90
SALICACEAE						
Casearia arborea (Rich.) Urb.	3	0.74	1.16	0.08	0.40	2.30
Xylosma glaberrima Sleumer	2	0.5	0.58	0.04	0.22	1.29
SAPINDACEAE						
Allophylus edulis (A.St.-Hil., A.Juss. & Cambess.) Radlk.	3	0.74	0.58	0.09	0.44	1.76
Allophylus leucoclados Radlk.	7	1.74	1.73	0.13	0.64	4.11
Allophylus petiolulatus Radlk.	1	0.25	0.58	0.01	0.04	0.87
Allophylus semidentatus (Miq.) Radlk.	1	0.25	0.58	0.02	0.10	0.93
Cupania oblongifolia Mart.	6	1.49	1.16	0.09	0.49	3.13
Sapindaceae sp.	1	0.25	0.58	0.01	0.07	0.89
TOTAL	403	100	100	19.3	100	300

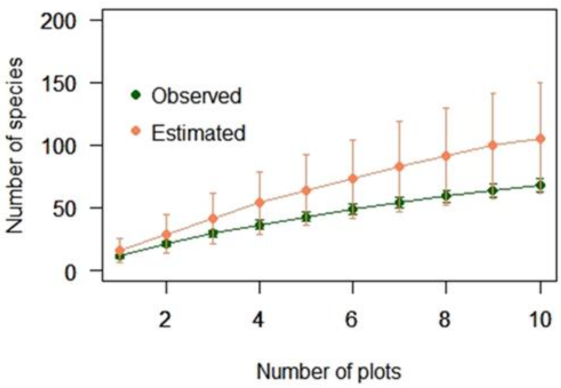

Figure 2. Rarefaction curve of the number of species sampled in SET, Rio de Janeiro.

The Shannon-Wiener diversity index (H') had intermediate values for Serra da Tiririca (3.69). Plots P2 (2.99) and P6 (2.86) had the highest values, and plots P9 (1.56) and P1 (1.88) had the lowest (Table 2). The analysis of individuals by species, based on Pielou's evenness (J'), showed maximum uniformity for plots P4 (0.95) and P2 (0.94) and regular uniformity for plots P9 (0.68) and P1 (0.76). The value to the entire community was 0.87 (Table 2).

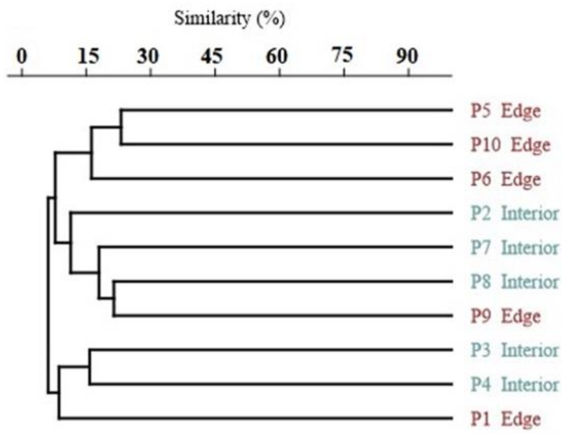

Figure 3. Jaccard similarity clustering dendrogram of plots installed in SET, Rio de Janeiro.

The total basal area was 19.3 m²/ha. The families Fabaceae, Meliaceae, and Anacardiaceae represented 84.9% of the absolute dominance (AoD). Likewise, the species *Gallesia integrifolia*, *Guarea guidonia*, *Guarea kunthiana*, and *Ficus luschnathiana* corresponded to 72.6% of the AoD. The species with the highest relative frequency were

Gallesia integrifolia (3.47%), *Piptadenia gonoacantha* (3.47%), and *Erythroxylum pulchrum* (2.89%), and the species with the highest importance values were *Gallesia integrifolia* (23.79), *Guarea guidonia* (14.70) and *Erythroxylum pulchrum* (13.96) (Table 1). The mean DBH and height of the trees were 20.42 ± 4.94 cm and 11.8 ± 2.35 m, respectively. The edges had an average DBH of 20.84 ± 5.61 cm and an average height of 11.7 ± 2.27 m, and the interior had an average DBH of 19.99 ± 4.13 cm and an average height of 11.9 ± 2.42 m. For DBH, the plots with the highest medians were P1 (31.94 cm) and P6 (27.06 cm), while P7 (14.80 cm) and P5 and P6 (17.19 cm for each plot) had the lowest medians. For height, plots P3 (16 m) and P1 (15 m) were among those with the highest medians, and P5 (8.5 m) and P8 (9 m) had the lowest (Table 2).

Table 2. Medians for diameter at breast height (DBH) and height, and classification of habitat type and diversity indices of the plots installed in SET, Rio de Janeiro. ± = standard deviation. * = Index value for the entire community, considering the abundance of species sampled.

Plots	**Habitat**	**N**	**Dendrometries**		**Diversity indices**	
			DBH (cm)	Height (m)	Shannon-Wiener (*H'*)	Pielou (*J'*)
P1	Edge	32	31.94 ± 16.18	15 ± 4.78	1.88	0.76
P2	Interior	35	18.78 ± 9.74	11 ± 3.24	2.99	0.94
P3	Interior	33	27.06 ± 12.07	16 ± 4.57	2.41	0.89
P4	Interior	26	17.83 ± 21.48	10.5 ± 4.81	2.44	0.95
P5	Edge	40	17.19 ± 4.49	8.5 ± 3.24	2.63	0.89
P6	Edge	49	17.19 ± 9.19	10 ± 3.10	2.86	0.91
P7	Interior	92	14.80 ± 8.66	13 ± 4.12	2.77	0.84
P8	Interior	32	21.49 ± 9.77	9 ± 3.85	2.59	0.92
P9	Edge	31	18.78 ± 6.72	12 ± 3.56	1.56	0.68
P10	Edge	33	19.10 ± 5.53	13 ± 3.10	2.27	0.88
Average		40.3	20.42 ± 4.94	11.8 ± 2.35	3,69*	0.87*

Discussion

For an Atlantic Forest remnant, the diversity and forest structure are related to deterministic patterns of ecosystems, and analyzing the tree composition, diversity, and forest structure of the largest coastal remnant in PESET is crucial to elucidate processes that may be interfering with the maintenance of this area over time. This study found a characteristic arboreal composition of dense rainforest, with representative families and species of the Atlantic Forest, and a remarkably heterogeneous forest structure, which may be the result of the resilience of these plant communities to anthropogenic pressures.

The Atlantic Forest is home to a huge portion of the diversity and endemism in Brazil, even though it is under intense anthropogenic pressure (Myers et al. 2000). It contains the most representative botanical families in terms of richness and abundance in the Neotropics (Gentry 1992), such as Fabaceae, Myrtaceae, and Meliaceae. These are the same families highlighted in this study and other studies conducted in the state of Rio de Janeiro (e.g. Kurtz and Araujo 2000; Borém and Oliveira-Filho 2002; Solórzano et al. 2012; Cruz et al. 2013; Cysneiros et al. 2016). One of the richest families in Brazil is Fabaceae (Flora do Brasil 2021), which is characterized by having relationships with nitrogen-fixing bacteria and growing in different habitats (Raza et al. 2020). Similar to Fabaceae in terms of richness, one of the most representative families in Brazilian coastal forests is Myrtaceae (Oliveira-Filho and Fontes 2000). The family Meliaceae, highlighted in this study for its abundance (behind Fabaceae), is one of the most widely distributed groups in Brazil (Flora do Brasil 2021). This is partly because the family has species with pioneer characteristics, such as *Guarea guidonia* (Oliveira et al. 2013). This species has high germination rates in gaps, edges, and slopes and is commonly associated with other typical secondary vegetation species (Carvalho et al. 2009; Oliveira et al. 2013; Guilherme et al. 2021).

Among the main species in this study, *Erythroxylum pulchrum* and *Astronium graveolens* were the most abundant. Both species are known for their occurrence in secondary vegetation and having numerous records from southeastern Brazil (Carvalho 2006; Loiola et al. 2007). In addition to the Atlantic Forest, *Astronium graveolens* is an emergent tree species found in the Amazon, Cerrado, Caatinga, and Pampas (Flora do Brasil 2021). In the same sense, in this study the species highlighted for being indicators of the edge (*P. gonoacantha*) and interior (*G. integrifolia*) habitats have already been widely reported in other studies about the Atlantic

Forest (e.g.Borém and Oliveira-Filho 2002; Dan et al. 2010; Gandra et al. 2011; Cysneiros et al. 2015). One of the reasons that *P. gonoacantha* occurs more frequently on edges than in the interior of SET maybe because the tree is a pioneer species, fast-growing, and very common in secondary vegetation (Carvalho 2004; Machado et al. 2021). In contrast, *G. integrifolia* is found more in dense forest interiors than in secondary vegetation and prefers deep, humid, and fertile soils (Lorenzi 1992).

Due to the great richness of habitats in tropical ecosystems, it is common to observe numerous tree species locally (Gentry 1992). This could explain why our species curve did not reach stability. However, although our plots show a heterogeneous floristic distribution, the comparison between the observed and estimated species showed that our sampling effort was insufficient. Likewise, we observed little similarity between plots and an intermediate level of diversity compared to other studies carried out in dense rainforests (e.g. Kurtz and Araújo 2000; Carvalho et al. 2009; Dan et al. 2010; Gandra et al. 2011; Solórzano et al. 2012; Cysneiros et al. 2015; Stefani et al. 2021) and SET (Barros 2008). Among the possible reasons for this outcome, the numerous undetermined species, sample inclusion criteria and sampling sufficiency (Caiafa and Martins 2007) could have influenced the lowest local diversity.

The variations that tropical forests undergo through many periods of disturbance and recovery at different chrono-spatial scales (Chazdon 2003) often result in heterogeneously structured mosaics. Thus, evaluating the forest structure is essential to determine the successional stages of a forest (Chazdon 2012). In this study, the diameter and height values seem to be characteristic of regenerating secondary vegetation. Similarly, the basal area found in SET could be considered between low to intermediate compared to other studies conducted in the Atlantic Forest (e.g. Borém and Oliveira-Filho 2002; Barros 2008; Gandra et al. 2011; França and Stehmann 2013; Cysneiros et al. 2015; Turchetto et al. 2018; Stefani et al. 2021) In part, the results of this work are within the expected variations regarding the successional processes related to the history of use and occupation of PESET. As already reported, the vegetation of SET has gone through intense devastation since the beginning of the colonial era (Barros 2008) and, even today, it is influenced by frequent deforestation and fires (INEA 2015). Therefore, this study on the tree composition and structure of SET aggregates crucial and complementary information, reflects a better ecological understanding of the diversity, and will contribute to the management and conservation of this remnant.

Conclusions

The largest remnant of dense submontane rainforest in PESET has tree vegetation at different successional stages. We recorded 403 trees distributed in 29 families, 59 genera, and 126 species. Fabaceae, Myrtaceae, and Meliaceae were the richest and most abundant families, while the most representative species were *Gallesia integrifolia* for the interior and *Piptadenia gonoacantha* for the edges. The remnant showed intermediate diversity and a total basal area of 19.3 m^2/ha. This study contributes to known about the tree and structural composition of SET and provides information that will help in the management and conservation of this remnant.

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