Research in Ecology
https://ojs.bilpublishing.com/index.php/re

ARTICLE

Structure of a Semideciduous Seasonal Forest in the National Forest of Ipanema, Brazil: Contributing to the Floristic Knowledge of a Poorly Studied Protected Area

Vinícius Londe[1*] Felipe Segala Ferreira[2] Fernando Roberto Martins[3]

1. Independent Researcher, Lisbon, 1070-118, Portugal
2. Graduate Course in Plant Biology, University of Campinas, Campinas, São Paulo, 13083-970, Brazil
3. Plant Biology Department, Institute of Biology, University of Campinas, Campinas, 13083-970, Brazil

ARTICLE INFO

Article history
Received: 22 July 2022
Received in revised form: 21 September 2022
Accepted: 26 September 2022
Published: 30 September 2022

Keywords:
Community structure
Floresta Nacional de Ipanema
Atlantic forest
Floristic inventory
Vulnerable species

ABSTRACT

Studies on composition and structure generate crucial information for characterizing plant communities and planning conservation actions. There are still substantial knowledge gaps in Brazilian protected areas, preventing design programs to mitigate biodiversity loss. This is the case of the National Forest of Ipanema (Ipanema NAFO) in São Paulo state, Brazil, where plant diversity remains uncalculated. To help fill this gap, in 1-ha of a seasonal semideciduous forest (SSF) stand on the Araçoiaba hill, the authors sampled all woody stems with dbh ≥ 5 cm in a total of 103 dead and 1,301 living plants representing 65 species, 57 genera, and 31 families. The number of species and families was lower than old-growth SSF and, together with the land-use history, which suggests the community is a secondary stand. The initial species *Guazuma ulmifolia*, *Machaerium stipitatum*, *Croton floribundus,* and *Aloysia virgata* totalized 50% of the living stems, whereas 37% of the other species summed up only 1.8%. The high abundance of these initial species and the presence of the climax species *Cariniana legalis*, *Holocayx balansae*, *Myroxylon peruiferum*, *Zanthoxylum caribaeum* and others indicate that the community is in an intermediate to advanced successional stage. Three species are considered vulnerable to extinction and 27 of least concern. Ipanema NAFO is an important conservation unit, sheltering some plants vulnerable to extinction and others locally rare. This study adds to other few studies about the flora of Ipanema NAFO, helping to estimate its biodiversity and planning conservation actions. Additionally, it is a source for defining reference values for ecological restoration in the Atlantic forest.

*Corresponding Author:
Vinícius Londe,
Independent Researcher, Lisbon, 1070-118, Portugal;
Email: vlonde.ecologia@gmail.com

DOI: https://doi.org/10.30564/re.v4i3.4916

1. Introduction

Understanding how vegetation is structured provides essential insights for the delimitation and characterization of plant communities [1]. Knowing the community structure makes it possible, for instance, to carry out comparisons between vegetation formations and follow vegetation development in "natural" and urban landscapes [2]. Floristic knowledge is important for mapping the global patterns of plant diversity and identifying priorities in collecting and compiling data on richness [3]. In addition, conducting floristic and phytosociological studies in old-growth and secondary fragments can lead to accumulating information indispensable to defining reference values to be achieved in the long-term process of ecological restoration [4].

Considering that Brazilian biomes are highly fragmented [5], it is much important to conduct research aiming to understand the composition and structure of the forest and non-forest remnants. There are 1,192 conservation units in Brazil, of which 428 are within the Atlantic Forest [6]. These protected areas are relevant for scientific research and provide economic benefits to the government and local communities through ecotourism and other activities [7]. However, recent studies indicate substantial knowledge gaps on biodiversity in most Brazilian protected areas [8]. Filling these gaps is vital to design programs for mitigating biodiversity loss and increasing ecosystems' resilience in the face of climate change [9]. Moreover, surveying ecological communities in conservation units can provide a base for evaluating how much biodiversity these units can protect. Recent studies have identified the forms of rarity of shrub and tree species occurring in the South American savannas and found that only about 10% of the rare species are protected within conservation units [10].

An example of a conservation unit that has been little studied is the National Forest of Ipanema (henceforth, Ipanema NAFO) in São Paulo state. A search (in March 2022) for the National Forest of Ipanema (in Portuguese) in the bibliographic database SciELO resulted in only thirteen studies, and most of them focused on fauna. Surveys on vegetation structure and composition are still scarce within this conservation unit. The few existing studies have focused mainly on vascular epiphytes and aquatic macrophytes [11-13]. There is a clear need for further investigations into the tree-shrub flora, adding information to the few studies carried out on this subject in Ipanema NAFO [14,15].

Given such gaps, we aimed to conduct a floristic survey and quantitatively describe the structure of a semideciduous seasonal forest (SSF) in the Ipanema NAFO. In addition, we classified the species according to their growth habits (trees, shrubs, palms, and lianas) and extinction risk status (vulnerable, endangered etc.).

2. Materials and Methods

2.1 Study Area

We carried out the study in the National Forest of Ipanema, a Federal Conservation Unit of sustainable use with about 5,070 hectares created in 1992 to protect, conserve and restore the remnants of native vegetation of the Atlantic Forest [16]. The Ipanema NAFO encompasses the municipalities of Iperó, Capela do Alto, and Araçoiaba da Serra in the hinterlands of São Paulo state, southeastern Brazil (Figure 1). The semideciduous seasonal forest (SSF) is currently the main vegetation type found in the Ipanema NAFO, but there are also fragments of broadleaf rain forest and Cerrado (savanna), and some eucalypt and native species monocultures [16]. The SSF constitutes one of the formations of the Atlantic Forest; it occurs in tropical warm seasonal climates with rainy summer and dry winter, during which up to 50% of the trees shed leaves. The SSF tree flora is very similar to that of the Atlantic broadleaf rain forest, and the transition between these two formations is a long gradient, in which the SSF occurs to the west of the rain forest ranging from 10 km to 1172 km from the coast, from 15 m to 1577 m above sea level, 16.3 °C to 25.8 °C mean annual temperatures, 753 mm~1741 mm average annual total precipitation, and 1310 mm to 1860 mm mean annual total potential evapotranspiration [17].

According to Köppens's climate classification, the Ipanema NAFO is Cfa in the south, transitioning toward Cwa to the north [16]. Climatic data collected from 2007 to 2020 at the nearest weather station (± 4 km) shows a dry and cold season between May and August and a wet and hot season between November and February (Figure 2). The average annual precipitation within this period was 1,027.51 mm, and the average yearly temperature was 21 °C [18].

Our floristic survey was carried out in Araçoiaba hill, one of the fifty known alkaline intrusions at the Paraná Basin periphery (southeast Brazil) and dates back approximately 123 million years. Three stratigraphic units occur in the region: crystalline basement (upper Precambrian), Group Tubarão (permo-carboniferous), and alkaline intrusion (lower cretaceous) [19]. The main soils types identified in the Ipanema NAFO were Red Latosol (Rhodic Oxysol in USDA system or Rhodic Ferralsol in FAO system), Litolic Neosol (Entisol or Leptosol), Red-Yellow Argisol (Ultisol or Acrisol), and Fluvic Neosol (Entisol or Fluvisol) [20]. In the studied stand, the soil is Litolic Neosol over amphibolite and granites.

It is relevant to notice that some historical facts occurred in the region where today is the Ipanema NAFO, and such facts contributed to modifying the original vegetation. For example, in 1589, the explorer Afonso Sardinha travelled the region searching for gold and found iron ore, and installed furnaces to mine it. By 1810, the Imperator Dom João VI created the first Brazilian steelmaker and called it "Fábrica de Ferro de Ipanema" (Ipanema Iron Factory) [16]. They also used the area to test seeds and agricultural machines, and limestone exploration occurred until the end of the 1970s.

2.2 Data Collection and Analysis

An area of 1-ha was selected for floristic and structural characterization on a hillside of the Araçoiaba hill (Figure 1), where the predominant vegetation type is SSF. The 1-ha area (100 × 100 m) selected for sampling was divided into 100 non-permanent contiguous plots of 100 m² each (10 m × 10 m). All woody stems with a diameter at breast height (dbh at 1.30-m height) equal to or greater than 5 cm inside the plots were tagged with numbered aluminium labels. Plants with multiple stems were included if at least one of the stems had dbh ≥ 5 cm. In this case, all trunks were measured and considered in the analysis. The sampling also included dead plants.

Monthly visits were made in the area over the year 2008 to collect fertile or sterile botanical material from the labelled stems. The botanic material collected was herborized and taken to the Laboratory of Taxonomy, Department of Plant Biology, University of Campinas (UNICAMP). The material was identified at the species or genera level by comparing exsiccates and with the aid of bibliographical surveys and taxonomists' help. After specimens' identification, the material collected was lodged in the UNICAMP herbarium (UEC). We updated the names of species, genera, and families according to the Brazil's Flora and Fungi platform (http://floradobrasil.jbrj.gov.br/).

We classified the identified species according to their growth habits (trees, shrubs, liana, or palm trees) and regionality (native or exotic) following the Brazil's Flora and Fungi. Additionally, we used the IUCN red list to check the species' extinction risk [21]. The community structure was described by calculating the phytosociological parameters of absolute and relative frequency, relative density and dominance, and sociological importance value. Phytosociological analyses were performed in FITOPAC 2.1 [22].

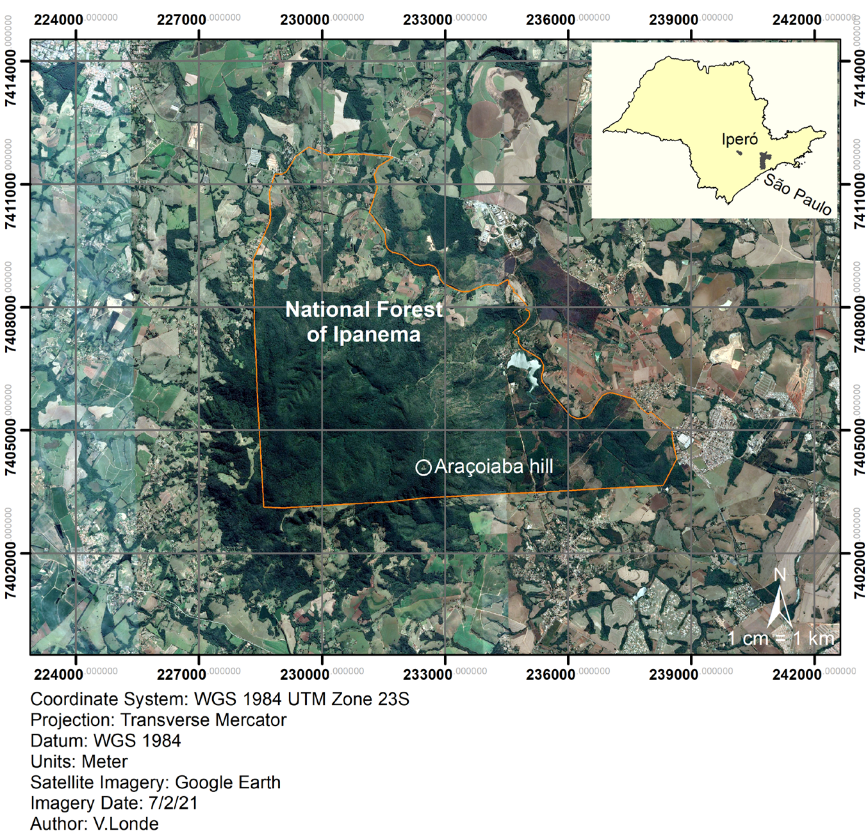

Figure 1. Satellite imagery with the location of the study area (near the Araçoiaba hill) within the National Forest of Ipanema, São Paulo state, southeast Brazil.

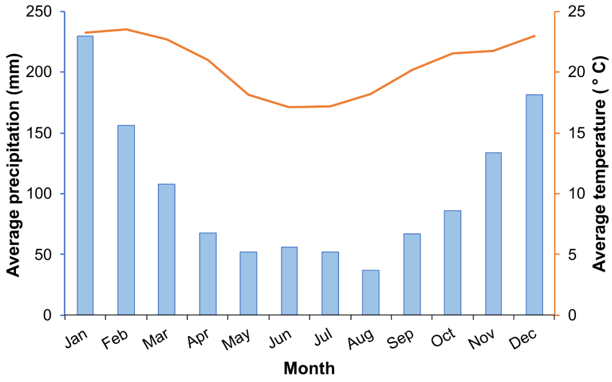

Figure 2. Average precipitation and temperature by month over 14 years (2007-2020) for the study region. Climatic data was collected in an automatic weather station at Sorocaba, São Paulo, about 4-km from the study area.

Source: [18] (station code: A713).

3. Results

In total, we sampled 1,404 stems, of which 1,301 were living and 103 standing dead stems. The living stems represented 65 species, 57 genera, and 31 families (Table 1). The most speciose families were Fabaceae (15 spp.) and Myrtaceae (6 spp.). As expected, trees were the predominant growth habit (57.9%), followed by shrubs/trees (33.3%), shrubs (6%), shrubs/lianas (1.4%), and palm trees (1.4%) (Table 1). Most species (54%) had not yet been classified according to their extinction risk, 41.5% were of least concern, and 4.5% were vulnerable (Table 1).

Guazuma ulmifolia (Malvaceae), *Machaerium stipitatum* (Fabaceae), *Croton floribundus* (Euphorbiaceae) and *Aloysia virgata* (Verbenaceae) were the species with the highest sociological importance value (IV) (Table 1). Together, these species summed up 54% of all the stems sampled and 50% of the total IV (Table 1). Although *Guazuma ulmifolia* was the second more abundant (high relative density) species, it held the highest IV due to the highest relative dominance, meaning that most of their stems were relatively large. *Machaerium stipitatum* was the most abundant (with the highest relative density) species, but the stems were relatively thinner (lower relative dominance), meaning that they should be younger than *G. ulmifolia*.

Despite having lower abundance (lower relative density), relatively large stems led *Croton floribundus* to achieve a high IV. *Aloysia virgata* was more abundant than *C. floribundus*, but had a similar IV due to a low relative dominance meaning thinner stems. Whereas these four species detained 50% of the living stems sampled, 24 other species were sampled with just one stem each and summed up only 1.8% of all living stems sampled. Dead stems had the third highest importance value (21.62%) in consequence of a relatively high number (relative density) of medium-sized stems (relative dominance) scattered all over the community space (relative frequency). We found that 35% of the species were represented by only one stem each (Table 1).

Table 1. Species sampled in a semideciduous seasonal forest fragment in the National Forest of Ipanema, São Paulo State, southeast Brazil. Species are ordered in descending IV (importance value) and classified according to their growth habit and extinction risk.

Family	Genera or species	Growth habit	Extinction risk	N	AbF	RD (%)	RF (%)	RDo (%)	IV
Malvaceae	*Guazuma ulmifolia* Lam.	Tree	LC	232	68	16.52	10.73	29.03	56.28
Fabaceae	*Machaerium stipitatum* Vogel	Tree	NA	356	80	25.36	12.62	17.15	55.13
-	Dead stems	-	-	103	55	7.34	8.68	5.61	21.62
Euphorbiaceae	*Croton floribundus* Spreng.	Tree	NA	76	38	5.41	5.99	7.93	19.33
Verbenaceae	*Aloysia virgata* (Ruiz & Pav.) Juss.	Shrub/Tree	NA	94	54	6.7	8.52	3.37	18.58
Fabaceae	*Parapiptadenia rigida* (Benth.) Brenan	Tree	LC	50	24	3.56	3.79	6.66	14.01
Sapindaceae	*Cupania vernalis* Cambess.	Tree	LC	61	35	4.34	5.52	2.28	12.14
Malvaceae	*Luehea* cf. *grandiflora* Mart.	Tree	NA	46	27	3.28	4.26	3.22	10.75
Rutaceae	*Zanthoxylum caribaeum* Lam.	Tree	NA	29	20	2.07	3.15	2.69	7.91
Cannabaceae	*Celtis iguanaea* (Jacq.) Sarg.	Shrub/Tree	LC	32	24	2.28	3.79	1.71	7.78
Salicaceae	*Casearia sylvestris* Sw.	Shrub/Tree	LC	40	20	2.85	3.15	1.21	7.22

Table 1 continued

Family	Genera or species	Growth habit	Extinction risk	N	AbF	RD (%)	RF (%)	RDo (%)	IV
Fabaceae	*Machaerium brasiliense* Vogel	Shrub/Tree	LC	33	13	2.35	2.05	1.06	5.46
Apocynaceae	*Tabernaemontana catharinensis* A.DC.	Shrub/Tree	NA	23	19	1.64	3	0.68	5.32
Malvaceae	*Ceiba* sp.	Tree	-	2	2	0.14	0.32	3.79	4.24
Meliaceae	*Trichilia silvatica* C.DC.	Shrub	VU	23	13	1.64	2.05	0.43	4.12
Arecaceae	*Syagrus* sp.	Palm tree	-	8	5	0.57	0.79	2.08	3.44
Primulaceae	*Myrsine gardneriana* A. DC	Shrub	NA	15	9	1.07	1.42	0.94	3.43
Annonaceae	*Annona neosericea* H.Rainer	Tree	NA	14	7	1	1.1	0.78	2.88
Fabaceae	*Machaerium nyctitans* (Vell.) Benth.	Tree	NA	18	4	1.28	0.63	0.85	2.76
Solanaceae	*Solanum pseudoquina* A.St.-Hil.	Tree	NA	9	7	0.64	1.11	0.67	2.42
Sapindaceae	*Dodonaea viscosa* (L.) Jacq.	Shrub/Tree	NA	12	6	0.85	0.95	0.61	2.41
Moraceae	*Maclura tinctoria* D.Don ex Steud.	Shrub/Tree	LC	7	7	0.5	1.1	0.63	2.23
Fabaceae	*Myroxylon peruiferum* L.f.	Tree	LC	8	6	0.57	0.95	0.6	2.12
Myrtaceae	*Campomanesia xanthocarpa* (Marti.) O.Berg	Tree	NA	10	7	0.71	1.1	0.26	2.07
Cannabaceae	*Trema micrantha* (L.) Blume	Shrub/Tree	LC	9	4	0.64	0.63	0.4	1.67
Rutaceae	*Zanthoxylum fagara* (L.) Sarg.	Shrub/Tree	LC	4	4	0.28	0.63	0.46	1.37
Fabaceae	*Senna multijuga* (Rich.) H.S.Irwin & Barneby	Shrub/Tree	NA	6	4	0.43	0.63	0.29	1.34
Fabaceae	*Albizia niopoides* (Benth.) Burkart	Shrub	NA	5	4	0.36	0.63	0.24	1.23
Moraceae	*Ficus* sp.	Shrub/Tree	-	5	4	0.36	0.63	0.21	1.2
Lauraceae	*Ocotea puberula* (Rich.) Nees	Tree	LC	4	4	0.28	0.63	0.15	1.07
Myrtaceae	*Eugenia francavilleana* O.Berg	Tree	NA	4	4	0.28	0.63	0.1	1.01
Nyctaginaceae	*Guapira opposita* (Vell.) Reitz	Shrub/Tree	NA	3	3	0.21	0.47	0.26	0.95
Urticaceae	*Urera baccifera* (L.) Gaudich. ex Wedd.	Shrub/Tree	NA	3	3	0.21	0.47	0.25	0.94
Lauraceae	*Nectandra megapotamica* (Spreng.) Mez	Tree	LC	4	3	0.28	0.47	0.07	0.83
Boraginaceae	*Cordia trichotoma* (Vell.) Arráb. ex Steud.	Tree	NA	2	2	0.14	0.32	0.35	0.81
Fabaceae	*Platypodium elegans* Vogel	Tree	LC	2	2	0.14	0.32	0.35	0.81
Fabaceae	*Holocalyx balansae* Micheli	Tree	LC	1	1	0.07	0.16	0.57	0.8
Sapindaceae	*Allophylus edulis* (A.St.-Hil., A.Juss. & Cambess.) Radlk.	Shrub/Tree	LC	3	3	0.21	0.47	0.09	0.77
Fabaceae	*Calliandra foliolosa* Benth.	Shrub/Tree	NA	6	1	0.43	0.16	0.13	0.72
Malvaceae	*Helicteres ovata* Lam.	Shrub	NA	4	2	0.28	0.32	0.08	0.68
Rutaceae	*Esenbeckia febrifuga* (A.St.-Hil.) A.Juss. ex Mart.	Tree	NA	3	2	0.21	0.32	0.09	0.61
Fabaceae	*Copaifera langsdorffii* Desf.	Tree	LC	2	2	0.14	0.32	0.1	0.56
Myrtaceae	*Campomanesia guazumifolia* (Cambess.) O.Berg	Tree	LC	2	2	0.14	0.32	0.05	0.5

Table 1 continued

Family	Genera or species	Growth habit	Extinction risk	N	AbF	RD (%)	RF (%)	RDo (%)	IV
Myrtaceae	*Eugenia pyriformis* Cambess.	Shrub/Tree	LC	2	2	0.14	0.32	0.03	0.49
Myrtaceae	*Eugenia* sp.	Shrub/Tree	-	2	2	0.14	0.32	0.02	0.48
Araliaceae	*Aralia excelsa* (Griseb.) J.Wen	Shrub/Tree	LC	2	1	0.14	0.16	0.1	0.4
Fabaceae	*Inga* cf. *striata* Benth.	Tree	LC	1	1	0.07	0.16	0.17	0.4
Fabaceae	*Enterolobium contortisiliquum* (Vell.) Morong	Tree	NA	1	1	0.07	0.16	0.17	0.39
Rhamnaceae	*Colubrina glandulosa* G.Perkins	Tree	LC	1	1	0.07	0.16	0.13	0.36
Sapindaceae	*Diatenopteryx sorbifolia* Radlk.	Tree	NA	1	1	0.07	0.16	0.13	0.36
Ebenaceae	*Diospyros inconstans* Jacq.	Shrub/Tree	LC	2	1	0.14	0.16	0.05	0.35
Fabaceae	*Inga affinis* DC.	Tree	NA	1	1	0.07	0.16	0.12	0.34
Lecythidaceae	*Cariniana legalis* (Mart.) Kuntze	Tree	VU	1	1	0.07	0.16	0.11	0.34
Proteaceae	*Roupala montana* var. *brasiliensis* (Klotzsch) K.S.Edwards	Shrub/Tree	NA	1	1	0.07	0.16	0.08	0.31
Opiliaceae	*Agonandra brasiliensis* Miers ex Benth. & Hook.f.	Tree	LC	1	1	0.07	0.16	0.07	0.3
Urticaceae	*Cecropia glaziovii* Snethl.	Tree	LC	1	1	0.07	0.16	0.06	0.29
Salicaceae	*Casearia gossypiosperma* Briq.	Tree	NA	1	1	0.07	0.16	0.04	0.27
Euphorbiaceae	*Alchornea glandulosa* Poepp. & Endl.	Shrub/Tree	LC	1	1	0.07	0.16	0.03	0.26
Fabaceae	*Peltophorum dubium* (Spreng.) Taub.	Tree	NA	1	1	0.07	0.16	0.03	0.26
Asteraceae	*Piptocarpha sellowii* (Sch.Bip.) Baker	Shrub/Liana	NA	1	1	0.07	0.16	0.02	0.25
Celastraceae	*Maytenus robusta* Reissek	Tree	NA	1	1	0.07	0.16	0.02	0.25
Celastraceae	*Monteverdia* cf *aquifolia* (Mart.) Biral	Tree	NA	1	1	0.07	0.16	0.02	0.25
Euphorbiaceae	*Alchornea glandulosa* subsp. *iricurana* (Casar.) Secco	Tree	NA	1	1	0.07	0.16	0.02	0.25
Myrtaceae	*Psidium guajava* L.	Tree	LC	1	1	0.07	0.16	0.02	0.25
Sapotaceae	*Chrysophyllum* cf *viride* Mart. & Eichler	Tree	NA	1	1	0.07	0.16	0.02	0.25
Sapotaceae	*Chrysophyllum marginatum* (Hook. & Arn.) Radlk.	Shrub/Tree	NA	1	1	0.07	0.16	0.02	0.25
Meliaceae	*Cedrela fissilis* Vell.	Tree	VU	1	1	0.07	0.16	0.01	0.24
Meliaceae	*Guarea macrophylla* Vahl	Tree	LC	1	1	0.07	0.16	0.01	0.24
Olacaceae	*Heisteria silvianii* Schwacke	Tree	NA	1	1	0.07	0.16	0.01	0.24
Rubiaceae	*Chomelia parvifolia* (Standl.) Govaerts	Shrub/Tree	NA	1	1	0.07	0.16	0.01	0.24
			Total	**1,404**	**633**	**100**	**100**	**100**	**300**

Acronyms: NA = not available; LC = Least Concern; VU = Vulnerable; N = number of stems; AbF = Absolute Frequency; RD = Relative Density; RF = Relative Frequency; RDo = Relative Dominance; IV = sociological importance value.

4. Discussion

Our study contributes with knowledge of community floristic composition and structure in the Ipanema NAFO, helping to estimate the protected area's plant diversity, which today remains uncalculated. There is information about the species richness of birds, mammals, fishes, and amphibians, but not for plants [16]. This study aids in documenting the Ipanema NAFO's flora, but we call for further surveys in other portions and vegetation types of the Ipanema NAFO to have a broader vision of its floristic diversity. If well-known, managed and interconnected, protected areas may effectively provide essential ecosystem services and prevent species extinctions [23].

The number of species and families we sampled was low compared to another survey in a different location on the Araçoiaba hill, in which 119 species and 43 families were recorded [14]. Such differences may be related to the study's sampling design as those authors sampled several vegetation types, whereas we surveyed just one formation type. However, this hypothesis seems not valid because the richness we sampled is lower in comparison with other surveys in nearby fragments of the SSF (whose sampling procedures are comparable). For example, in a forest remnant in Campinas municipality, the authors recorded 175 tree species in 49 families [24]. A survey in the Municipal Park of São Roque revealed 117 species in 47 families [25]. In the Grota Funda Municipal Park of Atibaia, the authors found 132 species belonging to 52 families [26].

Several factors may be related to the low species and family richness in our study area, including soil type, humidity, altitude, and human disturbance [27-29]. Most likely, the community we studied is a secondary forest and is still under recovery as the Araçoiaba hill has undergone several perturbation events [16], which may have culminated in the thinning of the stand's original vegetation. Researchers studying an SSF remnant within the Federal University of São Carlos campus at Sorocaba, a nearby municipality, found floristic results like ours: 79 species and 31 families [30]. Vegetation in their study area has been regenerating since the 1960s, reinforcing the idea that our community is also in recovery.

Two of the species we sampled have been considered exotic: *Psidium guajava* and *Aralia excelsa*. However, considering phylogenetic, fossil, archaeological and cultural data, it is most probable that *P. guajava* originated in the Cerrado (Brazilian savanna) and/or Humid Chaco [31]. *Psidium guajava* is a shade-tolerant species with a wide geographic range in different soil types [32] and considered an invader in many regions [33,34]. *Aralia excelsa* is the proper name of the basionym *Sciadodendron excelsum* Griseb., a pioneer heliophyte common in the northern Amazon Forest and Central America, but rare in the Atlantic Forest, where it occurs especially in the SSF [35,36].

Guazuma ulmifolia, *Machaerium stipitatum*, *Croton floribundus,* and *Aloysia virgata* were the species with the highest importance value. *Machaerium stipitatum* is considered an early secondary species [37], whereas *G. ulmifolia*, *C. floribundus*, and *A. virgata* are regarded as pioneers [38]. The fact that half of the stems sampled corresponded to pioneer and early secondary species indicates that the community studied is in a successional stage. However, the presence of climax species such as *Cariniana legalis*, *Holocalyx balansae*, *Myroxylon peruiferum*, *Zanthoxylum caribaeum* and others suggests that the successional stage is not initial anymore, but rather intermediate or advanced.

Dead stems are also relevant for community diversity. For instance, they constitute a habitat for many organisms [39,40], contribute a non-negligible proportion of the biomass and carbon stock in SSF [41,42], slowly release nutrients by decomposition, promote biodiversity by providing direct habitats and resources to many kinds of organisms that can serve as resources to higher trophic levels [43], and trigger gap dynamics, which allows for the persistence of many species that otherwise could not thrive in the forest [44], thus being critical for biodiversity [45]. Unhappily, there are few estimates of the proportion of standing dead trees in Brazilian forests since most researchers focus on species (living trees) richness; so, we have no comparison base to assess whether 7.34% of standing dead trees in our community lie within a "normal" range. The few estimates of standing dead tree necromass range 4 ton/ha~10 ton/ha in Amazon forests and 0.6 ton/ha~54.24 ton/ha in Atlantic forests [42]. In face of the wide variation of the latter, we consider our result to be expected.

Fortunately, most species were classified as least concerned of extinction. Still, *Cariniana legalis*, *Cedrela fissilis*, and *Trichilia silvatica* were considered vulnerable, meaning they are facing a high risk of extinction in the wild [21]. This result enhances the importance of Ipanema NAFO as a protected area and species' refugium. Climate change increases the risk of extinction, and protected areas have an important role as climate refugia [46]. Thus, governments and society should make more efforts to preserve protected areas worldwide. In addition, we call for more actions in classifying the risk of species extinction, as about half of the species we sampled in Ipanema NAFO were not ranked yet.

We noticed that few species were abundant in the community studied, corroborating the pattern found initially in the Amazon Forest [47] and then in the SSF [48,49]: the community's alpha diversity relies mainly upon a plethora of locally rare species. In fact, our results show a high abundance concentration in just four species, whereas 37% of the species sampled were scarce having just one stem sampled. Our results corroborate the observation that most species have low sociological importance value and are represented by only one stem in forest communities [50,51]. Limited abundance and distribution are characteristics that classify species as rare [52]. Still, rarity, in such a case, would be an adequate denomination only locally as the same species can be abundant in other regions [51]. Even so, locally rare species are vital for the ecosystem's multifunctionality and services provision [53]. Both rare and common species must be preserved, and understanding how they are spatially structured helps to set guidelines for conservation.

5. Conclusions

We suppose the community studied is a secondary forest, in the intermediate or advanced successional stage, having lower tree species richness than other mature SSFs in São Paulo State. Nevertheless, it shelters vulnerable and locally rare species. Our results follow the typical pattern regarding structure, showing that most stems represent few species. Our study adds knowledge about the National Forest of Ipanema's tree flora, helping to estimate its biodiversity and showing its importance for conservation.

Author Contributions

Vinícius Londe: Conceptualization, Validation, Writing — Original Draft; **Felipe Segala**: Conceptualization; Investigation, Formal Analysis; **Fernando Martins**: Conceptualization, Supervision, Writing — Review & Editing.

Conflict of Interest

The authors have no competing interests to declare that are relevant to the content of this article.

References

[1] Dengler, J., 2017. Phytosociology. International Encyclopedia of Geography: People, the Earth, Environment and Technology. 1-6.
DOI: https://doi.org/10.1002/9781118786352.wbieg0136

[2] Carnaúba, A.F., Ralph, L.N., Leão, S.L.M., et al., 2019. Natural and ecological succession in an urban fragment of the Atlantic Forest in Pernambuco, Brazil. Journal of Experimental Agriculture International 39, 1-10.
DOI: https://doi.org/10.9734/jeai/2019/v39i130326

[3] Kier, G., Mutke, J., Dinerstein, E., et al., 2005. Global patterns of plant diversity and floristic knowledge. Journal of Biogeography. 32, 1107-1116.
DOI: https://doi.org/10.1111/j.1365-2699.2005.01272.x

[4] Londe, V., Farah, F.T., Rodrigues, R.R., et al., 2020. Reference and comparison values for ecological indicators in assessing restoration areas in the Atlantic Forest. Ecological Indicators. 110, 105928.
DOI: https://doi.org/10.1016/j.ecolind.2019.105928

[5] Brazilian Institute of Geography and Statistics, 2015. Indicators of sustainable development: Brazil: 2015. IBGE: Rio de Janeiro. pp. 1-351.

[6] Instituto Socioambiental. Brazilian Protected Areas, 2022. https://uc.socioambiental.org/. (Accessed 15 March 2022).

[7] Souza, T.V.S.B., Thapa, B., Rodrigues, C.G.O., et al., 2019. Economic impacts of tourism in protected areas of Brazil. Journal of Sustainable Tourism. 27, 735-749.
DOI: https://doi.org/10.1080/09669582.2017.1408633

[8] Oliveira, U., Soares-Filho, B.S., Paglia, A.P., et al., 2017. Biodiversity conservation gaps in the Brazilian protected areas. Scientific Reports. 7, 9141.
DOI: https://doi.org/10.1038/s41598-017-08707-2

[9] Mackey, B.G., Watson, J.E.M., Hope, G., et al., 2008. Climate change, biodiversity conservation, and the role of protected areas: An Australian perspective. Biodiversity. 9, 11-18.
DOI: https://doi.org/10.1080/14888386.2008.9712902

[10] Maciel, E.A., Martins, F.R., 2021. Rarity patterns and the conservation status of tree species in South American savannas. Flora. 285, 151942.
DOI: https://doi.org/10.1016/j.flora.2021.151942

[11] Bataghin, F.A., Barros, F., Pires, J.S.R., 2010. Distribution of the community of vascular epiphytes in sites under different degrees of disturbance in the Ipanema National Forest, São Paulo, Brazil. Revista Brasileira de Botânica. 33, 501-512.
DOI: https://doi.org/10.1590/S0100-84042010000300012

[12] Bataghin, F.A., Pires, J.S.R., Barros, F., 2012. Vascular epiphytes at the edge and interior of a semideciduous forest in southeastern Brazil. Hoehnea. 39, 235-245.
DOI: https://doi.org/10.1590/S2236-89062012000200006

[13] Galindo, M.T., Almeida, V.P., 2013. Aquatic plants of two reservoirs in the National Forest of Ipanema, Iperó, São Paulo. Revista Eletrônica de Biologia. 6, 102-113.

[14] Albuquerque, G.B., Rodrigues, R.R., 2000. Vegetation of the Araçoiaba hill, National Forest of Ipanema, Iperó (SP). Scientia Forestalis. 58, 145-159.

[15] Silva, A.T., Mazine, F.F., 2016. Myrtaceae in the National Forest of Ipanema, São Paulo, Brazil. Ro-

driguésia. 67, 203-224.
DOI: https://doi.org/10.1590/2175-7860201667110
[16] ICMBio - Instituto Chico Mendes de Conservação da Biodiversidade, 2022. National Forest of Ipanema. https://www.icmbio.gov.br/flonaipanema/floresta-nacional-de-ipanema.html. (Accessed 15 March 2022).
[17] Eisenlohr, P.V., Oliveira-Filho, A.T., 2015., Revisiting patterns of tree species composition and their driving forces in the Atlantic forests of southeastern Brazil. Biotropica. 47, 689-701.
DOI: https://doi.org/10.1111/btp.12254
[18] INMET - National Institute of Meteorology, 2022. Meteorological database. https://bdmep.inmet.gov.br/#. (Accessed 10 March 2022).
[19] Davino, A., 1975. Geology of Araçoiaba Mountain, São Paulo State. Boletim IG. 6, 129-144.
[20] Ranzani, G., Freire, O., Kinjo, T., et al., 1965. Ipanema farm soils. ESALQ/USP: Piracicaba.
[21] IUCN, 2022. IUCN Red List of Threatened Species. Version 2021-3. https://www.iucnredlist.org/. (Accessed 10 March 2022).
[22] Shepherd, G.J., FITOPAC. 2010. Plant Biology Department, State University of Campinas. https://pedroeisenlohr.webnode.com.br/fitopac/. (Accessed 12 June 2019).
[23] le Saout, S., Hoffman, M., Shi, Y., et al., 2013. Protected areas and effective biodiversity conservation. Science. 342(6160), 803-805.
DOI: https://doi.org/10.1126/science.1239268
[24] Santos, K., Kinoshita, L.S., 2003. Floristic composition of the woody flora of the Ribeirão Cachoeira forest, Campinas, São Paulo State. Acta Botanica Brasilica. 17, 325-341.
DOI: https://doi.org/10.1590/S0102-33062003000300001
[25] Leite, E.C., Rodrigues, R.R., 2008. Phytosociology and successional characterization of a fragment of tropical seasonal forest in Southeastern Brazil. Revista Árvore. 32, 583-595.
DOI: https://doi.org/10.1590/S0100-67622008000300019
[26] Grombone, M.T., Bernacci, L.C., Meira-Neto, J.A.A., et al., 1990. Phytosociological structure of a semideciduous altitudinal forest at Parque Municipal da Grota Funda, Atibaia, São Paulo State. Acta Botanica Brasilica. 4(2), 47-64.
DOI: https://doi.org/10.1590/S0102-33061990000200004
[27] Ferreira, T.S., Higuchi, P., Silva, A.C., et al., 2015. Distribution and richness of rare tree species in Araucaria forest fragments, along an altitudinal gradient, in Santa Catarina State, Brazil. Revista Árvore. 39, 447-455.
DOI: https://doi.org/10.1590/0100-67622015000300005
[28] Pansini, S., Sampaio, A.F., Reis, N.F.C., et al., 2016. Palms richness and selectivity throughout environmental gradientes on Purus-Madeira interfluvial region, Porto Velho, RO, Brazil. Biota Amazônia. 6, 93-100.
DOI: http://dx.doi.org/10.18561/2179-5746/biotaamazonia.v6n2p93-100
[29] Lei, J., Chen, R., Gui, R., et al., 2020. Human disturbance reduces plant species diversity and stability of Phyllostachys pubescens forests. Research in Ecology. 2, 1-11.
DOI: https://doi.org/10.30564/re.v2i1.1181
[30] Corrêa, L.S., Cardoso-Leite, E., Castello, A.C.D., et al., 2014. Structure, floristic composition and successional characterization of fragments of semideciduous seasonal forest in southeast Brazil. Revista Árvore. 38, 799-809.
DOI: https://doi.org/10.1590/S0100-67622014000500004
[31] Arévalo-Marín, E., Casas, A., Landrum, L., et al., 2021. The taming of Psidium guajava: Natural and cultural history of a neotropical fruit. Frontiers in Plant Sciences. 12, 2138.
DOI: https://doi.org/10.3389/fpls.2021.714763
[32] Instituto Hórus, 2022. The Brazil invasive alien species database. https://bd.institutohorus.org.br/. (Accessed 17 March 2022).
[33] Biondi, D., Pedrosa-Macedo, J.H., 2008. Invasive plants found in the urban area of Curitiba, Paraná. Floresta. 38, 129-144.
[34] Fabricante, J.R., Ziller, S.R., Araújo, K.C.T., et al., 2015. Non-native and invasive alien plants on fluvial islands in the São Francisco River, northeastern Brazil. Check List. 11, 1-7.
DOI: https://doi.org/10.15560/11.1.1535
[35] Bilingual Terminological Dictionary, 2022. Sciadodendron excelsum. ESALQ/USP. http://www.esalq.usp.br/d-plant/node/690. (Accessed 21 July 2022).
[36] Durigan, G., Siquieira, M.F., Franco, G.A.D.C., et al., 2004. The tree and shrub flora of middle Paranapanema valley: a baseline study for the restoration of natural ecosystems. Researches on conservation and environmental recovery in western São Paulo State. Eds. Vilas Bôas, O., Durigan, G. Páginas e Letras: São Paulo. pp. 199-239.
[37] Benvenuti-Ferreira, G., Coelho, G.C., 2009. Floristics and structure of the tree component in a seasonal forest remnant, Chiapetta, Rio Grande do Sul State, Brazil. Brazilian Journal of Biosciences. 7, 344-353.
[38] Viveiros, E., Francisco, B.S., López, A.M.T., et al., 2021. Drivers of restoration trajectory of a community of regenerant plants: Natural regeneration or tree

seedling? Floresta e Ambiente. 28, 1-13.
DOI: https://doi.org/10.1590/2179-8087-FLORAM-2020-0082

[39] Carvalho, K.S., Vasconcelos, H.L., 2002. Community of ants that nest in dead twigs on the ground of Central Amazonian forest, Brazil. Revista Brasileira de Entomologia. 46, 115-121.
DOI: https://doi.org/10.1590/S0085-56262002000200002

[40] Vasconcellos, A., 2010. Biomass and abundance of termites in three remnant areas of Atlantic Forest in northeastern Brazil. Revista Brasileira de Entomologia. 54, 455-461.
DOI: https://doi.org/10.1590/S0085-56262010000300017

[41] Amaro, M.A., Soares, C.P.B., Souza, A.L., et al., 2013. Volume, biomass and carbon stocks in a seasonal semideciduous forest in Viçosa, Minas Gerais state. Revista Árvore. 37, 849-857.
DOI: https://doi.org/10.1590/S0100-67622013000500007

[42] Sena, P.H.A., Fonsêca, N.C., Lins-e-Silva, A.C.B., 2022. Non-negligible role of dead organic matter in a rainforest remnant in Northeast Brazil. Rodriguésia. 73.
DOI: https://doi.org/10.1590/2175-7860202273041

[43] Thorn, S., Seibold, S., Leverkus, A.B., et al., 2020. The living dead: acknowledging life after tree death to stop forest degradation. Frontiers in Ecology and the Environment. 18, 505-512.
DOI: https://doi.org/10.1002/fee.2252

[44] Muscolo, A., Bagnato, S., Sidari, M., et al., 2014. A review of the roles of forest canopy gaps. Journal of Forestry Research. 25, 725-736.
DOI: https://doi.org/10.1007/s11676-014-0521-7

[45] Moreira-Arce, D., Vergara, P.M., Fierro, A., et al., 2021. Standing dead trees as indicators of vertebrate diversity: Bringing continuity to the ecological role of senescent trees in austral temperate forests. Ecological Indicators. 129, 107878.
DOI: https://doi.org/10.1016/j.ecolind.2021.107878

[46] Haight, J., Hammill, E., 2020. Protected areas as potential refugia for biodiversity under climatic change. Biological Conservation. 241, 108258.
DOI: https://doi.org/10.1016/j.biocon.2019.108258

[47] Pires, J.M., Prance, G.T., 1978. The Amazon Forest: a natural heritage to be preserved. Extinction is Forever. Eds: Prance, G. T., Elias, T. S. The New York Botanical Garden: New York. pp. 158-194.

[48] Silva, L.Á., Soares, J.J., 2002. Phytosociological survey of arboreal vegetation of a mesophyllous semideciduous forest fragment, in municipality São Carlos, São Paulo State. Acta Botanica Brasilica, 16, 205-216.
DOI: https://doi.org/10.1590/S0102-33062002000200007

[49] Hack, C., Longhi, S.J., Boligon, A.A., et al., 2005. Fitossociological analisys of a deciduous seasonal forest fragment in Jaguari county, RS. Ciência Rural. 35, 1083-1091.
DOI: https://doi.org/10.1590/S0103-84782005000500015

[50] Torres, C.M.M.E., Jacovine, L.A.G., Neto, S.N.O., et al., 2017. Phytosociological analysis and importance value in terms of carbon in a seasonal semideciduous forest. Floresta e Ambiente. 24, 1-10.
DOI: https://doi.org/10.1590/2179-8087.099714

[51] Dias, P.B., Moreira, L.N., Silva, G.F., et al., 2019. Richness, structure and environmental relations in a National Forest in southeast Brazil. Revista Brasileira de Ciências Agrárias. 14, 1-8.
DOI: https://doi.org/10.5039/agraria.v14i4a6897

[52] Gaston, K.J., 1994. Rarity. Springer: Dordrecht. pp. 1-205.
DOI: https://doi.org/10.1007/978-94-011-0701-3

[53] Soliveres, S., Manning, P., Prati, D., et al., 2016. Locally rare species influence grassland ecosystem multifunctionality. Philosophical Transactions of the Royal Society B. 371, 20150269.
DOI: https://doi.org/10.1098/rstb.2015.0269