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Diversity and Composition of a Seed Bank in the Subtropical Atlantic Forest, Southern Brazil

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Abstract

The current study aimed to evaluate the seed bank diversity and composition found in the Municipal Natural Park São Francisco de Assis (PSFA), Santa Catarina, Brazil, located within the subtropical Atlantic Forest. Samplings were carried out within four different locations (n = 20 sample plots per location). All samples were kept in suspended beds for germination, growth, and subsequent species identification. We were able to identify 85 morphospecies (1,016 individuals). Most of them were categorized as pioneers. Pioneers were also the ecological category that had more individuals (73.12%). The predominant dispersion syndrome was zoochoric, with 58 taxa included. Our results indicate that the seeds are being provided by species that occur around the park, in some cases favored by recent landslides in the area.

Keywords: Biodiversity, forest ecology, germination, pioneer species.

1. INTRODUCTION AND OBJECTIVES

Seed banks are dynamic systems that control the flow of seeds into or out of the vegetation (Roizman, 1993) and are defined as all viable seeds present in the soil (Simpson et al., 1989). Seed entrance is marked by the addition of seeds through rain seeds from closer local communities, neighbor regions, or even distant places through anemochory and zoochory (Baider et al., 1999; Grombone-Guaratini & Rodrigues, 2002; Tres et al., 2007). On the other hand, seed exit is marked by predation, decomposers, age-related loss of vitality, or germination (Baker, 1989; Roizman, 1993). Seed banks act as a reservoir, waiting for biotic or abiotic signals that may indicate proper conditions to germinate (Silvertown, 1981). These signals can be triggered, for example, by the opening of clearings through tree falls (Whitmore, 1989).

In the tropics, Garwood (1989) highlights that one question that arises when studying the seed bank is if the forest regeneration came from seeds already in the seed bank or seeds recently dispersed (*i.e.* from the seed rain, an important topic since tropical forests are under risk and are highly fragmented; Frances & Harris, 2019). One of the most threatened tropical forests is the Atlantic Forest (AF), which has been historically devastated by human activities such as logging, agricultural expansion, and human settlement - and this devastation is still going on (Dean, 1997; Fundação SOS Mata Atlântica, 2021).

As an effect of forest devastation, the AF became a heavily fragmented domain, where most of its fragments are smaller than 50 ha and greatly distanced between themselves (Ribeiro et al., 2009). Owing to fragmentation processes in the AF is possible to observe an increase in research related to seed banks since these are a must to enable natural forest regeneration (Nóbrega et al., 2009). Fragmentation and modifications in forest remnants alter solar radiation, organic matter content, and humidity. They also influence the quality of forests by excluding the germination of plants that are late secondary or climax (Scherer & Jarenkow, 2006). Because of this, initial regenerating forests bear more soil seed banks than mature forests (Miranda Neto et al. 2021).

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Edge effects are another human problem related to fragmentation. In a fragmented forest such as a cloud forest, the richness and abundance seem to be related to this effect, possibly due to treefall gaps opening spaces for pioneer's germination (Machado et al., 2017). However, the dominance does not change significantly along the edge towards the interior of a subtropical forest (Lin & Cao, 2009). Another impact is the presence of some species like *Pteridium* sp. or bamboos, that can dominate the initial or secondary forest, having an impact on seed bank density and richness (Vinha et al., 2017, Lima et al. 2012). Lastly, environmental effects such as elevation (slope) also affect soil seed banks, with lower abundance and richness in steeper slopes.

Considering this, seed bank knowledge allows a proper understanding of forest regeneration dynamics and could help regional conservation approaches related to using native species as a means of restoring landscapes (Souza et al., 2006). In Santa Catarina state, southern Brazil, works related to seed banks are scarce. They can be summarized in Caldato et al. (1996) in the west; Tres (2006), in the north; Krieck et al. (2006), Schorn et al. (2013), and Seubert et al. (2016) in the Itajaí Valley, and Bechara et al. (2013) in the coast. In our work, we aim to improve the knowledge of seed banks in Santa Catarina by assessing the seed bank diversity and composition found in a protected area within Itajaí Valley.

2. MATERIALS AND METHODS

2.1. Study area

The Municipal Natural Park São Francisco de Assis (PSFA; Figure 1) is located at 26º55' S and 49º05 W and ranges from 35 to 150 m above sea level. The natural park embraces 23 ha of native vegetation covered by the Subtropical Moist Broadleaf Forest (Serra do Mar coastal forests; Dinerstein et al. 2017). Following Köppen (Alvares et al., 2013), the PSFA has a single climate type, Cfa, a humid subtropical climate with hot summer. The mean temperature ranges from 18ºC in the coldest month to 22ºC in the warmest. After 50 years without human influence in the park, the vegetation today has an acceptable degree of conservation and is dominated by *Euterpe edulis, Hieronyma alchorneoides, Psychotria nuda*, *Myrcia strigipes*, *Rudgea jasminoides*, *R. recurva*, *Sloanea guianensis,* and *Ouratea parviflora* (Sevegnani, 2003; Pastório et al., 2018).

Data was sampled in four areas that represent PSFA vegetation: Area 1 is in a lowland influenced by a stream. Its soil is sandy, greyish, litter poor, and has a greater density of Marantaceae family individuals. Area 2 is located at a slope summit and is also litter poor. Area 3 is located on the plain side of the slope and has abundant litter deposits. Area 4 is marked by a deep slope and is litter poor.

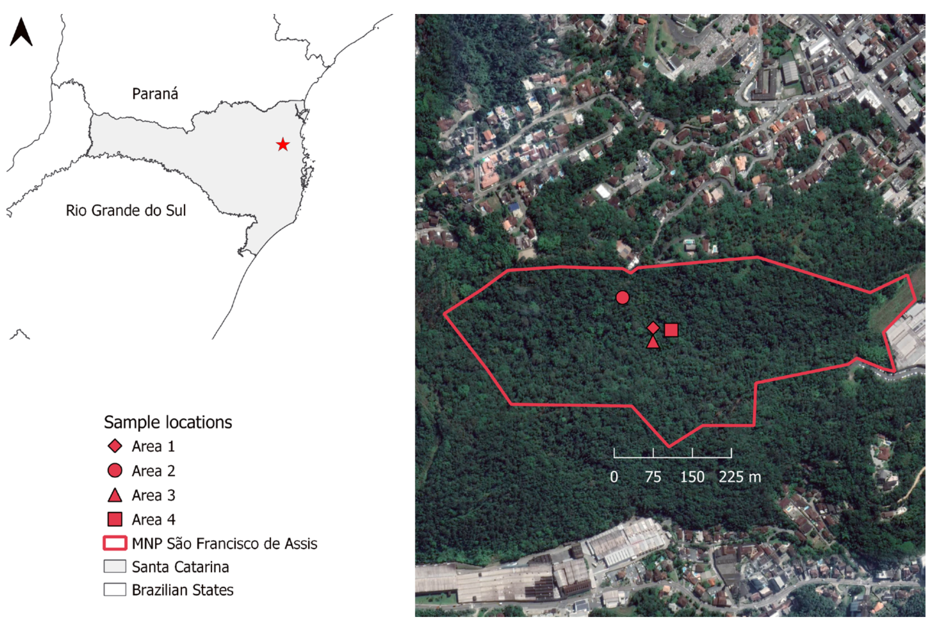

Figure 1. Study region and sample locations within the Municipal Natural Park São Francisco de Assis, southern Brazil. To avoid overlaps, not all 80 sample plots are shown. The satellite image was obtained from Google Earth Engine (Gorelick et al., 2017).

2.2. Data sampling

Soil samples were collected, between August 16 (2016) and September 16 (2016) using 80 sample plots of 20 x 20 cm (0.04 m^2) area and 5 cm of depth, removing the litter layer (as recommended by Santos et al., 2010). The 80 sample plots were distributed equally throughout four areas within the central section of the park (three areas) and the edge (one area).

Soil samples were stored in individual plastic bags for further processing: soil sifting and homogenization, disaggregation of earth conglomerates, and discard of any rough substrate (branches, rocks, roots) that may difficult seed germination. After processing, soil samples were disposed of in suspended garden beds for further germination. All garden beds were subjected to the same environmental conditions (e.g., temperature, light, and humidity) and were isolated from new propagules in a greenhouse. All garden beds were irrigated whenever necessary, depending on the weather conditions of the day.

2.3. Data analyses

Species were identified at the lowest taxonomical level possible using Flora do Brasil 2020 (2021), literature, and specialists' opinions. Taxa were classified regarding their growth form (trees, shrubs, and vines), ecological category (pioneer, early secondary, late secondary, and climax), and dispersal syndrome (anemochoric, autochoric, and zoochoric) following the Neotropical Tree Communities database (TreeCo; Lima et al., 2020).

3. RESULTS

After 334 days, germination occurred in 1,016 individuals distributed within 85 morphospecies, from which 52 were identified at the species level, 21 at genus, 11 at family, and one unidentified (Table 1 and 2). The morphospecies belongs to 36 botanical families, where Asteraceae had 19 morphospecies; Rubiaceae, 11; Solanaceae, 5, and Poaceae, 4.

Table 1. Families and species sampled from the seed bank in the Municipal Natural Park São Francisco de Assis, southern Brazil. — indicate that we were unable to determine the category.

Family	Species	Ecological classification	Growth form	Dispersal syndrome
Annonaceae	*Guatteria australis*	Early secondary	Tree	Zoochoric
Apocynaceae	Apocynaceae sp1	—	Vine	—
Araceae	*Anthurium* sp.	—	Herb	Zoochoric
	Philodendron missionum	—	Vine	Zoochoric
Arecaceae	*Euterpe edulis*	Late secondary	Tree	Zoochoric
	Geonoma sp.	Late secondary	Shrub	Zoochoric
Asteraceae	Asteraceae sp1	Pioneer	—	Anemochoric
	Asteraceae sp2	Pioneer	—	Anemochoric
	Asteraceae sp3	Pioneer	—	Anemochoric
	Asteraceae sp4	Pioneer	—	Anemochoric
	Asteraceae sp5	Pioneer	—	Anemochoric
	Asteraceae sp6	Pioneer	—	Anemochoric
	Baccharis anomala	Pioneer	Vine	Anemochoric
	Baccharis lateralis	Pioneer	Herb	Anemochoric
	Chromolaena laevigata	Pioneer	Shrub	Anemochoric
	Erechtites valerianifolius	Pioneer	Herb	Anemochoric
	Gamochaeta simplicicaulis	Pioneer	Herb	Anemochoric
	Mikania chlorolepis	Late secondary	Vine	Anemochoric
	Mikania glomerata	Pioneer	Vine	Anemochoric
	Mikania involucrata	Pioneer	Vine	Anemochoric
	Mikania lundiana	Late secondary	Vine	Anemochoric
	Mikania oreophila	—	Vine	Anemochoric
	Mikania sp1	—	Vine	Anemochoric
	Symphyopappus itatiayensis	Pioneer	Shrub	Anemochoric
	Vernonanthura discolor	Pioneer	Herb	Anemochoric

Table 1. Continued...

Family	Species	Ecological classification	Growth form	Dispersal syndrome
Bignoniaceae	*Handroanthus* sp.	Early secondary	Tree	Zoochoric
Bromeliaceae	Bromeliaceae sp1	—	Herb	Anemochoric
Cannabaceae	*Celtis iguanaea*	Pioneer	Shrub	Zoochoric
	Trema micrantha	Pioneer	Tree	Zoochoric
Clusiaceae	*Garcinia gardneriana*	Late secondary	Tree	Zoochoric
Cucurbitaceae	*Wilbrandia* sp.	—	Vine	Zoochoric
Cyperaceae	*Pleurostachys* sp.	—	Herb	—
	Scleria gaertneri	—	Herb	Zoochoric
	Scleria panicoides	—	Herb	Zoochoric
Euphorbiaceae	*Alchornea glandulosa*	Pioneer	Tree	Zoochoric
	Alchornea triplinervia	Early secondary	Tree	Zoochoric
	Dalechampia sp.	—	Vine	Anemochoric
Gesneriaceae	*Nematanthus fissus*	Early secondary	Herb	Zoochoric
Heliconiaceae	*Heliconia farinosa*	Late secondary	Herb	Zoochoric
Hypoxidaceae	*Hypoxis* sp.	—	Herb	Zoochoric
Marantaceae	*Goeppertia monophylla*	Late secondary	Herb	Zoochoric
	Maranta divaricata	Late secondary	Herb	Zoochoric
Melastomataceae	*Clidemia hirta*	Pioneer	Shrub	Zoochoric
	Miconia cinnamomifolia	Pioneer	Shrub	Zoochoric
Meliaceae	*Cedrela fissilis*	Early secondary	Tree	Anemochoric
Menispermaceae	*Cissampelos andromorpha*	Early secondary	Vine	Zoochoric
Moraceae	*Ficus gomelleira*	Early secondary	Tree	Zoochoric
	Ficus luschnathiana	Early secondary	Tree	Zoochoric
	Sorocea bonplandii	Late secondary	Tree	Zoochoric
Orchidaceae	*Prescottia* sp.	—	Herb	Anemochoric
Peraceae	*Pera glabrata*	Early secondary	Tree	Zoochoric
Phyllanthaceae	*Hyeronima alchorneoides*	Early secondary	Tree	Zoochoric
Phytolaccaceae	*Phytolacca* sp.	Pioneer	Herb	Zoochoric
	Phytolacca thyrsiflora	Pioneer	Herb	Zoochoric
Piperaceae	*Piper* sp.	—	Shrub	Zoochoric
Poaceae	*Ichnanthus pallens*	Early secondary	Herb	Zoochoric
	Ichnanthus sp.	Early secondary	Herb	Zoochoric
	Parodiolyra micrantha	Early secondary	Herb	Zoochoric
	Paspalum sp.	—	Herb	Zoochoric
Primulaceae	*Myrsine coriacea*	Pioneer	Tree	Zoochoric
Rosaceae	*Rubus* sp.	—	Herb	Zoochoric
Rubiaceae	*Coccocypselum hasslerianum*	Late secondary	Herb	Zoochoric
	Palicourea sessilis	Late secondary	Shrub	Zoochoric
	Psychotria carthagenensis	Late secondary	Tree	Zoochoric
	Psychotria nemorosa	Climax	Shrub	Zoochoric
	Psychotria sp1	—	—	Zoochoric
	Psychotria sp2	—	—	Zoochoric
	Rubiaceae sp1	—	—	Zoochoric
	Rubiaceae sp2	—	—	Zoochoric
	Rubiaceae sp3	—	—	Zoochoric
	Rudgea sp1	—	—	Zoochoric
	Rudgea sp2	—	—	Zoochoric

Table 1. Continued...

Family	Species	Ecological classification	Growth form	Dispersal syndrome
Rutaceae	*Zanthoxylum rhoifolium*	Early secondary	Tree	Zoochoric
Salicaceae	*Casearia decandra*	Late secondary	Tree	Zoochoric
	Casearia sylvestris	Late secondary	Tree	Zoochoric
Sapindaceae	*Dodonaea viscosa*	Pioneer	Shrub	Anemochoric
Solanaceae	*Cestrum* sp.	Early secondary	Shrub	Zoochoric
	Solanum americanum	Pioneer	Herb	Zoochoric
	Solanum mauritianum	Pioneer	Shrub	Zoochoric
	Solanum torvum	Pioneer	Herb	Zoochoric
	Solanum viarum	Pioneer	Shrub	Zoochoric
Symplocaceae	*Symplocos* sp.	—	Tree	Zoochoric
Urticaceae	*Cecropia glaziovii*	Pioneer	Tree	Zoochoric
Vitaceae	*Cissus* sp.	Early secondary	Vine	Zoochoric

The greatest number of individuals that germinated (Table 2) were found in Area 3 (416 individuals), followed by Area 1 (247), Area 4 (194), and Area 2 (160; see Table 3 and 4). The most abundant species were *Cecropia glaziovii* (284 individuals), *Trema micrantha* (153), *Clidemia hirta* (101), *Parodiolyra micrantha* (72), and *Miconia cinnamomifolia* (65). These species amounted to more than 65% of all individuals found (Table 2). An overall density of 317.5 individuals m^{-2} was observed. *Cecropia glaziovi* and *T. micrantha* had the greatest densities in the study region (88.75 and 47.81, respectively).

Table 2. The number of individuals found in four sampled areas (A12–A4), percentage values of each species considering the four areas studied, and density m^{-2} in the Municipal Natural Park São Francisco de Assis, southern Brazil.

Species	A1	A2	A3	A4	Total	%	Density m^{-2}
Cecropia glaziovii	117	71	61	35	284	27.95	88.7500
Trema micrantha	22	18	100	13	153	15.06	47.8125
Clidemia hirta	21	1	58	21	101	9.94	31.5625
Parodiolyra micrantha	0	9	63	0	72	7.09	22.5000
Miconia cinnamomifolia	26	6	4	20	56	5.51	17.5000
Myrsine coriacea	1	4	12	13	30	2.95	9.3750
Solanum americanum	3	5	18	1	27	2.66	8.4375
Pleurostachys sp.	0	3	21	0	24	2.36	7.5000
Goeppertia monophylla	8	3	8	3	22	2.17	6.8750
Vernonanthura discolor	0	2	8	3	13	1.28	4.0625
Euterpe edulis	2	5	0	5	12	1.18	3.7500
Psychotria carthagenensis	0	0	0	11	11	1.08	3.4375
Psychotria sp2	0	0	0	11	11	1.08	3.4375
Asteraceae sp2	1	3	1	4	9	0.89	2.8125
Mikania glomerata	1	2	0	6	9	0.89	2.8125
Mikania involucrata	7	0	1	0	8	0.79	2.5000
Asteraceae sp6	0	0	8	0	8	0.79	2.5000
Scleria panicoides	0	0	8	0	8	0.79	2.5000
Erechtites valerianifolius	1	2	1	3	7	0.69	2.1875
Ficus luschnathiana	2	0	2	3	7	0.69	2.1875
Piper sp.	0	0	3	3	6	0.59	1.8750
Ichnanthus sp.	0	1	4	1	6	0.59	1.8750
Zanthoxylum rhoifolium	0	5	0	1	6	0.59	1.8750
Solanum torvum	1	1	1	3	6	0.59	1.8750
Mikania lundiana	5	0	0	0	5	0.49	1.5625
Baccharis anomala	4	0	0	1	5	0.49	1.5625
Ichnanthus pallens	0	0	5	0	5	0.49	1.5625

Table 2. Continued...

Species	A1	A2	A3	A4	Total	%	Density m^{-2}
Casearia decandra	1	0	4	0	5	0.49	1.5625
Mikania chlorolepis	4	0	0	0	4	0.39	1.2500
Gamochaeta simplicicaulis	1	1	2	0	4	0.39	1.2500
Alchornea glandulosa	2	0	2	0	4	0.39	1.2500
Maranta divaricata	0	0	3	1	4	0.39	1.2500
Pera glabrata	1	0	0	3	4	0.39	1.2500
Hyeronima alchorneoides	4	0	0	0	4	0.39	1.2500
Phytolacca thyrsiflora	2	1	0	1	4	0.39	1.2500
Casearia sylvestris	0	2	0	2	4	0.39	1.2500
Mikania sp1	3	0	0	0	3	0.30	0.9375
Celtis iguanaea	0	0	3	0	3	0.30	0.9375
Scleria gaertneri	0	2	1	0	3	0.30	0.9375
Alchornea triplinervia	1	0	1	1	3	0.30	0.9375
Cissampelos andromorpha	0	2	1	0	3	0.30	0.9375
Palicourea sessilis	0	0	0	3	3	0.30	0.9375
Apocynaceae sp1	0	2	0	0	2	0.20	0.6250
Baccharis lateralis	0	1	1	0	2	0.20	0.6250
Handroanthus sp.	0	0	1	1	2	0.20	0.6250
Bromeliaceae sp1	0	0	0	2	2	0.20	0.6250
Paspalum sp.	0	0	2	0	2	0.20	0.6250
Coccocypselum hasslerianum	0	2	0	0	2	0.20	0.6250
Rudgea sp2	0	0	0	2	2	0.20	0.6250
Symplocos sp.	0	0	2	0	2	0.20	0.6250
Guatteria australis	0	0	0	1	1	0.10	0.3125
Anthurium sp.	0	0	0	1	1	0.10	0.3125
Philodendron missionum	0	0	0	1	1	0.10	0.3125
Geonoma sp.	0	0	0	1	1	0.10	0.3125
Mikania oreophila	1	0	0	0	1	0.10	0.3125
Symphyopappus itatiayensis	1	0	0	0	1	0.10	0.3125
Asteraceae sp1	0	1	0	0	1	0.10	0.3125
Asteraceae sp3	0	0	0	1	1	0.10	0.3125
Asteraceae sp4	0	1	0	0	1	0.10	0.3125
Asteraceae sp5	0	0	1	0	1	0.10	0.3125
Chromolaena laevigata	0	1	0	0	1	0.10	0.3125
Garcinia gardneriana	0	0	0	1	1	0.10	0.3125
Wilbrandia sp.	0	1	0	0	1	0.10	0.3125
Dalechampia sp.	0	1	0	0	1	0.10	0.3125
Nematanthus fissus	0	0	0	1	1	0.10	0.3125
Heliconia farinosa	0	0	1	0	1	0.10	0.3125
Hypoxis sp.	0	0	1	0	1	0.10	0.3125
Cedrela fissilis	1	0	0	0	1	0.10	0.3125
Ficus gomelleira	1	0	0	0	1	0.10	0.3125
Sorocea bonplandii	0	0	0	1	1	0.10	0.3125
Prescottia sp.	0	0	0	1	1	0.10	0.3125
Phytolacca sp.	0	0	0	1	1	0.10	0.3125
Rubus sp.	0	0	0	1	1	0.10	0.3125
Psychotria nemorosa	0	0	0	1	1	0.10	0.3125
Psychotria sp1	0	0	0	1	1	0.10	0.3125
Rubiaceae sp1	0	0	0	1	1	0.10	0.3125
Rubiaceae sp2	0	0	1	0	1	0.10	0.3125
Rubiaceae sp3	0	0	1	0	1	0.10	0.3125
Rudgea sp1	0	0	0	1	1	0.10	0.3125
Dodonaea viscosa	0	0	0	1	1	0.10	0.3125

Table 2. Continued...

Species	A1	A2	A3	A4	Total	%	Density m^{-2}
Solanum viarum	1	0	0	0	1	0.10	0.3125
Cestrum sp.	0	0	0	1	1	0.10	0.3125
Solanum mauritianum	0	0	1	0	1	0.10	0.3125
Cissus sp.	1	0	0	0	1	0.10	0.3125

Table 3. Densities of each growth form found in each study area (A1–A4). Indet = individuals that were not identified.

Area	Trees	Shrubs	Herbs	Vines	Indet	Total
A1	48.43	15.31	5.00	8.12	0.31	77.18
A2	32.81	2.50	10.31	2.50	1.56	49.68
A3	57.81	21.56	46.25	0.62	3.75	130.00
A4	28.43	15.93	7.18	2.50	6.56	60.62
Total	167.50	55.31	68.75	13.75	12.18	317.50

Concerning ecological categories (Table 1), 29 taxa (34.52%) were pioneers, followed by early secondary (19.05%), late secondary (16.67%), and climax (1.19%). The "unknown" category was assigned to 24 taxa. Pioneers were also the ecological category that had more individuals (73.12%), followed by early secondary (11.61%), late secondary (7.48%), and climax (0.09%). The most common growth form found was herbs (25 taxa), followed by trees (20), shrubs (13), and vines (13). The most abundant growth form was tree (52.75%), followed by herbs (21.65%), shrubs (17.42%), and vines (4.33%). The predominant dispersion syndrome was zoochoric, with 58 (88.58%) taxa included, followed by anemochoric (8.85%).

Table 4. Summary of the density m^{-2} per group and sampled area (A1–A4).

		Areas			
		A1	A2	A3	A4
Ecological classification	Pioneer	54.84	56.67	47.37	34.78
	Secondary	22.58	13.33	18.42	19.57
	Late secondary	16.13	13.33	10.53	19.57
	Climax	—	—	—	2.17
	Unknown	6.45	16.67	23.68	23.91
Growth form	Tree	38.71	20.00	23.68	30.43
	Shrub	12.90	10.00	13.16	17.39
	Herb	19.35	43.33	44.74	30.43
	Vine	25.81	16.67	5.26	6.52
	Unknown	3.23	10.00	13.16	15.22
Dispersal syndrome	Anemochoric	61.29	60.00	76.32	80.43
	Zoochoric	38.71	33.33	21.05	19.57
	Unknown	—	6.67	2.63	—

4. DISCUSSION

The dominant families that we found in the seed bank are commonly observed in early successional forests where pioneer species predominate (Araújo et al., 2006; Franco et al., 2012). Considering this, the seed bank in the PSFA is probably persistent, *i.e.*, composed of short-lived pioneer species, with long-lived seeds with facultative dormancy (Garwood 1989). However, the PSFA is covered by a well-conserved forest that hasn't been explored for 50 years. This mismatch between the seed bank (mostly pioneer species) and the forest structure (mostly secondary to climax species) can be explained by a few factors. Garwood (1989) highlights that climax species represent only a small proportion of all individuals in the seed banks of tropical forests (median = 3%). Also, these species have, usually, recalcitrant seeds that are characterized by having a limited lifespan (Pammenter & Berjak, 2000), creating an ephemerous seedling bank in tropical forests (Vázquez-Yanes & Orozco-Segovia 1993).

The presence of only one climax species can also be explained by mechanisms of dormancy in these taxa since climax species become seedlings in a very short time after dispersion (Baider et al., 1999), reducing the chances of being found in the seed bank. Following, the low density of the vulnerable *Euterpe edulis* (CNCFlora, 2021) — the most common species found in the park's forests (Sevegnani, 2003) — can be explained by several factors. Seeds of *E. edulis* are mostly dispersed closed to the parents, while few are carried out by a secondary dispersal event — with only 36% of seeds germinating before six months (Reis & Kageyama, 2020). In the study area, we could observe at some places a high density of *E. edulis* seedlings, indicating an aggregated pattern of germination and seed deposition. Apart from *E. edulis*, we too observed another threatened species with low density: *Cedrela fissilis* (VU). This species is characterized by quick germination (Oliveira & Barbosa, 2014) and aversion to humidity while stored (Martins & Lago, 2008), which possibly justified its low density. Other relevant species found in the forests that were not found in the seed bank are *Ocotea catharinensis* (VU), *O. odorifera* (VU), and *Virola bicuhyba* (EN) — species with seeds bigger than *E. edulis*. The species *Ocotea catharinensis* produce few seeds in number (Montagna et al., 2018), while *O. odorifera* has seeds capable to germinate only under adequate physical and morphological conditions (Zanotelli & Kissmann, 2017). Finally, most *V. bicuhyba* seeds are predated or naturally deteriorate in the field (Zipparro & Morellato, 2005). These reasons could support the absence of these species in the seed bank.

We waited 334 days until no new seed germinates to finish data collection. In this case, we likely sampled both seeds that germinate within a year of initial dispersal and seeds that remain in the soil for more than 1 year (Simpson 1989). Another explanation for finding few climax species in the samples is that since climax species are large-seeded, shade-tolerant, slow-growing, and long-lived species (Garwood 1989), our sample design did not capture these seeds. Our results can also be interpreted in light of the 2008 landslide in the park that created treefall gaps and the distance of the plots to forest edges, creating opportunities for pioneer species to establish.

Concerning species density, the greatest number of individuals m^{-2} found with *Cecropia glaziovii* and *Trema micrantha* — two pioneer species, possibly relates to their higher diaspore production and efficient dispersal — in addition to their phototropic and tegumental (respectively) dormancy, that is, the necessity of solar radiation and temperature to begin germination (Válio & Scarpa, 2001). These necessities allow their seeds to remain for a long time in the seed bank (Grombone-Guaratini & Rodrigues, 2002) while waiting for favorable conditions to germinate (Araujo et al., 2001). Moreover, the species density found for these taxa in our study was also observed by Grombone-Guaratini & Rodrigues (2002).

Although we observed an overall lower density of individuals in our study, especially in the slope area (see Table 3), when compared to others in the Atlantic Forest (Baider et al., 1999; Candiani, 2016), we observed a richness a few times higher than the ones found in the aforementioned studies. The greater richness we observed can be explained by the presence of urban surroundings around the park, which can act as a source of propagules. Further, another source of propagules could be related to the same landslide, which created treefall gaps within the park (Frank & Sevegnani, 2009). Apart from that, the environmental conditions of the greenhouse could promote or inhibit seed germination through solar radiation or an increase in temperature, facilitating the germination of herbs and/or early secondary species (Miranda Neto et al., 2017), a condition difficult to manage.

Regarding growth form, the observed dominance of trees and shrubs can be explained by ecological successional: as succession progresses, the number of tree-shrubs increases just as their seed viability in the soil (Baider et al., 2001) since these taxa need stable climatic conditions and minimal perturbance (Chambers, 1995; Pons, 2000) — and the park is located within a well-preserved area.

5. CONCLUSIONS

The results of this study indicate that the PSFA seed bank, despite the well-established forest, is composed basically of pioneer species. Climax species were not frequently found probably because of their short lifespan and recalcitrant seed type. Furthermore, the high presence of zoochoric species highlights the importance of this forest fragment as a source of propagules for other areas, thus, a stronghold for local fauna resources.

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REFERENCES

Alvares CA, Stape JL, Sentelhas PC, de Moraes Gonçalves JL, Sparovek G. Köppen's climate classification map for Brazil. Meteorol Zeitschrift 2013; 22(6):711-28.

Araújo FS de, Martins SV, Meira Neto JAA, Lani JL, Pires IE. Estrutura da vegetação arbustivo-arbórea colonizadora de uma área degradada por mineração de caulim, Brás Pires, MG. Revista Árvore 2006; 30:107-16.

Araujo MM, Oliveira FA, Vieira ICG, Barros PLC, Lima CAT. Densidade e composição florística do banco de sementes do solo de florestas sucessionais na região do Baixo Rio Guamá, Amazônia Oriental. Scientia Forestalis 2001; 59:115-30.

Baider C, Tabarelli M, Mantovani W. O banco de sementes de um trecho de uma Floresta Atlântica Montana (São Paulo-Brasil). Revista Brasileira de Biologia 1999; 59:319-28.

Baider C, Tabarelli M, Mantovani W. The soil seed bank during Atlantic forest regeneration in Southeast Brazil. Revista Brasileira de Biologia 2001; 61: 35-44.

Baker HG. Some aspects of the natural history of seed banks. In: Leck MA, Parker VT, Simpson RL, editors. Ecology of soil seed banks. Academic Press Inc: San Diego; 1989.

Bechara FC, Reis A, Trentin BE. Invasão biológica de *Pinus elliottii* var. *elliottii* no Parque Estadual do Rio Vermelho, Florianópolis, SC. Floresta 2013; 44(1):63-72.

Caldato SL, Floss PA, Croce DM, Longhi SJ. Estudo da regeneração natural, banco de sementes e chuva de sementes na Reserva Genética Florestal de Caçador, SC. Ciência Florestal 1996; 6(1):27-38.

Candiani G. Natural regeneration of trees species in the understory of *Eucalyptus saligna* Sm., Caieiras, SP. Ambiência 2016; 12(4):915-31.

Chambers JC. Relationships between seed fates and seedling establishment in an alpine ecosystem. Ecology 1995; 76(7):2124-2133.

CNCFlora. Centro Nacional de Conservação da Flora. [cited 2021 nov. 16]. Available from: http://cncflora.jbrj.gov.br/portal/pt-br/listavermelha.

Dean W. With broadax and firebrand: the destruction of the Brazilian Atlantic Forest. California. University of California Press, 1997.

Dinerstein E, Olson DM, Joshi A, Vynne C, Burgess ND, Wikramanayake E, et al. An Ecoregion-Based approach to protecting half the terrestrial realm. Bioscience 2017; 67(6):534-45.

Flora do Brasil 2020. Jardim Botânico do Rio de Janeiro. [cited 2021 nov. 30]. Available from: http://floradobrasil.jbrj.gov.br.

Frances S, Harris NL. Reducing tropical deforestation. Science 2019; 365:756-757.

Franco BKS, Martins SV, Faria PCL, Ribeiro GA. Densidade e composição florística do banco de sementes de um trecho de floresta estacional semidecidual no campus da Universidade Federal de Viçosa, Viçosa, MG. Revista Árvore. 2012; 36:423-32.

Frank B, Sevegnani L. Desastre de 2008 no Vale do Itajaí. Água, gente e política. Blumenau: Agência de Água do Vale do Itajaí; 2009.

Fundação SOS Mata Atlântica. Atlas dos remanescentes florestais da Mata Atlântica: período 2019/2020. São Paulo, Brasil; 2021.

Garwood N. Tropical soil seed banks: a review. In: Leck MA, Parker VT, Simpson RL, editors. Ecology of soil seed banks. Academic Press Inc: San Diego; 1989.

Gorelick N, Hancher M, Dixon M, Ilyushchenko S, Thau D, Moore R. Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment 2017; 202:18-27.

Grombone-Guaratini MT, Rodrigues RR. Seed bank and seed rain in a seasonal semi-deciduous forest in south-eastern Brazil. Journal of Tropical Ecology 2002; 18(5):759-74.

Krieck CA, Fink DF, Assunção LG, Zimmermann CE. Chuva de sementes *sob Ficus cestrifolia* (Moraceae) em áreas com vegetação secundária no Vale do Itajaí, Santa Catarina, Brasil. Biotemas 2006; 19(3):27-34.

Lima RAF, Oliveira AA, Pitta GR, Gasper AL de, Vibrans AC, Chave J et al. The erosion of biodiversity and biomass in the Atlantic Forest biodiversity hotspot. Nature Communications 2020; 11:6347.

Lima RAF, Rother DC, Muller AE, Lepsch I, Rodrigues RR. Bamboo overabundance alters forest structure and dynamics in the Atlantic Forest hotspot. Biological 2012; 147:32-39.

Lin L, Cao M. Edge effects on soil seed banks and understory vegetation in subtropical and tropical forests in Yunnan, SW China. Forest Ecology and Management 2009; 257:1344-1352.

Machado FS, França ACM, Santos RM, Borém RAT, Guilherme LRG (2017) Influence of the edge effect on a soil seed bank of a natural fragment in the Atlantic Forest. Iheringia, Sér. Bot 2017; 72:247-253.

Martins L, Lago AA. Conservação de semente de *Cedrela fissilis*: teor de água da semente e temperatura do ambiente. Revista Brasileira de Sementes 2008; 30:161-167.

Miranda Neto A, Martins SV, Silva KA, Lopes AT, Demolinari RA. Banco de sementes em mina de bauxita restaurada no Sudeste do Brasil. Floresta e Ambiente. 2017; 24:e00125414.

Miranda Neto A, Martins SV, Almeida Silva K. Soil seed banks in different environments: initial forest, mature forest, *Pinus* and *Eucalyptus* abandoned stands. Plant Biosystems 2021; 155:128-135.

Montagna T, Silva JZ, Pikart TG, Reis MS. Reproductive ecology of *Ocotea catharinensis*, an endangered tree species. Plant Biology 2018; 20:926-935.

Nóbrega AMF, Valeri SV, Paula RC, Pavani MCMD, Silva SA. Banco de sementes de remanescentes naturais e de áreas reflorestadas em uma várzea do rio Mogi-Guaçu-SP. Rev Árvore. 2009; 33:403-11.

Oliveira AKM, Barbosa LA. Efeitos da temperatura na germinação de sementes e na formação de plântulas de *Cedrela fissilis*. Floresta 2014;44(3):441-450.

Pammenter NW, Berjak P. Some thoughts on the evolution and ecology of recalcitrant seeds. Plant Species Biology 2020; 15:153-156.

Pastório FF, Bloemer HC, Gasper AL de. Floristic and structural composition of natural regeneration in a Subtropical Atlantic Forest. Floresta e Ambiente 2018; 25(4):e20170446.

Pons TL. Seed responses to light. In: Fenner M, editor. Seeds - the ecology of regeneration in plant communities. CAB International: Wallingford, UK; 2000.

Reis A, Kageyama PY. Dispersão de sementes do palmiteiro (*Euterpe edulis* Martius - Palmae). Sellowia 2000; 49-52:60-92.

Ribeiro MC, Metzger JP, Martensen AC, Ponzoni FJ, Hirota MM. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation 2009; 142:1141-53.

Roizman LC. Fitossociologia e dinâmica do banco de sementes de populações arbóreas de floresta secundária em São Paulo, SP [dissertação]. São Paulo: Universidade de São Paulo; 1993.

Santos DM, Silva KA, Santos JMFF, Lopes CGR, Pimentel RMM, Araújo EL. Variação espaço-temporal do banco de sementes em uma área de floresta tropical seca (Caatinga)-Pernambuco. Revista de Geografia 2010; 27(1):234-53.

Scherer C, Jarenkow JA. Banco de sementes de espécies arbóreas em floresta estacional no Rio Grande do Sul, Brasil. Brazilian Journal of Botany 2006; 29:67-77.

Schorn LA, Fenilli TAB, Krieger A, Pellens GC, Budag JJ, Nadolny MC. Composição do banco de sementes no solo em áreas de preservação permanente sob diferentes tipos de cobertura. Floresta 2013; 43(1):49-58.

Seubert RC, Maçaneiro JP, Budag JJ, Fenilli TAB, Schorn LA. Banco de sementes do solo sob plantios de *Eucalyptus grandis* no município de Brusque, Santa Catarina. Floresta 2016; 46(2):165-72.

Sevegnani L. Dinâmica de população de *Virola bicuhyba* (Schott) Warb. (Myristicaceae) e Estrutura Fitossociológica de Floresta Pluvial Atlântica, sob clima temperado úmido de verão quente, Blumenau, SC [tese]. São Paulo: Universidade de São Paulo; 2003.

Silvertown JW. Seed size, life span, and germination date as coadapted features of plant life history. The American Naturalist 1981; 118(6):860-4.

Simpson RL. Seed banks: general concepts and methodological issues. In: Leck MA, Parker VT, Simpson RL, editors. Ecology of soil seed banks. Academic Press Inc: San Diego; 1989.

Souza CM, Shimbo JZ; Rosa MR, Parente LL, Alencar AA, Rudorff BFT et al. Reconstructing three decades of land use and land cover changes in brazilian biomes with landsat archive and earth engine. Remote Sensing 2020; 12(17):2735.

Souza PA, Venturin N, Griffith JJ, Martins SV. Avaliação do banco de sementes contido na serapilheira de um fragmento florestal visando recuperação de áreas degradadas. Cerne 2006; 12(1):56-67.

Tres DR, Sant'Anna CS, Basso S, Langa R, Júnior UR, Reis A. Banco e chuva de sementes como indicadores para a restauração ecológica de matas ciliares. Revista Brasileira de Biociências 2007; 5(S1):309-11.

Tres DR. Restauração ecológica de uma mata ciliar em uma fazenda produtora *de Pinus taeda* L. no norte do estado de Santa Catarina [dissertação]. Florianópolis: Universidade Federal de Santa Catarina; 2006.

Válio IF, Scarpa FM. Germination of seeds of tropical pioneer species under controlled and natural conditions. Brazilian Journal of Botany 2001; 24:79-84.

Vázquez-Yanez C, Orozco-Segovia A. Patterns of seed longevity and germination in the Tropical Rainforest. Annual Review of Ecology and Systematics 1993; 24:69-87.

Vinha D, Alves LF, Zaidan LBP, Grombone-Guaratini MT. Influência da superabundância por *Aulonemia aristulata* (Bambuseae) sobre o banco de sementes transitório em um fragmento de Floresta Atlântica. Rodriguesia 2017; 68:1177-1186.

Whitmore TC. Canopy gaps and the two major groups of forest trees. Ecology. 1989; 70(6):536-8.

Zanotelli P, Kissmann C. Germinação de sementes de *Ocotea odorifera* (Vell.) Rohwer: temperatura de incubação e tratamentos pré-germinativos. Ciência e Natura 2017;39:16-21.

Zipparro VB, Morellato LPC. Predação de sementes de *Virola bicuhyba* (Schott) Warb. (Myristicaceae) em floresta atlântica no sudeste do Brasil. Brazilian Journal of Botany 2005; 28(3):515-522.