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Regeneration with or without seedling management: Serra do Mar slope, São Sebastião/SP

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Abstract

The survival of forest communities is based on the seedling bank, since the greater the diversity, the greater the probability of heterospecific replacements. This work aimed to verify, through the species composition, if there is natural regeneration of the clearing with and without management and if it is possible that the clearing regeneration occurs without the management. The study site covered a clearing and a fragment of the Atlantic Forest Biome, in the municipality of São Sebastião/SP, north coast of the state of São Paulo. Ten subplots of 0.5 m x 1.0 m were installed randomly in 8 transects of 2.0 m x 50.0 m, with and without seedling management, where the set of seedlings with up to 20 cm was sampled. At the end of the study, 266 individuals were found, grouped into 38 families and 5 life forms (arboreal, shrub, herbaceous, epiphyte and liana), later classified into: 45 species (60.81%), 23 genera (31.08%) and 6 families (8.10%). Myrtaceae and Rubiaceae stood out as the most species-rich families, with 8 and 6 species, respectively. In the clearing, 22.2% of the sampled species were found, while 77.8% belonged to the forest. The difference between the number of species in the clearing and in the forest fragment suggests that the invasive species *Melinis minutiflora* and *Scleria plusiophylla* can hinder the establishment of seeds, preventing the germination of native species. Therefore, for the clearing regeneration process to occur faster, human intervention is necessary in the management of invasive species. Accordingly, the elaboration of a revegetation project with monitoring and evaluation of the area of study was emphasized.

Keywords: Atlantic Forest. Phytosociological survey. Forest recovery indicators.

Introduction

In the Atlantic Forest, a biome considered a world hotspot (MYERS *et al*., 2000; ALMEIDA, 2016), human occupation has an area of greater intensity, therefore, this biome has a high level of imminent extinction threats, but on the other hand it has a high rate of biological diversity and endemism. The peculiarity and environmental heterogeneity have produced in the Atlantic Forest, with so many important factors, one of the greatest biodiversity on the planet, expressed in terms of genus or species richness. (MARTINI *et al*., 2007).

According to studies by Gouveia Souza (1998), during the 1980s there was an increase in tourist exploitation of the coastal areas of the country, with consequent growth in real estate and civil construction, with summer houses on the slopes amidst native vegetation.

In this context, the occupation of coastal areas in the north of the state of São Paulo, such as the slope areas of Serra do Mar in the municipality of São Sebastião, results in an unbalanced process of urban expansion based on economic growth vectors such as agriculture and industrialization.

Environmentally, the process of ecological degradation in Serra do Mar is continuous and occurs in several regions. Degradation of environments means loss of landscapes of high cultural importance, biological diversity and genetic heritage. (LAURANCE, 2010). Carpanezzi *et al*. (1992) described that a degraded environment is the one that, after disturbances, had its means of biotic regeneration suppressed due to vegetation. Meanwhile a balanced environment has mechanisms for its self-regeneration, such as: seed and seedling bank and seed rain (CALEGARI *et al*., 2011).

When suffering a disturbance, the environment simultaneously eliminates the vegetation and these mechanisms, thus showing little or no resilience (TURCHETTO, 2015).

Forest recovery indicators can designate the successful implementation of a restoration project in a degraded area; are excellent indicators: seed and seedling bank (HARPER, 1977; MARTINS, 2015). The seed bank is formed by seeds of local and allochthonous plants, disposed in the soil or litter (MORESSI *et al*., 2014; FENNER *et al*., 2005) and its study can reveal the seed permanence system (viability) - viable systems harbor the genetic and floristic potential that condition the resilience and ecological succession process of the area in question (LECK *et al*., 1989).

Therefore, through the analysis of seed composition, it is possible to develop strategies to direct an ecological succession process, in addition to elucidating the capacity of an ecosystem to recover after a disturbance (MORESSI *et al.*, 2014).

The seedling bank represents the regenerative potential of the adult arboreous community, a set of individuals developing in the understory of a forest (MELO *et al*., 2004). According to Fenner *et al.* (2005), the seedling stage is the one in which the plant no longer depends on seed reserves to maintain itself, but this interruption is gradual. It begins with seed germination and, in practice, it is considered the final stage when the individual has two or three leaves and a height of up to 50 centimeters (MELO *et al*., 2004). As a form of standardization so that it is possible to compare studies, Chami *et al*. (2011) considered in their study seedlings with Diameter at Breast Height (DBH) greater than 1 cm and height equal to or greater than 20 cm.

The more diverse the set of seedlings, the greater the probability of heterospecific substitutions occurring (MARTÍNEZ, 1991; OLIVEIRA, 1999). According to Bazzaz e Pickett (1980), the seedling bank, added to larger individuals, is essential for the recruitment of native species in an advanced successional stage, which may occur in a low number in clearing areas caused by an environmental degradation event.

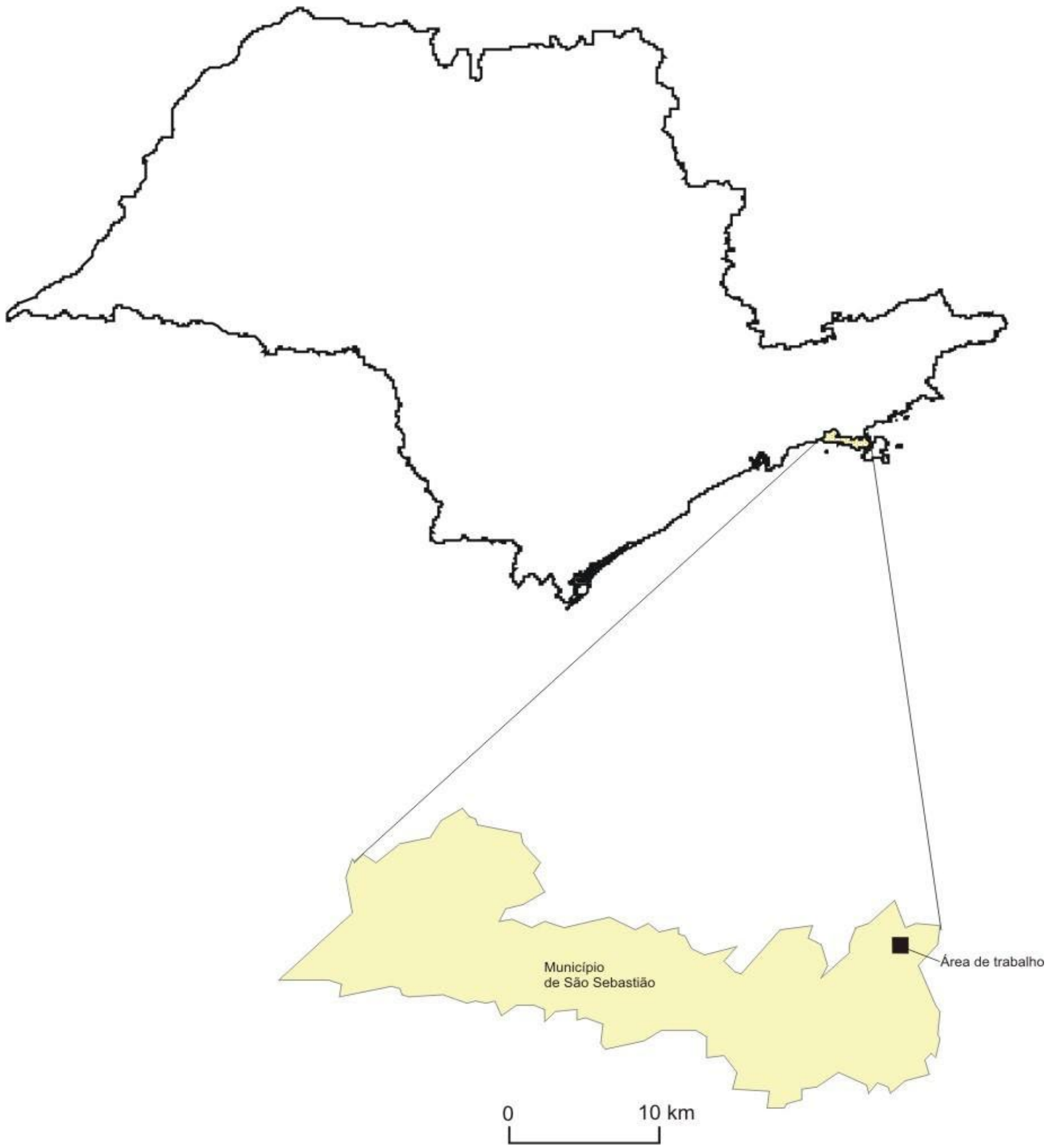
This study described the structure of the seedlings in a clearing and confronted them with the surrounding forest fragment. Hence, the objective was to verify if there is natural regeneration of the clearing and if it is possible that this regeneration occurs without the management by species composition.

Material and methods

Area of Study

The municipality of São Sebastião is located on the north coast of the State of São Paulo (FIGURE 1) between longitudes 45º25’03” W - 45º25’37” W and latitudes 23º44’10” S - 23º44’19” S, covers an approximate area of 410 km², of which around 70 % are located in the Parque Estadual da Serra do Mar (Serra do Mar State Park). The study was conducted at Sítio São Benedito (FIGURE 3), a place for environmental studies associated with São Marcos University. The original vegetation of the area in question is composed of the same one of its margins, classified as Dense Ombrophilous Forest (VELOSO *et al.*, 1991), a 4.8-hectare Atlantic Forest fragment between longitudes 45°25’30” W – 45°25’37’’ W and latitudes 23°44’10” S - 23°44’19” S, between 105 m and 235 m above sea level.

Figure 1 – Location of the area of study in the municipality of São Sebastião, in the State of São Paulo.



Source: Elaborated by the authors (2021).

Figure 2 – Aerial photo of the 4.8 ha area of Sítio São Benedito at São Marcos University.

Scale: 1:8000

Source: Funcate (2001).

Seedling sampling

The sampling of seedlings contained vascular plants up to 20 cm in height. The stratum was sampled in 8 transects of 2 m × 50 m, each comprising 10 fixed subplots of 0.5 m x 1.0 m. Each subplot was delimited with 4 wooden stakes joined by demarcation plastic tape (Figure 3). The transects were positioned in a paired way, each transect in the clearing having a corresponding one inside the forest.

Figure 3 – Photo showing transect-subplot in the clearing area.

Source: The authors (2004).

In view of the objective of the research and in with the purpose of determining the guidelines of the recovery model for the area and comparing it with the species sampled in the fragment (BAZZAZ; PICKET, 1980), an evaluation of the seedling stratum of the clearing was carried out. In each subplot, all individuals up to 20 cm in height were collected.

The samples consisted only of complete individuals and the independent portion (stoloniferous plants); each of them received a label, were pressed and dried in an oven at 60°C for 4 days, then counted and separated into morphospecies with a stereo microscope.

The individuals collected were compared with peers in more advanced ontogenetic stages or with exsiccates stored in the herbarium of the Instituto de Botânica de São Paulo, where they were identified. To identify the families, the works of Oliveira (1999) and the Flora Fanerogâmica da Serra da Jureia (MAMEDE *et al*., 2001) were references. All individuals were classified according to life form as arboreal, shrub, herbaceous, epiphyte and liana (FERRI *et al*., 1981). Finally, the updating of the scientific binomials was carried out according to the Platform – List of Species of Flora in Brazil.

From this list of species, secondary information was obtained in the literature on dispersion syndromes (anemochoric, autochoric and zoochoric) and successional classification (pioneer and non-pioneer)

The number of individuals corresponds to the number of trees of the same species sampled; the percentage of the total number of individuals was also calculated. The number of occurrences refers to the number of times the species occurred, considering the sampling points.

Results and discussion

Composition of species in the forest clearing

In the clearing area, 266 individuals were sampled, grouped into 38 families and 5 life forms, and later separated into 74 morphospecies and classified into: species 45 (60.81%), genera 23 (31.08%) and families 6 (8.10%), as shown in Table 1.

Table 1 - List of sampled species classified as to life form.

Family – Species	Life form	Family – Species	Life form
Acanthaceae		**Chrysobalanaceae**	
Acanthaceae sp.	Herbaceous	*Licania* sp.	Arboreal
Aphelandra ornata (Nees T.Anderson)	Herbaceous	**Commelinaceae**	
Justicia sp.	Herbaceous	*Commelina* sp.	Herbaceous
Lepidagathis (kameyamana Gnanasek. & Arisdason)	Herbaceous	*Dichorisandra thyrsiflora* (J.C.Mikan)	Herbaceous
Annonaceae		**Convolvulaceae**	
Duguetia lanceolata (A.St.-Hil.)	Arboreal	*Ipomoea* sp.	Liana
Guatteria australis (A.St.-Hil.)	Arboreal	**Cyperaceae**	
Araceae		*Scleria plusiophylla* (Steud)	Herbaceous
Anthurium penthaphyllum (Aubl.) (G.Don)	Epiphyte	**Dioscoreaceae**	
Anthurium sp.	Epiphyte	*Dioscorea multiflora* (Mart. ex Griseb).	Liana
Arecaceae		**Euphorbiaceae**	
Euterpe edulis (Mart.0	Arboreal	*Alchornea glandulosa (*Poepp. & Endl.)	Arboreal
Asclepiadaceae		**Fabaceae**	
Asclepiadaceae sp. 1	Liana	*Albizia* sp.	Arboreal
Aspleniaceae		*Hymenaea* sp.	Arboreal
Asplenium sp.	Epiphyte	*Inga marginata* Willd.	Arboreal
Asteraceae		*Piptadenia gonocantha* (Mart.) (J. F.) Macbr.	Arboreal
Eupatorium sp.	Shrub	**Gesneriaceae**	
Vernonia discolor (Spreng.) (H. Rob.)	Arboreal	*Codonante devosiana* (Mart.) (Hanst.)	Epiphyte
Mikania sp.	Liana	**Lauraceae**	
Bignoniaceae		*Nectandra grandiflora* (Nees & Mart.)	Arboreal
Tabebuia cassinoides (Lam.) (D.C.)	Arboreal	*Nectandra oppositifolia* (Nees & Mart.)	Arboreal
Ocotea dispersa (Nees) (Mez)	Arboreal	*Gomidesia* sp. 1	Arboreal
Lecythidaceae		*Gomidesia* sp. 2	Arboreal
Cariniana legalis (Mart.)(Kuntze)	Shrub	*Myrcia aethusa* (O.Berg) (N.Silveira)	Arboreal
Loganiaceae		*Myrcia splendens* (Sw.) 9DC.)	Arboreal
Spigelia beyrichiana (Cham. & Schltdl)	Hérbacea	**Orquidaceae**	
Magnoliaceae		*Orchidaceae* 1	Epiphyte
Magnolia ovata (A.St.-Hil.) (Spreng.)	Arboreal	*Orchidaceae* 2	Epiphyte

Family – Species	Life form	Family – Species	Life form
Malphigiaceae		**Phyllanthaceae**	
Tetrapterys sp.	Liana	*Hyeronima alchorneoides (*Allemão)	Arboreal
Malvaceae		**Piperaceae**	
Pseudobombax grandiflorum (Cavanilles) (A. Robyns)	Arboreal	*Peperomia* sp.	Epiphyte
Pavonia schiedeana Steud.	Shrub	*Piper* sp. 1	Shrub
Marantaceae		*Piper* sp. 2	Arboreal
Goeppertia zebrina (Sims) (Nees)	Herbaceous	**Poaceae**	
Maranta divaricata Roscoe	Herbaceous	*Melinis minutiflora* (P. Beauv.)	Herbaceous
Maranthaceae sp.	Herbaceous	**Rubiaceae**	
Marcgraviaceae		*Coccocypselum cordifolium* (Nees & Mart*.)*	Herbaceous
Marcgravia polyantha Delpino	Liana	*Malanea forsteronioides* (Müll.Arg.)	Liana
Melastomataceae		*Psycotria vellosiana (*Vell.) C.M.Taylor	Shrub
Miconia sp.	Arboreal	*Rubiaceae* sp. 1	Herbaceous
Tibouchina estrellensis (Raddi) (Cogn.)	Arboreal	*Rudgea* sp.	Arboreal
Meliaceae		*Pilocarpus* sp.	Arboreal
Guarea macrophylla Vahl	Arboreal	**Sapindaceae**	
Trichilia pallens (C. DC.)	Arboreal	*Cupania oblongifolia* Mart.	Arboreal
Monimiaceae		*Paullnia trigonia* (Vell.)	Arboreal
Mollinedia uleana Perkins	Arboreal	*Serjania* sp.	Arboreal
Moraceae		**Sapotaceae**	
*Ficus enormis (*Miq.) (Miq.)	Arboreal	*Chrysophyllum inornatum* (Mart.)	Arboreal
Myrtaceae		*Pouteria* sp.	Arboreal
Calypthrantes brasiliensis (Spreng.)	Arboreal	**Smilacaceae**	
Calypthrantes lucida (Mart. ex DC.)	Arboreal	*Smilax* sp.	Liana
Eugenia cerasiflora (Miq.)	Arboreal	**Solanaceae**	
Eugenia sp. 1	Arboreal	*Solanum pseudoquina* (A.St.-Hil)	Arboreal

Source: Elaborated by the authors (2021).

Myrtaceae and Rubiaceae stood out as the most species-rich families, with 8 and 6 species, respectively. Most families exhibited 1 to 2 species corresponding to 75.67 % of the total. Four morphospecies accounted for 36.84 % of the total records - *Calyptrantes grandiflora, Aranthaceae sp., Scleria plusiophylla and Melinis minutiflora*, being the last species the one with the highest occurrence percentage (19.55 %), establishing itself as an important invader of the clearing. The average number of individuals in the clearing was 2.1 individuals per subplot, while in the forest it was 3.25. In terms of composition, 77.8 % of the sampled species were found in sampling units in the interior of the forest and only 22.2 % were found in the clearing. The species responsible for such difference is *Melinis minutiflora* with 52 individuals sampled only in the clearing.

Invasive species are aggressive, have great soil stabilization potential and can prevent seed germination (CARMONA, 1992). Hoffmann e Haridasan (2008) found in their study that the presence of Melinis minutiflora hinders the recruitment process of woody plants, by preventing the penetration of seed rain. In addition, this species usually forms dominant clumps and produces greater biomass than native grasses (HOFFMANN *et al*., 2004), resulting in a high decline in the diversity of herbaceous species (PIVELLO *et al*., 1999). Therefore, the absence of management can delay the natural revegetation process and change the entire dynamics of ecological succession.

The fact that more primary species than climax ones were found is ecologically explainable as ruderal plants are normally herbaceous with fast development and high seed dispersal, have high aggressiveness and inhabit areas of low environmental stress and high intensity of degradation (LORENZI, 2008). According to Laurent *et al*. (2017), they are the ones who will fill the open niches in areas that have suffered disturbance, their function being to create an initial ecological succession environment. Therefore, the management of invasive species is recommended to accelerate the process of vegetation recovery in the clearing studied. As stated by Carvalho *et al*. (2000), the regenerating floristic composition in the clearings is similar to that existing in the native forest – demonstrating that the seedlings settled prior to the formation of the clearing are essential for its closure.

Composition of species in the forest

In the forest area, 200 individuals were sampled, grouped into 28 families, 56 genera and 72 species. Greater richness was detected for the following families: Myrtaceae (14 species), Fabaceae (8 species) and Lauraceae (6 species), totaling 38.4% of the sampled species (TABLE 2).

Table 2. List of species sampled in the forest area

Family - Species	SC	SD	Family - Species	SC	SD
Annonaceae			*Inga marginata* Willd.		
Duguetia lanceolata (A.St.-Hil.)	P	ZOO	*Piptadenia gonoacantha* (Mart.) J.	NP	ZOO
Guatteria australis (A.St.-Hil.)	NP	ZOO	*Schizolobium parahyba* (Vell.) Blake	NP	ZOO
*Annona neosericea (*H.Rainer)	NP	ZOO	**Lecythidaceae**		
Arecaceae			*Cariniana legalis* (Mart.) Kuntze	NP	ANE
Bactris setosa (Mart.)	NP	ZOO	**Malvaceae**		
Euterpe edulis (Mart.)	NP	ZOO	*Pseudobombax grandiflorum* (Cavanilles A. Robyns)	NP	ANE
Asteraceae			**Magnoliaceae**		
Vernonia discolor (Spreng.) (H. Rob.)	P	ANE	*Magnolia ovata* (A.St.-Hil.) Spreng.)	NP	ZOO
Bignoniaceae			**Meliaceae**		
Jacaranda micranta Cham.	NP	ANE	*Guarea macrophylla* (Vahl.)	NP	ZOO
Tabebuia cassinoides (Lam.) DC.	P	ANE	*Trichilia silvatica* (C.DC.)	NP	ZOO
Caricaceae			*Trichilia pallens* (C. DC.)	NP	ZOO
Jacaratia spinosa (Aubl.) A.DC.	P	ZOO	**Melastomataceae**		
Chrysobalanaceae			*Miconia latecrenata* (DC. Naudin)	P	ZOO
Licania hoehnei Pilg.	NP	ZOO	*Miconia* sp.	P	ZOO
Licania sp.	NP	ZOO	*Tibouchina estrellensis* (Raddi Cogn.)	P	ZOO
Euphorbiaceae			**Myristicaceae**		
Alchornea glandulosa (Poepp. & Endl.)	P	ZOO	*Virola oleífera* (Schott ex Spreng.) Warb.)	NP	ZOO

Family - Species	SC	SD	Family - Species	SC	SD
Hyeronima alchorneoides (Allemão)	NP	ZOO	**Monimiaceae**		
Fabaceae			*Mollinedia uleana* Perkins	NP	ZOO
Albizia sp.	NP	ZOO	**Moraceae**		
*Dahlstedtia pinatta (*Benth.) (Malme)			*Ficus enormis* ((Miq.) Miq.)	NP	ZOO
Holocalyx balansae (Micheli)	NP	ZOO	**Myrtaceae**		
Hymenaea sp.			*Calypthrantes grandiflora (*O. Berg)	NP	ZOO
Inga edwallii (Harms) (T.D.Penn.)	NP	ZOO	*Calypthrantes lucida* (Mart. ex DC.)	NP	ZOO
Campomanesia xantocarpa (Mart.) (O.Berg)	NP	ZOO	*Psychotria mapoureoides* (DC.)	NP	ZOO
Eugenia cerasiflora Miq.	NP	ZOO	*Rudgea* sp.	NP	ZOO
Eugenia cf. multicostata (D.Legrand)	NP	ZOO	**Rutaceae**		
Eugenia sp. 1	NP	ZOO	*Conchocarpus fontanesianus* ((A. St.-. Hil.) Kallunki & Pirani	NP	ZOO
Eugenia sp. 2	NP	ZOO	*Pillocarpus sp.)*	NP	ZOO
Gomidesia sp. 1	NP	ZOO	**Sapindaceae**		
Gomidesia sp. 2	NP	ZOO	*Allophyllus edulis* (A.St.-Hil., A.Juss.&Cambess.Hieron. ex Niederl.)	NP	ZOO
Marlierea parviflora (O.Berg)	NP	ZOO	*Cupania oblongifolia* (Mart.)	NP	ZOO
Myrcia cf. pubipetala (Miq.)	NP	ZOO	**Sapotaceae**		
Myrcia richardiana (O.Berg) Kiaersk.	NP	ZOO	*Chrysophyllum inornatum* Mart.	NP	ZOO
Myrcia rostrata (Sw.)(DC.)	NP	ZOO	*Ecclinusa ramiflora* (Mart.)	NP	ZOO
Plinia rivularis (Cambess.)	NP	ZOO	*Pouteria* sp.	NP	ZOO
Nyctaginaceae			**Solanaceae**		
Guapira opposita (Vell.) (Reitz)	NP	ZOO	*Solanum argenteum* (Dunal)	P	ZOO
Piperaceae			*Solanum pseudoquina* (A.St.-Hil.)	P	ZOO
Piper miquelianum (C.DC.0	NP	ZOO	**Symplocaceae**		
Piper sp.	NP	ZOO	*Symplocos celastrinea (*Mart.)	NP	ZOO
Rubiaceae			**Urticaceae**		
Alibertia myrcifolia (K.Schum.) (C.H.Perss. & Delprete)	NP	ZOO	*Urera bacífera ((*L.) Gaudich. ex Wedd.)	P	ZOO
Coussarea contracta ((Walp.) Müll.)	NP	ZOO			

Categorization in Successional Classification (CS): P=pionner, NP= non-pioneer; and Dispersal Syndrome (DS): ANE=anemochoric, ZOO= zoochoric.

Source: Elaborated by the authors (2021).

As in the present study, Davison (2009) compared an understory forest with a clearing in an area of Atlantic Forest and found that in both areas the family that stood out as predominant was Myrtaceae, with representatives *Calypthrantes lucida* and *Calypthrantes brasiliensis*.

Furthermore, the families Euphorbiaceae and Sapindaceae were found in both strata and are frequent in disturbed areas and on forest edges (PASTORIO, 2018). *Nectandra sp*. and *Eugenia sp*., with 4 species each, and *Myrcia s*p. with 3 species, got highlighted as well, being genera with high species richness for slope forests of the Atlantic Forest, as elucidated by Oliveira-Filho and Fontes (2000) in their studies.

Seventeen pioneers (24%) and fifty-five non-pioneers (76%) were sampled. Among the pioneers are: *Piptadenia gonoacantha, Solanum argentum, Schizolobium parahyba, Vernonia discolor and Micona spp*. The proportionally low number of pioneer species (compared to non-pioneers) is an expected characteristic for a mountainous relief region. Studies by Tabarelli and Mantovani (1999) highlight that this situation is due to the lower incidence of light.

Regarding the Dispersion Syndrome in the samples, 61 of the species (84.7%) are zoochoric, including: *Euterpe edulis, Eugenia sp., Myrcia sp., Nectandra sp., Miconia sp. and Allophyllus edulis*. As for anemochoric species, 11 species (15.3%) were found, of which the following stood out: *Schilozobium parahyba, Piptadenia gonoacantha and Vernonia discolor,* which are pioneer species, being important in the occupation and regeneration of open areas, where the fauna is sparse.

These results indicate a regeneration in medium/advanced stage, with a predominance of non-pioneer and zoochoric species. Species with a low number of individuals and low regeneration in the clearing were observed, indicating a tendency to replacement in a future process of ecological succession. Therefore, the need for monitoring and new studies focused on the restoration of the area is highlighted.

Conclusion

According to the status of seedlings, the clearing is undergoing a process of natural regeneration provided by the fragment in its surroundings, but this occurs with low diversity, since only 22.2% of the sampled species were found in the area of the clearing and the remaining 77.8% were in the interior of the adjacent forest.

The low richness is due to the presence of invasive species, such as *Melinis minutiflora*. Hence, the management of invaders is essential for the propagules of native species in the adjacent forest to succeed and establish themselves, helping in the natural regeneration and consequent recovery of the area. Therefore, for the regeneration process of the clearing to occur at a great rate, human intervention is needed in the management of invasive species.

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