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Floristic Composition of Restored Atlantic Riparian Forests on The Coast of São Paulo State, Brazil

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Abstract

Studies on floristic composition are important to evaluate the effectiveness of forest restoration and to support conservation of tropical forests. Presence of planted exotic species and low species richness in several riparian forests in Brazil led us to analyze the floristic composition of restored riparian areas in a region with one of the highest levels of vegetation cover in the Atlantic Forest and immersed in one of the largest centers of endemism in this hotspot. Restored areas were identified through consultation of licensing processes at the environmental agencies and field visits were carried out in these areas to identify planted species. Most restorations involved the planting of exotic species, low species richness and an inadequate proportion of native species, which can be harmful to the conservation and restoration of the Atlantic Forest. Dissemination of these results may alert the environmental agencies in order to avoid the approval of ineffective restorations.

Keywords: Biodiversity, conservation, endemism, native vegetation, planting of seedlings.

1. INTRODUCTION AND OBJECTIVES

Forest restoration is a global priority to increase forest cover and connect remnants (Banks-Leite et al., 2014) in areas degraded by adverse impacts of human development (Crouzeilles et al., 2016). In Brazil, more than one million ha of riparian forest have been deforested in the São Paulo State, making forest restoration urgently needed to mitigate this environmental impact (Rodrigues et al., 2009). Riparian forests are fundamental for the formation of ecological corridors, as they perform several ecosystem services (Giannini et al., 2017) and contribute to plant dispersion throughout the landscape (Lima & Zakia, 2004). Therefore, the restoration of riparian forests should be executed in case of deforestation to comply with the Native Vegetation Protection Law – NVPL (Law No 12.651/2012, known as the new Forest Code) (Brasil, 2012).

Forest restoration is the intentional reintroduction of native plant species that were eliminated from a degraded environment to initiate or accelerate the recovery of such ecosystem (SER, 2004). This practice is essential to minimize species extinction (Chazdon, 2008), to increase the functional connectivity of the landscape (Banks-Leite et al., 2014), and to subsidize the biodiversity conservation on a regional scale (Crouzeilles et al., 2016). Thereby, interactions essential for the functioning of the ecosystem (e.g., pollination and dispersion of seeds) and the provision of ecological processes can be restored (Menz et al., 2010).

Nevertheless, forest restoration through planting of seedlings has introduced over the years exotic species into riparian forests (Durigan et al., 2010; Brancalion et al., 2010), causing a significant loss of biological diversity in several restored riparian areas due to low species richness (Barbosa & Potomati, 2003). The lack of evaluation of restoration projects by trained professionals (Durigan et al., 2010) and the intense demand from environmental agencies can result in unsuccessful and ineffective forest restoration measures (Brancalion et al., 2010). For such reasons, the development of studies in restored areas is important to evaluate the effectiveness of forest restoration (Massi et al., 2022) and to provide insights on how to avoid or overcome failures (Campoe et al., 2014). The composition and structure of restored forest should be used as indicators for an effective analysis of the possibility of perpetuating the area (Bellotto et al., 2009). Frequency, density, and species richness are some key indicators used to evaluate vegetation structure and its composition in restored tropical forests (Ruiz-Jaen & Aide, 2005; Campoe et al., 2014).

To assess the suitability of species used in selected restored areas located on the coast of São Paulo State, we analyzed the floristic composition in riparian areas restored through the planting of seedlings in a region with one of the highest levels of vegetation cover in the Atlantic Forest (São Paulo, 2020). The data can contribute to the analysis of the effectiveness of restoration in the Atlantic Forest and to support the implementation of public policies for conservation of this hotspot.

2. MATERIALS AND METHODS

2.1. Study area

The riparian areas considered in this study are spread out over nine hydrographic sub-basins in the Baixada Santista watershed, central coast of the São Paulo State, southeastern Brazil (Figure 1). This region presents 79.1% of the territory covered by the Atlantic Forest (São Paulo, 2020) which characterizes it as one of the largest centers of endemism in this hotspot (Tabarelli & Mantovani, 1999).

According to the *Atlas dos Remanescentes Florestais da Mata Atlântica* (Fundação SOS Mata Atlântica, 2020), the different types of Atlantic Forest present in this region are Dense Ombrophilous Forest (in the coastal plain); Submontane Dense Ombrophilous Forest (present between 50 and 500 m high); Upper Montane Forest (present above 500 m of altitude); restingas and mangroves.

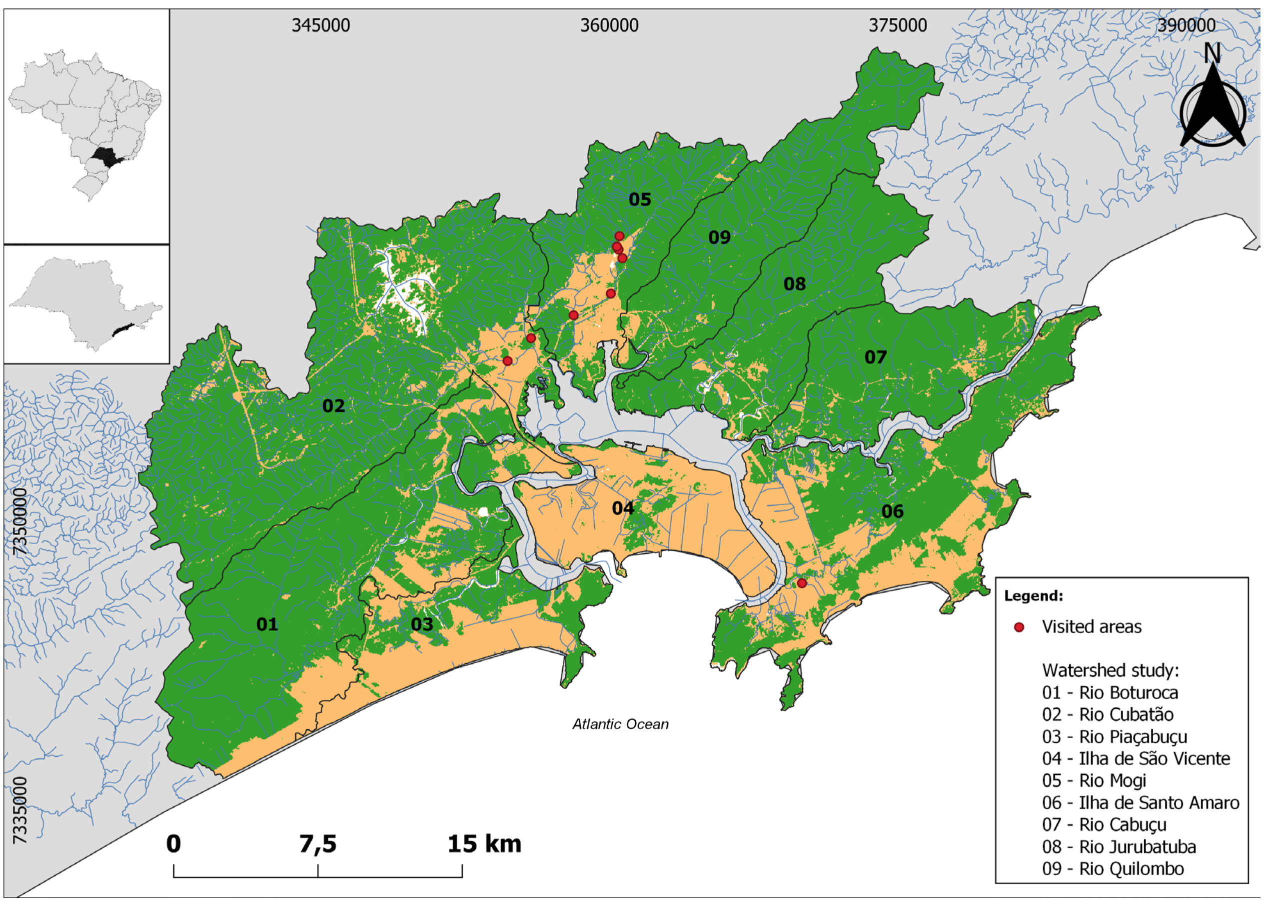

Figure 1. Location of restored riparian areas of study in Baixada Santista region. Supervised classification of satellite image (Landsat 8 Operational Land Imager – OLI/year 2021). Authors' collection. Remaining Atlantic Forest vegetation cover is represented in green, and the urban occupation is represented in orange.

Despite its biological importance, the region is highly susceptible to industrial and commercial expansion of related activities linked to the petrochemical complex industry of Cubatão and the largest port of Latin America located in Santos (Oscar-Júnior et al. 2019). Vegetation cover in the Baixada Santista has been replaced by urban settlements in some areas, and a large part of riparian forests in this region is susceptible to degradation due to channeling of rivers and streams by industries and enterprises (Cunha & Oliveira, 2015).

2.2. Data Collection

Environmental licensing processes of 25 restored riparian areas were consulted between 2019 and 2020 with the Environmental Agency of the São Paulo State (CETESB) to identify the degraded riparian areas that have been restored in the study region. Restoration projects previously elaborated to mitigate the degradation in riparian forests and approved by the environmental agency were analyzed to identify the species planted in each area. Field visits were carried out in nine urban restored riparian areas located on the banks of the Mogi, Córrego do Bugre, Perequê, Cubatão and Santo Amaro rivers (Figure 1 and Table 1).

We analyzed about seven ha of restored riparian areas in Dense Ombrophilous Forests. All specimens present in the planting lines in each restored riparian area were registered, identified and their height and circumference at breast height (CBH) were measured. Species were identified through examination of specialized literature, herbalized material (Unisanta Herbarium, HUSC), consultation with specialists and comparison with images available in the speciesLink database (CRIA, 2022). The collected material was deposited at HUSC.

Family names were standardized according to the Angiosperm Phylogeny Group - APG IV (Byng, 2016). Validation of species names and information about their origin are in accordance with Flora and Funga do Brasil (2022) and Tropicos v. 3.3.2.

Table 1. Location, deforested area and year of restoration of urban riparian areas.

Area	Sub-basin	River/Stream	Coordinates (UTM, SIRGAS 2000)	Deforested Area (ha)	Year of Restoration
Area 1	Rio Mogi	Córrego do Bugre	23 k 7364135 mS - 360462 mE	2.00	2010
Area 2		Córrego do Bugre	23 k 7364828 mS - 360512 mE	1.20	2010
Area 3		Córrego do Bugre	23 k 7364288 mS - 360375 mE	0.21	2010
Area 4		Rio Mogi	23 k 7364910 mS - 360063 mE	0.32	2011
Area 5		Rio Mogi	23 k 7360721 mS - 358127mE	2.15	2008
Area 6		Rio Mogi	23 k 7363682 mS - 360663 mE	0.04	2020
Area 7	Rio Cubatão	Rio Cubatão	23 k 7358344 mS - 354695 mE	1.03	2018
Area 8		Rio Perequê	23 k 7359570 mS - 356000 mE	0.01	2012
Area 9	Ilha de Santo Amaro	Rio Santo Amaro	23 k 7346800 mS - 370000 mE	0.05	2013

2.3. Data analysis

The proportion of native Atlantic Forest species found in the study sites was calculated based on the *Plantas da Floresta Atlântica* (Stehmann et al., 2009), and the proportion of species dispersion syndromes was calculated based on *Lista das Espécies Indicadas para a Restauração Ecológica para Diversas Regiões do Estado de São Paulo* (Barbosa et al., 2017).

Relative Density (RelDe), Relative Frequency (RelFr), Relative Dominance (RelDo) and Importance Value Index (IVI) were calculated for each species (Mueller-Dombois & Ellenberg, 1974) using the Fitopac 2.1 software (Shepherd, 2010). To verify the degree of threat faced by species planted in restoration areas, official lists of endangered species were consulted (São Paulo, 2016; Brasil, 2022).

3. RESULTS

We identified 98 species distributed in 31 families. The highest Importance Value Indexes (IVI) were obtained for *Guarea guidonia*, *Citharexylum myrianthum*, *Talipariti pernambucense*, *Inga sessilis*, *Cecropia pachystachya*, *Croton urucurana* and *Syagrus romanzoffiana* (Table 2).

Table 2. Species identified in restored areas. NInd = number of individuals, RelDen = relative frequency (ind./ha-1), RelFr = relative frequency, RelDo = relative dominance, IVI = importance value index.

FAMILY/SPECIES	RESTORED AREAS	N Ind	Rel Den	Rel Fr	Rel Do	IVI
ANACARDIACEAE						
Schinus molle L.	6	4	0.27	0.47	0	0.74
Schinus terebinthifolia Raddi	1, 2, 3, 5, 7, 8, 9	59	3.97	3.26	2.11	9.34
Tapirira obtusa (Benth.) J.D. Mitch.	8	1	0.07	0.47	0.05	0.59
ANNONACEAE						
Annona glabra L.	5, 9	8	0.54	0.93	0.25	1.72
Annona sylvatica A.St.-Hil.	1, 7	7	0.47	0.93	0.08	1.48
ARALIACEAE						
Heptapleurum actinophyllum (Endl.) Lowry & G.M. Plunkett	8	4	0.27	0.47	0.07	0.81
ARECACEAE						
Astrocaryum aculeatissimum (Schott) Burret	1, 3	8	0.54	0.93	0.05	1.52
Euterpe edulis Mart.	1	10	0.67	0.47	0.28	1.42
Phoenix cf. *roebelenii*	1	2	0.13	0.47	0.07	0.67
Syagrus romanzoffiana (Cham.) Glassman	1, 2, 5, 7, 8, 9	61	4.1	2.79	7.15	14.04
BIGNONIACEAE						
Handroanthus chrysotrichus (Mart. ex DC.) Mattos	1, 3	3	0.2	0.93	0.03	1.17
Handroanthus heptaphyllus (Vell.) Mattos	1, 2	3	0.2	0.93	0.06	1.19
Handroanthus impetiginosus (Mart. ex DC.) Mattos	1	1	0.07	0.47	0.01	0.54
Handroanthus umbellatus (Sond.) Mattos	2	1	0.07	0.47	0.03	0.57
Jacaranda cuspidifolia Mart.	6	5	0.34	0.47	0.01	0.8
Jacaranda macrantha Cham.	5	2	0.13	0.47	0.04	0.64
Jacaranda puberula Cham.	2	1	0.07	0.47	0.01	0.54
Tabebuia cassinoides (Lam.) DC.	3	2	0.13	0.47	0.01	0.6
Tabebuia insignis (Miq.) Sandwith	1	1	0.07	0.47	0.01	0.54
Tabebuia pentaphylla (L) Hemsl.	7, 8	18	1.21	0.93	1.02	3.16
Tabebuia roseoalba (Ridl.) Sandwith	7	11	0.74	0.47	0.01	1.21
BIXACEAE						
Bixa orellana L.	7	2	0.13	0.47	0	0.6
BORAGINACEAE						
Cordia superba Cham.	6	4	0.27	0.47	0	0.74
CALOPHYLLACEAE						
Calophyllum brasiliense Cambess.	1, 2, 3, 5, 9	44	2.96	2.33	0.76	6.04
CANNABACEAE						
Trema micrantha (L.) Blume	1, 5	6	0.4	0.93	0.16	1.49
COMBRETACEAE						
Terminalia glabrescens Mart.	1	1	0.07	0.47	0.02	0.55
EUPHORBIACEAE						
Alchornea glandulosa Poepp. & Endl.	1, 2, 5	5	0.34	1.4	0.36	2.09
Alchornea triplinervia (Spreng.) Müll.Arg.	2, 4, 5	5	0.34	1.4	0.17	1.9
Croton urucurana Baill.	1, 2, 3, 5, 6	74	4.98	2.33	7.25	14.55
Joannesia princeps Vell.	1	1	0.07	0.47	0.02	0.56
FABACEAE						
Albizia niopoides (Spruce ex Benth.) Burkart	6, 7	2	0.13	0.93	0	1.07

Table 2. Continued...

FAMILY/SPECIES	RESTORED AREAS	N Ind	Rel Den	Rel Fr	Rel Do	IVI
Andira anthelmia (Vell.) Benth.	1	2	0.13	0.47	0.03	0.63
Bauhinia forficata Link	2, 5	3	0.2	0.93	0.01	1.14
Centrolobium robustum (Vell.) Mart. ex Benth.	4	17	1.14	0.47	0.39	2
Cenostigma pluviosum (DC.) E. Gagnon & G.P. Lewis	1	1	0.07	0.47	0	0.53
Dahlstedtia muehlbergiana (Hassl.) M. J. Silva & A. M. G. Azevedo	1, 5	8	0.54	0.93	0.8	2.27
Erythrina speciosa Andrews	1, 2, 3, 5, 7, 8, 9	38	2.56	3.26	0.72	6.53
Inga edulis Mart.	1, 2, 5, 9	8	0.54	1.86	0.33	2.73
Inga laurina (Sw.) Willd.	2, 7	5	0.34	0.93	0.04	1.31
Inga marginata Willd.	3	2	0.13	0.47	0.07	0.67
Inga sessilis (Vell.) Mart.	1, 2, 3, 5, 7, 8	85	5.72	2.79	8.43	16.93
Machaerium nyctitans (Vell.) Benth.	5	2	0.13	0.47	0.1	0.7
Mimosa bimucronata (DC.) Kuntze	1, 2, 3, 5	34	2.29	1.86	2.18	6.33
Parapiptadenia rigida (Benth.) Brenan	6	4	0.27	0.47	0	0.74
Peltophorum dubium (Spreng.) Taub.	7	2	0.13	0.47	0	0.6
Piptadenia gonoacantha (Mart.) J. F. Macbr.	1, 2, 3	4	0.27	1.4	0.14	1.81
Poecilanthe parviflora Benth.	6, 7	8	0.54	0.93	0	1.47
Pterocarpus rohrii Vahl	5, 8	17	1.14	0.93	0.56	2.64
Schizolobium parahyba (Vell.) Blake	1, 2, 3, 5, 7	43	2.89	2.33	1.32	6.54
Senegalia polyphylla (DC.) Britton & Rose	1, 2, 3, 5	6	0.4	1.86	0.5	2.76
Senna multijuga (Rich.) H. S. Irwin & Barneby	3, 5 8	4	0.27	1.4	0.24	1.91
Senna pendula (Humb. & Bonpl. ex Willd.) H. S. Irwin & Barneby	6	3	0.2	0.47	0	0.67
Swartzia oblata R. S. Cowan	1	1	0.07	0.47	0.01	0.54
LAMIACEAE						
Aegiphila integrifolia (Jacq.) Moldenke	1, 4, 5	3	0.2	1.4	0.08	1.68
LAURACEAE						
Endlicheria paniculata (Spreng.) J. F. Macbr.	2	1	0.07	0.47	0.01	0.54
Nectandra megapotamica (Spreng.) Mez	4, 8	7	0.47	0.93	0.46	1.86
Persea willdenovii Kosterm	1	3	0.2	0.47	0	0.67
LECYTHIDACEAE						
Cariniana estrellensis (Raddi) Kuntze	1, 2, 3	4	0.27	1.4	0.12	1.78
LYTHRACEAE						
Lafoensia glyptocarpa Koehne	1, 7, 8	6	0.4	0.93	0.36	1.69
Lafoensia pacari A.St.-Hil.	6, 7	7	0.47	0.93	0.05	1.45
MALVACEAE						
Apeiba tibourbou Aubl.	6	1	0.07	0.47	0	0.53
Ceiba speciosa (A.St.-Hil.) Ravenna	1, 3, 4, 8	24	1.61	1.86	4.47	7.95
Guazuma ulmifolia Lam.	4, 5	39	2.62	0.93	6	9.55
Luehea divaricata Mart.	5, 6	15	1.01	0.93	0.33	2.27
Pachira aquatica Aubl.	1	1	0.07	0.47	0.03	0.57
Pseudobombax grandiflorum (Cav.) A. Robyns	1, 3, 4, 5	32	2.15	1.86	1.4	5.41
Talipariti pernambucense (Arruda) Bovini	5, 7, 9	85	5.72	1.4	11.14	18.25
MELIACEAE						
Cabralea canjerana (Vell.) Mart.	5	12	0.81	0.47	0.21	1.48

Table 2. Continued...

FAMILY/SPECIES	RESTORED AREAS	N Ind	Rel Den	Rel Fr	Rel Do	IVI
Cedrela fissilis Vell.	1, 5	5	0.34	0.93	0.41	1.67
Cedrela odorata L.	1	4	0.27	0.47	0.2	0.93
Guarea guidonia (L.) Sleumer	1, 3, 4	126	8.47	1.4	16.4	26.26
Guarea macrophylla Vahl	2	2	0.13	0.47	0.1	0.7
MORACEAE						
Ficus gomelleira Kunth	1	6	0.4	0.47	0.18	1.05
Ficus guaranitica Chodat	4	1	0.07	0.47	0.02	0.56
Ficus insipida Willd.	5	29	1.95	0.47	4.89	7.3
Ficus sp.	7	2	0.13	0.47	0.18	0.78
MYRTACEAE						
Eugenia brasiliensis Lam.	5	1	0.07	0.47	0.06	0.59
Eugenia uniflora DC.	2, 3, 7, 8	28	1.88	1.86	0.24	3.98
Plinia peruviana (Poir.) Govaerts	8	1	0.07	0.47	0.04	0.57
Psidium cattleyanum Sabine	1, 2, 3, 7, 8, 9	34	2.29	2.79	0.7	5.78
Psidium guajava L.	1, 3, 7	14	0.94	1.4	0.56	2.9
PHYLLANTHACEAE						
Hieronyma alchorneoides Allemão	5	2	0.13	0.47	0.05	0.65
POLYGONACEAE						
Triplaris americana L.	1, 3	2	0.13	0.93	0.02	1.09
PRIMULACEAE						
Ardisia humilis Vahl	8	13	0.87	0.93	0.34	2.14
Myrsine coriacea (Sw.) R.Br. ex Roem. & Schult.	5, 6	6	0.4	0.93	0	1.34
Myrsine umbellata Mart.	1, 4, 7	40	2.69	1.4	0.28	4.37
RHAMNACEAE						
Colubrina glandulosa Perkins	1, 2,	2	0.13	0.93	0.03	1.1
ROSACEAE						
Prunus myrtifolia (L.) Urb.	6	1	0.07	0.47	0.01	0.54
RUBIACEAE						
Genipa americana L.	1,4, 7	9	0.61	1.4	0.09	2.09
RUTACEAE						
Esenbeckia grandiflora Mart.	6	1	0.07	0.47	0.02	0.56
Murraya paniculata (L.) Jack	1	1	0.07	0.47	0.04	0.57
SAPINDACEAE						
Allophylus edulis (A.St.-Hil. et al.) Hieron. ex Niederl.	4	6	0.4	0.47	0.09	0.96
Matayba elaeagnoides Radlk.	1, 2	4	0.27	0.93	0.4	1.6
Sapindus saponaria L.	4, 7	35	2.35	0.93	0.22	3.5
Not identified	8	1	0.07	0.47	0.08	0.61
URTICACEAE						
Cecropia pachystachya Trécul	1, 2, 3, 4, 5, 7, 8, 9	82	5.51	3.72	5.65	14.89
VERBENACEAE						
Citharexylum myrianthum Cham.	1, 2, 3, 4, 5, 8	135	9.08	3.26	8.05	20.38
NOT IDENTIFIED	5, 6	1	0.07	0.47	0.02	0.56

The most representative families were Fabaceae (23 species) and Bignoniaceae (10 species). Regarding the number of individuals, Fabaceae is represented mainly by *I. sessilis* (81 individuals); Bignoniaceae is mainly represented by the exotic species *T. pentaphylla* (18 individuals) originally from Central America. Other species exotic to Brazil identified in the study areas, but with less ecological importance, are *A. humilis, H. actinophyllum, M. paniculata* and *P.* cf. *roebelenii.*

Among the planted species identified in the evaluated riparian areas, 71.42% (n=70) occur in Ombrophilous Forests. According to Flora e Funga do Brasil (2022), *T. cassinoides*, *H. umbellatus* and *C. robustum* are endemic to Ombrophilous Forests in the Atlantic complex. However, this species occur in other regions and vegetation types of Brazil (CRIA, 2022).

Regarding dispersal groups, 56.12% of the total identified species are zoochoric, 24.5% are anemochoric and 14.7% are autochoric. We could not identify 3.06% (n=3) among the total planted species due to the small size of the seedlings (inferior to 0.70 m). Most species (52.04%) are typical of secondary stages, but the proportion of pioneers individuals planted prevailed over secondary individuals in most restored riparian areas when each area was analyzed singly.

Distribution of number of species and number of individuals are very uneven between the riparian areas analyzed. Richness values range from nine species in Area 9 to 49 species in Area 1. *C. myrianthum* (Figure 2-A) was the most abundant species (135 individuals) and showed the highest relative density (9.08%) and relative frequency (3.26%). This species was found in most of restored riparian areas. In contrast, *G. guidonia* (Figure 2-B) showed the highest relative dominance (16.4%), highest IVI (26.26%) and the second relative density (8.47%). However, this species predominated in Area 1 (123 individuals) and showed relative frequency of 1.4%. *T. pernambucense* showed the second highest relative dominance (11.14%) due to the presence of 65 individuals planted in a single area (Area 7) (RelFre = 1.4%).

Among the planted species, 17 stand out for their relative values of density, frequency and dominance (Figure 3).

Figure 2. A. *Citharexylum myrianthum* - most abundant species. B. *Guarea guidonia* - dominant species.

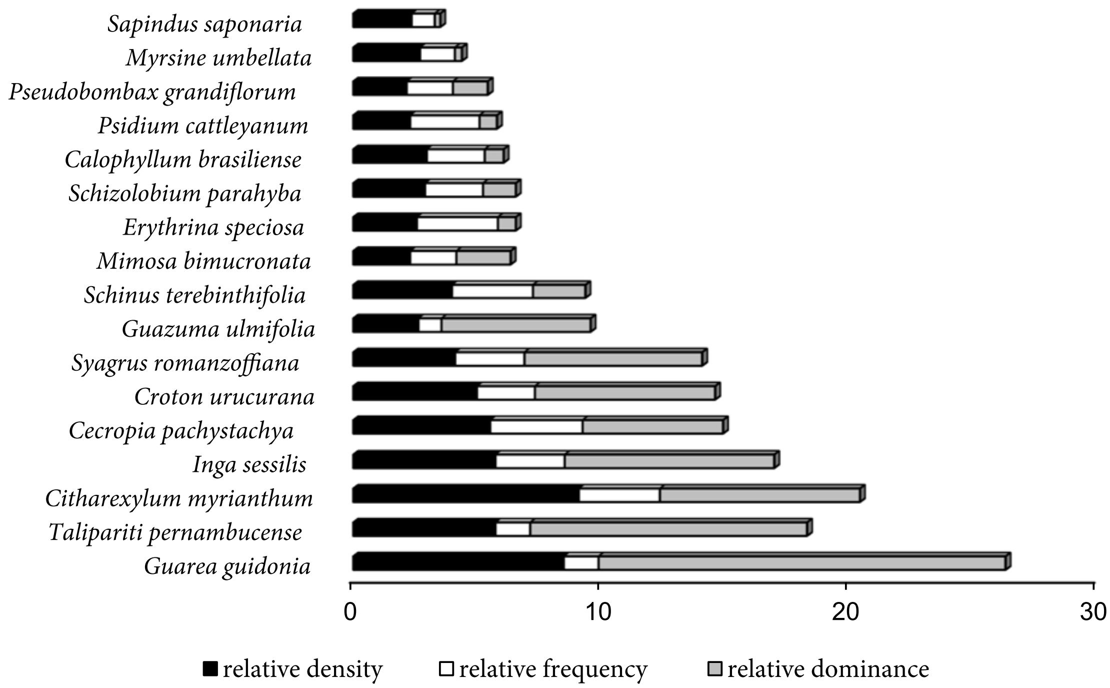

Figure 3. Relative density, frequency and dominance of the main species identified in restored riparian areas.

The most frequent species were *S. terebinthifolia* (3.97%), *C. pachystachya* (3.72%), *E. speciosa* (3.26%), *C. myrianthum* (3.26%), *I. sessilis* (2.79%), *S. romanzoffiana* (2.79%) and *P. cattleyanum* (2.79%). These species were identified in almost restored riparian areas, but just only *C. pachystachya* was planted in all areas. In addition to the presence of many specimens only in one area, 21 species identified in the restored riparian areas were represented by only one individual, as *A. tibourbou*, *E. grandiflora*, *E. brasiliensis*, *F. guaranitica*, *H. umbella*tus, *P. aquatica*, *P. peruviana*, *P. myrtifolia*, *T. obtusa, T. glabrescens* etc.

The majority of restored riparian areas showed a proportion inferior to 0.16% of threatened species. Four native species are vulnerable to extinction in Brazil (Brasil, 2022): *E. edulis*, *C. fissilis*, *C. odorata* and *T. cassinoides*. In São Paulo, *E. edulis*, *C. fissilis*, *C. odorata* are vulnerable to extinction and *T. cassinoides* is at risk of extinction according to Resolution No 57/2016 (São Paulo, 2016).

4. DISCUSSION

Our study showed that species that are exotic to the region and even to the country are being used in restoration projects required by Brazilian legislation. In addition, the low number of threatened species used, and the inadequate distribution of some species are harmful factors to restoration efforts and to the conservation of the Atlantic Forest. Planting of exotic species can cause ecological imbalances in the entire forest community (Brancalion et al., 2007), leading to local biological degradation (Reis et al., 2003). *H. actinophyllum*, for example, is considered invasive in Atlantic Forest (Instituto Hórus, 2020). *T. pentaphylla* is originally from Central America and is widely planted in urban landscaping; therefore, this species can be easily found in nurseries (Lorenzi, 2018).

Assis et al. (2013) also evidenced the planting of exotic species in 44 restored riparian forests on the central, northwest and southwest regions of the São Paulo State, such as *Syzygium cumini* (L.) Skeels and *Cordia myxa* L. (original from other countries). These authors, for instance, cited the planting of *Schizolobium parahyba* (Vell.) Blake (original from Dense Ombrophilous Forest) in this Seasonal Semideciduous Forest region. The problem is that even native species from Brazil can be considered exotic when planted outside of your extent of occurrence, since each different vegetation types have its own dynamics and floristic composition (Assis et al., 2013). In this study we found *T. pernambucense*, a typical species from mangrove areas (Stehmann et al., 2009; Lorenzi, 2016) represented by several individuals in Area 7. *L. pacari*, planted in two riparian areas, is originally from Cerrado (Lorenzi, 2016). For this reason, regional native species, especially ones typical of the local plant physiognomy, should be planted through forest restoration because they are more adapted to such environmental conditions and can contribute to the conservation of the region's diversity (Meli et al., 2017). These species have also a greater ability to attract pollinators and dispersers and can contribute to the recovery of the forest (Kageyama & Gandara, 2000).

Some studies have pointed out that achieving the highest possible species richness through planting is essential for a permanent forest restoration (Barbosa et al., 2003; Ribeiro et al., 2009), and increase of functional connectivity and for biodiversity conservation on a regional scale (Rodrigues et al., 2009; Brancalion et al., 2010). Rodrigues & Gandolfi (2004) also mentioned that high planted species richness in restored areas resulted in the maintenance of diversity, restored ecological processes, and led to the perpetuation of the environment. While the planting of a few species can form a forest cover in two or three years (Brancalion et al., 2019), the vegetation may in turn become biologically unviable and decline over the years due to a lesser capacity to offer ecosystem services (Brancalion et al., 2010).

Worldwide, high species richness has been long recognized as typical of riparian ecosystems (Pielech, 2021). Campos et al. (2011) and Joly et al. (2012) identified more than 130 species distributed in at least 38 families in riparian Atlantic Forest on the north coast of the São Paulo State. Therefore, the low number of species planted in riparian areas over the years may not lead to an increase in species richness. However, we must consider that the highest proportion of zoochory species identified in the analyzed riparian areas can accelerate the restoration processes due to the establishment of a plant-frugivore relationship as suggested by Morellato & Leitão-Filho (1992). In order to support ecological succession, the distribution of adequate proportions of pioneers and secondaries species in riparian areas needs to be carried out in compliance with Brazilian guidelines, such as the Resolution SMA No 32 that guide forest restoration in the São Paulo State (São Paulo, 2014).

Regarding the structure of riparian forests, *C. myrianthum* is abundant probably due to their availability in forest nurseries (Barbosa & Martins, 2003; Vidal & Rodrigues, 2019). According to Assis et al. (2013), *C. myrianthum* was the most abundant species in the restored riparian areas on the eastern, central, northwest and southwest regions of the São Paulo State. This species is recommended for restoration of riparian forests (Durigan et al., 2002) because it is typical of humid environments (Lorenzi, 2016). *Guarea guidonia* is a dominant species in riparian forests and has a lower frequency in dense vegetation cover (Lorenzi, 2016).

The planting of many individuals of *G. guidonia* and *T. pernambucense* in only one area can be a hamper to the development of other species. The increase in population growth rates of some native species can be much greater than that of the rest of the plant community and, consequently, this can favor the replacement of other native species. These species are called superdominant and can change vegetation structure, so impeding natural regeneration and allowing invasion of exotic species (Pivello et al., 2018). Species dominance might, therefore, reflect the environmental quality of restored sites through the years (Massi et al., 2022). However, it is important to highlight that the occurrence of species represented by few individuals is usual in the Atlantic Forest (Caiafa & Martins, 2010). Therefore, the reintroduction of species through enrichment plantings can provide intermediate populations and increase the persistence of species in the landscape (Banks-Leite et al., 2014).

This study identified only four threatened species in the restored areas: *E. edulis*, *C. fissilis*, *C. odorata* and *T. cassinoides*. The severity of biodiversity loss in the Atlantic Forest was estimated by Strassgburg et al. (2009) in 27-32% of endemic species threatened to extinction. However, the research conducted by Melo & Duran (2007) did not found threatened species in six restored areas in the São Paulo State, concluding then that restoration processes were performed only to recover the forest structure instead of biodiversity. A list prepared by Barbosa et al. (2017) proposes several threatened species that can be planted in Ombrophilous Forests, such as *Monteverdia brasiliensis* (Mart.) Biral and *Virola bicuhyba* (Schott ex Spreng) Warb.

The forest structuring phase occurs in up to 15 years, and the consolidation phase starts between 15 and 30 years. Thus, restoration phases should be ensured so that the forest can sustain itself, allowing the formation of communities (Brancalion et al., 2015). Based on these phases, monitoring is essential for an effective restoration. Furthermore, monitoring is an instrument for governments to decide which projects can be approved when restoration is mandatory to mitigate or compensate environmental impacts (Ruiz-Jaen & Aide, 2005).

The Secretariat for Infrastructure and Environment of the São Paulo State, through Resolution SMA No 32/2014 and Ordinance CBRN No 01/2015, stablishes protocols for analyzing the effectiveness of forest restoration, such as percentage of vegetation cover, richness, and density of regenerating native species (São Paulo, 2014; São Paulo, 2015).

5. CONCLUSIONS

Restoration of tropical forests with adequate floristic composition is essential to subsidize conservation of critical biodiversity hotspots such as the Atlantic Forest. Thus, the identification of planted species in restored areas is a necessary tool to promote awareness and to avoid the planting of exotic species in unbalanced proportions, specially of species that do not occur in the Atlantic Forest or in the vegetation physiognomy.

Regional native species should be preferably selected for planting in forest restoration areas to increase the functional connectivity of the landscape, and to contribute to the conservation of regional biodiversity. The restriction to planting native species that may hamper the colonization and development of other species may also contribute to an increase in local diversity, especially considering that some areas have become almost homogeneous forests of *G. guidonia* and *T. pernambucense*. For this reason, it is fundamental to adequately plant different native species to maximize the increase in species richness and, consequently, overall diversity.

Findings of this study have the potential to subsidize decision makers in the elaboration and implementation of restoration projects encouraging them to avoid the planting of exotic species, to consider the inadequate proportion of non-endemic species in the Atlantic Forest or the vegetation physiognomy.

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