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Structure and floristic diversity of remnant semideciduous forest under varying levels of disturbance

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ABSTRACT

The perturbation of Neotropical forests generates large disturbances in biological communities. The species that suffer least from the resulting habitat fragmentation are the pioneers, because they possess greater ability to inhabit disturbed environments. Therefore, it is expected that species diversity will be greater in areas subjected to intermediate disturbance, such as the opening of gaps, because a large number of pioneer species will develop and coexist with species of more advanced successional stages. This study aimed to compare two forest remnants that differed in size and disturbance intensity, in order to determine the effects of disturbances on species diversity and the size ratios of individual trees. This was accomplished with comparative analyses of diversity, richness and diameter ratios obtained for 10 plots at two semideciduous forest sites. We recorded a total of 85 species, of which 70 were in the private nature reserve Fazenda Santa Maria, 58 were in Iguaçu National Park, and 43 were at both sites. Diversity was greater in the more disturbed remaining forest, because this area showed higher species richness, which is in accordance with some premises of the intermediate disturbance theory. There was also an increase in the number of pioneer individuals, and the less disturbed area showed individuals with larger diameters, which is likely attributable to the removal of large individuals from the more disturbed area during the anthropogenic process of forest modification.

Key words: Intermediate disturbance, species richness, Neotropical forest, tree communities

Introduction

The constant disturbance of tropical forests, whether by natural events or human activities (destruction of vegetation and conversion or loss of habitat), has led to the fragmentation of these forests into small isolated patches. Disturbances occur more frequently in the fragments, drastically altering species richness, diversity and forest structure (Tanizaki-Fonseca & Moulton 2000; Campos 2006). Tropical forests in general have high spatial and temporal heterogeneity, which strongly influence species distribution patterns. Plant species in tropical forests grow and establish in a mosaic of different successional stages, whereby the distribution and density of plant populations are influenced by disturbance dynamics (Brokaw 1985; Young & Hubbell 1991).

Upon the occurrence of a natural disturbance in a forest, such as canopy openings or border effects, pioneer species increase in density in response to increased light availability. The same phenomenon occurs in response to anthropogenic disturbances such as selective logging or changes in land use, and varying intensities and frequencies of these disturbances have different effects on a plant community (Hill & Curran 2003; Laurance *et al.* 2006; Bongers *et al.* 2009). One observed effect is the decrease in diameter of trees and the occurrence of many small individuals (Gomes *et al.* 2004; Villela *et al.* 2006), due to the increased number of young individuals and pioneer species, and reduction of the number of large individuals by selective logging, for example. Such alterations in vegetation structure as a result of disturbance have been observed in several studies on effects of fragment size, edge dynamics, and canopy gaps on woody plant composition in the Atlantic Forest (Alves & Santos 2002; Bertoncini & Rodrigues 2008; Lopes *et al.* 2009; Oliveira *et al.* 2004; Oliveira *et al.* 2008; Ribeiro *et al.* 2009; Santos *et al.* 2008).

Considering those disturbances to the vegetation, it is expected that, as proposed in the intermediate disturbance theory (Connell 1978), higher species diversity may be maintained at moderate levels of disturbance frequency and intensity because superior competitors, which dominate communities at more advanced successional stages, are more susceptible to disturbance. Therefore, gaps are open for the development of pioneer species, which tolerate

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unfavorable conditions. Conversely, when disturbance levels are very high, after intense human intervention, for example, all species are at risk of being eliminated. This study therefore aimed to evaluate the effects of disturbance on tree species richness and diversity, as well as on the proportional distribution by diameter, in forest fragments, comparing two sites: a large area of continuous forest that is less disturbed; and a nearby forest fragment that is smaller and more heavily disturbed by human activities.

Material and Methods

Study area

To compare effects of increased disturbance on plant community in forest remnants, we selected two areas. One was a small private nature reserve, the Fazenda Santa Maria, hereafter referred to as the FSM, which was heavily disturbed, whereas the other was less disturbed, representing a large tract of more advanced stage forest, Iguaçu National Park (INP).

The FSM is located in the municipality of Santa Terezinha do Itaipu, in the state of Paraná, and covers 242 ha. This area has been protected since 1955 and was designated a private nature reserve in 1997. The fragment had suffered a moderate degree of human intervention prior to the year 1955, when several species of economic interest were extracted and forest loss in the surrounding land was pronounced. Therefore, edge effects are evident in the remnant, as are gaps caused by logging.

The INP is an ecological reserve in the southwestern region of the state of Paraná, created in 1939 and currently encompassing 185,262 ha (Salamuni *et al.* 2002). It contains patches of *Araucaria* forest (rain forest) and semideciduous forest (Veloso 1991; IBGE 2012).

Both sampled sites are fragments of semideciduous forest and are on the Third Paraná Plateau, near Foz do Iguaçu, with elevations ranging from 120 m to 540 m (Santos *et al.* 2006; Maack 2012). At both sites, the soils are red Oxisols and the climate is humid subtropical (Köppen type Cfa), with an annual mean temperature of 21.5°C and annual rainfall of approximately 1800 mm, of which two thirds are distributed from October to March, mainly in December and January (Bhering & Santos 2008; SIMEPAR 2011).

Sampling and Analysis

We installed 10 permanent plots using a 20 × 20 m spacing regime, for a total of 0.4 ha in each forest remnant. Plots were demarcated at a distance of approximately 400 m from the forest edge, preventing any clearing or trail opening. Plots in the INP were located between the coordinates 25°31'56.79"S;54°17'32.14"W and 25°31'55.56"S;54°17'22.61"W, and plots in the FSM were located between the coordinates 25°29'30.70"S;54°21'30.61"W and 25°29'32.94"S;54°21'41.36"W, and the distance between the two areas is approximately 8 km. Trees whose circumference at breast height (CBH) was ≥ 15 cm were included in the sampling, as per Rodrigues & Gandolfi (2004), as were bifurcated stems, if at least one had a diameter ≥ 15 cm. The selected individuals were numbered and observed monthly from September 2010 to November 2011, in order to sample the maximum number of species in flower.

When found, fertile specimens were collected, identified and processed using usual herbarium techniques (Mori *et al.* 1989; Bridson & Forman 2004). Voucher specimens were registered at Western Paraná State University Herbarium (code, UNOP). Sterile individuals were also collected, identified and added to a sterile collection in the UNOP Herbarium. For identification of the plant material, we used regional checklists, as well as identification keys, specific bibliography (Lorenzi 2002a, 2002b, 2010; Ramos *et al.* 2008) and comparison with specimens in the UNOP Herbarium and the Herbarium of the Curitiba Municipal Botanical Museum (code, MBM). The lists were produced with the botanical families organized according to the Angiosperm Phylogeny Group III guidelines (APG III 2009) and the species names and the authors organized according to the List of Species in the Flora of Brazil (Lista de Espécies da Flora do Brasil 2013).

We analyzed the data using the programs R, version 3.0.1 (R Development Core Team 2013), PAST (Hammer *et al.* 2001) and FITOPAC, version 2.1.2 (Shepherd 2010). Shannon diversity and evenness indices were obtained for the remnants, as were importance values (IVs) for each species. The IV is an outcome of phytosociological analysis, obtained by summing the percentages of relative density, relative frequency and relative dominance (Shepherd 2010). To compare diversity indices, we used Hutcheson's t-test (Hutcheson 1970; Zar 1999).

Rarefaction curves, with their respective 95% confidence intervals, were built according to the number of individuals, in order to compare the species richness estimated for both areas. Results of rarefaction curves constitute an unbiased comparison with other studies, because they are not influenced by variations in the density of individuals and can simulate small sample sizes (Colwell & Coddington 1994; Gotelli & Colwell 2001). Therefore, the curves were constructed to compare the estimated richness between sites, in case the sampling number were equal between them.

On the basis of data in the literature, were classified the species, by successional stage, as pioneer or non-pioneer species. As is well known, sites that are more disturbed, have canopy gaps or are under greater edge effects are colonized by greater numbers of species and individuals. Therefore, we made two calculations to determine the differences in patterns between the two sites: the chi-square test for total non-pioneer and pioneer species per site; and the chi-square test for proportions of individuals belonging to the pioneer and non-pioneer groups per site.

To examine the difference between the mean diameters in the studied fragments, we used the nonparametric Wilcoxon test at a 5% significance level to identify differences in distributions of tree diameters in the FSM and INP (Zar 1999). In addition, to determine the differences between the two sites, in terms of the diameter ratios, the number of individuals per class at intervals of 5 cm was calculated, as proposed by Soares *et al.* (2006), starting from a minimum inclusion diameter of 4.77 cm, corresponding to the minimum CBH of 15 cm.

Results

In the study area as a whole, we found a total of 1032 individuals belonging to 85 species (Tab. 1): 70 species were present in the FSM, 58 were present in the INP, and 43 were present at both sites. We sampled only one exotic species, *Citrus* X *aurantium*, which occurred in the INP.

The first 10 species, in order of IV, accounted for 50% of the total, reflecting a few species with high IVs. The species that were the most well represented, in terms of the number of individuals, were *Euterpe edulis*, *Sorocea bonplandii* and *Guarea kunthiana* (in both areas); *Chrysophyllum gonocarpum* and *Balfourodendron riedelianum* (in the FSM only); and *Citrus* X *aurantium* and *Trichilia catigua* (in the INP only).

The Shannon-Wiener diversity values were 2.71 for the IPN and 3.37 for the FSM (Tab. 2), and the difference between the two was statistically significant ($t=-6.48$, $p=1.33^{-11}$). The evenness values were 0.67 for the INP and 0.79 for the FSM. The higher richness in the FSM was observed in the rarefaction curves (Fig. 1).

As can be seen in Tab. 3, there was no significant difference between the two sites with respect to the number of species belonging to the analyzed successional groups, pioneer ($\chi^2=1.50$, $p=0.22$) and non-pioneer ($\chi^2=0.35$, $p=0.56$). Furthermore, the number of individuals belonging to the non-pioneer group did not differ between the two areas ($\chi^2=0.34$, $p=0.56$). However, the FSM had a significantly higher number of individuals of pioneer species than did the INP ($\chi^2=19.63$, $p=0.93^{-5}$) (Tab. 3).

The diameter class distribution was significantly different between the two sites ($W=110215.5$, $p=4.26^{-6}$). Despite the fact that individuals with a diameter < 15 cm accounted for 80% of the individuals in the FSM (n = 412) and 86% of the individuals in the INP (n = 447), the INP presented some specimens with a diameter > 70 cm, whereas the FSM did not (Fig. 2).

Discussion

The two analyzed areas shared important species for the Atlantic Forest Biome, such as *Aspidosperma polyneuron*, *Cedrela fissilis* and *Balfourodendron riedelianum*. These species are rare and endangered because they are attractive targets for illegal logging, which underscores the importance of preserving the remaining fragments of semideciduous forest (Hatschbach & Ziller 1995; Ribas *et al.* 2003; IUCN 2009).

Ten species collectively accounted for 50% of the total IV, and seven of those species occurred at both study sites. These high IVs may be related to large diameters, combined with a reasonable number of individuals, reflecting a higher basal area, as noted for *Aspidosperma polyneuron*, *Alchornea triplinervia*, *Cabralea canjerana* and *Chrysophyllum gonocarpum*, or to small diameters, combined with high numbers of individuals, as noted for *Euterpe edulis*; *Guarea kunthiana* and *Sorocea bonplandii*. In addition, excepting *G. kunthiana* and *S. bonplandii*, the five species with the highest IVs were also the most representative for basal area at both sites.

The Shannon-Wiener diversity indices differed between the INP and the FSM. Although other studies of semideciduous forest (Tab. 2) have yielded results consistent with those we obtained for the FSM, the index we obtained for the INP was lower than those reported in all of the studies we reviewed. The same pattern was observed for the evenness index for the INP, which was lower in the present study than in other studies, whereas the evenness index for the FSM was consistent with those of the same studies (Ivanauskas *et al.* 1999; Bianchini *et al.* 2003; Jurinitz & Jarenkov 2003; Silva *et al.* 2004; Costa-Filho *et al.* 2006; Prado-Júnior *et al.* 2011).

Connell (1978) proposed that higher species diversity is maintained under intermediate levels of disturbance. Such disturbances occurring at moderate frequency and intensity should promote increased environmental heterogeneity, because pioneer species coexist with species of more advanced successional stages (shade-tolerant species), thus increasing diversity. Therefore, it was not surprising that the more heavily disturbed FSM site, with a history of more intense human activity, had higher diversity and more individuals of pioneer species, which also directly affect diversity, than did the INP site, given that degradation and loss of natural habitat at intermediate levels enable a wider range of species to become established (Hunter 1996; Wilson 1997; Hernandez-Stefanoni 2005). Nunes *et al.* (2003) found similar results in a study conducted in a semideciduous forest, where the borders of fragments were more diverse than were the interiors, due to the emergence of light-demanding pioneer species. In dry areas of a tropical forest, similar to our study area, Bongers *et al.* (2009) showed that increases in pioneer species and diversity were interconnected with increased disturbance, supporting the theory of intermediate disturbance. However, the authors found that the occurrence of disorders did not significantly alter the diversity in wetlands.

We can conclude that the alterations caused by disturbances in the FSM did not lead to a significant increase in the richness of pioneer species, as would have been expected, but rather in the number of pioneer individuals compared to the pattern observed in the INP. Disturbed

Table 1. Families, species, number of individuals, successional groups and importance values of the analyzed fragments. Successional group (SG) of the species observed: pioneer (P) and non-pioneer (NP). Number of individuals for the species present in the Iguaçu National Park (INP) and Fazenda Santa Maria RPPN (FSM), basal areas for species in INP ((AB(INP)) and FSM (AB(FSM)) and importance values for species in INP (V(INP)) and FSM (V(FSM)).

Family	Scientific names	SG	INP	FSM	AB(INP)	AB(FSM)	V(INP)	V(FSM)
Anarcadiaceae	*Astronium graveolens* Jacq.	NP	0	3	0.00	0.14	0.00	0.77
Annonaceae	*Annona neosalicifolia* H.Rainer	NP	0	1	0.00	0.01	0.00	0.21
	Annona sylvatica A.St.-Hil.	P	1	4	0.03	0.39	0.30	0.95
Apocynaceae	*Aspidosperma polyneuron* Müll.Arg.	NP	5	13	1.58	1.52	3.04	3.68
	Aspidosperma tomentosum Mart.	NP	0	1	0.00	0.01	0.00	0.22
	Rauvolfia sellowii Müll.Arg.	NP	3	0	0.56	0.00	1.46	0.00
	Tabernaemontana fuchsiaefolia A. DC	P	0	1	0.00	0.03	0.00	0.23
Araliaceae	*Dendropanax cuneatus* (DC.) Decne. & Planch.	P	0	9	0.00	0.84	0.00	2.30
	Schefflera calva (Cham.) Frodin & Fiaschi	NP	0	3	0.00	0.11	0.00	0.73
Arecaceae	*Euterpe edulis* Mart	NP	159	125	2.33	2.58	15.04	12.18
	Syagrus romanzoffiana (Cham.) Glassman	NP	5	17	0.51	1.55	1.72	3.69
Bignoniaceae	*Jacaranda micrantha* Cham.	P	1	3	0.17	0.10	0.47	0.72
Boraginaceae	*Cordia americana* (L.) Gottschling & J.S.Mill.	NP	0	1	0.00	0.01	0.00	0.22
	Cordia ecalyculata Vell.	NP	2	13	0.04	0.41	0.56	2.26
Cannabaceae	*Trema micrantha* (L.) Blume	P	1	1	0.01	0.06	0.26	0.27
Cardiopteridaceae	*Citronella paniculata* (Mart.) R.A.Howard	NP	2	5	0.01	0.24	0.53	1.28
Caricaceae	*Jacaratia spinosa* (Aubl.) A.DC.	NP	0	9	0.00	0.63	0.00	1.95
Celastraceae	*Peritassa campestris* (Cambess.) A.C.Sm.	NP	0	1	0.00	0.03	0.00	0.23
Euphorbiaceae	*Actinostemon concolor* (Spreng.) Müll.Arg.	NP	4	2	0.03	0.00	0.49	0.44
	Alchornea triplinervia (Spreng.) Müll.Arg.	NP	12	11	1.48	2.43	3.95	3.93
Fabaceae	*Apuleia leiocarpa* (Vogel) J.F.Macbr.	NP	1	0	0.43	0.00	0.79	0.00
	Calliandra foliolosa Benth.	NP	1	1	0.02	0.02	0.29	0.23
	Enterolobium contortisiliquum (Vell.) Morong	NP	1	2	0.41	0.11	0.77	0.38
	Holocalyx balansae Micheli	NP	2	7	0.24	1.03	0.62	2.22
	Inga marginata Willd.	NP	7	3	0.19	0.03	1.85	0.65
	Inga striata Benth.	NP	1	1	0.01	0.02	0.27	0.23
	Lonchocarpus cultratus (Vell.) A.M.G.Azevedo & H.C.Lima	NP	1	11	0.13	0.79	0.42	2.24
	Lonchocarpus muehlbergianus Hassl.	NP	0	8	0.00	0.07	0.00	1.16
	Machaerium paraguariense Hassl.	NP	0	2	0.00	0.01	0.00	0.43
	Machaerium stipitatum Vogel	NP	2	4	0.02	0.17	0.54	1.00
	Mimosa bimucronata (DC.) Kuntze	P	0	2	0.00	0.21	0.00	0.63
	Parapiptadenia rigida (Benth.) Brenan	NP	6	2	0.58	0.27	1.87	0.69
	Peltophorum dubium (Spreng.) Taub.	NP	1	2	0.01	0.06	0.28	0.48
	Senegalia polyphylla (DC.) Britton & Rose	NP	0	3	0.00	0.47	0.00	1.11
Lamiaceae	*Aegiphila integrifolia* (Jacq.) Moldenke	P	2	4	0.40	0.16	0.81	0.70
Lauraceae	*Endlicheria paniculata* (Spreng.) J.F.Macbr.	NP	2	9	1.89	0.43	2.84	1.73
	Nectandra megapotamica (Spreng.) Mez.	NP	8	9	0.89	0.45	2.38	1.75
	Ocotea diospyrifolia (Meisn.) Mez	P	3	6	0.12	0.52	0.73	1.63
	Ocotea silvestris Vattimo-Gil	NP	7	1	0.40	0.15	2.10	0.36
	Ocotea puberula (Rich.) Nees	NP	0	1	0.00	0.31	0.00	0.52
Loganiaceae	*Strychnos trinervis* (Vell.) Mart	NP	1	2	0.01	0.00	0.27	0.44
Malvaceae	*Ceiba speciosa* (A. St.-Hil.) Ravena	NP	4	5	0.25	0.46	0.95	1.36
	Heliocarpus americanus L.	P	2	0	0.11	0.00	0.46	0.00

Continues.

Table 1. Continuation.

Family	Scientific names	SG	INP	FSM	AB(INP)	AB(FSM)	V(INP)	V(FSM)
Melastomataceae	*Miconia pusilliflora* (DC.) Naudin	NP	0	1	0.00	0.01	0.00	0.21
Meliaceae	*Cabralea canjerana* (Vell.) Mart.	NP	7	12	1.68	3.12	3.68	5.13
	Cedrela fissilis Vell.	NP	2	12	0.54	2.60	1.18	4.46
	Guarea guidonia (L.) Sleumer	NP	1	0	0.01	0.00	0.27	0.00
	Guarea kunthiana A.Juss.	NP	57	27	2.06	0.44	8.14	3.19
	Guarea macrophylla Vahl	NP	0	1	0.00	0.02	0.00	0.23
	Trichilia casaretti C.DC.	NP	0	1	0.00	0.02	0.00	0.23
	Trichilia catigua A.Juss.	NP	13	4	0.20	0.02	2.43	0.71
	Trichilia elegans A.Juss.	NP	2	0	0.01	0.00	0.53	0.00
	Trichilia pallida Sw.	NP	1	0	0.05	0.00	0.31	0.00
Moraceae	*Ficus insipida* Willd.	NP	3	0	0.69	0.00	1.62	0.00
	Maclura tinctoria (L.) D.Don *ex* Steud.	NP	9	3	1.19	0.42	3.01	1.05
	Sorocea bonplandii (Baill.) W.C.Burger *et al.*	NP	99	30	0.76	0.28	9.24	3.51
Myrsinaceae	*Myrsine umbellata* Mart.	NP	0	3	0.00	0.12	0.00	0.74
Myrtaceae	*Campomanesia guazumifolia* (Cambess.) O.Berg	NP	1	0	0.02	0.00	0.28	0.00
	Campomanesia xanthocarpa (Mart.) O.Berg	NP	1	8	0.01	0.70	0.27	1.94
	Eugenia burkartiana (D.Legrand) D.Legrand	NP	2	2	0.05	0.02	0.57	0.43
	Eugenia florida DC.	NP	0	1	0.00	0.00	0.00	0.21
	Eugenia ramboi D. Legrand.	NP	3	4	0.10	0.17	0.71	0.86
	Plinia rivularis (Cambess.) Rotman	NP	9	2	0.82	0.03	2.75	0.45
Peraceae	*Pera glabrata* (Schott) Poepp. *ex* Baill.	P	0	1	0.00	0.01	0.00	0.21
Phytolaccaceae	*Seguieria guaranitica* Speg.	P	1	1	0.01	0.02	0.26	0.23
Piperaceae	*Piper amalago* L.	NP	2	0	0.02	0.00	0.54	0.00
Rosaceae	*Prunus myrtifolia* (L.) Urb.	NP	0	4	0.00	0.51	0.00	1.21
Rutaceae	*Balfourodendron riedelianum* (Engl.) Engl.	NP	5	21	0.97	1.71	2.30	4.26
	Citrus X aurantium L.*	NP	22	0	0.75	0.00	3.89	0.00
	Pilocarpus pauciflorus A.St.-Hil.	NP	1	0	0.01	0.00	0.28	0.00
	Pilocarpus pennatifolius Lem.	NP	3	0	0.02	0.00	0.80	0.00
	Zanthoxylum caribaeum Lam.	NP	3	0	0.30	0.00	1.15	0.00
	Zanthoxylum petiolare A.St.-Hil. & Tul.	NP	0	2	0.00	0.01	0.00	0.29
Salicaceae	*Casearia decandra* Jacq.	NP	1	0	0.01	0.00	0.27	0.00
	Casearia sylvestris Sw.	NP	2	3	0.09	0.02	0.62	0.50
Sapindaceae	*Allophylus edulis* (A.St.-Hil. *et al.*) Hieron. *ex* Niederl.	P	1	4	0.03	0.15	0.30	0.84
	Diatenopteryx sorbifolia Radlk.	NP	4	0	2.59	0.00	4.03	0.00
	Matayba elaeagnoides Radlk.	NP	0	1	0.00	0.36	0.00	0.58
Sapotaceae	*Chrysophyllum gonocarpum* (Mart. & Eichler *ex* Miq.) Engl.	NP	9	34	1.06	3.63	2.86	7.37
	Chrysophyllum marginatum (Hook. & Arn.) Radlk.	NP	4	8	0.04	0.31	0.89	1.54
Solanaceae	*Cestrum bracteatum* Link & Otto	P	0	1	0.00	0.01	0.00	0.22
	Solanum argenteum Dunal	P	0	1	0.00	0.03	0.00	0.24
Urticaceae	*Cecropia pachystachya* Trécul	P	3	7	0.13	0.21	0.74	1.52
	Urera baccifera (L.) Gaudich. *ex* Wedd.	P	0	6	0.00	0.08	0.00	0.89
Violaceae	*Hybanthus bigibbosus* (A.St.-Hil.) Hassl.	NP	0	1	0.00	0.36	0.00	0.58
Total			518	514	27.08	32.22	100.00	100.00

* Exotic species

Table 2. Comparision of the parameters for both analyzed areas, as well as the values obtained in other studies conducted in Seasonal Semideciduous Forest remnants. Size of the sampling site in hectares (Area), circumference at breast height (CBH) used as inclusion criteria, bulk density (D) in individuals per hectare, Shannon-Wiener diversity (H') and evenness (J') for the sampling sites.

This work					
Local	**Area**	**CBH**	**D**	**H'**	**J'**
FSM	0.4	>15	1285	3.36	0.79
INP	0.4	>15	1295	2.71	0.67
Other studies conducted in Seasonal Semideciduous Forest					
Local/Reference	**Area**	**CBH**	**D**	**H'**	**J'**
Fazenda Santa Irene – SP (IVANAUSKAS *et al.*, 1999)	0.42	>15	2271	3.77	0.82
Parque Estadual Mata dos Godoy– PR (BIANCHINI *et al.*, 2003)	0.5	>15	1824	3.44	-
Serra do Sudeste – RS (JURINITZ e JARENKOV, 2003)	1	>16	2236	3.20	0.76
Zona da Mata Mineira – MG (SILVA *et al.*, 2004)	0.5	>15	2786	3.56	0.74
Estação Ecológica do Caiuá – PR (COSTA-FILHO *et al.*, 2006)	2.25	-	1239	3.32	0.77
Reserva Legal da Fazenda Irara – MG (PRADO-JÚNIOR *et al.*, 2011)	1	>15	-	3.47	0.81

areas are expected to show a pattern in which individuals in the smaller diameter classes are more numerous and there are fewer large trees. Individuals with a diameter < 15 cm predominated in the FSM and INP (respectively accounting for 80% and 86% of the total), this pattern (many individuals in the smaller diameter classes) being commonly observed in tropical forests (Meyer 1952). However, we observed a significant difference in the diameter distribution between the two sites, individuals with a CBH > 70 cm being found only in the INP. Although the FSM has a history of human disturbance, no timber extraction or other type of human activities has taken place there in the last 60 years. Nevertheless, this lack of large individuals may be due to mortality of older, larger individuals after intense disturbance or by timber extraction, as observed in remnants of Amazon rain forest (Laurance *et al.* 2000) and submontane Atlantic Forest (Carvalho & Nascimento 2009). Therefore, the exclusion of individuals of the canopy could favor an increase in the number of small individuals, suggesting that there was a change in the successional processes and in the current structural conformation in this forest fragment.

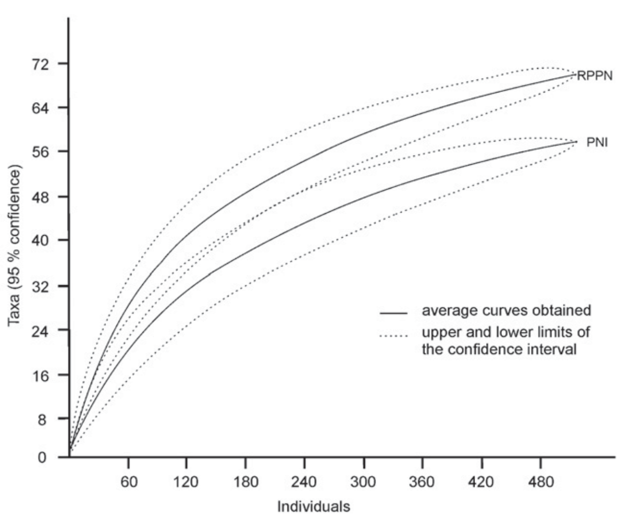

Figure 1. Rarefaction curves for the private nature reserve Fazenda Santa Maria (FSM) site and the Iguaçu National Park (INP) site, showing the relationship between the number of tree species and number of individuals sampled. Continuous lines indicate observed values, whereas dotted lines represent the upper and lower limits of the confidence interval.

The results obtained in the present study seem to agree with some premises of the intermediate disturbance theory, showing, as expected, an increase in diversity in the area with a known history of disturbance (the FSM) in relation to a more conserved one (INP). It would be useful to investigate a third area, with very high disturbance, to have a comparative that could confirm the hypothesis, because other potential determinants were not evaluated. In the FSM, the increased diversity is related to the increase in species richness. The FSM also showed a pattern of individuals in the smaller diameter classes, which is likely attributable to the extraction of large individuals during the anthropogenic process of forest modification.

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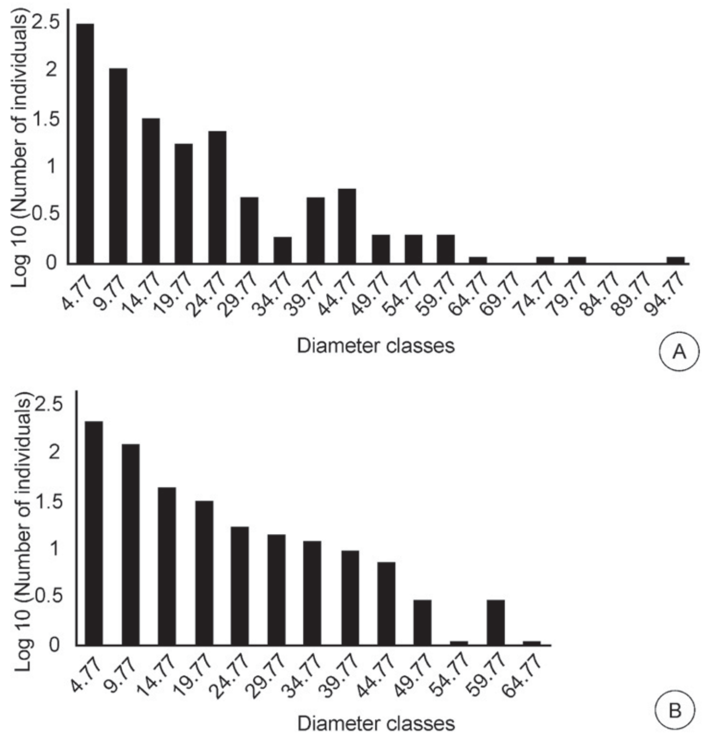

Figure 2. Diameter class distribution at intervals of 5 cm at the two sampling sites: a) Iguaçu National Park (INP) and b) the private nature reserve Fazenda Santa Maria (FSM).

Table 3. Number of species for successional groups: pioneers and non-pioneers; number of individuals for successional groups: pioneer and non-pioneer for Iguaçu National Park (INP) and Fazenda Santa Maria RPPN sites. According to values obtained by chi-square and p. Numbers followed by * differed significantly from the number in the same column with $p<0.05$ using the chi-square (χ^2) test.

	Pioneers species	Non-pioneers species	Pioneers individuals	Non-pioneers individuals
INP	9	49	15	481
FSM	15	55	51*	463
χ^2	1.50	0.35	19.63	0.34
p	0.22	0.56	0.93^{-5}	0.56

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