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Mixed rain forest in southeastern Brazil: tree species regeneration and floristic relationships in a remaining stretch of forest near the city of Itaberá, Brazil

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ABSTRACT

The aim of this work was to evaluate the floristic composition, richness, and diversity of the upper and lower strata of a stretch of mixed rain forest near the city of Itaberá, in southeastern Brazil. We also investigated the differences between this conservation area and other stretches of mixed rain forest in southern and southeastern Brazil, as well as other nearby forest formations, in terms of their floristic relationships. For our survey of the upper stratum (diameter at breast height [DBH] ≥ 15 cm), we established 50 permanent plots of 10 × 20 m. Within each of those plots, we designated five, randomly located, 1 × 1 m subplots, in order to survey the lower stratum (total height ≥ 30 cm and DBH < 15 cm). In the upper stratum, we sampled 1429 trees and shrubs, belonging to 134 species, 93 genera, and 47 families. In the lower stratum, we sampled 758 trees and shrubs, belonging to 93 species, 66 genera, and 39 families. In our floristic and phytosociological surveys, we recorded 177 species, belonging to 106 genera and 52 families. The Shannon Diversity Index was 4.12 and 3.5 for the upper and lower strata, respectively. Cluster analysis indicated that nearby forest formations had the strongest floristic influence on the study area, which was therefore distinct from other mixed rain forests in southern Brazil and in the Serra da Mantiqueira mountain range.

Key words: *Araucaria angustifolia*, Cluster analysis, ecotone, phytogeography, phytosociology

Introduction

When attributed to mixed rain forest, the term "mixed" refers to the presence of the gymnosperms *Araucaria angustifolia* (Bertol.) Kuntze (Brazilian pine) and *Podocarpus lambertii* Klotzsch ex Endl. (pinheiro-bravo) in association with primitive angiosperm genera, such as *Drimys* (Winteraceae), as well as *Ocotea*, *Cryptocarya* and *Nectandra* (Lauraceae). Klein (1960) divides Araucaria ecosystems into various successional stages, attributing the term "mixed forest" to their more mature stage. Veloso (1991) attributes the term "mixed rain forest" to all ecosystems containing *A. angustifolia*, which is always associated with broadleaf species. Rizzini (1997) supports the classification made by Klein (1960), stating that Araucaria forests represent the intermediate successional stage of mature forests without Araucaria. Therefore, there is no consensus on the classification of Araucaria forests. According to Jarenkow & Budke (2009), although the physiognomy might suggest some uniformity due to the occurrence of emergent Araucaria, floristic and phytosociological inventories reveal particular distinctions throughout the various Araucaria forests.

A large part of the remaining fragments of mixed rain forest in the state of São Paulo is located in the southern region of the state, near the state of Paraná, in the Upper Paranapanema River watershed. These fragments collectively cover an estimated 131 ha, only 14% of which corresponds to primary forest. The remainder consists of forest refuges at high altitudes in the Serra do Mar and Mantiqueira mountain ranges, accounting for 42,805 ha, only 39% of which is primary forest (Klein 1960; Veloso *et al.* 1991).

The current critical state of conservation of the mixed rain forest in Brazil calls for the collection of basic information about the composition, structure, richness and successional dynamics of its physiognomy, as well as the expansion of knowledge regarding the floristic and structural variations among the various stretches within its natural range, in order to inform decision-making regarding the conservation and

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restoration of these ecosystems, thus increasing the chances of success in the long term. However, such aspects merit in-depth scientific investigation, especially for stretches of forest in the state of São Paulo.

The purpose of this study was to characterize the floristic composition, richness and diversity of the upper and lower strata of a stretch of Araucaria forest in the state of São Paulo, investigating the floristic similarity between them. In addition, we sought to arrive at a more realistic classification of the vegetation in the area, taking into account the floristic composition of the current upper stratum and possible trajectories revealed by the lower stratum, not just its physiognomic character (mainly of the canopy). In short, we attempted to assess whether the fragment under study exhibited sufficient species richness (of trees and shrubs) to classify it as a typical remnant of mixed rain forest, investigating its floristic relationship with stretches of the same formation in southern Brazil and within the same state (São Paulo), in addition to surveys in the dense rain forest, semideciduous seasonal forest and deciduous forest within the state.

Materials and methods

Study area

The study was conducted at the Itaberá Ecological Station (located in the municipality of Itaberá, in the state of São Paulo), which is operated by the São Paulo State Forestry Institute and was created by decree (State Decree no. 26.890/1987). The area is located in the watershed of the Upper Paranapanema River, in the southern region of the state (23°50’47”S; 49°08’39”W). The Station preserves a fragment of mixed rain forest of approximately 180 ha drained by three tributaries of the Ribeirão das Lavrinhas River, at altitudes ranging from 680 m to 710 m.

The climate is temperate, without a true dry season (Cfb in the Köppen climate classification system). The hottest month is February, during which the average temperature is 22.5°C, and the lowest temperatures are observed between May and August, the monthly averages then ranging from 15.0°C to 16.7°C (observations from 1979 to 1990; Sentelhas *et al.* 1999). The average annual rainfall is 1405 mm, with monthly rainfall averages ranging from 47 mm in July to 184 mm in January, according to data from the Apiaí weather station, which is the weather station closest to the study area (Souza 2008).

In the interfluves of the area, there is red latosol (oxisol), red nitosol in the steeper areas and gleysol at the valley floors (Novais *et al.* 2009). The vegetation matrix of the region is composed of agricultural crops on gently curving terraces, which allows the mechanization of the various stages of production, interspersed with rangeland, forest plantations and small isolated fragments of forest. In the forest inventory of the state of São Paulo (Kronka *et al.*2005), the vegetation of the area was officially classified as mixed rain forest.

Sampling and data collection

For the phytosociological inventory, we selected an area that was relatively uniform in terms of topography and soil conditions (interfluves with gentle slopes, on red latosol), representative of the predominant condition of the Station. The area selected was in the interior of the fragment under study and thus free from the interference of the edge effect.

For our survey of the upper stratum, we established 50 permanent plots of 10 × 20 m, arranged contiguously and totaling 1 ha. We defined the upper stratum as trees and shrubs with a diameter at breast height (DBH, 1.3 m) ≥ 15 cm. For individuals ranging below breast height, we included only those that met the inclusion criterion for at least one of their branches.

To survey the lower stratum, we established, within each 10 × 20 m plot, five 1 × 1 m subplots, totaling 250 m² of the sample area (Fig. 1). The positioning of subplots was drawn by lot of coordinates of the upper left vertex, taking as reference the sides of the 10 × 20 m plot, known as Cartesian axes. To measure these coordinates in the field, we used a vertex. We sampled all tree or shrub individuals that were ≥ 30 cm in height and had a DBH < 15 cm.

Most of the individuals sampled in the upper and lower strata were identified in the field. When that was not possible, we collected botanical material and recorded dendrological characteristics (bark, flower/fruit color, scent, presence of exudates, etc.) for later identification. Aiming to expand the floristic survey, we also walked cross-country and drove motor vehicles along the principal trails of the Station to collect reproductive material of species that were or were not present in the phytosociological inventory plots.

All botanical material was duly numbered, arranged in presses, dehydrated and delivered to the Forest Ecology Sector of the São Paulo Forestry Institute, where it was identified through comparisons with materials at the Dom Bento Pickel Herbarium (code, SPSF), as well as by consulting experts of recognized competence and the specialized literature. The fertile specimens were incorporated into the collection of the same herbarium. We adopted the classification system proposed by the Angiosperm Phylogeny Group (APG III, 2009).

In order to assess the statistical power of the sampling used in each component, we plotted species accumulation curves by re-sampling individuals, with 10,000 interactions and 95% confidence intervals (Gotelli & Colwell 2001).

Statistical analysis

For both strata, we estimated the Shannon diversity index (H’, using a neperian logarithm and 95% jackknife confidence intervals), Pielou’s evenness index (J’; Pielou 1966) and the Jentsch mixture coefficient (MC; Hosokawa 1981). For this analysis, we used the Mata Nativa software (Cientec 2004).

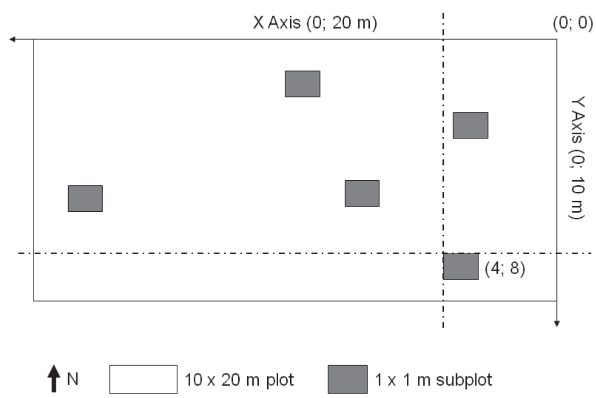

Figure 1. Sketch showing the location of five 1 × 1 m subplots within a 10 × 20 m plot (multi-level sampling), in a fragment of mixed rain forest at the Itaberá Ecological Station, Itaberá, in the state of Sãoa Paulo, Brazil. The dashed line shows the position of a subplot, selected by random drawing of coordinates of the upper left vertex, the reference points being the sides of the 10 × 20 m plot, which were taken as Cartesian axes.

We analyzed the floristic similarity between the upper and lower strata in order to detect possible changes between the current floristic composition, revealed by species present in the upper stratum, and possible trajectories associated with natural regeneration dynamics in the study area, inferred from the lower stratum. In this analysis, we used the Sorensen and Jaccard similarity indices.

In order to investigate the floristic relationship between the Itaberá Ecological Station and other stretches of mixed rain forest in southern and southeastern Brazil, as well as other formations surrounding the Station, we selected 52 phytosociological surveys conducted in the three southern states other than São Paulo, in upper montane, montane and submontane environments (Table 1). We gave preference to surveys with a minimum of one hectare of sampling area in which the inclusion criterion was DBH ≥ 4.8 cm. Nevertheless, due to the small number of and limited access to such studies, we considered some surveys that did not meet our requirements in terms of the sampling area and the inclusion criterion.

Based on floristic lists of each work, we prepared a binary presence/absence matrix, with species listed in rows and areas in columns. We included only the data related to specimens identified down to the species level, and we consulted the Botanical Garden of Rio de Janeiro (2010) to update the scientific names of species, including the occurrence of synonyms. The classification method used was hierarchical cluster analysis, which generates a dendrogram showing a hierarchical organization of the groups formed. As the coefficient, we used the Jaccard similarity index, with an agglomerative algorithm (the unweighted pair group method with arithmetic mean). In this analysis, we used the FITOPAC 1 software (Shepherd 1995).

To identify threatened species at the Itaberá Ecological Station, we consulted the Official List of Threatened Species in the State of São Paulo, issued by the São Paulo State *Secretaria do Meio Ambiente* (SMA, Department of the Environment; Resolution no. 48; São Paulo 2004), the Official List of Endangered Species in Brazil, issued by the *Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis* (IBAMA, Brazilian Institute for the Environment and Renewable Natural Resources; Directive no. 37; IBAMA 1993) and the International Union for Conservation of Nature (IUCN) Red List of Globally Threatened Species (IUCN 1994/2001). This analysis aimed to determine the relevance of this area of full protection of target plant populations, considering the critical state of conservation of the mixed rain forest in São Paulo.

Results and Discussion

Floristic composition

In the upper stratum, we sampled 1429 trees and shrubs belonging to 134 species, 93 genera and 47 families, one individual being identified only down to the genus level. In the lower stratum, we sampled 758 individuals belonging to 93 species, 66 genera and 39 families, one individual being identified only down to the family level only and another being identified only down to the genus level. In the upper and lower strata, we sampled, respectively, 75 and 4 standing dead individuals (5.25% and 0.53% of the total). In the phytosociological survey as a whole, we identified 161 species belonging to 104 genera and 51 families.

As of the 46th plot and 224th subplot in the upper and lower strata, respectively, the collector curve showed some stabilization, indicating the statistical power of the sampling. However, through the floristic survey conducted on several Station trails, we collected 16 species not sampled in the phytosociological survey, belonging to 16 genera and 13 families. Therefore, the total number of species recorded at the Itaberá Ecological Station in the present study rose to 177, representing 106 genera and 52 families (Table 2). The species that were exclusive to our floristic survey accounted for 8.9% of the species observed, which demonstrates its additional contribution to the knowledge of the local flora. This information could inform decisions regarding future management plans, forest restoration projects in surrounding areas, and environmental education initiatives aimed at raising awareness among the population about the need to and importance of preserving these last living witnesses to the original landscape.

The most species-rich families in the upper stratum were Lauraceae and Myrtaceae (12 species each); Rubiaceae (8 species); Euphorbiaceae, Fabaceae-Faboideae, Meliaceae and Salicaceae (6 species each); and Fabaceae-Mimosoideae, Rutaceae and Sapindaceae (5 species each). In the lower stratum, these were Myrtaceae (10 species); Rubiaceae (8 species); Melastomataceae (6 species); Meliaceae (5 species); and Fabaceae-Faboideae, Lauraceae, Fabaceae-Mimosoideae, Sapindaceae and Solanaceae (4 species each). It is of note that there was an abundance of families represented by a

Table 1. Phytosociological surveys used for floristic comparison among areas of mixed rain forest, dense rain forest, semideciduous seasonal forest and deciduous seasonal forest in the Brazilian states of São Paulo, Paraná, Santa Catarina and Rio Grande do Sul.

LC	Reference	Municipality - state	CF	Lat	Long	Alt	DBH	SR
AP	Godoy 2001	Apiaí and Iporanga - SP	MD	-	-	600	4.8	49
AP1	Godoy 2001	Apiaí and Iporanga - SP	MD	-	-	600	4.8	44
AP2	Godoy 2001	Apiaí and Iporanga - SP	MD	-	-	670	4.8	92
BC	Souza 2008	Barra do Chapéu - SP	MM	24°28’	49°01’	900	4.8	123
CB	Custódio Filho 2002	Capão Bonito - SP	MD	24°00’	48°00’	600	10.0	88
CÇ	Negrelle *et al*. 1992	Caçador - SC	UM	26°47’	51°01’	1100	5.0	43
CJ1	Los 2004	Campos do Jordão - SP	UM	22°45’	45°30’	1467	5.0	120
CJ2	Souza 2008	Campos do Jordão - SP	UM	22°41’	45°27’	1500	4.8	58
CM	Cielo Filho & Santin 2002	Campinas - SP	MS	22°53’	47°04’	685	4.8	105
CR	Rondon Neto *et al*. 2002(a)	Criúva - RS	MM	29°00’	55°56’	860	5.0	37
CS	Formento *et al*. 2004	Campo Belo do Sul - SC	UM	28°00’	50°49’	1017	3.3	70
CT1	Rondon Neto *et al*. 2002 (b)	Curitiba - PR	MM	25°26’	49°14’	-	5.0	77
CT2	Kozera *et al*. 2005(a)	Curitiba - PR	MM	-	-	900	3.3	103
CT3	Kozera *et al*. 2005(b)	Curitiba - PR	MM	-	-	900	10.0	77
GA	Durigan *et al*. 2000	Gália - SP	MS	22° 24’	49°42’	600	5.0	62
GC	Watzlawick *et al*. 2005	General Carneiro - PR	MM	26°26’	51°25’	900	3.3	39
GP1	Cordeiro & Rodrigues 2007	Guarapuava -PR	UM	25°21’	51°28’	1070	4.8	45
GP2	Silva 2003	Guarapuava -PR	UM	25°21’	51°28’	1100	4.8	55
GP3	Silva 2003	Guarapuava -PR	MM	25°21’	51°28’	-	4.8	42
IG	Ivanauskas *et al*. 1999	Itatinga - SP	MS	23°17’	48°33’	580	4.8	97
IT	Este estudo 2011	Itaberá - SP	MM	23°50’	49°08’	680	4.8	135
MC	Tomasulo & Cordeiro 2000	Mogi das Cruzes - SP	MD	-	-	810	4.8	133
NP	Nascimento *et al*. 2001	Nova Prata - RS	MM	28°56’	51°53’	660	9.5	55
PI	Seger *et al*. 2005	Pinhais - PR	MM	25°24’	49°07’	900	5.0	41
PR	Ivanauskas & Rodrigues 2000	Piracicaba - SP	SDM	22°39’	47°39’	554	4.8	110
RG1	Nascimento 1994	Ribeirão Grande - SP	MD	24°16’	48°25’	-	4.8	23
RG2	Nascimento 1994	Ribeirão Grande - SP	MD	24°16’	48°25’	-	4.8	52
RG3	Nascimento 1994	Ribeirão Grande - SP	MD	24°16’	48°25’	-	4.8	33
SA1	Mantovani *et al*. 1991	Salesópolis - SP	MD	-	-	850	4.8	29
SA2	Mantovani *et al*. 1991	Salesópolis - SP	MD	-	-	830	4.8	39
SA3	Mantovani *et al*. 1991	Salesópolis - SP	MD	-	-	840	4.8	42
SA4	Mantovani *et al*. 1991	Salesópolis - SP	MD	-	-	850	4.8	46
SB1	Dias 2004	Sete Barras - SP	MD	24°00’	47°55’	-	5.0	155
SB2	Dias 2004	Sete Barras - SP	MD	24°00’	47°55’	-	5.0	157
SB3	Aguiar 2003	Sete Barras - SP	MD	24°03’	47°59’	800	5.0	108
SB4	Dias *et al*. 2000	Sete Barras - SP	MD	24°00’	47°45’	-	10.0	152
SC	Silva & Soares 2002	São Carlos - SP	MS	21°55’	47°48’	850	5.0	77
SF1	Sonego *et al*. 2007	São Francisco de Paula - RS	MM	29°27’	50°25’	923	5.0	41
SF2	Sonego *et al*. 2007	São Francisco de Paula - RS	MM	29°27’	50°25’	923	10.0	41
SJ1	Durigan 1999	São João do Triunfo - PR	MM	25°34’	50°05’	780	10.0	51
SJ2	Sanqueta *et al*. 2002	São João do Triunfo - PR	MM	25°34’	50°05’	780	10.0	65
SJC	Silva 1989	São José dos Campos - SP	MD	23°12’	45°52	640-1040	4.8	195

Continues

Table 1. Continuation.

LC	Reference	Municipality - state	CF	Lat	Long	Alt	DBH	SR
SL1	Tabarelli *et al.* 1994	São Luiz do Paraitinga - SP	DM	24°21'	46°30'	-	3.2	36
SL2	Tabarelli *et al.* 1994	São Luiz do Paraitinga - SP	MD	24°21'	47°30'	-	3.2	36
SM1	Dias 1993	São Miguel Arcanjo - SP	MD	-	-	760	10.0	152
SM2	Custodio Filho 2002	São Miguel Arcanjo - SP	MD	24°00'	48°00'	1000	10.0	69
SM3	Custodio Filho 2002	São Miguel Arcanjo - SP	MD	24°00'	48°00'	800	10.0	78
SM4	Rodrigues *et al.* 2004	São Miguel Arcanjo - SP	DS	24°00'	47°45'	350	5.0	205
SM5	Lima & Moura 2006	São Miguel Arcanjo - SP	MD	24°20'	47°44'	700-900	4.8	156
SP	Baitello *et al.* 1992	São Paulo - SP	MD	23°22'	46°26'	850-1200	10.0	140
SR	Leite & Rodrigues 2008	São Roque - SP	MS	23°31'	47°06'	850-1025	4.8	117
UB1	Sanchez 1999	Ubatuba - SP	MD	-	-	600	4.8	106
UB2	Sanchez 1999	Ubatuba - SP	MD	-	-	1000	4.8	91

LC – location code; SP – São Paulo; PR – Paraná; SC – Santa Catarina; RS – Rio Grande do Sul; CF – class formation; MM – montane mixed rain forest; UM – upper montane mixed rain forest; MD – montane dense rain forest; SD – submontane dense rain forest; MS – montane semideciduous seasonal forest; MDS – montane deciduous seasonal forest; SR – species richness. Lat – latitude (south); Long. - longitude (west); Alt – Altitude (in m); DBH – Diameter at breast height (in cm), breast height being defined as 1.30 m.

single species — 21 (44.7%) of those in upper strata and 19 (48.7%) of those in the lower strata. In the upper stratum, Moraceae, Myrtaceae, Rubiaceae, Meliaceae and Arecaceae accounted for 11.6%, 11.3%, 6.4%, 6.3%, and 5.2% of the individuals sampled, respectively). The predominance of these families is largely due to high relative densities observed for *Sorocea bonplandii* (11.5%), *Eugenia ligustrina* (6.1%), *Rudgea jasminoides* (3.4%), *Trichilia catigua* (3.1%) and *Syagrus romanzoffiana* (3.7%), respectively. In the lower stratum, Rubiaceae, Moraceae, Myrtaceae, Rutaceae and Meliaceae accounted for 32.2%, 13.5%, 11.5%, 6.8%, and 5.0% of the individuals sampled, respectively. The species *Psychotria suterella* (19.1% of the total), *S. bonplandii* (13.5% of the total) and *Helietta apiculata* (4.5% of the total) accounted for more than half of the individuals identified in their respective families (Rubiaceae, Moraceae and Rutaceae). In addition, *Faramea montevidensis* and *Rudgea* cf. *jasminoides*, respectively, accounted for 6.5% and 3.7% of the Rubiaceae identified, whereas *Eugenia ramboi* (4.75%) was the most common Myrtaceae. Among the Meliaceae, no single species was predominant.

The most species-rich genera in the upper stratum were *Ocotea* and *Nectandra* (8 species and 3 species, respectively accounting for 66.7% and 25.0% of the Lauraceae species); *Casearia* (4 species, 66.7% of the Salicaceae); *Eugenia* and *Myrcia* (4 species each, both accounting for 33.3% of the Myrtaceae); *Machaerium*, (4 species, 66.7% of the Leguminosae); *Trichilia* (4 species, 66.7% of the Meliaceae); *Solanum* (3 species, 75.0% of the Solanaceae) and *Zanthoxylum* (3 species, 60.0% of the Rutaceae). In the lower stratum, these were *Eugenia*, *Miconia* and *Trichilia* (5 species, 5 species and 4 species, accounting for 50.0%, 83.3% and 80% of the Myrtaceae, Melastomataceae and Meliaceae, respectively). Therefore, only two of the nine genera that were prominent in the upper stratum were also prominent in the lower stratum.

Of the species sampled in both strata, nine are under some degree of threat regarding their conservation: *Chionanthus filiformis*, *Ilex paraguariensis*, *Mollinedia argyrogyna* and *Solanum bullatum*, all four of which are classified as being dependent on conservation measures (IUCN 1994); *A. angustifolia* , classified as vulnerable (SMA 2004), endangered (IBAMA 1993) or critically endangered (IUCN 2001); *Euterpe edulis*, classified as vulnerable (SMA 2004) or endangered (IBAMA 1993); *Aspidosperma polyneuron* and *Cedrela fissilis*, both classified as endangered (IUCN 1994); and *Aspidosperma tomentosum*, classified as endangered (SMA 2004). The occurrence of these species in the fragment studied underscores their ecological importance, contributing to the conservation of their populations, although *E. edulis* is not a native species, according to reports by former employees of the Station. Those former employees informed us that the species was deliberately introduced in the 1960s, and, after having established itself, expanded throughout the forest. It is noteworthy that the limiting the size of continuous protected areas can have a negative effect on the maintenance of species that are rare or have been overexploited in the past, especially those with intrinsic dispersion difficulty over long distances. It is known that many plant species in forests that are at an advanced successional stage produce large seeds or fruits that are in turn dispersed by a small number of larger animals, which also require well-maintained and relatively extensive continuous stretches of forest for their survival (Galetti *et al.* 2010). All species listed, with the exception of *E. edulis* and *A. polyneuron*, were represented by less than 10 individuals in each of the strata.

Rare species, i.e., those sampled from a single individual, accounted for 35 (25.9%) of the species sampled in the upper stratum, one of those (*S. bullatum*) being endangered. In the lower stratum, there were 26 such

Table 2. List of woody species sampled in a fragment of mixed rain forest at the Itaberá Ecological Station, Itaberá, Brazil.

FAMILY / Genus and species	Local name(s)	Collector and exsiccate*	Stratum	
			Upper**	Lower***
ANACARDIACEAE				
Astronium graveolens Jacq.	guaritá, aroeirão		X	X
Lithraea molleoides (Vell.) Engl.	aroeira-brava		X	
Tapirira guianensis Aubl.	peito-de-pombo	RLRS 140	X	
ANNONACEAE				
Duguetia lanceolata A.St.-Hil.	pindaíva, corticeira	RLRS 141	X	X
Guatteria australis A.St.-Hil.	araticum		X	X
Porcelia macrocarpa (Warm.) R.E. Fr.	banana-de-macaco		X	
Xylopia brasiliensis Spreng.	Pindaíba	RTP 1001	X	
Xylopia langsdorfiana St.Hilaire & Tulasne	Cedrinho	RTP 100		
APOCYNACEAE				
Aspidosperma polyneurum Müll.Arg.	peroba-rosa		X	X
Aspidosperma tomentosum Mart.	pereiro-do-campo		X	X
Tabernaemontana laeta Mart.	mata-pasto		X	
AQUIFOLIACEAE				
Ilex dumosa Reissek	mate, erva-mate	RLRS 143		
Ilex paraguariensis A.St.-Hil.	mate, erva-mate		X	
ARALIACEAE				
Dendropanax cuneatus (DC.) Decne. & Planch.	maria-mole	RLRS 53	X	X
Dendropanax monogynus (Vell.) Seem.		RLRS 118		
Schefflera angustissima (Marchal) Frodin	mandioqueira		X	
Schefflera calva (Cham.) Frodin & Fiaschi	mandioqueiro		X	
ARAUCARIACEAE				
Araucaria angustifolia (Bertol.) Kuntze	pinheiro-brasileiro	RLRS 68	X	
ARECACEAE				
Euterpe edulis Mart.	palmito-juçara		X	X
Syagrus romanzoffiana (Cham.) Glassman	jerivá, coco-babão		X	
ASTERACEAE				
Dasyphyllum brasiliense (Spreng.) Cabrera	guaiapá-parreira			X
BIGNONIACEAE				
Jacaranda macrantha Cham.	caroba		X	X
BORAGINACEAE				
Cordia americana (L.) Gottschling & J.S.Mill.	guajuvira		X	X
CANNABACEAE				
Celtis iguanaea (Jacq.) Sarg.	gumbixava			X
Trema micrantha (L.) Blume	crindiúva		X	
CARDIOPTERIDACEAE				
Citronella paniculata (Mart.) R.A. Howard	pau-de-corvo		X	X
CARICACEAE				
Jacaratia heptaphylla (Vell.) A. DC.	jaracatiá		X	
CELASTRACEAE				
Maytenus aquifolia Mart.	espinheira-santa		X	X

Continues

Table 2. Continuation.

FAMILY Genus and species	Local name(s)	Collector and exsiccate*	Stratum Upper**	Stratum Lower***
Maytenus evonymoides Reissek				X
CLETHRACEAE				
Clethra scabra Pers.	peroba-café		X	
COMBRETACEAE				
Terminalia triflora (Griseb.) Lillo	capitãozinho		X	
CYATHEACEAE				
Cyathea atrovirens (Langsd. & Fisch.) Domin	samambaiaçú		X	
ELAEOCARPACEAE				
Sloanea lasiocoma K. Schum.	sapopema		X	X
Sloanea monosperma Vell.	sapopema			X
EUPHORBIACEAE				
Acalypha gracilis Spreng.		RLRS 142		
Actinostemon concepcionis (Chodat & Hassl.) Hochr.	folha-fedorenta	RLRS 71	X	X
Alchornea glandulosa Poepp.	tapiá, pau-jangada		X	
Alchornea triplinervia (Spreng.) Müll.Arg.	canela-raposa		X	
Croton floribundus Spreng.	capixingui		X	X
Sebastiania klotzschiana Müll.Arg.	branquinho		X	X
Tetrorchidium rubrivenium Poepp.	canemaçu		X	
FABACEAE - CAESALPINIOIDEAE				
Cassia leptophylla Vogel	falso-barbatimão		X	
Copaifera langsdorffii Desf.	copaíba, pau-d´óleo	RLRS 54	X	X
Copaifera trapezifolia Hayne			X	X
Holocalyx balansae Micheli	alecrim-de-campinas			X
FABACEAE - MIMOSOIDEAE				
Inga marginata Willd	ingá-feijão		X	X
Inga sessilis (Vell.) Mart.	ingá-ferradura	RLRS 83		X
Inga striata Benth.	ingá-banana		X	
Parapiptadenia rigida (Benth.) Brenan	angico-cedro		X	X
Piptadenia gonoacantha (Mart.) J.F.Macbr.	pau-Jacaré	RLRS 55/120	X	X
Senegalia polyphylla (DC.) Britton & Rose	monjoleiro	RLRS 79	X	
FABACEAE - FABOIDEAE				
Centrolobium tomentosum Guillem. *ex* Benth.	araribá	RLRS 130		
Dalbergia frutescens (Vell.) Briton				X
Exostyles godoyensis Soares-Silva & Mansano		RLRS 93; RTP 1009	X	X
Lonchocarpus subglaucescens Mart. *ex* Benth.	embira-de-sapo	RLRS 155	X	
Machaerium nyctitans (Vell.) Benth.	bico-de-pato		X	X
Machaerium paraguariense Hassl.	jacarandá-branco		X	
Machaerium scleroxylon Tul.	caviúna		X	
Machaerium stipitatum (DC.) Vogel	sapuvinha		X	X
Machaerium vestitum Vogel	cateretê	RLRS 85		
LAURACEAE				
Endlicheria paniculata (Spreng.) J.F.Macbr.	canela-peluda	TMR 13		X

Continues

Table 2. Continuation.

FAMILY Genus and species	Local name(s)	Collector and exsiccate*	Stratum Upper**	Stratum Lower***
Nectandra lanceolata Nees	canela-amarela		X	
Nectandra megapotamica (Spreng.) Mez	canela-imbuia	RLRS 77	X	
Nectandra oppositifolia Nees & Mart.	canela-amarela	RLRS 119	X	X
Ocotea bicolor Vattimo-Gil	canela-fedida		X	
Ocotea corymbosa (Meisn.) Mez	canela-fedorenta		X	
Ocotea diospyrifolia (Meisn.) Mez		RLRS 57	X	
Ocotea elegans Mez	canela-parda	RLRS 78	X	X
Ocotea indecora (Schott) Mez			X	X
Ocotea pulchella (Nees & Mart.) Mez	canela-lageana	RLRS112/116/123	X	
Ocotea silvestris Vattimo-Gil	canela	RLRS 48/TMR 15	X	
Ocotea sp.			X	
Persea willdenovii Kosterm.		RTP 1002	X	
LAXMANNIACEAE				
Cordyline spectabilis Kunth & C.D.Bouché	guaraíva		X	X
LECYTHIDACEAE				
Cariniana estrellensis (Raddi) Kuntze	jequitibá-rosa		X	
LOGANIACEAE				
Strychnos brasiliensis Mart.	estralo			X
MALVACEAE				
Ceiba speciosa (A.St.-Hil.) Ravenna	paineira	RLRS 156	X	X
Guazuma ulmifolia Lam.	araticum-bravo		X	
Luehea divaricata Mart.	açoita-cavalo	RTP 108/41	X	
MELASTOMATACEAE				
Miconia doriana Cogn.		RLRS 98	X	X
Miconia hymenonervia (Raddi) Cogn.				X
Miconia latecrenata (DC.) Naudin				X
Miconia petropolitana Cogn.	jacatirão-mirim	RLRS 39	X	X
Miconia rigidiuscula Cogn.				X
Miconia tristis Spring				X
MELIACEAE				
Cabralea canjerana (Vell.) Mart.	canjerana	RLRS 162/158	X	
Cedrela fissilis Vell.	cedro-rosa		X	
Guarea macrophylla Vahl	marinheiro	RLRS 56		X
Trichilia catigua A.Juss.	catiguá	RTP 1008	X	X
Trichilia claussenii C. DC.	catiguá-vermelho	RLRS 159	X	X
Trichilia elegans A.Juss.	canela-do-mato	RLRS 160, TMR 5	X	X
Trichilia pallida Sw.	catiguá, marinheiro	TMR21	X	X
MONIMIACEAE				
Mollinedia argyrogyna Perkins	corticeira	RLRS 72	X	
Mollinedia clavigera Tul.	cidreira-do-mato	RLRS 94		
Mollinedia elegans Tul.		RLRS 88	X	
Mollinedia schottiana (Spreng.) Perkins	guatambú-langanha			X

Continues

Table 2. Continuation.

FAMILY / Genus and species	Local name(s)	Collector and exsiccate*	Stratum Upper**	Stratum Lower***
Mollinedia uleana Perkins		RLRS 87		X
MORACEAE				
Ficus insipida Willd.	mata-pau	RLRS95,TMR17		
Ficus luschnathiana (Miq.) Miq.	gameleira-vermelha	TMR 14	X	
Sorocea bonplandii (Baill.) W.C.Burger, Lanj. & de Boer	falsa-espinheira-santa	RLRS 63/59	X	X
MYRSINACEAE				
Rapanea loefgrenii Mez	pororoca	RLRS 38/96	X	X
Rapanea umbellata (Mart.) Mez	capororocão	TMR 7	X	
MYRTACEAE				
Calyptranthes concinna DC.	guamirim-de-facho	TMR 8		X
Calyptranthes grandifolia O.Berg	guamirim-chorão		X	
Campomanesia guazumifolia (Cambess.) O.Berg	sete-capotes		X	X
Campomanesia xanthocarpa (Mart.) O.Berg	guabirobeira		X	X
Eugenia dodonaeifolia Cambess.				X
Eugenia hiemalis Cambess.	guamirim-miúdo	RTP 1000		
Eugenia ligustrina (Sw.) Willd		RLRS 60, RTP 1000	X	
Eugenia ramboi D.Legrand	batinga-branca	RTP 997	X	X
Eugenia stenophylla O.Berg			X	X
Eugenia uniflora L.	pitangueira	RTP 998	X	X
Myrcia laruotteana Cambess.	cambuí	TMR 6	X	
Myrcia multiflora (Lam). DC.	cambuí		X	
Myrcia pulchra (O.Berg) Kiaersk			X	
Myrcia rostrata DC.	guamirim-miúdo		X	X
Myrciaria floribunda (H.West *ex* Willd.) O.Berg	camboim			X
Myrciaria rivularis (Cambess.) O.Berg			X	
Myrciaria tenella (DC.) O.Berg	cambuí	RLRS 50		
Psidium sp.				X
NYCTAGINACEAE				
Guapira opposita (Vell.) Reitz	maria-mole	RLRS 179	X	X
OLEACEAE				
Chionanthus filiformis (Vell.) P.S.Green	pitaguará	RLRS 69	X	X
OPILIACEAE				
Agonandra brasiliensis Miers *ex* Benth. & Hook.f.	mamica-de-cadela		X	
PERACEAE				
Pera glabrata (Schott) Poepp. *ex* Baill.	tabocuva	TMR 11	X	
PHYTOLACCACEAE				
Seguieria langsdorffii Moq.	laranja-do-mato		X	
PIPERACEAE				
Piper arboreum Aubl.		RTP 1011		X
Piper cf. *bowiei* Yunck.				X
PROTEACEAE				
Roupala brasiliensis Klotzsch	carvalho-brasileiro			X

Continues

Table 2. Continuation.

FAMILY / Genus and species	Local name(s)	Collector and exsiccate*	Stratum	
			Upper**	Lower***
RHAMNACEAE				
Colubrina glandulosa Perkins	saguraji		X	
Rhamnidium elaeocarpum Reissek	saguaraji-amarelo		X	X
ROSACEAE				
Prunus myrtifolia (L.) Urb.	pessegueiro bravo		X	X
RUBIACEAE				
Alibertia concolor (Cham.) K.Schum.			X	
Alibertia myrciifolia Spruce *ex* K.Schum.	marmemelinho		X	X
Amaioua intermedia Mart. *ex* Schult. & Schult.f.	café-de-bugre		X	X
Chomelia obtusa Cham. & Schltdl.			X	
Faramea montevidensis (Cham. & Schltdl.) DC.		RTP 1007	X	X
Ixora venulosa Benth.	ixora	RLRS 174	X	X
Psychotria longipes Müll.Arg.		RLRS 147		
Psychotria stachyoides Benth.				X
Psychotria suterella Müll.Arg.	cafezinho-roxo		X	X
Rudgea gardenioides (Cham.) Müll.Arg.	arapoca	RLRS 146		
Rudgea jasminoides (Cham.) Müll.Arg.	jasmim-do-mato	RLRS 148/61	X	X
Rudgea cf. *jasminoides* (Cham.) Müll.Arg.	jasmim-do-mato			X
RUTACEAE				
Esenbeckia febrifuga (A.St.-Hil.) A.Juss. *ex* Mart.	chupa-ferro	RLRS 99		
Helietta apiculata Benth.	canela-de-veado	TMR16	X	X
Pilocarpus pennatifolius Lem.	crista-de-peru	RLRS 101	X	X
Zanthoxylum caribaeum Lam.	arruda-brava		X	
Zanthoxylum fagara (L.) Sarg.	mamica-de-porca		X	
Zanthoxylum monogynum A.St.-Hil.	maminha-de-porca		X	X
SALICACEAE				
Casearia decandra Jacq.	guassatonga		X	X
Casearia gossypiosperma Briq.	pau-de-espeto		X	
Casearia obliqua Spreng.			X	
Casearia sylvestris Sw.	café-do-mato		X	
Prockia crucis P. Browne *ex* L.	marmeladinha	RTP 995	X	X
Xylosma tweediana (Clos) Eichler	espinho-de-judeu		X	
SAPINDACEAE				
Allophylus edulis (A.St.-Hil. *et al.*) Hieron. *ex* Niederl.	três-folhas-do-mato		X	X
Cupania tenuivalvis Radlk.	camboatá-miúdo	RLRS 45	X	X
Cupania vernalis Cambess.	camboatá-vermelho	RLRS 42	X	X
Diatenopteryx sorbifolia Radlk.	maria-preta	TMR 12	X	
Matayba elaeagnoides Radlk.	camboatá-branco	RTP 1005	X	X
SAPOTACEAE				
Chrysophyllum gonocarpum (Mart. & Eichler *ex* Miq.) Engl.	aguaí-da-serra		X	X
Chrysophyllum marginatum (Hook. & Arn.) Radlk.	aguaí-vemelho		X	
Pouteria gardneriana (A.DC.) Radlk.	aguaí-guaçu		X	

Continues

Table 2. Continuation.

FAMILY Genus and species	Local name(s)	Collector and exsiccate*	Stratum Upper**	 Lower***
SOLANACEAE				
Brunfelsia pauciflora (Cham. & Schltdl.) Benth.	manacá			X
Cestrum intermedium Sendtn.	coerana		X	X
Solanum argenteum Dunal				X
Solanum bullatum Vell.	joá-açu	RLRS 121/126/166	X	
Solanum pseudoquina A.St.-Hil.	falsa-quina	RLRS 132		
Solanum sanctae-catharinae Dunal	joá-manso, Juá	RLRS 167	X	X
Solanum swartzianum Roem. & Schult.		TMR 1	X	X
STYRACACEAE				
Styrax acuminatus Pohl	jacutinga	RLRS 163		
Styrax camporum Pohl	benjoeiro		X	
Styrax pohlii A.DC.	árvore-de-bálsamo		X	
URTICACEAE				
Cecropia glaziovii Snethl.	embaúba-vermelha		X	
Cecropia pachystachya Trécul	embaúba-do-brejo		X	
VERBENACEAE				
Verbenaceae 1		TMR 29		X
VOCHYSIACEAE				
Vochysia magnifica Warm.	cinzeiro-da-serra		X	
Vochysia tucanorum Mart.	pau-de-tucano	TMR 18/19		

*Initials of the collector and the accession number(s) of the exsiccate(s) deposited at the Dom Bento Pickel Herbarium (code, SPSF); **including individuals with a diameter at breast height ≥ 15 cm; ***including individuals with a diameter at breast height < 15 cm and an overall height ≥ 30 cm.

species (28% of the species sampled), one of which (*A. tomentosum*) is endangered.

Diversity

For the upper stratum, we estimated the H' at 4.12 (4.11 < H' < 4.30, using 95% jackknife confidence intervals). The community showed low dominance, as evidenced by the estimated J' and MC values (0.84 and 1:10.51, respectively). All of these values are higher than those typically found for stretches of Araucaria forest in the state of São Paulo and in southern Brazil in general. Using the same methodology, Souza (2008) estimated H' and J' at 3.08 and 0.73, respectively, for an area near the city of Campos do Jordão (in the state of São Paulo), compared with 3.81 and 0.70, respectively, for an area that had been regenerating for the last 120 years near the city of Barra do Chapéu (also in the state of São Paulo). Also in the Campos do Jordão area, Los (2004) evaluated six discontinuous blocks of 0.25 ha each and reported an H' of 3.43. For southern Brazil, H' values found in the literature vary widely, ranging from 2.76 (Rondon-Neto *et al.* 2002) to 3.67 or higher (Reginato & Goldenberg 2007). Unfortunately, differences in sampling methodology, historical uses of areas and landscape conditions, as well as other factors, complicate comparisons across studies. In the lower stratum, these values were also high, although less dramatically so: H' = 3.5 (3.46 <H' <3.72, using 95% jackknife confidence intervals); J' = 0.77; and MC = 1:8.06. Souza (2008) also highlighted the great diversity of this stratum near Campos do Jordão (H' and J' of 3.81 and 0.84, respectively) and Barra do Chapéu (3.44 and 0.79, respectively). Unfortunately, the lower strata of Araucaria forests have been poorly studied, resulting in a scarcity of studies for comparisons, and the limitations mentioned above for the upper stratum also apply here. Nevertheless, the fact that high diversity was also detected in the lower stratum underscores the importance of the area for conservation and hence the importance of proper management of this regeneration, so that the values identified are maintained or increased.

The confidence intervals estimated for H' indicate that the upper stratum contains greater species diversity (alpha) than does the lower stratum, although this index is influenced by the number of individuals sampled (Durigan 2009).

The high diversity observed in both strata at the Station is likely due to its geographical position, inserted into an area of ecological tension. On Guapiara Plateau, where the Station is located, in addition to the mixed rain forest, other forest settings occur, ranging from dense rain forest, near the Paranapiacaba mountain range, to stretches of savanna (*cerrado*) and semideciduous seasonal forest further inland (Ab'Saber 2003). According to Jarenkow & Budke (2009), the floristic richness of Araucaria forests decreases with increasing latitude, being greater in areas of contact with other forest formations, in which cases the araucaria plays a secondary role in forest structure.

Floristic similarity

The upper and lower strata were very similar floristically (with Jaccard and Sorensen indices of 0.40 and 0.57, respectively), having 65 species in common. More than two thirds of the lower stratum species also occurred in the upper stratum. However, a little over half the species present in the upper stratum were not sampled in the lower stratum. Therefore, pronounced floristic changes in the area are expected in the long term, with likely physiognomic changes associated to it, chiefly because of local extinction of its typical emerging species, *A. angustifolia*, not sampled in lower stratum.

Comparing our survey with that of a remaining stretch of the same formation in Campos do Jordão (Souza, 2008), we observed low floristic affinity between the areas (Jaccard and Sorensen indices of 0.08 and 0.15, respectively, considering the species sampled in both strata), with only 18 species in common. Even if we consider only those individuals identified down to the species level, the figures do not change. Analyzing only the upper stratum, the indices are even lower (0.05 and 0.10, respectively), even if we consider only the individuals identified down to the species level (0.06 and 0.11, respectively), with only 10 species in common. The same goes for the lower component (0.06 and 0.11, respectively, for all species, compared with 0.06 and 0.12, respectively, for only those identified down to the species level), with only eight species in common. The low floristic similarity observed might be explained by the natural disjunction between areas (approximately 390 km away in a straight line, 22°41'30"S; 45°27'52"W), given that this formation begins to become naturally fragmented in the southern part of the state of São Paulo, recurring at higher altitudes in the Serra do Mar and Mantiqueira mountain ranges. In addition, the Itaberá stretch is strongly influenced by neighboring forest formations, which results in it being mischaracterized floristically as a typical remnant of Araucaria forest, according to the latter approach (considering only specimens identified down to the species level). Another factor would be the distinct conditions of the landscape, particularly in terms of the extent of continuous protected area, given the previously mentioned effects that it can have on the flora.

The Itaberá Ecological Station most resembles a remnant of Araucaria forest in its most proximate regions, on the slopes of the Serra de Paranapiacaba mountain range (approximately 70 km away in a straight line, at 24°28'S; 49°01'W), an area also evaluated by Souza (2008), which has been regenerating for the last 120 years near the municipality of Barra do Chapéu. Considering both strata, there is a certain floristic affinity between the areas (Jaccard and Sorensen indices of 0.20 and 0.34, respectively), with 53 species in common. However, these cannot be considered floristically similar, even if we consider only the species identified down to the species level, with Jaccard and Sorensen indices of 0.22 and 0.37, respectively. In the upper stratum, the Jaccard and Sorensen indices were 0.21 and 0.35, respectively, for all species, compared with 0.23 and 0.37, respectively, for only those identified down to the species level, with 45 species in common. The greatest floristic similarity was observed in the lower stratum (Jaccard and Sorensen indices of 0.27 and 0.43, respectively, for all species, compared with 0.31 and 0.48, respectively, for only those identified down to the species level), with 36 species in common. Therefore, the lower strata of the two areas are floristically similar, according to the Jaccard index for all species sampled and according to both indices for only those identified down to the species level. Therefore, it is expected that, over the long term, there will be an increase in similarity between the upper strata of the two areas.

Cluster analysis

The matrix compiled from floristic listings comprised 1095 species, reflecting the floristic heterogeneity among the 53 areas considered. The most common species in the mixed rain forest were as follows: *A. angustifolia* (100%); *Campomanesia xanthocarpa* (90%); *Casearia decandra* (90%); *Ocotea puberula* (75%); *Jacaranda puberula* (75%); *Allophylus edulis* (75%); *Matayba elaeagnoides* (75%); *Rapanea umbellata* (75%); *Sapium glandulatum* (70%); *Sebastiania commersoniana* (70%); *I. paraguariensis* (70%) *Ocotea pulchella* (70%); *Vernonia discolor* (65%); *Styrax leprosus* (65%); *Ilex theezans* (60%); *Prunus myrtifolia* (60%); *Cedrella fissilis* (60%); *Clethra scabra* (55%) and *Schinus terebinthifolius* (50%). Of those, only *A. angustifolia* is considered to be exclusive to Araucaria forests (Stehmann 2009), although *C. xanthocarpa*, *S. commersoniana* and *S. leprosus* have also been identified only in such forests. Jarenkow & Budke (2009), in a review of floristic patterns in this formation, also demonstrated the high frequency of most of these species (above 80% in the 38 surveys evaluated), the exceptions being *O. puberula*, *J. puberula*, *O. pulchella*, *I. theezans* and *C. scabra.*

Considering the four areas of Araucaria forest in the state of São Paulo, we noted that they have only nine species in common: *A. angustifolia*, *Cabralea canjerana*, *C. decandra*, *Guatteria australis*, *Myrcia fallax*, *Ocotea bicolor*, *R. umbellata*, *R. jasminoides* and *Solanum swartzianum.* Of those, *C. canjerana*, *C. decandra*, *G. australis*, *M. fallax* and *R. umbellata* have also been shown to occur in ≥ 50% of the areas of dense rain forest evaluated in the state. In addition, *M. fallax* has been identified in semideciduous seasonal forests within the state, indicating its wide geographic distribution.

For the mixed rain forest evaluated in the present study, diversity (H') varied considerably, from 2.2 to 4.12. However, methodological differences between surveys, some of which have used different indices or none at all, hinder comparisons across studies.

As can be seen in the dendrogram obtained from the cluster analysis (Fig. 2), there were four major groups, one survey, conducted in Ubatuba (Sanchez 1999), standing apart. The cophenetic correlation coefficient obtained is considered high, showing that the groups formed are consistent; that is, the results are robust and reliable.

The first group comprises the majority of surveys conducted in the dense rain forest in the state of São Paulo (Serra do Mar and Serra de Paranapiacaba mountain ranges). We noticed that the areas evaluated near the municipalities of Sete Barras, São Miguel Arcanjo and Capão Bonito had greater floristic affinity, possibly due to their geographical proximity, thus forming a more cohesive subgroup. The most common species in that group were *C. canjerana*, *Alchornea triplinervia*, *Guapira opposita*, *Casearia sylvestris*, *C. decandra*, *Tapirira guianensis*, *Annona neosericea*, *Maytenus robusta*, *Endlicheria paniculata*, *S. bonplandii*, *Myrcia splendens* and *Amaioua intermedia*, all occurring in at least half of the areas considered.

The second major group comprised surveys conducted in areas of dense rain forest in southern Brazil and near Campos do Jordão. The segregation of the two surveys conducted in the state of São Paulo is notable and probably reflects the effect of the natural geographic disconnect within the formation. The indicator species in this subgroup were *Ilex taubertiana*, *Baccharis oreophila*, *Piptocarpha macropoda*, *O. bicolor*, *Ocotea glaziovii*, *Persea willdenovii*, *Calyptranthes lucida*, *Symplocos falcata* and *R. jasminoides.* Jarenkow & Budke (2009) point out that these areas have many species typical of upper montane environments, especially the Melastomataceae of the *Miconia* and *Tibouchina* genera, increasing intragroup dissimilarity. However, there were no *Tibouchina* spp. sampled in either of the two areas considered.

The third group comprised three surveys conducted near the municipality of Ribeirão Grande (in the state of São Paulo), in the dense rain forest of the Serra de Paranapiacaba mountain range. The areas evaluated in this group showed low floristic affinity with nearby areas, such as those evaluated near São Miguel Arcanjo, Capão Bonito and Sete Barras (Group 1), exhibiting the floristic heterogeneity of the region. The most frequent species in this group were *S. terebinthifolius*, *Myrsine coriacea*, *Campomanesia guaviroba* and *M. splendens.*

The fourth group comprised surveys conducted in seasonal semideciduous forests (near the cities of São Carlos, Campinas and Gália) and in a seasonal deciduous forest (near the city of Piracicaba), all within the state of São Paulo. These areas showed low floristic similarity with semideciduous forests further south; hence, which appeared to have no significant influence on the vegetation at the Itaberá Ecological Station. The indicator species in this group were *A. polyneuron*, *Myroxylon peruiferum*, *Ceiba speciosa* and *Metrodorea nigra*.

The present study fell into the first group, the area evaluated showing low floristic affinity with stretches of the Araucaria forest near Campos do Jordão and in southern Brazil. The vegetation at the Itaberá Ecological Station showed greatest similarity to a stretch of seasonal semideciduous forest near the municipality of São Roque, in the state of São Paulo (Leite & Rodrigues 2008), despite greater distance (approximately 210 km in a straight line) in comparison with the stretch of mixed rain forest near Barra do Chapéu and with the seasonal semideciduous forest near the municipality of Itatinga (approximately 100 km away in a straight line, located within the Paranapanema area, the same geomorphological unit as the Itaberá Ecological Station). These four surveys were grouped to form a subgroup, albeit showing low similarity among them, distinguished from other surveys of dense rain forest in São Paulo. The surrounding forest formations apparently had the greatest influence on areas of mixed rain forest in the southern part of the state of São Paulo, given that they proved to be isolated from other stretches of this formation, defining them as ecotones. The classification of the vegetation at the Itaberá Ecological Station as mixed rain forest is maintained for its physiognomic aspect (occurrence of *A. angustifolia*) rather than the floristic composition itself. This appears to be regional in scope, as was also observed by Souza (2008) in the Barra do Chapéu survey.

Distribution of the species sampled at the Itaberá Ecological Station

Of the 178 species sampled in our floristic and phytosociological surveys, 134 (74.9%) were found in dense rain forest (26 species being exclusive to this formation); 129 (72.1%) were found in seasonal semideciduous forest (16 being exclusive); 57 (31.8%) were found in mixed rain forest (four being exclusive); 21 (11.7%) were found in seasonal deciduous forest (one, *Chomelia obtuse*, being exclusive); 31 (17.3%) were found in coastal woodland (*restinga*, none being exclusive); 19 (10.6%) were found in savanna forest (*cerradão*) and *cerrado stricto sensu* (none being exclusive); and one (0.6%), *Trichilia pallida*, was found to have a wide distribution in the Amazon, *cerrado* and Atlantic forest. There were 15 species that remained unclassified because of a lack of data in the literature, as well as their incomplete identification (Stehmann *et al.* 2009).

This floristic complexity, which translated to a mosaic of species of different origins, was expected, because, as previously mentioned, the Itaberá Ecological Station is within a region of ecological tension and is at an advanced successional stage, which, according to Klein (1960) favors

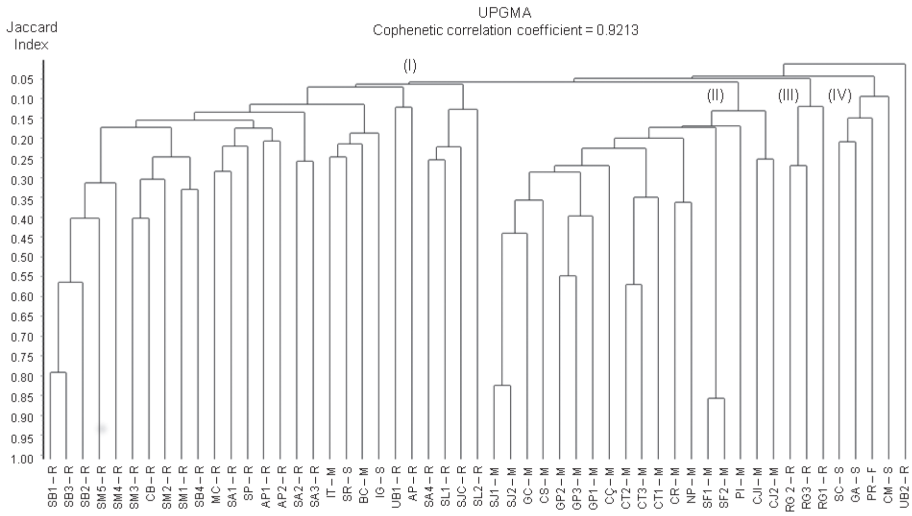

Figure 2. Dendrogram of floristic similarity between phytosociological surveys conducted in areas of dense rain forest (R), mixed rain forest (M), semideciduous forest (S) and deciduous forest (F) in southern Brazil and in the state of São Paulo, using the Jaccard index as the coefficient and the unweighted pair group method with arithmetic mean (UPGMA) to group the areas.

the invasion of broadleaf species from the highlands and forests of the Atlantic coast. However, it is again of note that the literature reviewed might contain errors, given the many controversies on the geographic distribution of these species among other literary sources and experts of recognized competence.

On the basis of the large number of species that were exclusive to dense rain forest and seasonal semideciduous forest, as well as the broader distribution of their exclusive species within the community, makes it obvious that there has been considerable invasion of the study area, in which typical mixed rain forest species have been supplanted by the invading species, altering the character of the area, i.e., making it less typical of a mixed rain forest. This pattern supports the hypothesis proposed by Klein (1960), in which the dynamic imbalance typical of mixed forests, in the current climate regime, would be caused by the greater competitive ability of the broadleaf forest species in the surrounding areas.

The process of forest fragmentation can reduce and isolate areas favorable to the survival of populations, resulting in local extinctions. In ecotones, that process can drastically alter the dynamics of plant communities and reduce regional biodiversity. The absence of characteristic elements of mixed rain forest in the lower stratum can influence the trajectory of areas subject to natural regeneration processes, such as forest clearing dynamics. In this scenario, open areas can be colonized by widely distributed pioneer species (generalist species common to the surrounding formations).

The impact of a reduction in area and of fragmentation can be mitigated by landscape management aimed at greater connectivity, enabling recolonization following local extinction, as well as facilitating the maintenance of metapopulations. Densification of species in danger of local extinction should also be considered as a means of avoiding genetic erosion of the remaining populations. For the mixed rain forest, even reforestation with *A. angustifolia* alone can be a viable alternative for greater connectivity, because the species acts as a catalyst for the regeneration of other species under its canopy.

If no management action is taken, the defining species of this formation will become locally extinct and the vegetation at the Itaberá Ecological Station will no longer be officially classified as mixed rain forest (Veloso 1991), but rather as a transitional community between dense rain forest and seasonal semideciduous forest. In other words, this fragment corresponds to what Klein (1960) called "mixed rain forest" or "mixed forest", consisting primarily of species characteristic of subtropical rain forest, with patches of pine occurring sporadically, mostly made up of older (adult or rachitic) individuals. Therefore, the current official classification of the vegetation at the Itaberá Ecological Station is based more on the few remaining *A. angustifolia* individuals than on the floristic composition itself, naturally tending to be abandoned for long periods or artificially sustained by management practices. The rigor of the official Brazilian classification of vegetation, as proposed by Veloso (1991), notwithstanding, a nomenclature more in line with the reality in the field would be "forest in transition from dense rain forest to seasonal semideciduous forest", given that *A. angustifolia* no longer dominates the phytophysiognomy of the unit.

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