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Structure of the Tree Component and Indicator Species in Different Types of Forests in the Itajaí-Mirim River, Southern Brazil

João Paulo de Maçaneiro, Lauri Amândio Schorn, Lúcia Sevegnani and Alexander Christian Vibrans

Universidade Regional de Blumenau – FURB, Centro de Ciências Tecnológicas, Departamento de Engenharia Florestal, Rua São Paulo, 3250, Blumenau, SC, Brazil, CEP 89030-000.

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ABSTRACT

Forest inventories are important for understanding the forest structure and the indicator species. However, very few studies have evaluated the current vegetation structure and the indicator species in the Itajaí-Mirim river in southern Brazil. This study aimed to analyze the structure of the tree component and detect indicator species in different forest types in the Itajaí-Mirim river, in southern Brazil. Another objective of this study was to update information on forest resources and current state of conservation of forests along the Itajaí-Mirim river in southern Brazil. The vegetation was sampled by installing 15 sample plots of 4,000 m² distributed systematically along the Itajaí-Mirim river, where all the tree individuals with DBH $\geq$ 10 cm were measured. The Submontane Forest type was characterized with density of 630.9 ind.ha^{-1}, basal area of 23.08 m².ha^{-1} and the species with the highest indicator value were *Tapirira guianensis* Aubl., *Aparisthmium cordatum* (A.Juss.) Baill, *Brosimum glaziovii* Taub. And *Miconia cinnamomifolia* (DC.) Naudin. The Montane Forest type showed 740.4 ind.ha^{-1} of density, 27.27 m².ha^{-1} of basal area and the main indicator species was *Alsophila setosa* Kaulf. However, the presence of typical secondary forest species indicates that de forest along Itajaí-Mirim river are altered and still in succession process. In this regard, greater attention should be paid to the restoration and conservation of these forests.

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INTRODUCTION

The Atlantic Forest is recognized as one of the 35 world hotspots for the conservation of biodiversity (Ribeiro *et al.*, 2011) and is the focus of studies which aims to establish guidelines for the biologic diversity conservation presented in the different phytophysiognomies contained in its area (Ribeiro *et al.*, 2009; Tabarelli *et al.*, 2010). Atlantic Forest area is heterogeneous, with different phytophysiognomies vegetation and high richness of species that often outweighs those from amazon forests (Thomas *et al.*, 1998). Dense Ombrophylous Forest is one of the richest in number of species among vegetation phytophysiognomies of Atlantic Forest (Leite and Klein, 1990; IBGE, 2012). This forest is characterized by showing well-defined shrubs, with phanerophytes subdivided in macro, meso, micro and nanophanerophytes, besides wooden lianas and vasculars and avasculars epiphytes in abundance, which distinguish this formation from other types.

In Santa Catarina, Southern Brazil, Atlantic Dense Ombrophylous Forest is divided in different vegetation formation types, characterized mainly by the vegetation physiognomy associated to the altimetry quota: Alluvial, Lowlands, Submontane, Montane and High Montane (IBGE, 2012). In these formations, the vegetation occur in a gradual basis and environmental factors as elevation, weather, relief, topography, soils and history of using of the natural resources can influence in the variation of the composition and structure of these forests (Maçaneiro *et al.*, 2015). For this reason, each vegetation formation can show a set of tree species adapted to determined environmental conditionswhich characterize the vegetation type (Klein, 1980; Sevegnani, 2002; IBGE, 2012) and to know which these species are can provide valuable information to conservational programs.

Atlantic Dense Ombrophylous Forest originally covered 29.282 km² of Santa Catarina state, 31% of the area, though, because of a historic process of use and occupation of its natural resources, it reduces to

Corresponding Author: João Paulo de Maçaneiro, Universidade Regional de Blumenau – FURB, Centro de Ciências Tecnológicas, Departamento de Engenharia Florestal, Rua São Paulo, 3250, Blumenau, SC, Brazil, CEP 89030-000.
E-mail: jpmacaneiro@gmail.com

just 40,4% of its original cover, constituted by forest fragments up to 50 ha (Vibrans *et al*., 2013). Generally speaking, these forests are mostly represented by secondary forests at a medium or advanced stage of regeneration, becoming rare the remains with primary forests.

In Southern Brazil, the floristic composition and phytosociology structure of Santa Catarina's Dense Ombrophylous Forest have been studied a lot (Reitz, 1958; Vibrans*et al*., 2012), especially in Vale do Itajaí (Klein, 1979; 1980; Sevegnani, 2002; Schorn, 2005; Schorn and Galvão, 2006; 2009; Maçaneiro *et al*., 2015). However, studies that evaluate consistently the current stage of conservation of the forests along Itajaí-Mirim river, place where this research was carried out, are scarce and in these studies are included historic works since 1950 (Veloso and Klein, 1957; 1959; Klein, 1979; 1980). Subsequently, the Floristic-Forest Inventory of Santa Catarina (IFFSC) carried out a survey of the forests remains of the state in the ages of 2007 to 2011 (Vibrans *et al*., 2012) in order to obtain quantitative and qualitative information about the current stage of conservation of the forests.

In this way, the main goals of this work have been to: i) Evaluate the structure of the trees components and detect the possible indicators tree species in different types of forests along Itajaí-Mirim river in Southern Brazil and; ii) generate updated information about the forest resources, highlighting the main tree species that character the forests and about the current stage of conservation along Itajaí-Mirim river in Southern Brazil.

MATERIALS AND METHODS

Itajaí-Mirim river has a drainage area of approximately 1,700 km² and is inserted in the watershed of Itajaí river in Santa Catarina (26°54' and 27°33'S and 48°38' and 49°27'W) (Minatti-Ferreira and Beaumord, 2004). The predominant forest cover is constituted by the Atlantic Dense Ombrophylous Forest in the formations Alluvial, Lowlands, Submontane, Montane and High Montane (Sevegnani, 2002; IBGE, 2012).

According to the Köppen classification, Itajaí-Mirim river is characterized by two climate types: Cfa – subtropical mesothermal humid climate with hot summer and Cbf – temperate mesothermal humid climate with mild summer. The climate types are defined mainly by the difference of temperature due to the altitude variation. The annual temperature average ranges between 16 to 20ºC with total annual rainfall of 1,330 to 1,700 mm and relative humidity of 82 to 86% (EPAGRI, 2002).

The data used in this study came from 15 sample plots (UA) introduced over the Itajaí-Mirim river by the Floristic-Forest Inventory of Santa Catarina – IFFSC (Vibrans *et al*., 2010; 2012). Those UA were systematically distributed in forests remains from a grid of points of 10 x 10 km. The UA were composed by a conglomerate with total area of 4,000 m², constituted by four subunits of 20 x 50 m (1,000 m²). Each subunit was composed by 10 subplots of 10 x 10 m (100 m²), where all the individuals with DAP ≥ 10 cm were measured. The botanic material collected was identified by the comparison with exsiccates present in the Dr. Roberto Miguel Klein Herbarium, from Universidade Regional de Blumenau (FURB), also by consulting experts of several institutions and herbaria in Brazil.

The UA were classified due to the type of forest based on the criteria proposed by IBGE (2012). To describe the structure of the vegetation were used the subplots of 10 x 10 m, where were calculated the classic phytosociological parameters of Muller-Dombois and Ellenberg (2002), in other words, density, frequency and absolute and relative dominance and the percentage of importance of each tree species. The species also were classified by ecological group, adopting the methodology suggested by Oliveira-Filho (1994) in the following categories: pioneer species (P), light-demanding climax (CL) shade-tolerant climax (CS).

The differential species of each forest type were found by the Indicator Species Analysis (ISA) in the PC-ORD 6.0 (McCune and Mefford, 2011). For this analysis it was used a presence and absence species matrix and was implemented the algorithm of Tichý and Chytrý (2006), especially to correct distortions caused by groups with different sizes.

RESULTS AND DISCUSSION

The density of trees and the basal area registered was higher in the Montane Forest when compared to the Submontane Forest (Table 1). Those values are compatible with the results found by Schorn *et al*. (2012) to the Santa Catarina's Dense Ombrophylous Forest, which accused 684.9 ind.ha^{-1} and 23.80 m².ha^{-1}, respectively. In general, studies undertaken in the Dense Ombrophylous Forest in Santa Catarina registered that the Montane Forest presented greater density of individuals when compared to the Submontane Forest (Martins, 2010; Lingner *et al*., 2013), and this result may be granted to the weather conditions caused by the elevation increase, to the soil type or, still, to the historic of use of the natural resources, increasing considerably the number of tree individuals with low diameters (Roderjan *et al*., 2002).

The tree species with higher density of trees and absolute frequency in the Submontane Forest were *Aparisthmium cordatum*, *Tapirira guianensis* and *Miconia cinnamomifolia*. The two first species are considered climax tolerant shady and were found with high density and frequency in the plant communities ascertained high on the hillside from the cities of Itajaí, Blumenau, Gaspar and Brusque (Klein, 1980; Maçaneiro *et al*., 2015). On the other hand, *Miconia cinnamomifolia* is considered to be a pioneer species, very usual in the secondary forests in different stages of regeneration from Vale do Itajaí region, where lots of times was the only one dominant species (Klein, 1980). Once inside the primary forest this species was rarely found.

In the Montane Forest the tree species with higher density of trees with absolute frequency were *Alsophila setosa*, *Alchornea triplinervia* and *Psychotria vellosiana*. The species *Alsophila setosa* is considered a shade-tolerant climax and can be found with high density of trees inside well-conserved forests from Vale do Itajaí (Veloso and Klein, 1957; 1959; Sehnem, 1978; Maçaneiro *et al*., 2015). In addition, Veloso and Klein (1957) registered densities that ranged of 22 to 527 ind.ha^{-1} to this species in different primary plant communities from the city of Brusque (SC). Sylvestre and Kurtz (1994) pointed that inside secondary forests this species presents high density of trees, allowing the formation of dense groupings. In the other hand, the species *Alchornea triplinervia* and *Psychotria vellosiana* are considered pioneers and are confined to open environments, fragment edges and secondary forests, not developing with great vitality inside conserved forests (Klein, 1980; Smith, 1988; Delprete *et al*., 2005).

In the Submontane Forest the tree species *Tapirira guianensis*, *Hyeronima alchorneoides* and *Miconia cinnamomifolia* presented higher dominance (DoR = 16.6%) and percentage of importance (IP = 13.2%). Klein (1980) mentioned that *Miconia cinnamomifolia* was a dominant species in the secondary forests of Vale do Itajaí. Such finding was also verified by Schorn (2005) who registered this species as the most dominant in a forest in medium stage of regeneration. Besides that, Klein (1980) points that throughout the process of succession of the secondary forests from Vale do Itajaí, *Miconia cinnamomifolia* was gradually substituted by other demanding species in terms of environmental conditions as, for example, *Tapirira guianensis*, *Ocotea aciphylla* and *Hyeronima alchorneoides*, among others. In the current study, the high structural importance of this three species is a strong indicative that the Submontane Forest of Itajaí-Mirim river finds itself significantly altered concerning to its structure (Maçaneiro *et al*., 2015).

In the Montane Forest the species *Alchornea triplinervia* and *Psychotria vellosiana* presented the higher dominance (DoR = 14.6%). However, the most important species was *Alsophila setosa*, mainly because of its high density and frequency values (Table 1). Veloso and Klein (1957; 1959) and Klein (1980) mentioned that *Alchornea triplinervia* was represented just by old individuals inside the primary forests from Vale do Itajaí. Though, Schorn *et al*. (2012) pointed this species, followed by*Alsophila setosa* and *Psychotria vellosiana*, as the most important from Santa Catarina's Dense Ombrophylous Forest. The fact that *Alchornea triplinervia* and *Psychotria vellosiana* are the second and third most important species in the Montane Forest of Itajaí-Mirim river demonstrates the altered condition that this forest finds itself, once this species have already been registered in historic works made on the same river basins, as infrequent in primary forests and a lot frequents in secondary forests with different stages of regeneration (Veloso and Klein, 1957; 1959; Klein, 1979; 1980).

Table 1: Phytosociological parameters for the ten most important species of forest types in the Itajaí-Mirim river, Southern Brazil. EG = ecological groups, P = pioneer species, CL = light-demanding climax, CS = shade-tolerant climax; DA = absolute density (ind.ha^{-1}); DR = relative density (%); DoA = absolute dominance (m².ha^{-1}); DoR = relative dominance (%); FA = absolute frequency (%); FR = relative frequency (%); IP = importance percentage (%).

SUBMONTANE FOREST								
SPECIES	EG	DA	DR	DoA	DoR	FA	FR	IP
Tapirira guianensis	CS	27.6	4.38	1.46	6.32	19.57	4.01	4.90
Miconia cinnamomifolia	P	29.4	4.65	1.13	4.90	20.00	4.10	4.55
Hyeronima alchorneoides	CS	19.7	3.13	1.24	5.39	13.19	2.71	3.74
Aparisthmium cordatum	CS	29.8	4.72	0.50	2.18	14.47	2.97	3.29
Euterpe edulis	CS	21.5	3.40	0.27	1.19	14.04	2.88	2.49
Sloanea guianensis	CS	14.5	2.29	0.66	2.88	10.64	2.18	2.45
Cyathea phalerata	CS	23.2	3.68	0.37	1.61	8.09	1.66	2.32
Aspidosperma australe	CS	7.9	1.25	0.77	3.34	7.23	1.48	2.02
Cabralea canjerana	CS	8.8	1.39	0.61	2.66	8.09	1.66	1.90
Psychotria vellosiana	P	15.3	2.43	0.29	1.27	9.36	1.92	1.87
Sub-total	-	197.7	31.32	7.30	31.74	124.68	25.57	29.53
Total	-	630.9	100.00	23.08	100.00	487.66	100.00	100.00
MONTANE FOREST								
Alsophila setosa	CS	76.1	10.28	0.89	3.25	29.38	5.23	6.26
Alchornea triplinervia	P	29.8	4.02	2.88	10.55	18.93	3.37	5.98
Psychotria vellosiana	P	32.6	4.41	1.12	4.10	19.77	3.52	4.01
Ocotea catharinensis	CS	17.5	2.36	0.98	3.58	11.58	2.06	2.67
Guapira opposita	CS	18.0	2.44	0.58	2.14	13.84	2.47	2.35
Bathysa australis	CS	18.0	2.44	0.68	2.50	11.58	2.06	2.33
Guatteria australis	CS	13.5	1.82	0.48	1.74	12.43	2.21	1.92
Cryptocarya aschersoniana	CS	11.7	1.58	0.70	2.56	8.47	1.51	1.89
Cabralea canjerana	CS	11.2	1.51	0.65	2.40	9.60	1.71	1.87
Ocotea aciphylla	CS	15.7	2.13	0.31	1.12	9.60	1.71	1.65
Sub-total	-	244.1	32.99	9.27	33.94	145.18	25.85	30.93
Total	-	740.4	100.00	27.27	100.00	561.30	100.00	100.00

Were found 19 indicator species in the types of forests analyzed (Table 2) with indicator values statistically significant ($P < 0.05$). In the Submontane Forest the species with higher indicator value (IV > 70%) were *Tapirira guianensis*, *Aparisthmium cordatum*, *Brosimum glaziovii* and *Ilex brevicuspis*.

The two first species present wide distribution in Santa Catarina's Dense Ombrophylous Forest, may occurring since the Lowlands (Negrelle, 2006; Lingner *et al*., 2013), Submontane (Klein, 1979, 1980; Maçaneiro *et al*., 2015) and Montane (Veloso and Klein, 1957; Martins, 2010).The species *Brosimum glaziovii* occured only in the Submontane Forest. Also, this species was considered with "insufficient data" by MMA (2008) and Lingner *et al*. (2013) registered low density for this species in Santa Catarina's Dense Ombrophylous Forest (DA = 1 ind.ha^{-1}), demonstrating that its population must be better studied. The species *Ilex brevicuspis* occurred only in the Submontane Forest. Edwin and Reitz (1967) mentioned this species as typical of Mixed Ombrophylous Forest and occurring sporadically in the Dense Ombrophylous Forest.

The species *Alsophila setosa* occurred only in the Montane Forest and besides being the species with the higher structural importance in this forest type (IP = 6.3%), also presented the higher indicator value (IV = 79.8, P < 0.05) (Table 2). This finding also was verified by Schorn *et al*. (2012) and Lingner *et al*. (2013) to Santa Catarina's Dense Ombrophylous Forest and the authors suggested that the lack of use and exploration of this species in the past might have influenced in its prominent structure importance in the forests nowadays.

Table 2: List of indicator species for forest types in the Itajaí-Mirim river, Southern Brazil. EG = ecological groups, P = pioneer species, CL = light-demanding climax, CS = shade-tolerant climax; IV = indicator value (significant at P < 0.05).

FOREST TYPES / SPECIES	EG	IV	*P* value
Submontane Forest			
Tapirira guianensis	CS	79.8	0.008
Aparisthmium cordatum	CS	70.7	0.011
Brosimum glaziovii	CS	70.7	0.011
Ilex brevicuspis	CL	70.7	0.013
Nectandra membranacea	CS	57.7	0.041
Psychotria carthagenensis	CL	57.7	0.041
Miconia cinnamomifolia	P	61.2	0.043
Pourouma guianensis	CL	57.7	0.046
Andira fraxinifolia	CL	57.7	0.047
Virola bicuhyba	CL	57.0	0.048
Montane Forest			
Alsophila setosa	CS	79.8	0.007
Posoqueria latifolia	CS	61.2	0.037
Cryptocarya aschersoniana	CS	61.2	0.041
Coussarea contracta	CS	62.0	0.041
Eugenia involucrata	CS	62.0	0.044
Myrcia hebepetala	CS	62.0	0.044
Coccoloba warmingii	CL	62.0	0.044
Guatteria australis	CS	57.0	0.047
Cinnamomum glaziovii	CS	56.5	0.048

Conclusion:

In relation to the structure of the types of forests analyzed, some of the most important species as *Alchornea triplinervia* and *Miconia cinnamomifolia* are pioneers and occur preferably in open environment and edge of forests with high insolation. However, also were registered as most important species *Tapirira guianensis*, *Hyeronima alchorneoides* and *Alsophila setosa*, considered as shade-tolerant climax and occur preferably inside secondary forests in advanced stage of regeneration in Vale do Itajaí region, Southern Brazil.

The types of forests analyzed have differences between each other concerning to the species with higher indicator value. In this way, the Submontane Forest presented a set of indicator species differentiated when compared to the Montane Forest. This result shows that environmental factors can be influencing in the dataset, and studies that involve this line of research must be developed to list the determinants factors of the floristic standards.

The Submontane and Montane forests among Itajaí-Mirim river in Southern Brazil are altered in terms of its structures, because lots of the tree species registered are typical of secondary forests in medium or advanced stage of regeneration. However, these forests are in advanced stage in the process of structure rebuilding and must increase their phytophysiognomy complexity with the progress of the successional process.

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Australian Journal of Basic and Applied Sciences, 9(33) October 2015, Pages: 392-397

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